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The state of knowledge regarding pertussis amongst young adults

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Abstract

Pertussis remains a serious health problem to this day. Even though a successful vaccine campaign reduced the morbidity rate in most countries, it still is a present and concerning disease. The sickness is especially dangerous to infants and young children, as it may result in serious health complications, and even death. The aim of this study was to determine how much do young adults know about this condition, and how often does pertussis occur within this population, as well as within its family members. Materials and methods: data was collected with use of an authorial survey, which was handed around a group of 201 freshmen medical students in contact, in April 2022. Results: Most of the students possess basic knowledge regarding aetiology, routes of transmission and symptoms of pertussis, but lack information about the vaccines, treatment, course of the disease and specific at-risk groups. Some students were diagnosed with the condition in the past, and some have a family member diagnosed with it sometime. Conclusion: Young adults have basic knowledge regarding pertussis, but they should be educated about some aspects of this sickness, with

use of social campaigns or advertisements. Only some of the people are affected by pertussis during their life, as the disease is relatively rare in developed countries. A possibility of getting a booster shot of pertussis vaccine should be touted.

Key words: whooping cough, *Bordetella pertussis*, infectious disease

INTRODUCTION

Pertussis is a bacterial disease causing an inflammation of the respiratory system, with such conditions as tracheitis and bronchitis. It is caused by a Gram-negative coccobacillus *Bordetella pertussis*. The most recognisable symptom of the illness is a “whooping cough” [1]. The sickness is spread by the sick people, who are highly contagious [3]. The disease is dangerous especially to infants and young children, and in some cases can be fatal, as it can lead to such complications as pneumonia, lung damage or encephalitis [1,2]. It is important to remember that pertussis can also affect adults, with the severity based on such factors as age, co-existing diseases, or the number of doses of the vaccine taken (whether one took a booster shot in adulthood), and in some cases, complications such as rib fracture or hernia are possible [1]. Due to effective vaccination of the population, started in the 1960s', the sickness remained under control for a long time. In recent years, according to the Polish National Institute of Public Health/National Institute of Hygiene, there can be observed fluctuations in the number of cases of pertussis in Poland. The rising anti-vax movement, as well as the income of the immigrants, which are often not vaccinated (because there might occur difficulties with the vaccination process, e.g. in Ukraine [4]) are some of the factors responsible for the growth of the sickness rate. The aim of this study was to check whether young adults know basic facts about pertussis, which are crucial to avoid this disease and proceed correctly if they get infected, and to determine the amount of people who have been affected by this disease in the past, or had their family member struggling with it.

MATERIALS AND METHODS

Research group consisted of one hundred ninety-nine freshmen students of medicine, from the Medical University of Lublin in Poland. Within this number, there were one hundred twenty-six women and seventy-three men. The age distribution ranged from eighteen to twenty-five years old, with the average age of 19,9. The majority of the students were either nineteen or twenty years old. The data for this study was collected in contact, with the use of an auctorial survey, which was presented to the research group in April 2022.

RESULTS

There were gathered at least one representative from almost every Polish voivodeship (excluding Kuyavian-Pomeranian and Opole). Most of the students came from Lublin (46%), Masovian (20%) and Subcarpathian (16%) voivodeships. The majority of the respondents hailed from cities with populations up to one hundred thousand (34%) or up to ten thousand (22%). It is worth mentioning that 20% of the research group lived in a city with up to half a million inhabitants. About 45% of the examined group claimed to have a family member working in a job that brings the risk of getting infected with *B. pertussis*.

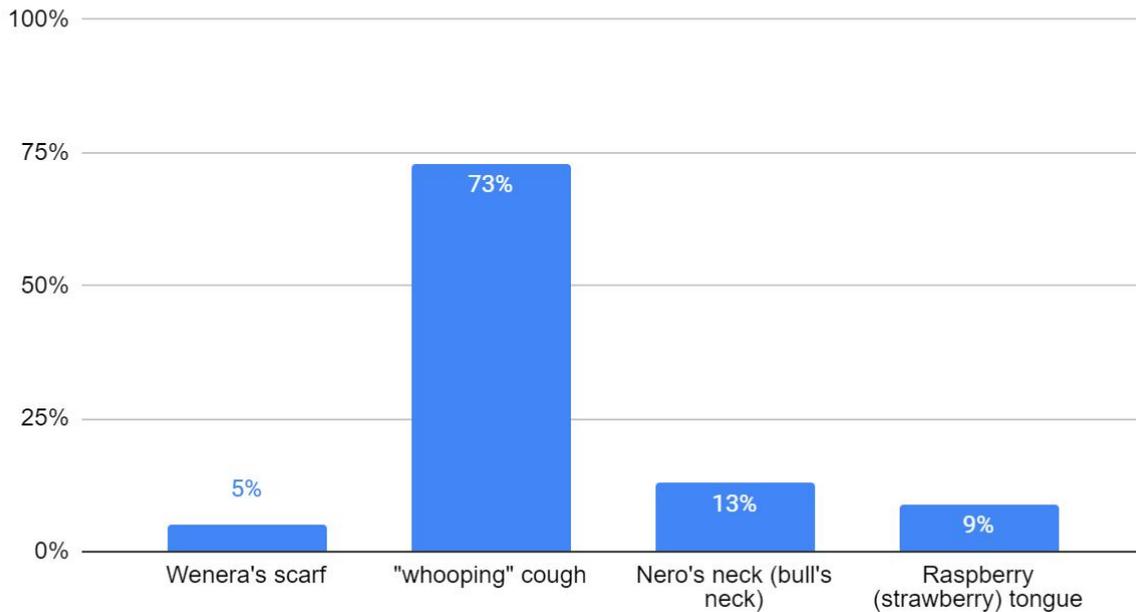
About 59% of the students knew that pertussis is a bacterial disease. The rest of the group considered it as a viral (36%), parasitic (3%) or fungal (2.5%) illness. Then, 72% of the respondents stated that the sickness can not be transmitted by animals. As mentioned before, pertussis is highly contagious, and a sick human can spread the disease amongst the healthy population. The majority of the students (88%) knew about the contagiousness. The next question, with the multiple choice option and regarding the aetiology of the illness, concerned the possible ways of spreading it amongst people. Most of the respondents picked a droplet route of infection (86%). The other routes were: blood (21%), contact (e.g. contaminated surfaces, 16%) and inhalant (15%).

The next questions concerned the vaccine. Almost 75% of the students responded that it is mandatory to vaccinate. Then, we asked if it is necessary to get a booster dose in adulthood, after completing the full mandatory course of vaccination. 37% of students answered that you ought to take one booster dose, 39% of them think that you should take multiple booster doses, whilst 25% of the research group considers the mandatory course of vaccination enough to get a lifetime pertussis immunity. The majority of the students (62%) claimed to be vaccinated for the disease, 8% said the opposite, and 30% did not remember whether they had the vaccine or not. Amongst the vaccinated respondents, about half of them (52%) took a booster shot in adulthood. We also wanted to check the adults' knowledge regarding the vaccine itself, thus we asked what diseases it immunises for, and what antigens are used to make it. Most of the students (57.5%) knew that it provides immunisation for pertussis, tetanus and diphtheria, 20% did not know that antigens are used to make this vaccine, 13.5% thought it protects only against pertussis, and 9% chose that the vaccine is made of pertussis and tuberculosis antigens. Finally, we asked whether pregnant women can get vaccinated. The majority of the respondents (69%) did not know the answer, 21% thought you can not get this vaccine if you are pregnant, and only 11% picked that you can.

Later on, the research group were asked whether they have checked the level of pertussis antibodies in the past. Only two of the students (1%) responded positively. Furthermore, in the next question they had to answer what was the reason for taking this test. One student responded that she did the test because of the suspicion of pertussis when she was younger.

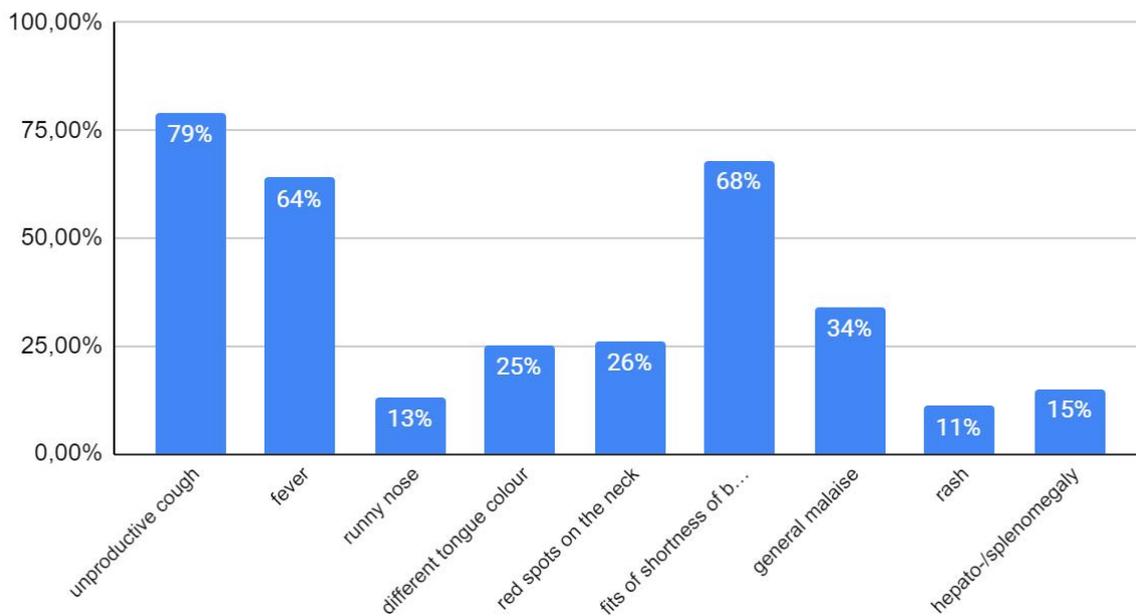
The next part of the survey consisted of two questions regarding the symptoms of the disease. Firstly, the students were asked about the characteristic (pathognomonic) symptom of pertussis. The results are shown on Figure 1.

Figure 1- The pathognomonic symptom of pertussis.



Next, the respondents had to pick multiple general symptoms of the sickness from the list. The percentage of the choices is presented on Figure 2.

Figure 2- Symptoms of pertussis.



The other question that the students had to answer concerned how much time does the disease last. Most of the respondents chose that pertussis lasts up to two weeks (45%) or up to a month (38%). The remaining ones picked the options “a few months” (15%) and “up to a week” (2%).

Further on, in the survey there were included questions regarding the severe course of the sickness. The first one was related to the mortality of pertussis. The majority (76%) of the students responded that the disease can be fatal, 22% did not know whether one could die because of it, and 2,5% claimed that the sickness can not be a cause of death. The next question applied to what are the at-risk groups of people who might get the severe course of pertussis. The students could make multiple choices. And so, the respondents picked patients with chronic diseases (45%), children up to twelve years old (42%), infants (37%), elderly people above sixty years old (35%) and pregnant women (27%).

The next part of the survey concerned the treatment of pertussis. The research group had to decide what drugs are used in the therapy. The majority chose antibiotics (54%), 24% picked symptomatic treatment (antifebrile and anti-inflammatory drugs, such as paracetamol/acetaminophen or ibuprofen), 21% claimed that antiviral pharmaceuticals, such as aciclovir, are the right treatment option, and 3% chose antifungal drugs, e.g. azoles. We also asked the respondents whether it is crucial to begin the treatment at the right moment for the therapy to succeed, or not. About 80% of our research group answered that delaying the start of the treatment might cause the appearance of health complications, 10% claimed that it does not matter when the therapy starts, as it always succeeds, and 10% stated that being on medications makes no odds to the treatment of pertussis. The final question regarding the therapy concerned hospitalisation. Half of the respondents answered that it is not mandatory to put infected patients away in the hospital, but in some cases, there might be a need to do so. The rest of the students claimed that each patient with pertussis has to be hospitalised on the isolation ward (34%), or did not know the answer to this question (16%).

The last part of the survey consisted of personal questions. The first one regarded whether the respondent had ever been diagnosed with pertussis. Only 2% of the research group answered positively. The other question determined how many of our respondents have a family member that has been diagnosed with the sickness in the past. Six people (3%) claimed to have such a person in their family. Amongst them, 50% were not vaccinated, 33% were, and 17% did not know if the member took the vaccine.

DISCUSSION

Nowadays, people often treat pertussis as a bygone problem. This is not the right attitude, as the disease is still present in our lives. The introduction of the vaccines decreased the yearly number of cases of the sickness. For example, in Canada, in 1942 the incidence rate of pertussis totaled almost 160 per 100 000 population, whereas in 2015- less than 20 per 100 000 population [5]. However, this does not mean that the disease is gone. According to the Polish National Institute of Public Health/National Institute of Hygiene, in 2018 the morbidity rate of pertussis in Poland equaled 4,03 per 100 000 population. In 2020, the same rate shrank down to 1,94 per 100 000 population, and in 2021 was even lower- 0,47 per 100 000 population. In comparison, according to the European Centre for Disease Prevention and Control (ECDC), in 2018 the incidence rate of pertussis totaled 15.1 per 100 000 population in Germany, 7.1 per 100 000 population in Czechia (Czech Republic), and 6,9 per 100 000 population in Slovakia [6]. This shows that the Polish rate is relatively lower than the ones of the neighbouring countries.

Working in some jobs brings risk of *B. pertussis* infection, and therefore people who operate in these jobs are considered an at-risk group of pertussis. The best example of such an occupation is the health care system. In the study of Özer et al., about 21% of the examined group (paediatric hospital employees) had a high level of anti-pertussis IgG antibodies, suggesting recent infection [7]. The

other work that has a high pertussis infection risk is teaching. The disease often appears as a school outbreak within students' population, thus teachers are at risk of being infected too. Such an outbreak is described in the paper of *Tessier et al.*, and took place in the first quarter of 2019 in the United Kingdom [8]. In our study, almost every second respondent claimed to have a family member working in a job that can be classified as an at-risk group of *B. pertussis* infection.

Pertussis is caused by an aerobic Gram-negative rod called *Bordetella pertussis*. Its main virulence factors are: filamentous hemagglutinin (FHA), pertussis toxin (PT), pertactin (Prn), adenylate cyclase toxin (ACT) and tracheal cytotoxin (TCT). FHA is responsible for the bacteria adherence to the ciliated cells in the respiratory tract. PT causes an unregulated cAMP production in the infected cells, which is also an effect of ACT activity [9,10]. The infection can be spread from other sick people through airborne droplet transmission [11,12]. The majority of our study group evinced basic knowledge regarding aetiology, contagiousness and transmission ways of pertussis.

There are many pertussis-effective vaccines available in the world. The first one was developed in the 1940s. It was a whole-cell pertussis vaccine (wP), and it has been combined with diphtheria and tetanus antigens (DTwP), so that it provided immunity to all three diseases. Unfortunately, it was associated with such post-injection complications as injection site pain, fever or more serious conditions. Thus, another vaccine was made, with the use of acellular compound and aluminium adjuvant (aP). And so, highly-developed countries began to change the DTwP vaccine to DTaP one, which was not as reactogenic, and had similar efficiency, according to the tests [13]. However, the study of *Versteegen et al.* shows that children who received DTwP vaccine are less susceptible to the disease throughout next years [14]. According to the Polish Vaccination Programme for 2022, children must receive the whole-cell DTP vaccine in second, third/fourth, fifth/sixth and sixteenth/eighteenth months of life, then the acellular DTaP vaccine in sixth year of life, an acellular Tdap vaccine with lowered pertussis and diphtheria antigens content, and additionally a Td vaccine, which contains of tetanus and diphtheria antigens in nineteen year of age. This is a mandatory vaccination course in Poland. However, the rising anti-vax movement is often a cause of hesitancy, or withdrawal of vaccinating one's child. According to the *Nguyen et al.* study, almost 24% of the examined parents admitted that they were not convinced of vaccinating their child with various vaccines [15]. Such hesitation can be dangerous to one's children. For example, in 2014 there was a pertussis outbreak in California, and from 222 cases of the disease, only 24% of the sick children were vaccinated adequately to their age [16]. There are many reasons why parents do not want to vaccinate themselves or their offspring. For example, in South Asia there can be observed lower vaccination rate within Muslim families, than within other religions [17]. Sometimes parents are overwhelmed with the amount of vaccinations, as their child receives many in a short time [15]. However, in case of pertussis, multiple vaccinations are necessary to gain proper immunisation. The majority of our students know that it is mandatory to vaccinate for pertussis in Poland, and that it is a combination vaccine that also provides immunity for diphtheria and tetanus. Most of the respondents have been vaccinated.

It is worth mentioning that children are not the only group that should be vaccinated. Pertussis also affects adults, many of whom have not received the booster dose of the vaccine in their adult life. In 2017, Center for Disease Control and Prevention (CDC) revealed that only about 32% of the adults aged more than nineteen years old have received the Tdap vaccine, and about 63% have received Td or Tdap vaccine [18]. The symptoms of pertussis infection can be not as characteristic in adults as in children, and thus the diagnosis process is much more difficult. The disease confirmation is also a challenge, since the diagnostic tests are effective mainly in the first phase of pertussis, and many

adults seek doctors' help much later [19]. Elderly people often suffer from conditions such as chronic obstructive pulmonary disease (COPD), asthma, diabetes and obesity, which additionally increase the risk of the sickness [20]. The acellular vaccines are safe for adults, and only mild complications, such as swelling, pain, nausea and vomiting might occur after the injection, and the vaccine effectively boosts immunity to pertussis, causing the antibodies level growth [21]. The disease itself can cause such complications as urinary incontinence, rib fractures, pneumonia and many more, therefore adults, especially the elderly and patients with chronic diseases, should be vaccinated [22]. The current CDC-endorsed guidelines suggest vaccinating adults every 10 years to ensure the lasting pertussis protection [23]. Our study group's knowledge regarding the booster dose of the vaccine is uneven, as some students suggested that adults should receive only one booster dose, some claimed that they should vaccinate multiple times, and some- that it is not necessary to get a booster dose, as the immunity remains for the whole life after the mandatory course of vaccination. About half of our students took a booster dose of the vaccine in adulthood. This correlates with the study of *Maltezou et al.*, where about 48% of the dental students in Greece received the booster dose [24].

Another group of people that should consider vaccinating are pregnant women. Getting a vaccine during pregnancy very often raises concerns, but multiple studies were carried out, and it is currently an advised approach. The American College of Obstetricians and Gynecologists recommends vaccinating in the period from 27th to 36th week of pregnancy [25]. The newborns are the group with the highest risk of possibly fatal complications of pertussis, and even though the vaccination of pregnant mothers might decrease the child's response to the first mandatory vaccines, it is still advised to do so [26, 27]. Some studies showed that receiving a Tdap vaccine during pregnancy might increase a risk of fever and chorioamnionitis, but nonetheless, the overall benefits eclipse the risks [28]. In our research group, the majority of the students did not know whether pregnant women can get vaccinated for pertussis, which shows that the awareness regarding vaccinating amongst this group needs to be raised.

The pathognomonic symptom of pertussis is a paroxysmal cough, which occurs more often during the night. It is called "whooping cough", because of the sound produced during the paroxysm. During coughing, cyanosis and vomiting may occur. Apart from this, the early symptoms of the disease are similar to those appearing in typical upper respiratory tract infections [26]. Our respondents in large part picked the right pathognomonic symptom, as well as the co-existing, milder symptoms.

The disease typically goes off with three stages. They are catarrhal, paroxysmal and convalescent stages [29]. The first phase lasts up to two weeks, and is marked by mild symptoms. The paroxysmal stage, characterised normally by "whooping cough", can last up to ten weeks. The last, convalescent phase, usually lasts two to three weeks, and during this time, a recovery is being made. The cough can sometimes be persistent, and can last several months [30]. Our research group answered variously to the question regarding how much the disease lasts.

As mentioned before, for some people pertussis might be especially dangerous, as it might lead to serious health problems. These at-risk groups are young children (particularly infants), people with conditions such as obesity, COPD, asthma or diabetes, and the elderly [31]. The study of *He et al.* showed that patients with COVID-19 were more likely to get pertussis than the COVID-19 negative patients [32]. This demonstrates that other infectious respiratory diseases might increase the risk of pertussis. Some studies conducted in the past have also suggested that children who suffered from pertussis in the past, are more likely to develop asthmatic symptoms, and are more likely to catch respiratory infections [33]. Young children have the highest pertussis mortality rate, with estimated

160 700 deaths worldwide within children under 5 years old in 2014 [34]. There are some risk factors that may cause fatal complications of the disease. According to *Shi et al.*, these factors are low birth weight, younger age, and some symptoms appearing during the course of the sickness, such as cyanosis, lymphocytosis or pulmonary hypertension [35]. Children who are not vaccinated are also at risk of severe pertussis, with the most common complication being pneumonia [36]. The other possible complications of the disease, especially within adults, are insomnia, urinary incontinence, apnea, rib fracture, sinusitis and otitis media [1], but there were also described cases of acute carotid dissection [37], pneumomediastinum [38] or angioedema [39]. In our study, most of the students knew that the disease can be a life threat, but there is a need to educate them about the at-risk groups that are endangered to the severe pertussis.

Even though these complications are not very common, some of them can be a serious health threat, which is why prophylaxis such as vaccines is very important. However, recent events show that there are more factors that can help prevent the disease. From late 2019, the world has been struggling with the COVID-19 pandemic. In most countries, protective measures were introduced, in order to minimise the number of cases within the population. These measures included a.o. protective face masks, sanitising hands and surfaces or keeping distance from other people. A study conducted by *Matczak et al.* shows that these precautions caused a massive reduction of pertussis cases in France [40]. The other study, conducted in England by *Tessier et al.* demonstrated the same outcome [41]. Furthermore, the case of COVID-19 successful vaccines showed the effectiveness of vaccines against infectious diseases, which can help persuade more people to get vaccinated for pertussis in the future.

When sometimes prophylaxis fails, there is space for an effective treatment that can heal patients from pertussis. In order to start the therapy, the disease confirmation is needed. The golden diagnostic standard in this case is the bacteria culture. However, it is time-consuming as it takes some days to complete. It is also accessible during the first two weeks of coughing. There is also another diagnosis possibility, which includes PCR assay. It can be collected up to the fourth week of coughing. The positive test outcome, with the typical symptoms (whooping cough, vomiting after the paroxysm) confirms the diagnosis [42, 43]. According to the currently CDC- endorsed guidelines, sometimes if the course of disease is suggestive, and especially if the patient is younger than 1 year old, the treatment should begin without the test confirmation of the disease [44]. The same guidelines suggest treating with azithromycin, clarithromycin or erythromycin. The faster the therapy begins, the better, and if the treatment begins during the catarrhal stage, the later occurring symptoms can be milder [44]. However, these guidelines suggest using azithromycin with caution within infants younger than one month and within patients with heart disease. A paper of *Kow and Hasan* implies that azithromycin should also not be used in treating patients with COVID-19 and co-existing pertussis infection [45]. Nevertheless, azithromycin, as well as other macrolides, remain the standard treatment of pertussis amongst younger children. Most of our respondents chose antibiotics as the right therapy, and stated that delaying it might cause health complications, but the majority was not decisive.

As mentioned before, pertussis is a highly contagious disease, and can easily spread to healthy people. Hospitalisation is necessary only in grave cases, especially within young children. A study conducted by *Fiasca et al.* showed that between 2007 and 2018, there were 4262 children hospitalised because of pertussis in Italy [46]. According to the CDC, about half of children younger than 1 year old need hospitalisation [47]. The majority of our research group correctly responded that hospitalisation is not necessary, but may be needed in some severe cases. However, it is worth mentioning that in Poland it is mandatory to report every case of pertussis to the Main Sanitary Inspectorate.

Nowadays, the disease is not very common in developed countries, thanks to the successful vaccination programme. This confirms that pertussis occurrence is higher within unvaccinated populations. In their paper, *McGirr* and *Fisman* estimated that the possibility of getting the disease is increasing 1.33 times every year after taking the last dose of the vaccine [48]. In our study, only 2% of the respondents have ever had pertussis diagnosed. The small morbidity rate correlates with the high vaccination rate within the tested population. However, some of the students mentioned that the disease was present in their family at some point, and it seems that in the majority of cases it concerned unvaccinated people.

CONCLUSIONS

The chance of getting infected with *B. pertussis* in adult life is slim. However, the unvaccinated people, as well as the ones with some comorbidities, are at-risk groups of pertussis. Young children are the most endangered of serious health complications of the disease, which is why future parents need to have basic knowledge regarding this condition, in order to protect their children, and in some cases be able to recognise symptoms of the threat. This research shows that young adults know some facts about pertussis, especially its aetiology, routes of infection and symptoms. There again, there is a need to improve their knowledge about the treatment, the course of disease, the at-risk groups and vaccines. In order to increase the awareness regarding pertussis, there should be organised social campaigns or advertisements, which would educate the society. The possibility of getting a booster dose of vaccine in adulthood should be touted. There is also a space for further studies, which would cover the knowledge regarding the disease within other populations, such as general practitioners.

References

- Kilgore PE, Salim AM, Zervos MJ, et al. Pertussis: Microbiology, Disease, Treatment, and Prevention. *Clin Microbiol Rev.* 2016; 29(3): 449-486. <https://doi.org/10.1128/CMR.00083-15>
- Bernstein H, McNally VV. Pertussis Vaccination-A Critical Priority for Us All. *JAMA Netw Open.* 2021; 4(8): e2119365. <https://doi.org/10.1001/jamanetworkopen.2021.19365>
- Esposito S, Principi N. Prevention of pertussis: An unresolved problem. *Hum Vaccin Immunother.* 2018; 14(10): 2452-2459. <https://doi.org/10.1080/21645515.2018.1480298>
- Podavalenko AP, Nessonova TD, Zadorozhna VI, et al. EPIDEMIOLOGICAL ANALYSIS OF PERTUSSIS MORBIDITY IN UKRAINE. *Wiad Lek.* 2021; 74(7): 1628-1633.
- Thommes E, Wu J, Xiao Y, et al. Revisiting the epidemiology of pertussis in Canada, 1924-2015: a literature review, evidence synthesis, and modeling study. *BMC Public Health.* 2020; 20(1): 1749. <https://doi.org/10.1186/s12889-020-09854-4>
- European Centre for Disease Prevention and Control. Pertussis In: ECDC. Annual epidemiological report for 2018. Stockholm: ECDC; 2020. Accessed 22 Jul 2022
- Özer S, Oğuz VA. Pediatric hospital healthcare workers and pertussis; a seroprevalence study. *Turk J Pediatr.* 2021; 63(3): 355-362. <https://doi.org/10.24953/turkjp.2021.03.002>

Tessier E, Campbell H, Ribeiro S, et al. Investigation of a pertussis outbreak and comparison of two acellular booster pertussis vaccines in a junior school in South East England, 2019 [published correction appears in Euro Surveill. 2022 Jan;27(2):]. *Euro Surveill.* 2021; 26(12): 2000244. <https://doi.org/10.2807/1560-7917.ES.2021.26.12.2000244>

Centers for Disease Control and Prevention. *Epidemiology and Prevention of Vaccine-Preventable Diseases*. Hall E., Wodi A.P., Hamborsky J., et al., eds. 14th ed. Washington, D.C. Public Health Foundation, 2021. Accessed 23 Jul 2022

Belcher T, Dubois V, Rivera-Millot A, et al. Pathogenicity and virulence of *Bordetella pertussis* and its adaptation to its strictly human host. *Virulence.* 2021; 12(1): 2608-2632. <https://doi.org/10.1080/21505594.2021.1980987>

Trainor EA, Nicholson TL, Merkel TJ. *Bordetella pertussis* transmission. *Pathog Dis.* 2015; 73(8): ftv068. <https://doi.org/10.1093/femspd/ftv068>

Ather B, Mirza TM, Edemekong PF. Airborne Precautions. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing; May 22, 2022.

Kapil P, Merkel TJ. Pertussis vaccines and protective immunity. *Curr Opin Immunol.* 2019; 59: 72-78. <https://doi.org/10.1016/j.coi.2019.03.006>

Versteegen P, Bonačić Marinović AA, et al. Long-Term Immunogenicity upon Pertussis Booster Vaccination in Young Adults and Children in Relation to Priming Vaccinations in Infancy. *Vaccines (Basel).* 2022; 10(5): 693. <https://doi.org/10.3390/vaccines10050693>

Nguyen KH, Srivastav A, Lindley MC, et al. Parental Vaccine Hesitancy and Association With Childhood Diphtheria, Tetanus Toxoid, and Acellular Pertussis; Measles, Mumps, and Rubella; Rotavirus; and Combined 7-Series Vaccination. *Am J Prev Med.* 2022; 62(3): 367-376. <https://doi.org/10.1016/j.amepre.2021.08.015>

Phadke VK, Bednarczyk RA, Salmon DA, et al. Association Between Vaccine Refusal and Vaccine-Preventable Diseases in the United States: A Review of Measles and Pertussis. *JAMA.* 2016; 315(11): 1149-58. <https://doi.org/10.1001/jama.2016.1353>

Kachoria AG, Mubarak MY, Singh AK, et al. The association of religion with maternal and child health outcomes in South Asian countries. *PLoS One.* 2022; 17(7): e0271165. <https://doi.org/10.1371/journal.pone.0271165>

Centers for Disease Control and Prevention (CDC) (2017) Vaccination coverage among Adults in the United States, National Health Interview Survey. <https://www.cdc.gov/vaccines/imz-managers/coverage/adultvaxview/pubs-resources/NHIS-2017.html>. Accessed 25 Jul 2022

Choi JH, Correia de Sousa J, Fletcher M, et al. Improving vaccination rates in older adults and at-risk groups: focus on pertussis. *Aging Clin Exp Res.* 2022; 34(1): 1-8. <https://doi.org/10.1007/s40520-021-02018-3>

Jenkins VA, Savic M, Kandeil W. Pertussis in high-risk groups: an overview of the past quarter-century. *Hum Vaccin Immunother.* 2020; 16(11): 2609-2617. <https://doi.org/10.1080/21645515.2020.1738168>

Xu J, Liu S, Liu Q, et al. The effectiveness and safety of pertussis booster vaccination for adolescents and adults: A systematic review and meta-analysis. *Medicine (Baltimore).* 2019; 98(16): e15281. <https://doi.org/10.1097/MD.00000000000015281>

Kandeil W, Atanasov P, Avramioti D, et al. The burden of pertussis in older adults: what is the role of vaccination? A systematic literature review. *Expert Rev Vaccines.* 2019; 18(5): 439-455. <https://doi.org/10.1080/14760584.2019.1588727>

Havers FP, Moro PL, Hunter P, et al. Use of Tetanus Toxoid, Reduced Diphtheria Toxoid, and Acellular Pertussis Vaccines: Updated Recommendations of the Advisory Committee on Immunization Practices — United States, 2019. *MMWR Morb Mortal Wkly Rep* 2020; 69: 77–83.

Maltezou HC, Rahiotis C, Tseroni M, et al. Attitudes toward Vaccinations and Vaccination Coverage Rates among Dental Students in Greece. *Int J Environ Res Public Health.* 2022; 19(5): 2879. <https://doi.org/10.3390/ijerph19052879>

Update on immunization and pregnancy: tetanus, diphtheria, and pertussis vaccination. Committee Opinion No. 718. American College of Obstetricians and Gynecologists. *Obstet Gynecol* 2017; 130: e153–7.

Decker MD, Edwards KM. Pertussis (Whooping Cough). *J Infect Dis.* 2021; 224(12 Suppl 2): S310-S320. <https://doi.org/10.1093/infdis/jiaa469>

Skoff TH, Blain AE, Watt J, et al. Impact of the US Maternal Tetanus, Diphtheria, and Acellular Pertussis Vaccination Program on Preventing Pertussis in Infants <2 Months of Age: A Case-Control Evaluation. *Clin Infect Dis.* 2017; 65(12): 1977-1983. <https://doi.org/10.1093/cid/cix724>

Vygen-Bonnet S, Hellenbrand W, Garbe E, et al. Safety and effectiveness of acellular pertussis vaccination during pregnancy: a systematic review. *BMC Infect Dis.* 2020; 20(1): 136. <https://doi.org/10.1186/s12879-020-4824-3>

Di Camillo C, Vittucci AC, Antilici L, et al. Pertussis in early life: underdiagnosed, severe, and risky disease. A seven-year experience in a pediatric tertiary-care hospital. *Hum Vaccin Immunother.* 2021; 17(3): 705-713. <https://doi.org/10.1080/21645515.2020.1791617>

Centers for Disease Control and Prevention. Pertussis (Whooping Cough): Signs and Symptoms. <https://www.cdc.gov/pertussis/about/signs-symptoms.html>. Accessed 25 Jul 2022.

Macina D, Evans KE. Pertussis in Individuals with Co-morbidities: A Systematic Review. *Infect Dis Ther.* 2021; 10(3): 1141-1170. <https://doi.org/10.1007/s40121-021-00465-z>

He F, Xia X, Nie D, et al. Respiratory bacterial pathogen spectrum among COVID-19 infected and non-COVID-19 virus infected pneumonia patients. *Diagn Microbiol Infect Dis.* 2020; 98(4): 115199. <https://doi.org/10.1016/j.diagmicrobio.2020.115199>

de Greeff SC, van Buul LW, Westerhof A, et al. Pertussis in infancy and the association with respiratory and cognitive disorders at toddler age. *Vaccine*. 2011; 29(46): 8275-8. <https://doi.org/10.1016/j.vaccine.2011.08.112>

Yeung KHT, Duclos P, Nelson EAS, et al. An update of the global burden of pertussis in children younger than 5 years: a modelling study. *Lancet Infect Dis*. 2017; 17(9): 974-980. [https://doi.org/10.1016/S1473-3099\(17\)30390-0](https://doi.org/10.1016/S1473-3099(17)30390-0)

Shi T, Wang L, Du S, et al. Mortality risk factors among hospitalized children with severe pertussis. *BMC Infect Dis*. 2021; 21(1): 1057. <https://doi.org/10.1186/s12879-021-06732-1>

Wang C, Zhang H, Zhang Y, et al. Analysis of clinical characteristics of severe pertussis in infants and children: a retrospective study. *BMC Pediatr*. 2021; 21(1): 65. <https://doi.org/10.1186/s12887-021-02507-4>

Viticchi G, Falsetti L, Baruffaldi R, et al. Acute carotid dissection in an adult caused by pertussis. *J Stroke Cerebrovasc Dis*. 2013; 22(8): e635-6. <https://doi.org/10.1016/j.jstrokecerebrovasdis.2013.01.008>

Monaco F, Barone M, Manfredi VG, et al. Pneumomediastinum as a complication of critical pertussis. *Clin Respir J*. 2016; 10(6): 772-776. <https://doi.org/10.1111/crj.12285>

Bal C, Baumgartner R, Gompelmann D, et al. Angioedema as a predominant symptom of Bordetella pertussis infection. *BMJ Case Rep*. 2021; 14(3): e239243. <https://doi.org/10.1136/bcr-2020-239243>

Matczak S, Levy C, Fortas C, et al. Association between the COVID-19 pandemic and pertussis derived from multiple nationwide data sources, France, 2013 to 2020. *Euro Surveill*. 2022; 27(25): 2100933. <https://doi.org/10.2807/1560-7917.ES.2022.27.25.2100933>

Tessier E, Campbell H, Ribeiro S, et al. Impact of the COVID-19 pandemic on Bordetella pertussis infections in England. *BMC Public Health*. 2022; 22(1): 405. <https://doi.org/10.1186/s12889-022-12830-9>

Oh SC, Park SM, Hur J, et al. Effectiveness of rapid multiplex polymerase chain reaction for early diagnosis and treatment of pertussis. *J Microbiol Immunol Infect*. 2021; 54(4): 687-692. <https://doi.org/10.1016/j.jmii.2020.05.012>

Center for Disease Control and Prevention. Pertussis Diagnosis Confirmation. <https://www.cdc.gov/pertussis/clinical/diagnostic-testing/diagnosis-confirmation.html>. Accessed 02 Aug 2022.

Center for Disease Control and Prevention. For Clinicians: Pertussis Treatment. <https://www.cdc.gov/pertussis/clinical/treatment.html>. Accessed 02 Aug 2022.

Kow CS, Hasan SS. Macrolides for patients with COVID-19 and concurrent pertussis infection. *Diagn Microbiol Infect Dis*. 2021; 99(2): 115245. <https://doi.org/10.1016/j.diagmicrobio.2020.115245>

Fiasca F, Necozone S, Mattei A. Pertussis in Italy: how to protect the "unprotectable"? *Hum Vaccin Immunother.* 2021; 17(4): 1136-1141. <https://doi.org/10.1080/21645515.2020.1806673>

Center for Disease Control and Prevention. Fast Facts about Whooping Cough. <https://www.cdc.gov/pertussis/fast-facts.html>. Accessed 03 Aug 2022.

McGirr A, Fisman DN. Duration of pertussis immunity after DTaP immunization: a meta-analysis. *Pediatrics.* 2015; 135(2): 331-43. <https://doi.org/10.1542/peds.2014-1729>