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Epidemiological investigation of a pertussis outbreak among schoolchildren in Burkina Faso, 2019

Abdoul Kader Ilboudo[1,2*], Assana Cissé[1], Madi Savadogo[1], Moussa Sana[3], Nina Gouba[1,7], Yaya Sourabié[4], Remis Nayaga[5], Dieudonné Tialla[1], Moumouni Zongo[6], Issaka Yaméogo[6] and Zékiba Tarnagda[1]

Abstract

Introduction Pertussis remains among the top ten most common fatal aetiologies of acute respiratory infections worldwide. This study reports findings from the first laboratory-confirmed pertussis outbreak among primary schoolchildren in Burkina Faso.

Methods A cross-sectional study was conducted during an outbreak in the districts of Sabou and Sapouy following an alert from the national surveillance system. Suspected pertussis cases were investigated, with oropharyngeal/nasopharyngeal samples and sociodemographic and clinical data collected. Samples were analyzed using multiplex rRT-PCR and the FTD-33 Kit (Fast Track Diagnostics, Luxembourg). Descriptive statistics were conducted, and factors associated with pertussis positive cases were assessed using the Chi-square test and univariate logistic regression.

Results A total of 92 suspected pertussis cases with no fatal outcomes were identified among the schoolchildren in two different clusters during the investigation. The overall attack rate of the two clusters were 18.4% (92/499). Fifteen (16.6%) cases were biologically confirmed. The average age was 8.9 years, and 62% (57/92) were female. Rhinovirus (17.3%) and adenovirus (7.6%) were the most prevalent respiratory viruses detected among the suspected cases. *Streptococcus pneumoniae* (58.7%) and *Haemophilus influenzae* (56.5%) were the most common bacteria detected. A significant association was found between sore throat and confirmed cases (OR = 3.5, CI 95% [1.01–11.9]).

Conclusion Despite extensive vaccination in several countries, pertussis can still cause outbreaks. Preventive measures, such as booster vaccinations for children outside the Expanded Program of Immunization (EPI) target age, are necessary.

Keywords Pertussis, Outbreak, Investigation, Schoolchildren, Epidemiology, Whooping Cough

*Correspondence:
Abdoul Kader Ilboudo
ilboudokader@yahoo.fr
[1] Laboratoire National de Référence-Grippes (LNR-G), Institut de Recherche en Sciences de la Santé (IRSS), Ouagadougou, Burkina Faso
[2] International Livestock Research Institute, Animal and Human Health Program, Nairobi, Kenya
[3] Direction Régionale de la Santé et de l'Hygiène Publique du Centre-Ouest, Ministère de la Santé et de l'Hygiène Publique, Koudougou, Burkina Faso
[4] District Sanitaire de Sabou, Direction Régionale de la Santé et de l'Hygiène Publique du Centre-Ouest, Ministère de la Santé et de l'Hygiène Publique, Sabou, Burkina Faso
[5] District Sanitaire de Sapouy, Direction Régionale de la Santé et de l'Hygiène Publique du Centre-Ouest, Ministère de la Santé et de l'Hygiène Publique, Sapouy, Burkina Faso
[6] Direction de la Protection de la Santé de la Population, Ministère de la Santé et de l'Hygiène Publique, Ouagadougou, Burkina Faso
[7] Université Nazi-Boni, Bobo-Dioulasso, Burkina Faso

Introduction

Pertussis, or whooping cough, is an endemic acute respiratory infection mainly caused by *Bordetella pertussis*. It is highly contagious and can spread rapidly from person to person through contact with airborne droplets. The burden of pertussis remains high among children in several low- and middle-income countries (LMICs) despite good vaccination coverage [1, 2]. In the previous two decades, there has been an increase in pertussis cases. The resurgence of the disease is linked to several factors. These include the waning immunity after acellular vaccination, the antigenic variability of *Bordetella pertussis* strains compared to vaccine strains, and improvements in diagnostic tools for whooping cough [3, 4]. In addition, the real burden of pertussis is largely underestimated since adolescents and adults tend to experience a mild clinical form of the disease similar to the common cough [1].

Globally, an estimated 24.1 million pertussis cases and 160,700 deaths occurred in 2014 among children under five years of age, including 7.8 million cases and 92,500 deaths in Africa [5]. Recurrent outbreaks have occurred in Sub-Saharan Africa in the last two decades. Notable outbreaks were described in Nigeria in 2015, 2018, and 2019 [6, 7]; in Ethiopia in 2015, 2017, 2018, and 2019 [8–13]; in Ghana in 2016 [14]; and Liberia in 2019 [15]. The surveillance of pertussis in most LMICs is problematic due to the weakness of the surveillance system, the difficulties of accessing an etiological diagnosis, and the poor clinical recognition of the disease, especially among adults [1]. In Burkina Faso, pertussis is a target disease of the Expanded Program of Immunization (EPI), which is under surveillance and mandatory reporting. The epidemiology of the disease is not well described among a population with relatively good vaccine coverage combined with DTC-HBV-HIB [16, 17]. To the best of our knowledge, no outbreak involving laboratory-confirmed cases of pertussis has been previously described in Burkina Faso. This study aimed to investigate an outbreak of pertussis in two health districts in 2019 and to explore coinfection with other viral and bacterial respiratory tract pathogens.

Context

The outbreak occurred in two different villages in the administrative region of Centre-Ouest. During epidemiological week 16 of 2019, the Sabou Health District Surveillance Office reported an unusual respiratory event in a public primary school in the village of Namanegma. The event was characterized by episodes of coughing attacks, vomiting, and subconjunctival haemorrhage in clusters of schoolchildren. The index patient in the village of Namanegma was a 13-year-old girl who presented with symptoms of acute respiratory infection (ARI) on April 7, 2019 (Epidemiological week 13), with coughing attacks, fever, and vomiting. A case of pneumonia was suspected after clinical investigation. According to the parents interviewed, she was not fully vaccinated; however, no written evidence, such as a vaccination card, was available to confirm this. Other similar cases occurred after this first case in the same primary school and another neighbouring village named Sala within the health district of Sapouy. Response measures were quickly implemented by the teams of the health districts of Sabou and Sapouy. The main actions included raising awareness in schools and villages, administering erythromycin-based antibiotics, and vaccinating suspected and contact cases.

Methods

Study area and population

The health districts of Sabou and Sapouy (Fig. 1) covered a total population of 115,482 and 270,578 people, respectively. The villages of Namanegma and Sala hosted 2,352 and 11,745 inhabitants, respectively. Among the two primary schools, 352 and 147 schoolchildren were registered, respectively. All schoolchildren and teachers from the two primary schools who presented with clinical signs of pertussis between March 1st and 25th, April 2019, were included in the study. Other children from the two villages who were in close contact with a suspected case were also included. The surveillance staff of the health districts and the community health workers conducted active research on the patients.

Fig. 1 Situation map of the districts and outbreaks sites

Case definition

We used three case definitions as follows:

- *A suspected case* was defined as any person living in the outbreak area who presented with a cough illness of any duration, with or without paroxysm, and without a more likely diagnosis during the period of the outbreak.
- An *epidemiologically confirmed case* was defined as a person with a cough belonging to a classroom where a case was biologically confirmed [18].
- A *laboratory-confirmed case* met the suspected case definition with laboratory confirmation by rRT-PCR.

Study design

A cross-sectional study was conducted among school children and staff from the primary schools of Namanegma and Sala from March 1st to April 25th, 2019.

Data and sample collection procedures

A data collection form was administered to all suspected patients to collect sociodemographic and clinical data. The demographic data collected included age and sex, while the clinical data comprised the presence or history of fever, sampling delay, sore throat, diarrhea, posttussive vomiting, subconjunctival hemorrhage, and vaccination status for pertussis. Oropharyngeal (OP) and/or nasopharyngeal (NP) swabs were taken from each child and placed in a viral transport medium (Copan Diagnostics®). Immediately after collection, the specimens were transported to the National Influenza Reference Laboratory (NIRL) in cold packs. Upon arrival at the national reference laboratory, the samples were aliquoted into three aliquots, one of which was used for immediate analysis. The other aliquots were stored at −80 °C for future additional investigations.

Laboratory testing procedures

The OP and/or NP samples collected from the field were analysed in NIRL. The samples were individually analysed for respiratory pathogens using eight real-time reverse transcriptase polymerase chain reactions (rRT-PCRs) with an FTD-33 test kit (Fast Track Diagnostics, Luxembourg). The kit included 33 pathogens to be screened: 21 virus types and subtypes (influenza A, influenza A subtype A (H1N1) pdm09, influenza B, and influenza C; parainfluenza viruses 1, 2, 3 and 4; coronaviruses NL63, 229E, OC43 and HKU1; human metapneumoviruses A and B; rhinoviruses; respiratory syncytial viruses A and B; adenoviruses; enteroviruses; parechoviruses; bocaviruses); 11 bacterial types (*Mycoplasma pneumoniae*; *Chlamydia pneumoniae*; *Streptococcus pneumoniae; Haemophilus influenzae; Haemophilus influenzae type B; Staphylococcus aureus; Moraxella catarrhalis; Bordetella* species (excluding *Bordetella parapertussis*); *Klebsiella pneumoniae*; *Legionella* species; *Salmonella* species; and one fungal type (*Pneumocystis jirovecii*).

Statistical analysis

The chi-square test (χ^2) was used to compare categorical variables, and Student's t-test or the Mann–Whitney test was used for the means. Univariate logistic regression was performed to evaluate associations between the dependent variable (biologically confirmed cases) and independent variables. Crude odds ratios (ORs) and 95% confidence intervals (95% CIs) were calculated. Statistical analysis was performed using STATA® version 17.0 (StataCorp).

Ethics approval and consent to participate

In Burkina Faso, outbreak investigations are conducted by the Ministry of Health through the national surveillance system for public health purposes. The Ministry of Health implements the surveillance system as a public health initiative following Law No. 23/94/ADP on the public health code and ARRET No 2023–83/MSHP/CAB/PM/MSHP, which outlines the organization and responsibilities of disease surveillance services in Burkina Faso [19]. Consequently, the national ethics committee (Comité d'éthique pour la recherche en Santé au Burkina Faso) determined that ethics approval was not required to carry out the investigation and publication. However, children under the age of 16 were included only after obtaining informed oral consent from their parents or legal guardians, in accordance with the Helsinki Declaration [20]. Consent to participate was obtained directly from children aged 16 years old and over. Additionally, written informed consent was obtained from the parent or legal guardian to identify images of all participants under the age of 18. This consent included permission to publish photographs.

Results

Demographic and clinical characteristics of the participants

A total of 92 suspected pertussis cases were identified during the investigation, with 59.8% originated from the village of Sala. In addition, 62% of the patients were female, and the average age of the children was 8.9 years (ranging from 1 to 17 years old). The average sampling delay (duration between the beginning of symptoms and sample collection) was 10 days (ranging from 0 to 34 days). The main clinical symptoms presented included cough (100%), sore throat (48.9%), and post-tussive

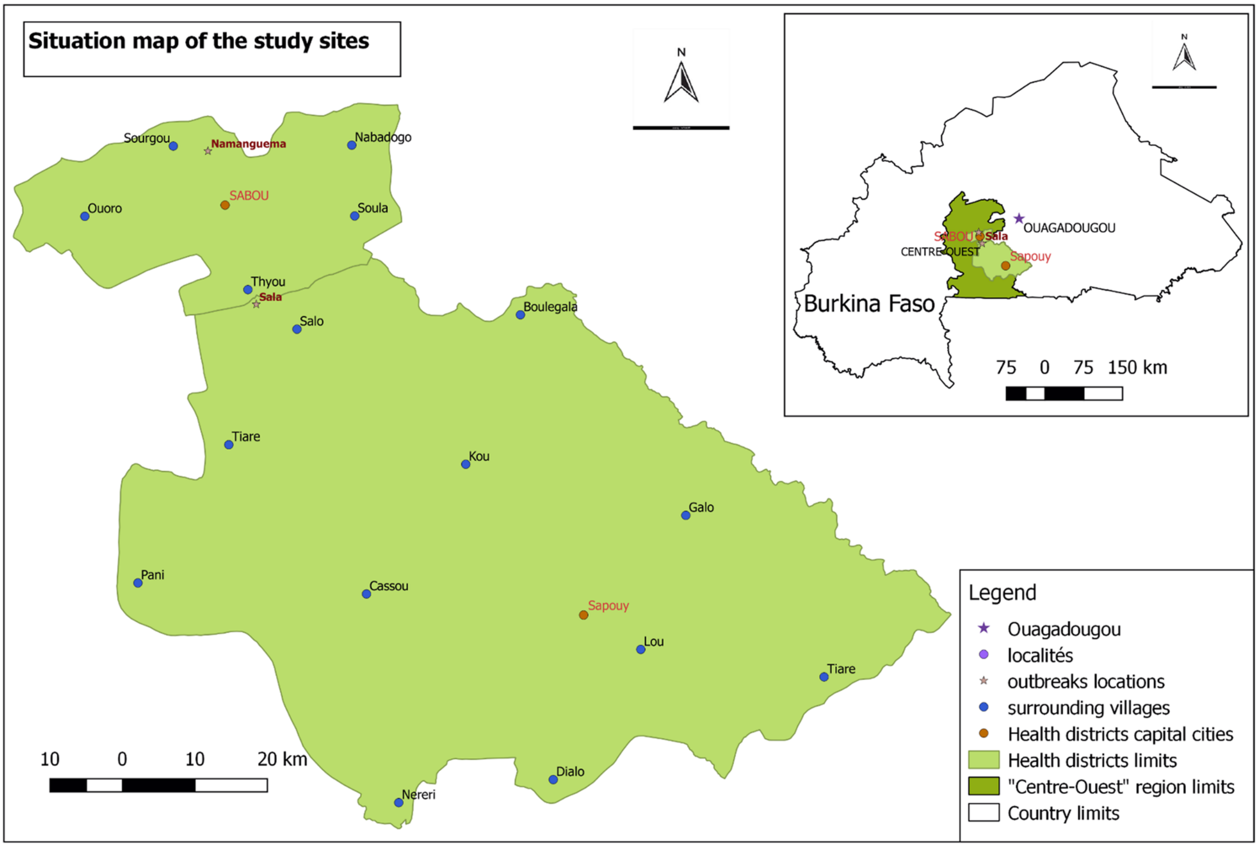

Fig. 2 An eight years old school boy with suspected pertussis presenting with subconjunctival hemorrhage

vomiting (33.7%). A total of 14.1% of the cases experienced subconjunctival hemorrhage (Fig. 2). The whopping cough vaccination status was unknown (no written proof) for most of the suspected cases (71.7%) (Table 1). A significant association was found between the presence of a sore throat and biologically confirmed cases [OR = 3.5 CI 95% (1.01–11.9)] (Table 2).

Epidemic curve, attack rate, and vaccination coverage

The epidemic curve indicates that the first case occurred on March 15th, 2019 (EpiWeek 9), in the village of Sala. The number of cases then increased gradually in this village, reaching a peak of 23 in epidemiological week 14. For Namanegma primary school, the first case occurred in epidemiological week 13, with a peak of 15 cases in epidemiological week 15. The number of cases decreased and finally stopped at week 18 (Fig. 3). The two outbreak clusters were limited to the two primary schools in the two villages. Considering the total number of pupils and the population of the two villages, the respective attack rates were estimated to be 17.6% for Namanegma primary school and 37.4% for the primary school of Sala "A". At the village scale, the attack rates were 15.7 and 4.7 per 1000 inhabitants, respectively. The combined vaccination coverage for the two villages of interest for the pentavalent 3 vaccine (DTC-HBV-HIB) was estimated at 96.1% in 2019 [21].

Pathogens identified

A total of 15/92 (16.6%) biologically confirmed cases (Bordetella *spp.*) were detected among the suspected samples collected. From the collected samples, 32 other viral and bacterial pathogens that are common etiologies of acute respiratory infections were tested. Viral pathogens were detected in 26.1% of the total samples, while 84.8% of cases involved bacterial pathogens in their samples. With a prevalence of 17.3% and 7.6%, rhinovirus and adenovirus, respectively, were the most common viral pathogens detected. *Streptococcus pneumoniae* (58.7%) and *Haemophilus influenzae* (56.5%) were the most frequently detected bacterial pathogens (Fig. 4).

Discussion

This study investigated a pertussis outbreak in two separate primary schools in neighbouring villages during the same period in an area with relatively good vaccination

Table 1 Characteristics of patients suspected of having pertussis

Variables	*Pertussis* suspected cases		Total N (%)
	Primary school of Namanegma n (%)	Primary school of Sala "A" n (%)	
Age			
0–6 years	1 (2.70)	16 (29.1)	17 (18.4)
7–10 years	22 (59.5)	27 (49.1)	49 (53.3)
11–17 years	14 (37.8)	12 (21.8)	26 (28.3)
Sampling delay			
0–4 days	11 (29.7)	0 (0)	11 (12.0)
5–15 days	22 (59.5)	37 (67.3)	59 (64.1)
16–34 days	4 (10.8)	18 (32.7)	22 (23.9)
Sex			
Male	12 (32.4)	23 (41.8)	35 (38.0)
Female	25 (67.6)	32 (58.2)	57 (62.0)
History of fever			
Yes	5 (13.5)	20 (36.4)	25 (27.2)
No	32 (86.5)	35 (63.6)	67 (72.8)
Sore throat			
Yes	31 (83.8)	14 (25.4)	45 (48.9)
No	6 (16.2)	41 (74.6)	47 (51.1)
Diarrhea			
Yes	1 (2.7)	0 (0)	1 (1.1)
No	36 (93.3)	54 (100)	90 (98.9)
Posttussive vomiting			
Yes	14 (37.8)	17 (30.9)	31 (33.7)
No	23 (62.2)	38 (69.1)	61 (66.3)
Subconjunctival hemorrhage			
Yes			13 (14.1)
No			79 (85.9)
Vaccination status			
Not vaccinated	2(5.4)	7(12.73)	9(9.8)
Vaccinated	0(0)	17(30.9)	17(18.5)
Unknown	35(94.6)	31(56.4)	66(71.7)

Table 2 Factors associated with biologically confirmed pertussis patients

Variables	*Pertussis* biological confirmed cases		p-value
	Number of biological positive (%)	Crude OR (95% CI)	
Age			
0–6 years	3 (20)	1 (base)	–
7–10 years	7 (46.7)	0.7 (0.2–3.4)	0.74
11–17 years	5 (33.3)	1.1 (0.2–5.4)	0.869
Sampling delay			
0–4 days	2 (13.3)	2.2 (0.27–18.36)	0.459
5–15 days	11 (73.4)	2.3 (0.46–11.29)	0.308
16–34 days	2 (13.3)	1 (base)	–
Sex			
Male	5 (33.3)	1 (base)	
Female	10 (66.7)	1.3 (0.4–4.1)	0.682
History of fever			
Yes	2 (13.3)	0.4 (0.07–1.7)	0.203
No	13 (86.7)	1 (base)	–
Sore throat			
Yes	11 (73.3)	3.5 (1.01–11.9)	0.047*
No	4 (26.7)	1 (base)	–
Diarrhea			
Yes	0 (0)		
No	15 (100)	1 (base)	
Posttussive vomiting			
Yes	6 (40.0)	1.4 (0.4–4.3)	0.56
No	9 (60.0)	1 (base)	
Vaccination status			
Not vaccinated	2 (13.3)	1 (Base)	
Vaccinated	1 (6.7)	0.2 (0.02–2.8)	0.244
Unknown	12 (80.0)	0.8 (0.1–4.2)	0.771

* $P < 0.05$

coverage. This study aimed to describe and analyse the, pertussis outbreak's clinical, epidemiological and biological aspects. The presence of *Bordetella spp.* was also biologically confirmed for the first time in suspected cases in the country.

- Sociodemographic and clinical characteristics

The outbreak occurred in the primary schools of two neighbouring villages. Schools are known as a preferred location for outbreaks of pertussis [18]. The well-known vulnerability of children to infection and the close contact between pupils in classrooms may favour the rapid spread of the disease. In addition, children and adolescents constitute a high-risk category for the onset and spread of pertussis even if they have received immunization in their first year of life [1]. This is related to a decline in immunity from acellular vaccination, widely administered in developing countries through expanded national immunization programmes. The occurrence of pertussis epidemics in schools was reported in previous studies in France [22], China [23, 24], England [25] and the United States of America [26]. Despite high vaccination coverage in children and adults in most countries, the persistence of the infection may be due to decreased immunity in older children and adults [1]. This decrease in immunity among adults creates a pool of individuals who can serve as a reservoir for the disease [27].

Fifty-seven (57%) of the suspected patients were female. According to previous studies, females seem to be more affected by pertussis than males. Indeed, the risk of pertussis increased by 1.8 times in females during the

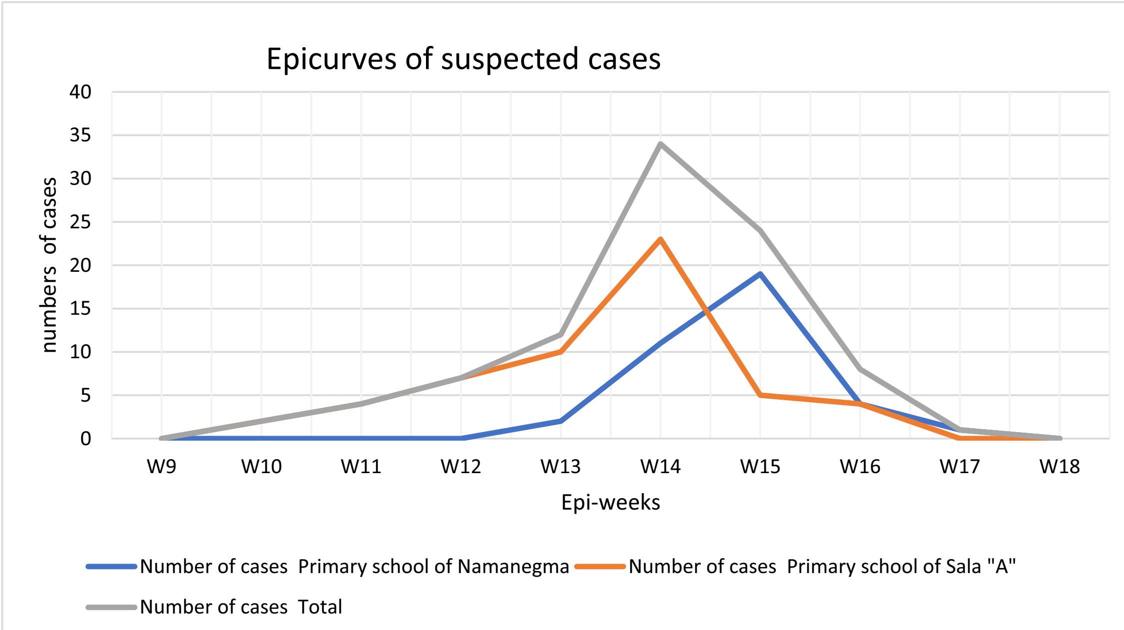

Fig. 3 Epidemiological curve of the whooping cough suspected cases in the primary schools of Namanegma and Sala "A"

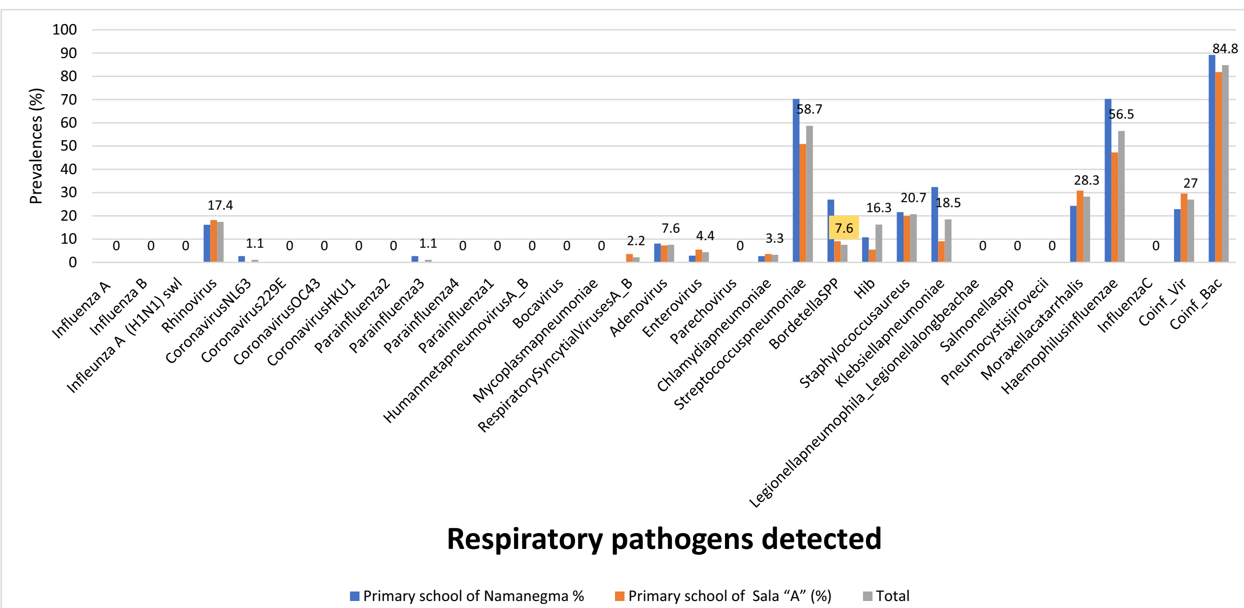

Fig. 4 Prevalence of *Bordetella spp*. and other pathogens among the suspected cases. Hib: *Haemophilus influenzae* type b, Coinf_vir: viral coinfection, Coinf_Bac: bacterial coinfection

outbreak described by Berger et al. in France [18]. Similar results were reported by Brennan et al. in the United States of America [28] and a case–control study conducted in Ethiopia by Almaw et al., in 2017. Physiological differences between females and males regarding the immune response to infection can explain this difference in morbidity between the sexes. The production of lymphocytes seems to be lower in females than in males in cases of infectious diseases such as whooping cough, leading to excess morbidity and mortality in this group

[29, 30]. However, our study did not find a statistically significant association between sex and biologically confirmed cases.

The classic sign of pertussis was the case definition used to identify suspected pertussis cases. Cough was present in all suspected cases, while fever or a history of fever was reported in only 27.2% of suspected cases. However, we noted the presence of certain characteristic signs, such as postcough vomiting (33.7%) and subconjunctival hemorrhage (14.1%). The World Health Organization (WHO) case definition is the one most commonly used in investigations and includes classic signs such as coughing with paroxysm and postcoughing vomiting [1, 31]. These symptoms were predominant in suspected cases from the 2019 pertussis epidemic in Nigeria, with postcough vomiting occurring in 78.8% of cases and paroxysmal cough in 40.4% of cases. Similar patterns were described in the pertussis epidemic in Mali in 2016 [32], Niger in 2019 [33] and the Central African Republic [34].

Attack rate and epi-curve

The calculated in-school attack rate was high in our investigation. The transmission of pertussis particularly increases in crowded environments such as the typical primary school classrooms found throughout the country. Whooping cough is transmitted mainly through airway droplets spread during a cough from an infected person to a non-infected person [2]. A high attack rate was detected in a similar pertussis outbreak that occurred in a military schools in France [18], Nigeria [35], and Ethiopia [13]. The duration of the epidemic in our study was approximately eight weeks. However, the analysis also highlighted the long delay between the occurrence of the first cases and the start of the investigation by the local authorities in charge of epidemiological surveillance. The maximum delay between the onset of symptoms and the investigation was 34 days in our series. This highlights the weaknesses of the alert system in rural areas and the poor implementation of community-based surveillance. In addition, the response system at the central level often faces logistical difficulties. In our study, the peak number of cases occurred 6 and 7 weeks after the beginning of the first and second clusters, respectively.

Vaccination coverage

The relatively high vaccination coverage appears to be similar to that of the rest of the country. Similar trends were reported in recent outbreaks in Nigeria in 2015 [7], Ethiopia in 2017 [12], and Mali in 2016 [32]. The occurrence of pertussis outbreaks in populations with good vaccination coverage is well described. This was the case in Ethiopia in the Northwest Region [8] and in the epidemic that occurred in a military school in France in 2010 [18]. These outbreaks could be related to a decrease in protection conferred by vaccination, especially in adolescence and adulthood. Additionally, the antigenic variability of *Bordetella pertussis* in the face of widely administered acellular vaccinations may also play a role. Among the cases in our study, the vaccination status was difficult to document, resulting in a large number of patients with an unknown vaccination status. This difficulty arises from the weak traceability system of the vaccination, which relies primarily on the vaccination booklet issued to the parents [16]. The administration of a preschool booster vaccine (between 3 and 5 years old) as recommended is still not yet implemented as a preventive action [2].

Detection of other pathogens

Our study also explored viral and bacterial coinfections in suspected pertussis patients. Rhinovirus and adenovirus were the most frequently detected viruses in suspected cases. Both pathogens were described as the most frequent viral etiological agents of mild upper respiratory tract infections in children [36]. Although rhinovirus is often reported as an etiological pathogen of acute respiratory infections, it is also frequently found in asymptomatic patients [37, 38]. Viral coinfections with pertussis were described in hospital-based studies in Peru [39], China [40], and Turkey [41]. In addition to rhinovirus and adenovirus, respiratory syncytial virus (RSV) and parainfluenza virus were the most prevalent in these studies. The differences in terms of the study subjects included in these studies (severely hospitalized patients) may increase the chances of detecting more severe etiological pathogens of ARIs, such as RSV. A study investigating viral coinfection during a pertussis outbreak in Australia reported a strong association between coinfection and case severity [42].

The most prevalent bacterial pathogens in suspected pertussis patients were *Streptococcus pneumoniae* and *Haemophilus influenzae*. These two bacteria are commonly found in the respiratory tract both in carriage studies, and among symptomatic patients. This asymptomatic carriage seems to be more important in developing countries [43]. It cannot be excluded that the significant presence of these pathogens in the respiratory tract of suspected pertussis patients is simply due to asymptomatic carriage prior to infection with *Bordetella pertussis*. However, several studies have shown that *Streptococcus pneumoniae* is a major cause of acute respiratory infection with severe and fatal outcomes [37, 44].

Study limitations

Our study involved several limitations. Regarding the small number of biologically confirmed cases, we were limited to univariable analysis and could not perform multivariable modeling to control for potential confounding factors. This limitation restricts our ability to account for the influence of variables such as age, sex, and vaccination status on the outcomes. Additionally, the vaccination status of many patients was not available, leading to biases in the univariable analysis. The delay between the occurrence of initial cases and the start of the investigation highlights weaknesses in the local alert and response system. This delay prevents capturing more biologically confirmed cases. Future studies should use larger sample sizes, comprehensive data collection, or case–control designs to better understand pertussis outbreak dynamics and address current limitations.

Conclusion

The first objective of this study was to describe findings from the first laboratory-confirmed pertussis outbreak in Burkina Faso. This study also highlighted the increasing role of pertussis as an etiology of ARIs in Burkina Faso. Many efforts have been made during recent decades to ensure good pertussis vaccination coverage among children through the Expanded Program of Immunization. However, the occurrence of pertussis outbreaks signals the need to reinforce the EPI in rural areas and implement new strategies to prevent the waning of immunity after vaccination. This study also revealed the role of multiplex rRT-PCR as a key tool for case confirmation and detecting other pathogens. This is an opportunity to increase the promptness and specificity of the response to clusters of acute respiratory infection by early biological confirmation of the cases. Given these risk factors, greater attention should be paid to administering the pertussis vaccine to children at preschool age (between 3 and 5 years old).

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Author contributions

Conceptualization and study design: AKI, ZT, NG; data analysis: AKI; Laboratory analysis: AC, ZT; Investigation, data collection, and management: AKI, AC,MS,YS,RN, MZ,IY,; writing—original draft: AKI; Manuscript review and editing: AKI, AC,MS, MS,NG,DT,YS,RN, MZ,IY, ZT. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

See 'Ethics approval and consent to participate' in the section methodology of the manuscript.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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