Ten-year analysis of the epidemiologic characteristics of whooping cough in Kyrgyzstan

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Abstract

Background: Although whooping cough is vaccine-preventable, its incidence is increasing globally, including in Kyrgyzstan.

Aim: To investigate the epidemiologic characteristics of whooping cough among children in Bishkek, Kyrgyzstan.

Methods: We collected and analysed data on 802 children aged 0–14 years, clinically diagnosed with whooping cough, and admitted at the Republican Clinical Infectious Diseases Hospital, Bishkek, Kyrgyzstan, from February 2014 to February 2024.

Results: Polymerase chain reaction test of the respiratory samples confirmed all the children positive for *Bordetella pertussis*. There was no case of *Bordetella parapertussis*. We observed a distinct cyclical pattern of the incidence of whooping cough during the 10-year period, with a significant peak in 2018. Between 2021 and 2023, the majority (60.0%) of cases occurred among infants <1 year old. Among the children, 58.7% were not vaccinated, while 41.3% had incomplete diphtheria, tetanus and polio vaccination. Severe cases were common among infants with comorbidities such as anaemia and hypoxia.

Conclusions: Our findings show that whooping cough incidence is increasing among children in Bishkek. There is therefore a need to strengthen prevention efforts, including public awareness and education, childhood immunisation and maternal vaccination, and intensify detection, diagnosis and isolation to reduce transmission.

Keywords: pertussis, whooping cough, vaccination, immunisation, children, infant, Kyrgyzstan

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Introduction

Pertussis (whooping cough) is a highly contagious acute respiratory infection that causes severe illness in children and persistent cough in adolescents and adults. It is most commonly caused by *Bordetella pertussis* or *Bordetella parapertussis* and spreads through airborne droplets (*1*,*2*). Whooping cough remains a serious health concern globally and a significant cause of childhood mortality, especially in low-resource settings (*2*). It affects millions annually, causing high mortality among unvaccinated infants and children (*3*–*5*). Global incidence remains high and case fatality rate among infants may reach 4.0% in low-income countries (*6*,*7*).

Pertussis spreads through droplets and presents with progressive cough, inspiratory whoop and post-tussive vomiting. It remains contagious during the catarrhal phase and for up to 3 weeks after the onset of paroxysmal cough, indicating the need for strict isolation (*1*). In infants, it may first present with apnoea or cyanosis (*8*). Mothers are often identified as the source of infection in newborns who have not completed their vaccination (*1*). Early antibiotics intake can reduce disease progression (*6*).

Laboratory confirmation is typically achieved through nasopharyngeal culture or polymerase chain reaction (PCR) (*1*). The Pertussis Severity Score (PSS) helps assess clinical severity by combining objective and clinical parameters. The maximum score is 15 and it accounts for the duration of hospitalisation, oxygen need and complications (*9*,*10*).

In Kyrgyzstan, diphtheria, tetanus and polio (DTP) immunisation is scheduled for early infancy, with a booster at 2 years (*27*). However, despite routine vaccination, the United Stated Centres for Diseases Control and Prevention (CDC) has reported an increase in pertussis cases among vaccinated and unvaccinated individuals (attributed to waning immunity) (*13*). Re-emergence has been observed globally. Recent reports from Russia and China indicate increasing incidence and decreasing immunity (*15-18*). A cross-sectional study in Islamic Republic of Iran found significant waning immunity among children and adolescents, reinforcing the need for booster doses (*28*). In Kyrgyzstan, the incidence has increased sharply, up to 9-fold since 2021 (*19*).

This study was conducted to investigate the increasing pertussis burden in Bishkek, Kyrgyzstan.

Materials and methods

This descriptive, observational study investigated trends and factors contributing to the increasing pertussis incidence in Bishkek, Kyrgyzstan. Data for February 2014 to February 2024 were retrospectively collected from the medical records of 802 confirmed whooping cough cases at Republican Clinical Infectious Diseases Hospital. Inclusion was based on predefined criteria and consent was obtained from the parents or guardians of the children. Disease progression and hospital courses during treatment were documented. Whooping cough diagnosis was confirmed using PCR or bacteriological culture.

Inclusion and exclusion criteria

Children aged 0–14 years were included in the study. Age groupings were based on clinical relevance and observed disease severity patterns. Infants <1 year represented a high-risk group if they had incomplete primary DTP vaccination. Vaccination status was not used as a criterion for inclusion or exclusion. However, it was recorded for each patient from their medical records and later analysed to evaluate its relationship with disease incidence and severity. Children with similar symptom presentations and children with bronchial obstruction syndrome were excluded.

Statistical analysis

We performed descriptive statistical analysis using SPSS version 17 for Windows. The annual whooping cough case trends were calculated by dividing the number of confirmed hospital admissions due to pertussis by the total paediatric admissions at the Republican Clinical Infectious Diseases Hospital for each year. This approach helped identify temporal patterns and fluctuations in disease frequency over the 10-year study period.

Results

PCR test confirmed all the children positive for *Bordetella pertussis*. No case of *Bordetella parapertussis* was detected. We observed a distinct cyclical pattern in the incidence of whooping cough, with notable peaks at 2–3-year intervals (Figure 1). A significant peak occurred in 2018, with the number of cases considerably higher than 2015 and 2017. This peak was followed by a sharp decrease in 2019 and 2020, during which incidence remained relatively low. However, there was a resurgence in reported cases in 2023, with 437 cases registered. As of February 2024, 312 new cases had been reported, 8 times higher than the entire 2023.

Further analysis for 2021 and 2023 showed that the majority of cases (60.0%) occurred among infants <1 year old, and 40.0% among children aged 1–14 years. Among infants, the highest incidence was seen among those aged 0–3 months, who had not received the primary DTP vaccine. The majority (70.7%) of children aged >1 year were 1–3 years old and 29.3% were 4–14 years old. There were more females (57%) than males (43%) (Table 1). Of the children, 58.7% were unvaccinated and 41.3% had incomplete DTP vaccination, which likely contributed to the occurrence and severity of the disease.

Vaccination status by age group

The majority (72.0%) of infants aged <1 year were unvaccinated, 62.0% of children aged 1–14 years had

Figure 1 Annual number of whooping cough cases in Bishkek, Kyrgyzstan, 2014–2024

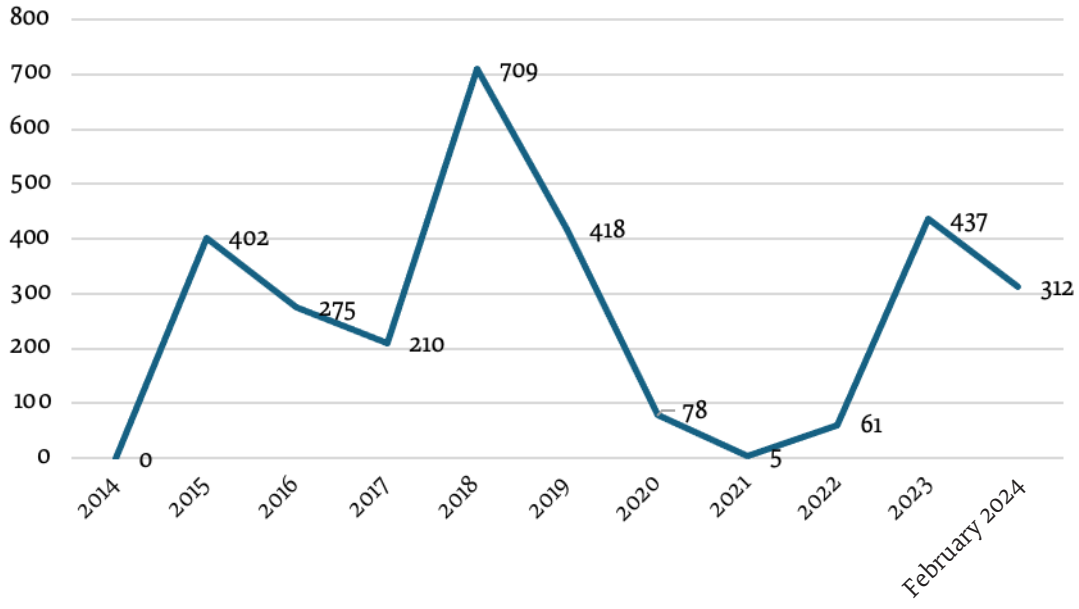

Table 1 Sociodemographic and epidemiologic characteristics of the study participants, Bishkek, Kyrgyzstan, 2014–2024

Characteristics	Study population (*n* = 802)	
	n	%
Gender		
Male	345	43.0
Female	457	57.0
Age at admission (years)		
<1	485	60.0
1–14	318	40.0
Vaccination status		
Unvaccinated	470	58.7
Incomplete	331	41.3
Complete	0	0
Associated factors		
Mother vaccinated during pregnancy	57	7.0
Family members with respiratory issues	457	57.0
Associated pathologies		
Anaemia	401	50.0
Hypoxia	200	25.0
Initial diagnosis (at admission)		
Whooping cough	449	56.0
Acute viral respiratory infection	160	20.0
Measles	188	23.5
Day of admission after onset of cough		
1st day	0	0
3rd day	115	14.3
5th day	229	28.6
7th day	344	42.9
9th day	115	14.3
Severity of disease (based on PSS score)		
Severe	476	59.4
Moderate	326	40.6
Mild	0	0
Complications in infants		
Pneumonia	402/485	83.0
Pertussis encephalopathy	83/485	17.0
Complications in school-age children		
Scleral haemorrhages	32/318	10.0
Otitis media	16/318	5.0
Pulmonary atelectasis	13/318	4.0
Children without complications	257/318	81.0
Length of hospital stay (Mean SD)	7± 2.3	

incomplete DTP vaccination, and none had received a booster dose. The incomplete immunisation in both age groups appears to be a significant contributor to disease incidence and severity.

The majority (57.0%) of infections were transmitted through adults who had prolonged cough symptoms, while in 43.0% of cases the source of infection remained unidentified. Several factors influencing the severity of the disease were identified. Notably, 50.0% of the children had anaemia and 25.0% of those aged <1 year presented with hypoxia.

Regarding the initial diagnosis, 56.5% of the patients were referred to the hospital with a confirmed diagnosis of whooping cough, 20.0% were initially diagnosed with acute respiratory viral infection (ARVI) and 23.5% were mistakenly diagnosed with measles before developing whooping cough (nosocomial infection).

No child was admitted on the first day of cough onset, but the number of hospital admissions significantly increased by the third day. The highest (42.9%) hospital admission was on the seventh day of illness, suggesting that many patients had developed severe symptoms by this time.

In terms of disease severity, 59.4% of the children presented with severe forms of whooping cough and 40.6% had moderate forms. The common complications in infants were pneumonia (83.0%) and *Pertussis encephalopathy* (17.0%). Among the school-aged children, 81.0% presented without complications; however, 10.0% developed scleral haemorrhage, 5.0% suffered from otitis media and 4.0% experienced pulmonary atelectasis.

On average, the children were hospitalized for 7 days (±2.3 days). The majority (67.0%) of children experienced severe disease, which resulted in longer hospital stay. The average hospital stay was shorter for children without complications (33.0%).

Discussion

Our findings reveal a cyclical pattern in whooping cough incidence in Bishkek, with peaks occurring every 2–3 years. A notable shift was observed in the age distribution, with an increase in the number of cases among preschool and school-aged children. Compared to earlier studies from 2010–2013, the proportion of older children affected increased significantly by 2023 (40.0%, $P < 0.0001$). This trend aligns with studies by Masseria et al and Winter et al, which highlight a resurgence in whooping cough among older children, likely due to waning post-vaccination immunity (*20*,*21*).

Infants remained the most vulnerable group, consistent with previous data. However, the increasing incidence among older children and adults may have contributed to the increased transmission to unimmunized infants. In our cohort, 57.0% of infections were linked to adults with persistent cough. This highlights the need for enhanced awareness among caregivers and health workers about the importance of maternal and adult vaccination. Maternal immunisation, as supported by Andrea et al, has proven effective in protecting infants during their early months of life (*22*).

Table 2 **Length of hospital stay for children with whooping cough**

Length of hospital stay in days		
In infants	With pneumonia	9.0 ± 2.3
	With encephalopathy	9.5 ± 2.3
In children 1–14 years	With pulmonary atelectasis	7.5 ± 2.5
	With otitis media	6.5 ± 2.7
	With scleral haemorrhages	5.5 ± 2.3
In children 1–14 years	Without complications	4.5 ± 2.0

Vaccination coverage remains a key concern. Over half (58.7%) of the hospitalised children were unvaccinated, and 41.3% had incomplete immunisation. Disruptions during the COVID-19 pandemic further contributed to these immunisation gaps, particularly in Bishkek, which reported the majority of cases. Similar post-pandemic surges in whooping cough have been documented in Italy and other places (*14,23*). These findings support the need to reinforce immunisation programmes and expand booster vaccination coverage, especially among older children and adults (*30*).

Booster vaccinations have shown promise in enhancing long-term immunity. Studies have shown that natural infections and booster doses strengthen immune memory, potentially curbing resurgence (*23,24*). Integrating booster shots into national schedules could help restore herd immunity and protect infants.

Clinical severity was higher among infants, particularly those with comorbidities such as anaemia and hypoxia. Among these, 59.4% had severe disease, with complications like pneumonia (83.0%) and encephalopathy (17.0%). Similar findings have been reported by Heda et al, where delayed diagnosis in hypoxic infants led to respiratory failure (*25*).

Hospital stay duration correlated with disease severity and complications. Infants with pneumonia and encephalopathy required longer admissions, whereas children without complications had significantly shorter stays. These trends support early clinical diagnosis and targeted care for improving treatment outcomes. Previous studies have noted improved prognosis with timely intervention, particularly in the youngest age groups, following the introduction of prenatal vaccination (*20*).

In summary, our findings underscore the urgent need for renewed vaccination strategies, public health awareness, and timely clinical response to mitigate the rising burden of pertussis in Kyrgyzstan.

Study limitations

This retrospective study lacked immunological data, limiting insights into underlying susceptibility. It relied on hospital records, which may have omitted relevant clinical variables. Although age groupings were clinically appropriate, future studies should consider stratification based on key DTP milestones, such as 5 months and 2 years, and include immune profiling to enhance analysis.

Conclusion

Whooping cough incidence in Bishkek, Kyrgyzstan, is increasing among infants and school-aged children. Strengthening immunisation—particularly timely administration of primary and booster doses—is vital to control outbreaks. Maternal vaccination and early infant immunisation remain crucial. Prompt detection, diagnosis, isolation and public awareness can help reduce transmission. Public campaigns and digital outreaches should emphasize booster dose compliance. A combined approach involving vaccination, early medical attention and education is essential to protect high-risk groups, especially infants.

Analyse décennale des caractéristiques épidémiologiques de la coqueluche au Kirghizistan

Résumé

Contexte : Bien que la coqueluche soit une maladie évitable par la vaccination, son incidence augmente dans le monde entier, y compris au Kirghizistan.

Objectif : Étudier les caractéristiques épidémiologiques de la coqueluche chez les enfants à Bichkek (Kirghizistan). **Méthodes :** Nous avons collecté et analysé les données concernant 802 enfants âgés de 0 à 14 ans, diagnostiqués cliniquement avec la coqueluche et hospitalisés à l'Hôpital républicain des maladies infectieuses de Bichkek entre février 2014 et février 2024.

Résultats : Le test d'amplification en chaîne par polymérase des échantillons respiratoires a confirmé que tous les enfants étaient positifs pour *Bordetella pertussis*. Aucun cas de *Bordetella parapertussis* n'a été détecté. Nous avons observé une tendance cyclique distincte de l'incidence de la coqueluche au cours de cette période de 10 ans, avec un pic significatif en 2018. Entre 2021 et 2023, la majorité des cas (60 %) concernaient des nourrissons âgés de moins d'un an. Parmi les enfants, 58,7 % n'étaient pas vaccinés et 41,3 % avaient une vaccination incomplète contre la diphtérie, le tétanos et la poliomyélite. Les formes sévères étaient fréquentes chez les nourrissons présentant des comorbidités telles que l'anémie et l'hypoxie.

Conclusion : Nos résultats montrent que l'incidence de la coqueluche augmente chez les enfants à Bichkek. Il est donc nécessaire de renforcer les efforts de prévention, notamment la sensibilisation et l'éducation du public, la vaccination des enfants et des mères, ainsi que d'intensifier la détection, le diagnostic et l'isolement afin de réduire la transmission.

تحليل الخصائص الوبائية للسعال الديكي (الشاهوق) في قيرغيزستان

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الخلاصة

الخلفية: على الرغم من إمكانية الوقاية من السعال الديكي باللقاحات، فإن معدل الإصابة به في ازدياد على مستوى العالم، وكذلك في قيرغيزستان.

الأهداف: هدفت هذه الدراسة الى استقصاء الخصائص الوبائية للسعال الديكي لدى الأطفال في بيشكيك، قيرغيزستان.

طرق البحث: جمعنا وحللنا بيانات عن 802 طفلا من سن الولادة حتى سن 14 عامًا من الأطفال الذي شُخِّصوا سريريًّا بالسعال الديكي، وأدخلوا المستشفى الجمهوري للأمراض المعدية السريرية، في بيشكيك بقيرغيزستان، خلال الفترة من فبراير/ شباط 2014 إلى فبراير/ شباط 2024.

النتائج: أكد اختبار تفاعل البوليميراز المتسلسل (PCR) لعينات الجهاز التنفسي أن جميع الأطفال مصابون بالبُورْديتيلَة الشَّاهوقِيَّة. ولم توجد أي حالة بُورْديتيلَة نَظيرَة الشَّاهوقِيَّة. ولاحظنا نمطًا دوريًّا واضحًا لمعدل الإصابة بالسعال الديكي خلال السنوات العشر، مع بلوغ ذروة كبيرة في عام 2018. وبين عامَي 2021 و2023، حدثت غالبية الحالات (60٪) في صفوف الرضع الذين تقل أعمارهم عن عام واحد. وكانت نسبة الأطفال غير المُلقَّحين 58.7٪، بينما كانت نسبة الذين لم يُكملوا تلقيحهم ضد الدفتيريا والتيتانوس وشلل الأطفال 41.3٪. وكانت الحالات الشديدة شائعة بين الرُّضع المصابين بأمراض مصاحبة، مثل فقر الدم ونقص التأكسج.

الاستنتاجات: تشير نتائجنا إلى أن معدل الإصابة بالسعال الديكي في ازدياد بين الأطفال في بيشكيك. ولذلك يلزم تعزيز جهود الوقاية، ومنها التوعية العامة والتثقيف، وتحصين الأطفال وتلقيح الأمهات، وتكثيف الكشف والتشخيص والعزل للحد من انتقال العدوى.

References

1. Lauria AM, Zabbo CP. Pertussis. In: StatPearls. Treasure Island: StatPearls Publishing, 2025. https://www.ncbi.nlm.nih.gov/books/NBK519008/.
2. Dou M, Macias N, Shen F, Bard JD, Domínguez DC, Li X. Rapid and accurate diagnosis of the respiratory disease pertussis on a point-of-care biochip. E Clin Med. 2019;8:72-77. https://doi.org/10.1016/j.eclinm.2019.02.008.
3. Decker MD, Edwards KM. Pertussis (whooping cough). J Infec Dis. 2021;224(4):S310–S320. https://doi.org/10.1093/infdis/jiaa469.
4. Marshall KS, Quinn HE, Pillsbury AJ, et al. Australian vaccine preventable disease epidemiological review series: pertussis, 2013–2018. Comm Dis Intell. 2022;46. https://doi.org/10.33321/cdi.2022.46.3.
5. Etskovitz H, Anastasio N, Green E, May M. Role of evolutionary selection acting on vaccine antigens in the re-emergence of Bordetella Pertussis Diseases 2019;7(2):35. https://doi.org/10.3390/diseases7020035.
6. Bettiol S, Wang K, Thompson MJ, et al. Symptomatic treatment of the cough in whooping cough. Cochrane Database Syst Rev. 2012;(5).CD003257.pub4. https://doi.org/10.1002/14651858.
7. Nitsch-Osuch A, Kuchar E, Modrzejewska G, et al. Epidemiology of pertussis in an urban region of Poland: time for a booster for adolescents and adults. Respirat Regul Clin Adv 2013;203-212. https://doi.org/10.1007/978-94-007-4546-9_26.
8. Cherry JD, Tan T, Wirsing von König CH, et al. Clinical definitions of pertussis: Summary of a global pertussis initiative round-table meeting, February 2011. Clin Infec Dis 2012;54(12):1756-1764. https://doi.org/10.1093/cid/cis302.
9. Marshall H, Clarke M, Rasiah K, et al. Predictors of disease severity in children hospitalized for pertussis during an epidemic. Ped Infec Dis J 2015;34(4):339-345. https://doi.org/10.1097/INF.0000000000000577.
10. Selbuz S, Çiftçi E, Özdemir H, et al. Comparison of the clinical and laboratory characteristics of pertussis or viral lower respiratory tract infections. J Infec Dev Countries 2019;13(09):823-830. https://doi.org/10.3855/jidc.10558.
11. Lindstrand A, Cherian T, Chang-Blanc D, et al. The world of immunization: achievements, challenges, and strategic vision for the next decade. J Infec Dis. 2021;224(Supplement_4):S452-S467. https://doi.org/10.1093/infdis/jiab284.

12. World Health Organization. Pertussis reported cases and incidence. Geneva: World Health Organization, 2022. https://immunizationdata. who. int/pages/incidence/pertussis. html.

13. Centers for Disease Control and Prevention. Pertussis (whooping cough). Washington DC: Centers for Disease Control and Prevention, 2022. https://www.cdc.gov/pertussis/downloads/pertuss-surv-report-2019-508.pdf.

14. Government of Canada. Pertussis (whooping cough): For health professionals. Vancouver: Government of Canada, 2022. https://www.canada.ca/en/public-health/services/immunization/vaccine-preventable-diseases/pertussis-whooping-cough/healthprofessionals.html.

15. Maslyaninova AE, Radchenko TS, Arakelyan RS, Kurbangalieva AR. Epidemiological aspects of whooping cough in children. Avicenna Bull. 2023;25(3):414–423. https://vestnik-avicenna.tj/upload/uf/8ba/2023_3.pdf.

16. Bogvilene YA, Martynova GP, Evreimova SV, Komarova BL, Karasev AV. Pertussis in children: Clinical and epidemiological features, the possibilities of vaccine prevention. Epidem Vacc Prev. 2021;20(6):56-62. https://doi.org/10.31631/2073-3046-2021-20-6-56-62.

17. Smout E, Mellon D, Rae M. Whooping cough rises sharply in UK and Europe. BMJ 2024;385:q736. doi:10.1136/bmj.q736.

18. Zhu Y, Zhang W, Hu J, et al. Seroprevalence of pertussis in Chinese population during 2010-2022: A systematic review and meta-analysis. http://dx.doi.org/10.2139/ssrn.4677011.

19. Chechetova SV, Kadyrova RM, Dzholbunova ZK, Khalupko EA, Chynyeva DK, Karamurzaeva GA, et al. Dynamics of incidence of vaccine-preventable infections over the last 20 years in kyrgyzstan. 2022;1:119-128. https://doi/10.54890/1694-6405_2022_1_119.

20. Masseria C, Martin CK, Krishnarajah G, et al. Incidence and burden of pertussis among infants less than 1 year of age. Ped Infec Dis J 2017;36(3):e54-e61. https://doi.org/10.1097/INF.0000000000001440.

21. Winter K, Harriman K, Zipprich J, et al. California pertussis epidemic, 2010. J Ped. 2012;161(6):1091-1096. https://doi.org/10.1016/j.jpeds.2012.05.041.

22. Parisi A, Nuñez O, López-Perea N, Masa-Calles J. Reduced pertussis disease severity in infants following the introduction of pertussis vaccination of pregnant women in Spain, 2015-2019. Vaccine 2024;42(11):2810-6. PMID:38531728. https://doi.org/10.1016/j.vaccine.2024.03.028

23. van Schupppe E, Froberg J, Venkatsburamanian PB, et al. Prior exposure to B. Pertussis shapes the mucosal antibody response to acellular pertussis booster vaccination. Nat Commun. 2022;13:7429. https://doi.org/10.1038/s41467-022-35165-w.

24. Poeta M, Moracas C, Albano C, Petrarca L, Maglione M, Pierri L, et al. Pertussis outbreak in neonates and young infants across Italy, January to May 2024: implications for vaccination strategies. Euro Surveill. 2024;29(23):2400301. https://doi.org/10.2807/1560-7917.ES.2024.29.23.2400301.

25. Versteegen P, Pinto MV, Barkoff AM, van Gageldonk PG, van de Kassteele J, van Houten, et al. Responses to an acellular pertussis booster vaccination in children, adolescents, and young and older adults: A collaborative study in Finland, the Netherlands, and the United Kingdom. E Bio Med 2021;65. https://doi.org/10.1787/b23c7d13-en .

26. Nataprawira HM, Somasetia DH, Sudarwati S, Kadir, et al. Case report critical pertussis in a young infant requiring mechanical ventilation. Annals Med. 2024;56(1). https://doi.org/10.1155/2013/125043.

27. Mogasale V, Mogasale VV, Ramani E, Lee JS, Park JY, Lee KS, Wierzba TF. Revisiting typhoid fever surveillance in low- and middle-income countries: lessons from systematic literature review of population-based longitudinal studies. BMC Pub Health 2015;15:731. https://doi.org/:10.1186/s12889-015-2091-9.

28. Noel G, Badmasti F, Nikbin VS, Zahraei SM, Madec Y, Tavel D, Aït-Ahmed M, Guiso N, Shahcheraghi F, Taieb F. Transversal sero-epidemiological study of Bordetella pertussis in Tehran, Iran. Plos One 2020;15(9):e0238398. https://doi.org/:10.1371/journal.pone.0238398.

29. Abenova M, Shaltynov A, Jamedinova U, Ospanov E, Semenova Y. The association between parental child vaccination refusal rate and the impact of mass vaccination against COVID-19 in Kazakhstan: an interrupted time series analysis with predictive modelling of nationwide data sources from 2013 to 2022. Vaccines 2024;12(4):429. https://doi.org/:10.3390/vaccines12040429.

30. Miller JE, Clements M, Elliott MN, et al. Health insurance coverage and access to care for children in low-income families: a comparison of public and private insurance. BMJ 2014;348:g3668. doi:10.1136/bmj.g3668.