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Antibiotic prescribing practices according to the AWaRe classification among children under 5 of age attending public primary care centres in four West African countries: a cross-sectional study (AIRE project, 2021–2022)

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ABSTRACT

Objective To describe antibiotic prescribing practices using the WHO AWaRe (*Access*, *Watch*, *Reserve*) classification in West African children under 5 years of age attending public primary health centres (PHCs).

Design Cross-sectional study.

Setting The AIRE project implemented the systematic use of pulse oximetry into integrated management of childhood illness consultations in West African countries (Burkina Faso, Guinea, Mali and Niger). We described antibiotic prescriptions for outpatient children at 16 PHCs and for severe cases referred at district hospitals.

Patients Between 14 June 2021 and 19 June 2022, 15 854 outpatients were included: 968 neonates and young infants (0–28 days) and 14 886 children (2–59 months). Among them, 78 (8.1%) neonates and young infants and 385 (2.6%) children were hospitalised. We evaluated 58 hospitalised neonates and young infants and 275 hospitalised children, respectively.

Main outcome measures Frequency of antibiotic prescriptions according to the AWaRe classification recommended by WHO.

Results At the PHC level, proportions of neonates and young infants with ≥1 antibiotic prescription were 83%, 62%, 71% and 59% in Burkina Faso, Guinea, Mali and Niger, respectively. A total of 805 antibiotics were prescribed (85% *Access* and 13% *Watch*). The proportions of children with ≥1 antibiotic prescription reached 71%, 66%, 63% and 36% in Burkina Faso, Guinea, Mali and Niger, respectively. Out of the 9630 antibiotics prescribed, 93% were *Access* (mainly amoxicillin), and 7% *Watch*. At the hospital level, *Watch* antibiotics were mainly prescribed for severe cases referred. No *Reserve* antibiotics were prescribed.

Conclusions High proportions of antibiotics were prescribed to outpatient children included, the appropriateness of which needs further study. Nevertheless, in every country, the proportion prescribed in the *Access* group reached the minimum threshold of 60% of all antibiotic prescriptions, as recommended by WHO.

Trial registration number PACTR202206525204526.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ WHO has established the AWaRe (*Access, Watch, Reserve*) classification of antibiotics to better monitor antibiotic use worldwide, with a national target of at least 60% A*ccess* antibiotics compared with all antibiotic prescriptions.

⇒ Few studies in West Africa have used the AWaRe classification in analyses of antibiotic prescribing, and in addition, most of these were based on adult inpatients.

WHAT THIS STUDY ADDS

⇒ Our study reports high proportions (>60% in Burkina Faso, Guinea and Mali) of antibiotic prescriptions for ill children attending consultation under 5 years of age.

⇒ *Access* antibiotics, mainly *amoxicillin*, were mainly prescribed at primary health centres (respecting the minimal WHO threshold of 60%).

⇒ At the hospital level, *Watch* antibiotics were more commonly used.

⇒ No *Reserve* antibiotics were prescribed.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The high rate of antibiotic prescriptions may contribute to potential overconsumption, underscoring the critical need for monitoring prescribing practices to prevent unnecessary antibiotic use in children.

INTRODUCTION

Despite significant progress, children living in West Africa continue to suffer from a high mortality burden, mainly due to infectious diseases.[1] Antibiotics used to treat bacterial infections have saved millions of lives. However, the burden of infectious diseases in low-income countries, combined with insufficient and inadequate healthcare worker training, limited diagnostic capacity and access to medicines, leads to frequent over and inappropriate use of antibiotics.[2–4] Therefore, the effectiveness of antibiotics is seriously compromised by inappropriate use, driving the emergence of antimicrobial resistance. According to WHO, antimicrobial resistance occurs when bacteria, viruses, fungi and parasites evolve over time and no longer respond to drugs, making the treatment of infections more complex and increasing the risk of spread, severe disease and death.[5] The West African region has the highest mortality rate associated with antimicrobial resistance worldwide.[6]

The WHO *Access*, *Watch* and *Reserve* (AWaRe) antibiotic classification was introduced in the Essential Medicine List in 2017 to guide antibiotic prescribing based on international recommendations, drug spectrum and resistance profile.[7–9] Antibiotics are divided into three groups: *Access*, *Watch* and *Reserve*. The *Access* group, with low resistance potential, is available for frontline treatment. The *Watch* group has an increased resistance potential. They are only recommended for specific limited infections and should be monitored. The third group, *Reserve*, includes broad-spectrum antibiotics that should be considered as a last resort.[7] This classification aims to guide the prescription of antibiotics towards those least likely to contribute to antibiotic resistance, specifically *Access* antibiotics, regardless of the care level (inpatient and outpatient settings). WHO has established a country-level target that at least 60% of total antibiotic consumption should consist of *Access* group antibiotics.

In the literature, data on antibiotic prescribing for children, including neonates, at primary health centres (PHCs) remain scarce in West Africa.[10 11] Few studies report a high frequency of prescriptions, but these are primarily conducted among inpatients or African countries outside West Africa.[10 12 13] Moreover, only a limited number of studies have incorporated the AWaRe classification into analyses of antibiotic prescribing in West Africa.

The AIRE operational project conducted in four West African countries (Burkina Faso, Guinea, Mali and Niger) aimed to improve the detection of severe hypoxaemia by introducing the systematic use of pulse oximeters (PO), as part of integrated management of childhood illness (IMCI) consultations at the frontline.[14] We conducted a subanalysis of data from the AIRE parent study to describe and compare antibiotic prescribing practices across different countries. Specifically, we examined adherence to the WHO AWaRe classification for children under 5 years of age at both the PHC level and the hospital level for severe referred cases.

METHODS

Study design and inclusion criteria

As part of the AIRE research project, a cross-sectional population-based study was conducted over 12 months (14 June 2021 to 19 June 2022) in 16 public PHCs (4 per country) and 8 district hospitals in 4 countries (Burkina Faso, Guinea, Mali, Niger) to evaluate the implementation of PO use in IMCI guidelines. IMCI consultations refer to healthcare encounters that focus on the IMCI, where healthcare providers assess, diagnose and treat children under 5 years of age according to standardised protocols that emphasise the early detection and management of common childhood diseases. During this consultation, the clinician classified all children as simple, moderate or severe cases according to this IMCI protocols.[15] At baseline, healthcare workers were trained in IMCI national protocols integrating PO.

All children, except those aged 2–59 months classified as non-respiratory 'simple cases' were eligible for PO use and were enrolled in this study with parental consent.[16] Children identified as severe cases according to IMCI guidelines or with severe hypoxaemia (defined as SpO_2 <90%) using PO were eligible for hospital referral, and followed up in a short-term prospective cohort (14 days). The research protocol has been published elsewhere.[14]

For this subanalysis, all the children under 5 years of age (neonates and young infants and children) attending IMCI consultations at the PHC for the first time were included.

We defined 'neonates and young infants' as all children under 59 days of age to align with the operational definition of IMCI and reflect field clinical practices. However, to facilitate future comparisons, we also stratified the results into two age categories according to the WHO definition: neonates (0–28 days) and young infants (29–59 days). These stratified results are presented in online supplemental files 1 and 2. Neonates and young infants include those born at home or discharged from the clinic who later return for follow-up consultations, often due to postnatal complications or routine examinations.

Data collection

At all study sites, data were collected using an electronic case report form developed with REDCap software by dedicated data collectors at PHC and hospital levels. Sociodemographic and clinical individual data, including IMCI classifications and treatment prescribed at the PHC level or hospital level, were collected. We considered the child's first visit only.

Due to inconsistencies between medical records and collected data for children hospitalised in Niger, only the verified and corrected hospital records were included for this country (87/217, 40%).

Outcomes

Proportions of children with systemic antibiotic drug prescriptions among all outpatients (at PHC level) and

inpatients (at hospital level) were computed by country. Each prescribed antibiotic was classified into three categories (*Access*, *Watch*, *Reserve*) according to the AWaRe classification in the latest WHO Essential Medicines List for children under 12 years (EMLc 22nd edition, 2021—online supplemental file 3).[17] The AWaRe classification of antibiotics remains consistent, regardless of the care level at which children receive treatment. Antibiotics not included in one of the three groups were defined as *Unclassified*. By country, we compared the proportion of *Access* antibiotics with the minimal target set by the WHO General Programme of Work 2019–2023, recommending that at least 60% of all antibiotics prescribed should be *Access* antibiotics.[7] No threshold is defined for *Watch* or *Reserve* antibiotics.

Statistical analysis

All descriptive statistical analyses were stratified by health facilities (PHC and hospital) and compared between countries using a χ^2 test, with Yates correction if necessary, for categorical variables, or, a Kruskal-Wallis test for continuous variables. Sociodemographic and clinical characteristics were described separately for each age category. We analysed antibiotic prescriptions by quantifying the proportion of children enrolled who had received at least one antibiotic, and according to the AWaRe classification. Then, we determined the proportion of *Access, Watch* and *Reserve* antibiotics, calculated as the number in each antibiotics' group divided by the total number of antibiotics prescribed.

Sankey diagrams were created to illustrate the evolution of prescribing practices between the PHC and hospital levels for the subgroup of severe cases transferred to the hospital,[18] considering the most frequently prescribed antibiotics for children. In case of a tie, the *Watch* group was used. Analyses were performed using R software V.4.1.3 (2022-03-10), and we considered results statistically significant at $p<0.05$.

Sensitivity analyses

We conducted sensitivity analyses to determine whether the non-respiratory cases excluded from the AIRE project

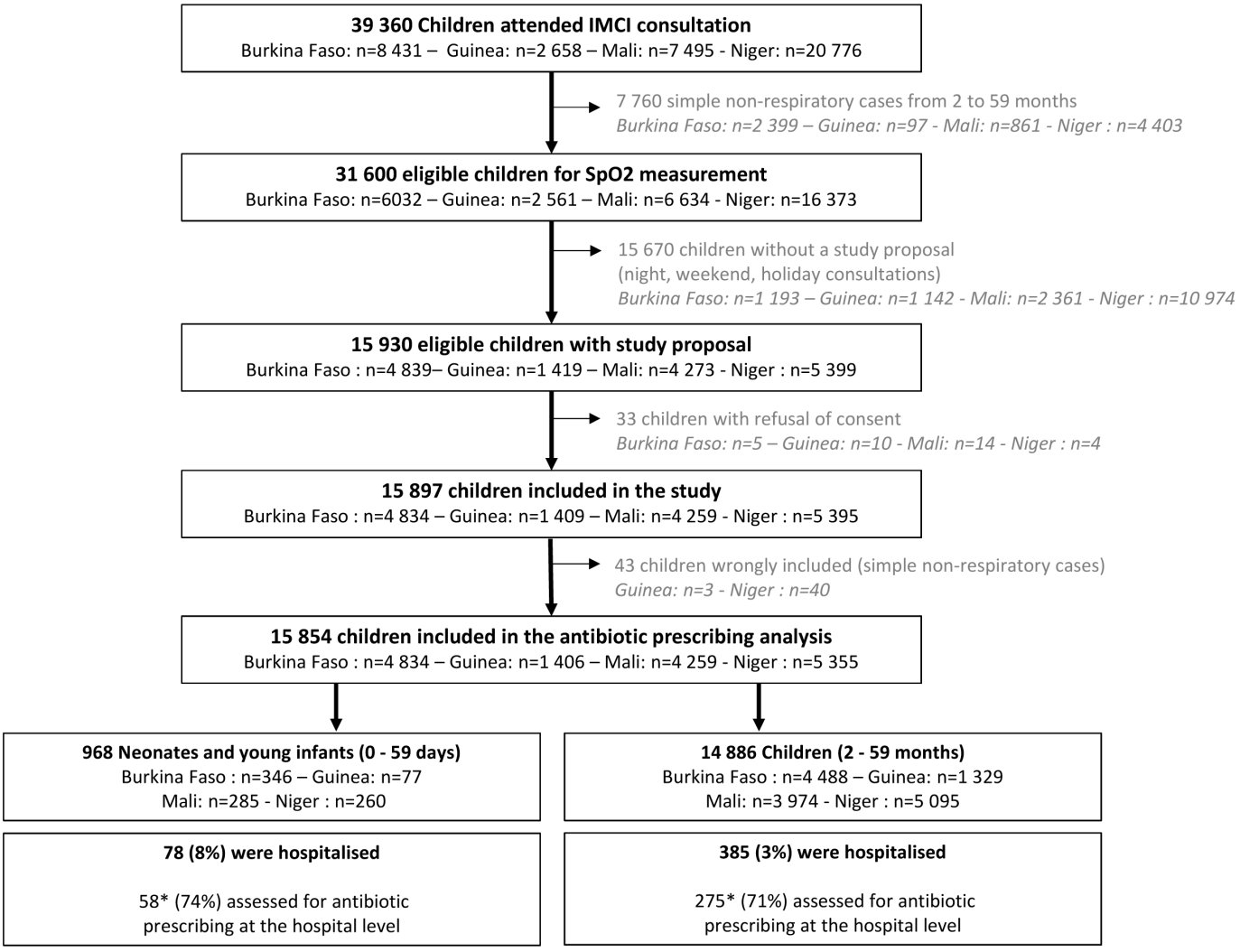

Figure 1 Flowchart, inclusion process of children under 5 years of age in the AIRE research project 2021–2022. *Some hospitalised cases from Niger could not have been evaluated due to poor data quality. IMCI, integrated management of childhood illness.

Table 1 Characteristics and antibiotic prescriptions of neonates and young infants (0–59 days) enrolled at the PHC level, AIRE project 2021–2022 (n=968)

	Burkina Faso N=346	Guinea N=77	Mali N=285	Niger N=260	Overall N=968
Sociodemographic and clinical characteristics					
Female sex—n (%)	176 (50.9)	41 (53.2)	141 (49.5)	115 (44.2)	473 (48.9)
Child's age (in days)—median (IQR)					*
0–28	160 (46.2)	45 (58.4)	181 (63.5)	161 (61.9)	547 (56.5)
29–59	186 (53.8)	32 (41.6)	104 (36.5)	99 (38.1)	421 (43.5)
Mother mainly responsible for the child—n (%)	343 (99.1)	77 (100.0)	282 (98.9)	255 (98.1)	957 (98.9)
Child caregiver literacy, cannot read and write—n (%)	274 (79.2)	45 (58.4)	219 (76.8)	144 (55.4)	682 (70.5)*
Time between onset of illness and consultation (days)—median (IQR)	2 (1–2)	3 (2–3)	2 (1–3)	3 (2–4)	2 (1–3)*
Medication use before IMCI consultation—n (%)	9 (2.6)	6 (7.8)	17 (6.0)	24 (9.2)	56 (5.8)*
Main IMCI diagnostics†—n (%)					
Severe pneumonia or very serious disease	15 (4.3)	24 (31.2)	100 (35.1)	42 (16.2)	181 (18.6)*
Pneumonia	3 (0.9)	35 (45.5)	NA	50 (19.2)	88 (9.0)*
Signs of diarrhoea or dehydration	0 (0.0)	2 (2.6)	1 (0.4)	1 (0.4)	4 (0.4)
Local bacterial infection	5 (1.4)	35 (45.5)	22 (7.7)	11 (4.2)	73 (7.5)*
Feeding problem or malnutrition	1 (0.3)	7 (9.1)	6 (2.1)	28 (10.8)	42 (4.3)
No IMCI diagnostic specified‡‡	322 (93.1)	3 (3.9)	160 (56.1)	107 (41.2)	500 (51.7)
Final IMCI classification integrating pulse oximeter use—n (%)					*
Severe case	43 (12.4)	28 (36.4)	97 (34.0)	41 (15.8)	209 (21.6)
Moderate case	83 (24.0)	32 (41.6)	46 (16.1)	84 (32.3)	245 (25.3)
Simple case	220 (63.6)	17 (22.1)	142 (49.8)	135 (51.9)	514 (53.1)
Antibiotic prescriptions					
Prescription of drug(s) at PHC level, n (%)	335 (96.8)	63 (81.8)	249 (87.4)	206 (79.2)	853 (88.1)*
Prescription of any systemic antibiotic(s), n (%)—100%	286 (82.7)	48 (62.3)	203 (71.2)	154 (59.2)	691 (71.4)*
One antibiotic	254 (89.9)	48 (100.0)	161 (79.3)	136 (88.4)	601 (87.0)
Two antibiotics	25 (8.7)	–	22 (10.8)	17 (11.0)	65 (9.4)
Three antibiotics	4 (1.4)	–	20 (9.9)	1 (0.6)	25 (3.6)
Any *Access* antibiotics, n (%)	250 (87.4)	42 (87.5)	174 (85.7)	140 (90.9)	606 (87.7)
Amoxicillin	221 (77.3)	36 (75.0)	148 (72.9)	114 (74.0)	519 (75.1)
Amoxicillin+Clavulanic acid	0 (0.0)	0 (0.0)	2 (1.0)	0 (0.0)	2 (0.3)
Ampicillin	26 (9.1)	0 (0.0)	16 (7.9)	16 (10.4)	58 (8.4)
Cloxacillin	0 (0.0)	1 (2.1)	0 (0.0)	9 (5.8)	10 (1.4)
Cotrimoxazole	1 (0.3)	0 (0.0)	0 (0.0)	1 (0.6)	2 (0.3)
Gentamicin	27 (9.4)	2 (4.2)	35 (17.2)	11 (7.1)	75 (10.8)
Metronidazole	7 (2.4)	3 (6.3)	6 (3.0)	5 (3.2)	21 (3.0)
Any *Watch* antibiotics, n (%)	37 (12.9)	6 (12.5)	52 (25.6)	7 (4.5)	102 (14.8)*
Azithromycin	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.3)	2 (0.3)
Ceftriaxone	7 (2.4)	0 (0.0)	33 (16.3)	5 (3.2)	45 (6.5)
Erythromycin	30 (10.5)	6 (12.5)	24 (11.8)	0 (0.0)	60 (8.7)
Any *Reserve* antibiotics, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Any *Unclassified* antibiotics, n (%)	0 (0.0)	0 (0.0)	1 (0.5)	10 (6.5)	11 (1.6)*
Oxacillin	0 (0.0)	0 (0.0)	0 (0.0)	10 (6.5)	10 (1.4)
Norfloxacin	0 (0.0)	0 (0.0)	1 (0.5)	0 (0.0)	1 (0.1)

Continued

Table 1 Continued

	Burkina Faso N=346	Guinea N=77	Mali N=285	Niger N=260	Overall N=968

IQR (Q1–Q3).
*Significant (<0.05) comparison test (χ^2 distribution with correction if necessary or Kruskal-Wallis test).
†Main diagnostic according to the medical record.
‡IMCI not specified correspond to children for whom no diagnosis or only the absence of diagnosis was ticked.
IMCI, integrated management of childhood illness; NA, not applicable; PHC, primary health centre.

might have impacted our estimates by assessing potential maximum biases (online supplemental file 4). We evaluated two scenarios: one in which none of the excluded children received antibiotics and another in which all did. This approach enabled us to estimate the range of the true proportion of antibiotic prescriptions among all children aged 2–59 months attending PHCs.

Ethics statement

This project was registered by the Pan African Clinical Trials Registry on 15 June 2022 (PACTR202206525204526). All data were anonymised, and only securely accessible to researchers. This paper is based on a subanalysis derived from data collected in the parent study.

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of our research.

RESULTS

Study population

Between 14 June 2021 and 19 June 2022, 39 360 children attended IMCI consultations at the 16 PHC, of whom 31 600 (80.3%) were eligible for SpO_2 measurement (figure 1). Overall, 15 854 children under 5 years of age (50.1%) were included in the antibiotic prescribing analysis: 968 neonates and young infants (6.1%) and 14 886 children (93.9%).

Antibiotic prescriptions in neonates and young infants

Among the 968 neonates and young infants, 547 (56.5%) were neonates (0–28 days) and 421 (43.5%) were young infants (29–59 days) (table 1). Nearly 49% were female. Main IMCI diagnostics were related to pneumonia or severe pneumonia (27.6%), or local bacterial infection (7.5%) but differed significantly between countries. Overall, 21.6% were classified as 'severe IMCI cases'

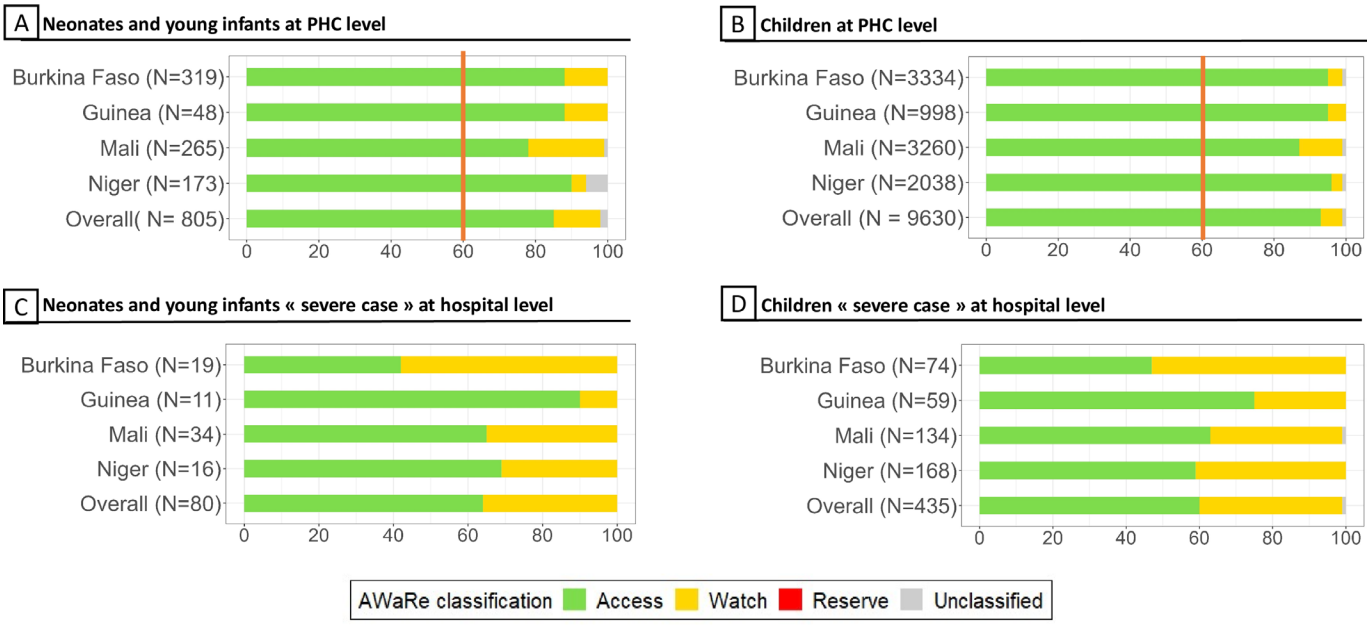

Figure 2 Percentage stacked bar chart, share of *Access, Watch, Reserve* and *Unclassified* antibiotic prescriptions among neonates and young infants (0–59 days) at primary health centre (PHC) level (A) and at hospital level (C) and among children (2–59 months) at PHC level (B) and hospital level (D), by country, AIRE project 2021–2022. The colour code green, yellow and red respect the AWaRe classification, *Access, Watch, and Reserve*, respectively. The grey colour reflects the *Unclassified* antibiotics. The 60% threshold bar represents the proportion to reach at least 60% of *Access* antibiotic according to WHO AWaRe recommendation.

(integrating PO), varying significantly from 12.4% in Burkina Faso to 36.4% in Guinea (p<0.05).

At the PHC level, 71.4% of neonates and young infants included received a prescription for systemic antibiotics, with significant variation between countries, ranging from 59.2% in Niger to 82.7% in Burkina Faso (p<0.001) (table 1). This rate was estimated at 69.1% among neonates (0–28 days) and 74.3% among young infants (29–59 days) (online supplemental files 2 and 3).

Within all PHCs, *Access* antibiotics were the most prescribed antibiotics. Among children with an antibiotic prescription, 87.7% received at least 1 *Access* antibiotic (table 1). These were mainly *amoxicillin*, followed by *gentamicin*, prescribed in 75.1% and 10.8% of children, respectively. A total of 805 antibiotics were prescribed, with 85% categorised as *Access* (p=0.526, figure 2). The proportion of *Watch* antibiotics prescribed varied between countries, ranging from 4.5% to 25.6% in Niger and Mali (p<0.001), mainly represented by *erythromycin* (table 1).

Of the 209 severe cases, 78 (37.3%) were hospitalised in district hospitals but we were able to evaluate antibiotic prescriptions for 58 neonates and young infants (figure 1, table 2). Their main diagnostics were infection or respiratory depression, or neonatal sepsis. All the neonates and young infants hospitalised in Guinea and Niger, and >60% in Burkina Faso and Mali received at least one antibiotic (table 2). Among neonates and young infants with an antibiotic prescription overall, 85.7% (36/42) had an *Access* antibiotic (mainly *gentamicin*), and 69.0% (29/42) had *Watch* antibiotics (*ceftriaxone*).

In all countries, the proportion of *Watch* antibiotics used at the hospital level increased compared with

Table 2 Characteristics and antibiotic prescriptions at the hospital level of neonates and young infants (0–59 days) enrolled at the primary health centre level and transferred, AIRE project 2021–2022 (n=58/968)

	Burkina Faso N=18	Guinea N=6	Mali N=26	Niger* N=8	Overall N=58
Female sex—n (%)	5 (27.8)	4 (66.7)	12 (46.2)	3 (37.5)	24 (41.4)
Child's age (in days)					
0–28	14 (77.8)	4 (66.6)	20 (76.9)	7 (87.5)	45 (77.6)
29–59	4 (22.2)	2 (33.4)	6 (23.1)	1 (12.5)	13 (22.4)
Transfer on the day of the consultation IMCI—n (%)	17 (77.8)	6 (100)	24 (92.3)	7 (87.5)	53 (91.4)
Main diagnostics†—n (%)					
Infection or respiratory depression	3 (16.6)	1 (16.7)	7 (26.9)	5 (62.5)	16 (27.6)
Neonatal sepsis or bacterial infection	7 (38.9)	1 (16.7)	5 (19.2)	3 (37.5)	16 (27.6)
Others infections (malaria or gastroenteritis)	1 (5.6)	2 (33.3)	1 (3.8)	0 (0.0)	4 (6.9)
Malnutrition	2 (11.1)	1 (16.7)	2 (7.7)	0 (0.0)	5 (8.6)
Others (preterm delivery, trauma, drowning)	4 (22.2)	1 (16.7)	8 (30.8)	0 (0.0)	13 (22.4)
Prescription of drug(s) at the hospital level, n (%)	12 (66.7)	6 (100)	20 (76.9)	8 (100)	46 (79.3)
Prescription of any systemic antibiotic(s), n (%)—100%	12 (66.7)	6 (100)	16 (61.5)	8 (100)	42 (72.4)
One antibiotic	6 (50.0)	1 (16.7)	1 (6.2)	0 (0.0)	8 (19.0)
Two antibiotics	5 (41.7)	5 (83.3)	13 (81.3)	8 (100.0)	31 (73.8)
Three antibiotics or more	1 (8.3)	0 (0.0)	2 (12.5)	0 (0.0)	3 (7.2)
Any *Access* antibiotics, n (%)	6 (50.0)	6 (100)	16 (100)	8 (100)	36 (85.7)‡
Amoxicillin	0 (0.0)	2 (33.3)	0 (0.0)	0 (0.0)	2 (4.8)
Amoxicillin+Clavulanic acid	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.4)
Ampicillin	2 (16.7)	4 (66.7)	3 (18.8)	3 (37.5)	12 (28.6)
Gentamicin	3 (25.0)	2 (33.3)	16 (100)	8 (100)	29 (69.0)
Metronidazole	2 (16.7)	2 (33.3)	3 (18.8)	0 (0.0)	7 (16.7)
Any *Watch* antibiotics, n (%)	11 (91.7)	1 (16.7)	12 (75.0)	5 (62.5)	29 (69.0)
Ceftriaxone	11 (91.7)	1 (16.7)	12 (75.0)	5 (62.5)	29 (69.0)
Any *Reserve* antibiotics, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Any *Unclassified* antibiotics, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

*Only on the medical record monitored.
†Main diagnostic according to the medical record.
‡Significant (<0.05) comparison test (χ^2 distribution with correction if necessary or Kruskal-Wallis test).
IMCI, integrated management of childhood illness.

PHC level (figure 2). Some neonates and young infants without any antibiotic prescription at the PHC received a *Watch* antibiotic, as first-line at the hospital level.

Antibiotic prescriptions in children

Among the 14886 children, 47.1% were female, with a median age of 20 months and an IQR of 10–36 months (table 3). We observed significant between-country differences in IMCI diagnoses. In Burkina Faso, the main diagnoses were malaria (43.2%) and pneumonia (34.7%). In Guinea, 37.8% had severe pneumonia or very severe illness, and 89.9% had malaria. In Mali, 34.2% had pneumonia, 67.1% had malaria and 19.4% had feeding or malnutrition issues. In Niger, 53.7% had malaria and 22.1% had pneumonia. The percentage of severe IMCI cases varied significantly, from 3.8% in Burkina Faso to 45.1% in Guinea (p<0.001).

At PHC, the percentage of children with at least one antibiotic prescription varied significantly between countries (p<0.001), ranging from 36.3% in Niger to 70.8% in Burkina Faso (table 3). Overall, we estimated that the prevalence of children who received an antibiotic at the end of consultations was 56.4%. Based on the hypothesis of maximum biases for the children excluded from the study sample (non-respiratory simple cases), we estimate that the true prevalence of antibiotic prescribing among all children aged 2–59 months attending PHC ranges between 37% and 71% (online supplemental file 4).

Among the 8392 children with an antibiotic prescription, 95% received an *Access* antibiotic, mainly *amoxicillin* (82.6% of those with any antibiotic), followed by *cotrimoxazole* (6.2%). Therefore, *Access* antibiotics exceeded 85% of all antibiotics prescribed (figure 2). Children prescribed *Watch* antibiotics represented 7.8% of those with antibiotic prescriptions, with erythromycin accounting for 3.8% and ceftriaxone for 2.8%. This proportion varied significantly between countries, 3.3%, 4.7%, 5.6% and 15.8% in Niger, Burkina Faso, Guinea and Mali, respectively.

Of the 1736 children classed as severe cases, 385 (22.2%) were admitted to hospital (figure 1). We were able to evaluate antibiotic prescriptions for 275 children (71%). The percentage of hospitalised children receiving at least one antibiotic were estimated at 77.3% in Mali, 85.1% in Burkina Faso, 85.2% in Guinea and 100% in Niger (table 4). Among them, the percentage of children with *Access* antibiotic prescription was estimated at 82.0% overall, varying from 60.0% in Burkina Faso to 94.9 in Niger, represented by *ampicillin* and *gentamicin*. Overall, 70.3% received *Watch* antibiotics (mainly *ceftriaxone*). The proportion of *Watch* antibiotics varied from 28.8% in Guinea to 95% in Burkina Faso (table 4).

The evolution of prescribing practices to children between PHC and hospital level shows an increased use of *Watch* antibiotics at hospital, often in the first line (figure 3).

DISCUSSION

This descriptive study examines antibiotic prescribing patterns using the AWaRe classification for over 15000 children under 5 years of age across 16 public PHCs in four West African countries. Despite country-specific variations, regardless of diagnosis, antibiotics were frequently prescribed, especially to neonates and young infants. *Access* antibiotics, mainly amoxicillin, dominated prescriptions (95% for children, 88% for neonates and young infants), while *Watch* antibiotics were less common (15% for neonates and young infants, 8% for children). In severe cases referred to hospitals, *Watch* antibiotics were prescribed more often, usually alongside *Access* antibiotics like ceftriaxone-gentamicin. *Reserve* antibiotics were not used.

Antibiotic prescription in children under 5 years of age at frontline is thus very common. Several factors may explain these high proportions. First, this study was conducted in settings characterised by a high prevalence of infectious diseases.[19–21] Second, few resources were available to support appropriate prescriptions characterised by a lack of qualified healthcare providers and diagnostic tools (except malaria rapid diagnostic tests) at the frontline.[2–4 22] Therefore, probabilistic antibiotic therapy is widely used by clinicians to manage childhood illness in this context.[2 3 23] Finally, we can mention the pressure that families put on clinicians to obtain drugs.

Our results indicate significant differences in antibiotic prescription rates among children and neonates/young infants across countries. These variations may stem from differences in national healthcare systems. Burkina Faso and Niger provide full free healthcare for children, which may encourage earlier medical attention and reduce severe cases and antibiotic prescription rates. In contrast, Guinea and Mali have partial policies, potentially leading to delayed care, which may explain the higher proportion of severe cases observed in these countries.[24 25] Additionally, health workers may receive varying training on IMCI guidelines and the risks of antimicrobial resistance associated with overprescription.[2 3 26] Furthermore, each country has tailored the IMCI guidelines to its specific context, resulting in differences in diagnostic protocols and recommended antibiotics.

Despite Niger and Burkina Faso implementing the same free healthcare policy and having similarly qualified personnel, significant differences in antibiotic prescription rates exist. In Burkina Faso, four PHCs are rural, while Niger has two urban and two rural PHCs, suggesting urban PHCs may prescribe fewer antibiotics due to better access. Additionally, Burkina Faso uses an electronic IMCI tool, whereas Niger relies on a paper-based version, which may lead to missed treatment opportunities due to oversight or non-compliance. A last key difference between the countries is the integration of the AWaRe classification into their respective National Lists of Essential Medicines (LNME). In Burkina Faso, the AWaRe classification has been incorporated, with four *Reserve* antibiotics, although their use is restricted

Table 3 Characteristics and antibiotic prescriptions of children (2–59 months) enrolled at the PHC level, AIRE project 2021–2022 (n=14 886)

	Burkina Faso N=4488	Guinea N=1329	Mali N=3974	Niger N=5095	Overall N=14 886
Sociodemographic and clinical characteristics					
Female sex—n (%)	2125 (47.3)	652 (49.1)	1826 (45.9)	2415 (47.4)	7018 (47.1)
Child's age (in months)—median* (IQR)	21 (10–36)	20 (10–35)	24 (11–36)	16 (9–32)	20 (10–36)†
Mother mainly responsible for the child—n (%)	4388 (97.8)	1281 (96.4)	3869 (97.4)	4936 (96.9)	14 474 (97.2)†
Child caregiver literacy, cannot read and write—n (%)	3807 (84.8)	828 (62.3)	3343 (84.1)	2748 (53.9)	10 726 (72.1)†
Time between onset of illness and consultation (days)—median (IQR)	2 (1–2)	3 (2–3)	2 (1–3)	3 (2–3)	2 (2–3)†
Medication use before IMCI consultation—n (%)	533 (11.9)	137 (10.3)	686 (7.2)	504 (9.9)	1860 (12.5)†
Main IMCI diagnostics*—n (%)					
Severe pneumonia or very serious disease	39 (0.9)	503 (37.8)	81 (2.0)	72 (1.4)	695 (4.7)†
Pneumonia	1558 (34.7)	315 (23.7)	1360 (34.2)	1128 (22.1)	4361 (29.3)†
Signs of diarrhoea or dehydration	51 (1.1)	23 (1.7)	87 (2.2)	160 (3.1)	321 (2.2)†
Malaria	1940 (43.2)	1196 (89.9)	2666 (67.1)	2735 (53.7)	8537 (57.4)†
Anaemia	44 (1.0)	143 (10.8)	55 (1.4)	166 (3.3)	408 (2.7)†
Feeding problems or malnutrition	203 (4.5)	72 (5.4)	772 (19.4)	489 (9.6)	1536 (10.3)†
No IMCI diagnostic specified‡‡	1049 (23.4)	66 (5.0)	332 (8.4)	1280 (25.1)	2727 (18.3)
Final IMCI classification integrating PO use—n (%)					†
Severe case	171 (3.8)	600 (45.1)	691 (17.4)	274 (5.4)	1736 (11.7)
Moderate case	3282 (73.1)	662 (49.8)	2914 (73.3)	3682 (72.3)	10 540 (70.8)
Simple case	1035 (23.1)	67 (5.0)	369 (9.3)	1121 (22.0)	2592 (17.4)
Missing	0 (0.0)	0 (0.0)	0 (0.0)	18 (0.4)	18 (0.1)
Antibiotic prescriptions					
Prescription of drug(s) at PHC level, n (%)	4481 (99.8)	1142 (85.9)	3639 (91.6)	4646 (91.2)	13 908 (93.5)†
Prescription of any systemic antibiotic(s), n (%)—100%	3176 (70.8)	878 (66.1)	2487 (62.6)	1851 (36.3)	8392 (56.4)†
One antibiotic	3032 (95.5)	760 (86.6)	1955 (78.6)	1687 (91.1)	7434 (88.6)
Two antibiotics	130 (4.1)	116 (13.2)	294 (11.8)	142 (7.7)	682 (8.1)
Three antibiotics or more	14 (0.4)	2 (0.2)	238 (9.6)	22 (1.2)	276 (3.3)
Any *Access* antibiotics, n (%)	3049 (96.0)	836 (95.2)	2288 (92.0)	1798 (97.1)	7971 (95.0)†
Amoxicillin	2724 (85.8)	708 (80.6)	1958 (78.7)	1543 (83.4)	6933 (82.6)
Amoxicillin+Clavulanic acid	0 (0.0)	0 (0.0)	2 (0.1)	2 (0.1)	4 (0.0)
Ampicillin	100 (3.1)	23 (2.6)	281 (11.3)	113 (6.1)	517 (6.2)
Benzathine benzylpenicillin	0 (0.0)	0 (0.0)	4 (0.2)	0 (0.0)	4 (0.0)
Cefalexin	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.1)	2 (0.0)
Cloxacillin	0 (0.0)	21 (2.4)	0 (0.0)	11 (0.6)	32 (0.4)
Cotrimoxazole	189 (6.0)	67 (7.7)	74 (3.0)	191 (10.3)	521 (6.2)
Doxycycline	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	1 (0.0)
Gentamicin	60 (1.9)	1 (0.1)	330 (13.3)	75 (4.1)	466 (5.6)
Metronidazole	109 (3.4)	129 (14.7)	201 (8.1)	36 (1.9)	475 (5.7)
Any *Watch* antibiotics, n (%)	148 (4.7)	49 (5.6)	393 (15.8)	62 (3.3)	652 (7.8)†
Azithromycin	0 (0.0)	6 (0.7)	0 (0.0)	40 (2.2)	46 (0.5)
Cefixime	0 (0.0)	13 (1.5)	0 (0.0)	0 (0.0)	13 (0.2)
Ceftriaxone	29 (0.9)	4 (0.5)	201 (8.1)	4 (0.2)	238 (2.8)
Ciprofloxacin	17 (0.5)	0 (0.0)	26 (1.0)	8 (0.4)	51 (0.6)
Erythromycin	103 (3.2)	26 (3.0)	179 (7.2)	10 (0.5)	318 (3.8)
Any *Reserve* antibiotics, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Continued

Table 3 Continued

	Burkina Faso N=4488	Guinea N=1329	Mali N=3974	Niger N=5095	Overall N=14 886
Any *Unclassified* antibiotics, n (%)	3 (0.1)	0 (0.0)	4 (0.2)	2 (0.1)	9 (0.1)†
Penicillin	3 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.0)
Oxacillin	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.1)	2 (0.0)
Norfloxacin	0 (0.0)	0 (0.0)	4 (0.2)	0 (0.0)	4 (0.0)

IQR (Q1–Q3).
*Main diagnostic according to the medical record.
†Significant (<0.05) comparison test (χ^2 distribution with correction if necessary or Kruskal-Wallis test).
‡IMCI not specified correspond to children for whom no diagnosis or only the absence of diagnosis was ticked.
IMCI, integrated management of childhood illness; PHC, primary health centre.

to hospitals. This may explain the limited use of these antibiotics in outpatient settings. In contrast, Guinea, Mali and Niger have not yet integrated the AWaRe classification into their LNMEs. In Mali, ceftaroline is the only listed *Reserve* antibiotic, while no *Reserve* antibiotics are included in the LNMEs of Guinea or Niger, limiting their availability and use in these countries.

Overprescribing or misuse of antibiotics can have harmful effects, including unnecessary costs to families, undesirable side effects in children and risks of antibiotic resistance or stock shortage at the public health level.[27] WHO has recommended that *Access* antibiotic prescriptions represent at least 60% of the total antibiotic consumption by 2023.[8 28] *Access* antibiotics are active against a wide range of commonly encountered susceptible pathogens while having a lower potential for resistance than other groups. In our study, despite the high levels of antibiotic prescriptions observed, the *Access* group prescribed respected the WHO threshold (>60%) recommended at the PHC level, and according to the AWaRe classification, representing lower resistance risks. However, the widespread use of *Watch* antibiotics, particularly in Mali, requires further monitoring. In addition, the appropriateness of these prescriptions remains unevaluated and overprescribing cannot be ruled out.

Several studies in the literature have reported high rates of antibiotic prescriptions in sub-Saharan Africa, particularly among paediatric populations.[24 29–31] In Senegal, nearly 60% of children under 5 years of age who received outpatient care were prescribed antibiotics in 2019, with ceftriaxone, gentamicin and ampicillin being the most commonly used antibiotics.[32] Another study in Senegal corroborated these findings, showing that penicillins were the most frequently prescribed antibiotics, accounting for 52.8% of prescriptions.[33] In Burkina Faso, a study involving both children and adults assessed antibiotic prescription rates across various healthcare settings. The study found that antibiotic use was more common following consultations in health centres (54.8%) than formal pharmacies or informal medicine vendors. Additionally, the study highlighted a predominant use of *Access* antibiotics (85.2%) and a limited use of *Watch* antibiotics (14.8%), aligning closely with our findings.[34]

However, there is limited knowledge about outpatient paediatric antibiotic prescribing practices based on the WHO's AWaRe classification in West Africa. Most existing studies focus primarily on hospital data. For instance, a multicountry survey on antibiotic use among hospitalised patients under 19 years of age according to the AWaRe classification provides data from African countries other than those included in our study.[10]

Our study has several limitations to consider. First, the study lacks national representativeness. The sites were selected based on specific criteria to ensure the successful implementation of the PO in PHC for the AIRE project, such as internet access, a sufficient number of IMCI consultations and accessibility. This selection process excluded a significant number of potential sites. Moreover, the AIRE project was conducted in only four public PHCs per country, predominantly in rural areas, excluding private health centres. Although the project provided training on IMCI practices to healthcare workers and supplied essential medicines, including antibiotics, we do not feel this heavily influenced how healthcare workers prescribed antibiotics in real-life situations.

Second, the selection of children in the AIRE study (excluding about 20% of children aged 2–59 months classified as 'simple cases without respiratory signs' and children without proposition of the study), may have biased the antibiotic prescription rate compared with all children under 5 years of age, but could be generalisable to those children who were ill overall. To address this limitation, we conducted a sensitivity analysis based on the assumption of maximum biases for the children excluded from the study sample (simple non-respiratory cases). This allowed us to estimate the CI within which the true rate of children receiving an antibiotic prescription among all children consulting at the PHC is likely to fall. In fact, the lower bound of 37% is already quite high.

Additionally, considering the child's first visit to the PHC, it is possible that antibiotics were prescribed during subsequent encounters. Given the very high proportion of *Access* antibiotics prescribed, the overall AWaRe classification is unlikely to change. However, it is likely that broader-spectrum antibiotics would have been prescribed during later encounters or in cases of

Table 4 Characteristics and antibiotic prescriptions at the hospital level of children (2–59 months) enrolled at the primary health centre level and transferred, AIRE project 2021–2022 (n=275/14 886)

	Burkina Faso N=47	Guinea N=61	Mali N=88	Niger* N=79	Overall N=275
Female sex—n (%)	20 (42.6)	32 (52.5)	44 (50.0)	34 (43.0)	130 (47.3)
Child's age (in months)—median (IQR)	24 (12–34)	18 (12–30)	19 (11–35)	21 (12–25)	21 (12–31)
Transfer on the day of the consultation IMCI—n (%)	45 (95.7)	55 (90.2)	75 (85.2)	77 (97.5)	252 (91.6)
Main diagnostics†—n (%)					
Infection or respiratory depression	5 (10.6)	1 (1.6)	10 (11.3)	14 (17.7)	30 (10.9)‡
Neonatal sepsis or bacterial infection	3 (6.4)	2 (3.3)	4 (4.5)	3 (3.8)	12 (4.4)‡
Others infections (malaria or gastroenteritis)	29 (61.7)	47 (77.0)	47 (53.4)	45 (57.0)	168 (61.1)‡
Malnutrition	7 (14.9)	3 (4.9)	19 (21.6)	16 (20.3)	45 (16.4)‡
Others (preterm delivery, trauma, drowning)	2 (4.3)	8 (13.1)	2 (2.3)	1 (1.3)	13 (4.7)‡
Prescription of drug(s) at the hospital level, n (%)	43 (91.5)	61 (100.0)	81 (92.0)	79 (100.0)	264 (96,0)‡
Prescription of any systemic antibiotic(s), n (%)—100%	40 (85.1)	52 (85.2)	68 (77.3)	79 (100.0)	239 (86.9)‡
One antibiotic	17 (42.5)	45 (86.5)	15 (22.1)	4 (5.1)	81 (33.9)
Two antibiotics	14 (35.0)	7 (13.5)	43 (63.2)	63 (79.7)	127 (53.1)
Three antibiotics or more	9 (22.5)	0 (0.0)	10 (14.7)	12 (15.2)	31 (12.9)
Any *Access* antibiotics, n (%)	24 (60.0)	39 (75.0)	58 (85.3)	75 (94.9)	196 (82.0)‡
Amoxicillin	3 (7.5)	1 (1.9)	8 (11.8)	4 (5.1)	16 (6.7)
Amoxicillin+Clavulanic acid	1 (2.5)	0 (0.0)	2 (2.9)	2 (2.5)	5 (2.1)
Ampicillin	3 (7.5)	36 (69.2)	17 (25.0)	17 (21.5)	73 (30.5)
Gentamicin	14 (35.0)	5 (9.6)	49 (72.1)	74 (93.7)	142 (59.4)
Metronidazole	14 (35.0)	1 (1.9)	8 (11.8)	3 (3.8)	26 (10.9)
Cotrimoxazole	0 (0.0)	1 (1.9)	0 (0.0)	0 (0.0)	1 (0.4)
Any *Watch* antibiotics, n (%)	38 (95.0)	15 (28.8)	48 (70.6)	67 (84.8)	168 (70.3)‡
Cefixime	0 (0.0)	0 (0.0)	1 (1.5)	0 (0.0)	1 (0.4)
Ceftriaxone	38 (95.0)	15 (28.8)	45 (66.2)	66 (83.5)	164 (68.6)
Ciprofloxacin	0 (0.0)	0 (0.0)	3 (4.4)	1 (1.3)	4 (1.7)
Erythromycin	1 (2.5)	0 (0.0)	0 (0.0)	1 (1.3)	2 (0.8)
Any *Reserve* antibiotics, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Any *Unclassified* antibiotics, n (%)	0 (0.0)	0 (0.0)	1 (1.5)	0 (0.0)	1 (0.4)
Norfloxacin	0 (0.0)	0 (0.0)	1 (1.5)	0 (0.0)	1 (0.4)

IQR (Q1–Q3).
*Only on the medical record monitored.
†Main diagnostic according to the medical record.
‡Significant (<0.05) comparison test (χ^2 distribution with correction if necessary or Kruskal-Wallis test).
IMCI, integrated management of childhood illness.

persistent illness. However, we believe that including the child's first consultation in our analysis helps illustrate compliance with IMCI recommendations by highlighting the antibiotics prescribed in response to the initial health event. Moreover, antibiotic stockouts at health centres or hospitals were not considered in our analyses. We cannot determine how these shortages may have influenced antibiotic prescriptions, as families can also obtain antibiotics from external sources, such as private pharmacies, if they are unavailable at the PHC level.

Moreover, at hospital level, our analysis focused only on severe cases transferred from PHCs to hospitals, limiting generalisability to all hospitalised patients. Despite these limitations, our study provides original estimates according to the AWaRe classification of antibiotic use for both outpatients and referred inpatients, at the country level, that are useful to inform national policies.

CONCLUSION

This study examined antibiotic prescribing practices for over 15 000 children, including neonates and young infants, attending PHCs in four West African countries. In a context of scarce frontline data and inefficient

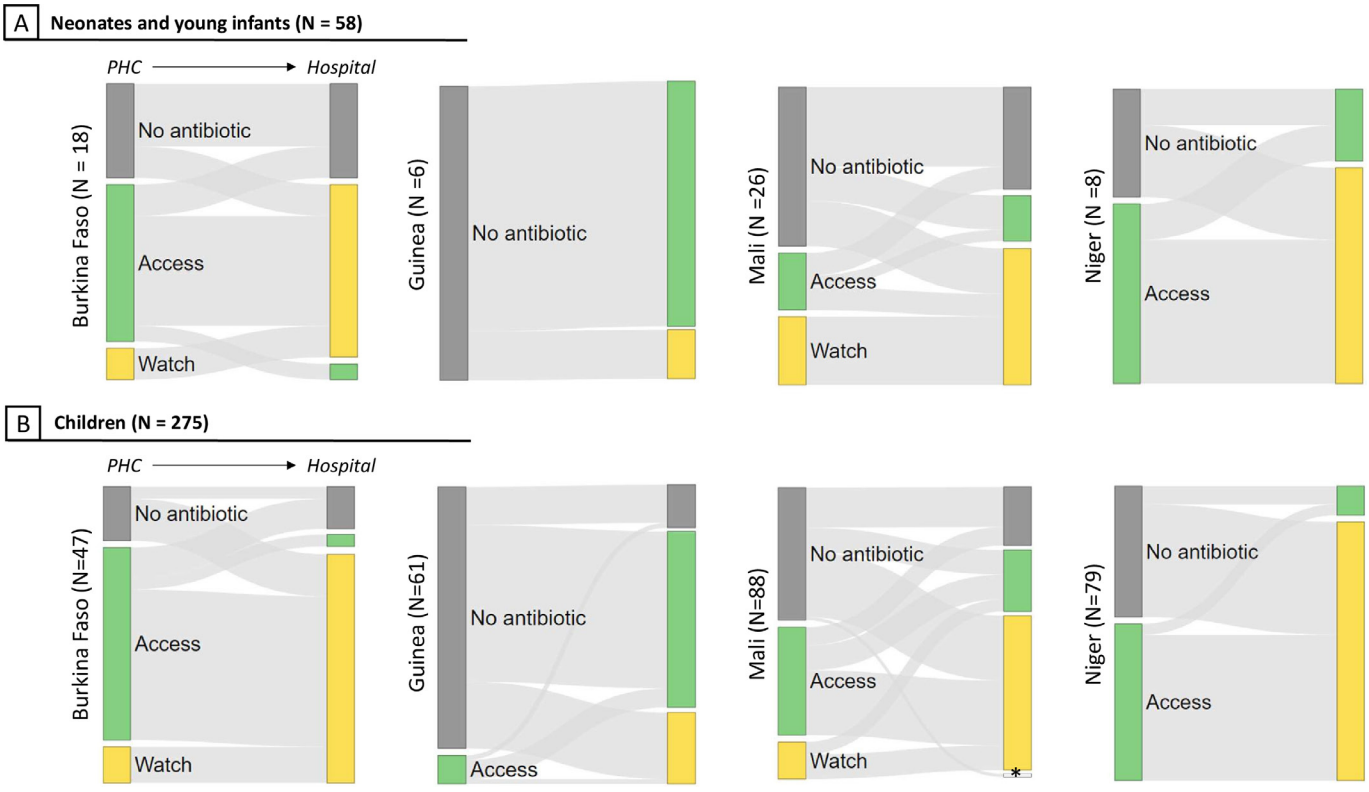

Figure 3 Sankey diagram, evolution of prescriptions according to the AWaRe classification for neonates and young infants (A, n=58) and children (B, n=275) transferred from the primary health centre (PHC) to the hospital, AIRE project 2021–2022. The colour code green, yellow, red respects the AWaRe classification, respectively *Access, Watch* and *Reserve*. In this diagram, the grey colour reflects the absence of antibiotics and the asterisk reflects *Unclassified* antibiotics.

surveillance systems, our results showed that despite the high proportion of antibiotics prescribed, most were in the *Access* group, meeting the WHO threshold. To preserve the effectiveness of antibiotics and reduce child mortality from resistant infections, ongoing monitoring of prescribing is crucial. Improving antimicrobial use involves promoting the use of primary *Access* antibiotics and limiting *Watch* antibiotics to their appropriate use.[28] To this end, a more detailed analysis assessing the appropriateness of antibiotic prescribing practices is underway to guide antibiotic stewardship in our specific context.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained from parent(s)/guardian(s).

Ethics approval The AIRE research protocol, the information notice (translated in vernacular languages), the written consent form and any other relevant document have been submitted to each national ethics committee, to the Inserm Institutional Evaluation Ethics Committee (IEEC) and to the WHO Ethics Review Committee (WHO-ERC). All the aforementioned ethical committees reviewed and approved the protocol and other key documents (Comité d'Ethique pour la Recherche en Santé (CERS), Burkina Faso n°2020-4-070; Comité National d'Ethique pour la Recherche en Santé (CNERS), Guinea n°169/CNERS/21; Comité National d'Éthique pour la Santé et les Sciences de la vie (CNESS), Mali n°127/MSDS-CNESS; Comité National d'Ethique pour la Recherche en Santé (CNERS) Niger n°67/2020/CNERS; Inserm IEEC n°20-720; WHO-ERC n° ERC.0003364). All ethical approval and the National Institute for Health and Care Excellence guidelines were attached in the study protocol proof section of the submission system. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. The datasets generated and analysed during the current study are not publicly available. Access to processed deidentified participant data will be made available to any third party after the publication of the main AIRE results stated in the Pan African Clinical Trial Registry Study statement (PACTR202206525204526, registered on 15 June 2022), on a motivated request (concept sheet), and after the written consent of the AIRE research coordinator (VL, valeriane.leroy@inserm.fr, Inserm U1295 Toulouse, France, orcid.org/0000-0003-3542-8616) obtained after the approval of the AIRE publication committee, if still active.

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REFERENCES

1 UNICEF, Organisation Mondiale de la Santé (OMS). Groupe de la banque mondiale, nations unies. levels and trends in child mortality. 2020. Available: https://www.unicef.org/reports/levels-and-trends-child-mortality-report-2020 [accessed 30 Mar 2023]
2 Mambula G, Nanjebe D, Munene A, *et al*. Practices and challenges related to antibiotic use in paediatric treatment in hospitals and health centres in Niger and Uganda: a mixed methods study. *Antimicrob Resist Infect Control* 2023;12:67.
3 Ouedraogo AS, Jean Pierre H, Bañuls AL, *et al*. Emergence and spread of antibiotic resistance in West Africa : contributing factors and threat assessment. *Med Sante Trop* 2017;27:147–54.
4 Willcox ML, Peersman W, Daou P, *et al*. Human resources for primary health care in sub-Saharan Africa: progress or stagnation? *Hum Resour Health* 2015;13:76.
5 World Health Organization. Antimicrobial resistance. 2020. Available: https://www.who.int/fr/news-room/fact-sheets/detail/antimicrobial-resistance [Accessed 28 Dec 2022].
6 Murray CJL, Ikuta KS, Sharara F. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *Lancet* 2022;399:629–55.
7 World Health Organization. WHO access, watch, reserve (AWaRe) classification of antibiotics for evaluation and monitoring of use. 2021.
8 Zanichelli V, Sharland M, Cappello B, *et al*. The *WHO AWaRe (Access, Watch, Reserve) antibiotic book* and prevention of antimicrobial resistance. *Bull World Health Org* 2023;101:290–6.
9 World Health Organization. The selection and use of essential medicines 2021: report of the 23rd WHO expert committee. 2021. Available: https://www.who.int/publications-detail-redirect/WHO-MHP-HPS-EML-2021.01 [Accessed 14 Feb 2024].
10 Hsia Y, Lee BR, Versporten A, *et al*. Use of the WHO Access, Watch, and Reserve classification to define patterns of hospital

antibiotic use (AWaRe): an analysis of paediatric survey data from 56 countries. *Lancet Glob Health* 2019;7:e861–71.
11 Darkwah TO, Afriyie DK, Sneddon J, *et al*. Assessment of prescribing patterns of antibiotics using National Treatment Guidelines and World Health Organization prescribing indicators at the Ghana Police Hospital: a pilot study. *Pan Afr Med J* 2021;39:222.
12 Wieters I, Johnstone S, Makiala-Mandanda S, *et al*. Reported antibiotic use among patients in the multicenter ANDEMIA infectious diseases surveillance study in sub-saharan Africa. *Antimicrob Resist Infect Control* 2024;13:9.
13 Knowles R, Sharland M, Hsia Y, *et al*. Measuring antibiotic availability and use in 20 low- and middle-income countries. *Bull World Health Organ* 2020;98:177–187C.
14 Hedible GB, Louart S, Neboua D, *et al*. Evaluation of the routine implementation of pulse oximeters into integrated management of childhood illness (IMCI) guidelines at primary health care level in West Africa: the AIRE mixed-methods research protocol. *BMC Health Serv Res* 2022;22:1579.
15 World Health Organization. Integrated management of childhood illness - chart booklet. 2014. Available: https://www.who.int/publications/m/item/integrated-management-of-childhood-illness [Accessed 04 Aug 2023].
16 Nair H, Nokes DJ, Gessner BD, *et al*. Global burden of acute lower respiratory infections due to respiratory syncytial virus in young children: a systematic review and meta-analysis. *Lancet* 2010;375:1545–55.
17 World Health Organization. Model list of essential medicines – 22nd list, 2021. Geneva: World Health Organization; 2021. Available: https://www.who.int/publications-detail-redirect/WHO-MHP-HPS-EML-2021.02 [accessed 28 Dec 2022]
18 Opeyemi Esther Omiwale. RPubs - how to create a sankey diagram. 2022. Available: https://rpubs.com/oomiwale1/926103 [Accessed 04 Aug 2023].
19 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.
20 Ahinkorah BO, Budu E, Seidu A-A, *et al*. Socio-economic and proximate determinants of under-five mortality in Guinea. *PLoS One* 2022;17:e0267700.
21 Liu L, Oza S, Hogan D, *et al*. Global, regional, and national causes of under-5 mortality in 2000–15: an updated systematic analysis with implications for the Sustainable Development Goals. *Lancet* 2016;388:3027–35.
22 Willcox ML, Kumbakumba E, Diallo D. Circumstances of child deaths in Mali and Uganda: a community-based confidential enquiry. *Lancet Glob Health* 2018;6:e691–702.
23 Adisa R, Orherhe OM, Fakeye TO. Evaluation of antibiotic prescriptions and use in under-five children in Ibadan, SouthWestern Nigeria. *Afr Health Sci* 2018;18:1189–201.
24 Sana B, Kaboré A, Hien H, *et al*. Study considering the use of medicines in children receiving free care. *Pan Afr Med J* 2019;34:194.
25 Atchessi N, Ridde V, Haddad S. Combining user fees exemption with training and supervision helps to maintain the quality of drug prescriptions in Burkina Faso. *Health Policy Plan* 2013;28:606–15.
26 Chukwu EE, Oladele DA, Enwuru CA, *et al*. Antimicrobial resistance awareness and antibiotic prescribing behavior among healthcare workers in Nigeria: a national survey. *BMC Infect Dis* 2021;21:22.
27 Dadgostar P. Antimicrobial Resistance: Implications and Costs. *Infect Drug Resist* 2019;12:3903–10.
28 World Health Organization. Antimicrobial stewardship programmes in health-care facilities in low- and middle-income countries: a WHO practical toolkit. 2019.71. Available: https://apps.who.int/iris/handle/10665/329404 [accessed 24 Feb 2023]
29 Auta A, Ogbonna BO, Adewuyi EO, *et al*. Prevalence and factors associated with the use of antibiotics in non-bloody diarrhoea in children under 5 years of age in sub-Saharan Africa. *Arch Dis Child* 2019;104:518–21.
30 Efunshile AM, Ezeanosike O, Nwangwu CC, *et al*. Apparent overuse of antibiotics in the management of watery diarrhoea in children in Abakaliki, Nigeria. *BMC Infect Dis* 2019;19:275.
31 Labi A-K, Obeng-Nkrumah N, Sunkwa-Mills G, *et al*. Antibiotic prescribing in paediatric inpatients in Ghana: a multi-centre point prevalence survey. *BMC Pediatr* 2018;18:391.
32 Ardillon A, Ramblière L, Kermorvant-Duchemin E, *et al*. Inappropriate antibiotic prescribing and its determinants among outpatient children in 3 low- and middle-income countries: A multicentric community-based cohort study. *PLoS Med* 2023;20:e1004211.
33 Padget M, Tamarelle J, Herindrainy P, *et al*. A community survey of antibiotic consumption among children in Madagascar and Senegal: the importance of healthcare access and care quality. *J Antimicrob Chemother* 2017;72:564–73.
34 Valia D, Ingelbeen B, Nassa GJW, *et al*. Antibiotic use by clinical presentation across all healthcare providers in rural Burkina Faso: a healthcare visit exit survey. *J Antimicrob Chemother* 2024;79:2534–42.