Review

Two years of the COVID-19 pandemic from a child's perspective: A narrative review

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Abstract

The coronavirus disease 2019 (COVID-19) pandemic has been ongoing since 2020. This period is characterized by a significant change in people's lifestyles. Children are a particularly affected group. In order to determine the impact of the pandemic on children's lives, scientific publications available in PubMed, Google Scholar, and The United Nations Children's Fund (UNICEF) Innocenti's Children and COVID-19 Library were reviewed, and the statistical data made available by the Polish Ministry of Health on incidence, death and vaccination rates was analyzed. Even if children were not infected with the virus, they felt the effects of the pandemic through restrictions in the daily functioning of schools, service facilities and households. Despite the relatively mild symptoms accompanying infections in pediatric patients, as well as the low rates of hospitalization and mortality, the pandemic have had numerous negative effects on children's mental and physical health that may trigger further "non-communicable epidemics". Weight changes, limitations in physical activity, and the intensification of social and emotional problems will certainly have a negative impact on their future lives. The introduction of vaccination for children over the age of 5 brought hope, but since then, it has been accompanied by controversy and uncertainty. Further research is necessary to determine the impact of the COVID-19 pandemic on children.

Keywords: vaccination, child, COVID-19, pandemic, SARS-CoV-2

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Introduction

The coronavirus disease 2019 (COVID-19) pandemic is a phenomenon that has changed the functioning of individuals and society, not only in medical but also in economic and social terms. The first cases of this pathogen were reported in November 2019 in Hubei Province, China.[1] Since then, the virus has spread to all continents, resulting in the World Health Organization (WHO) declaring a worldwide pandemic on March 11, 2020.[1] The family of coronaviruses, known to man before the pandemic, was thought to be the cause of seasonal and local epidemics in the Middle East (Middle East respiratory syndrome (MERS)).[2] However, none of the previously reported coronaviruses contributed to a pandemic outbreak on such a large scale.

The pandemic and related restrictions have had a significant impact on people's lives. This is especially true of individuals who are distinct from the general adult population, including children and the elderly. These groups stand out in terms of infectious diseases and public health due to their immunological, cognitive and social differences when compared to young and middle-aged adults. Studies from around the world point to old age as a risk factor for a severe course of a severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection.[3] Age >65 years is the most important factor in terms of the severity of the disease, and this is especially true for groups aged >80 years. In addition, male gender, Black and South Asian race, smoking, pregnancy, obesity, and concomitant diseases (e.g., oncological diseases, chronic obstructive pulmonary disease (COPD), heart and kidney failure, hypertension, sickle cell anemia, Down syndrome, or type 2 diabetes) are important risk factors.[3] Respiratory and cardiovascular dysfunction that progresses with age is cited as the cause of this increased risk.[3]

The abovementioned factors, which are specific to the elderly, do not exclude the possibility of a severe course of COVID-19 in the pediatric population. Furthermore, the condition of children is often overlooked in different sorts of research and reports. This is evidenced by the fact that the exact share of children and adolescents suffering from COVID-19 in Poland is unknown.[4] Moreover, it was initially believed that children were immune to SARS-CoV-2 infection and did not manifest any clinical signs of the disease.[5] Although they have relatively milder symptoms of COVID-19 compared to adults, the disease is also a major problem in this age group.[5,6] The most common clinical manifestations among pediatric patients are fever, cough and a runny nose. Gastrointestinal (vomiting and diarrhea), skin (rash) and neurological (headache, seizures) symptoms are also quite common. The clinical manifestation of COVID-19 in children and adults also includes the oral cavity, where blistering, ulceration and exfoliative stomatitis are the most common,[7] with ulcerations primarily affecting the palate and tongue.[7] Fungal infections are also widespread, but in children, the most serious oral complication is Kawasaki-like syndrome.[7] These conditions are mostly due to an exacerbation of the symptoms of pre-COVID-19 diseases, and the COVID-19-specific oral manifestation is a loss of taste and smell.[7]

The disproportionality is also evident in the number of publications on COVID-19. Research papers focusing on adults significantly outnumber publications on adolescents or children. The aim of this study is to analyze the available publications and statistical data on the epidemiology, clinical symptoms and impact of the COVID-19 pandemic on children worldwide and in Poland.

Material and methods

According to the Act of January 6, 2000, from the Ombudsman for Children, a child is a person from conception until reaching the age of majority (18 years in Poland). This definition was adopted in the present paper, excluding intrauterine infections in fetuses.[8] A literature review was conducted using PubMed, Google Scholar, and The United Nations Children's Fund (UNICEF) Innocenti's Children and COVID-19 Library. The following search terms and their combinations, both in English and in Polish, were used when reviewing the aforementioned databases: "COVID-19", "child", "COVID-19 vaccination", "Poland", and "influence." The analyzed publications about COVID-19 were dated from 2020 to 2022, and described different waves of the pandemic, with a focus on the more recent ones. Other articles included in the review were published no earlier than 2015. The review process began on March 15, 2022, and continued for 1 month, until April 2022, with the addition of data from the Polish guidelines published in June 2022.[30]

Initially, the list of titles and abstracts from the available papers was examined, then the authors analyzed the full texts of the chosen publications. Full-text publications from the entire COVID-19 pandemic period were included in the study. Original papers, legal acts, review papers, and case reports were analyzed. No restrictions were applied with respect to the country of origin, but preference was given to publications written by Polish authors. There were also no restrictions regarding the methodology of the analyzed studies. Abstracts, posters and reviews were excluded. A non-systematic approach was used to analyze the included publications.

Statistics published by the Polish Ministry of Health on COVID-19 morbidity, mortality and vaccination rates for this pathogen among children and adults were also reviewed.[43] They were valid for the time when the review was conducted (March and April of 2022). The quoted excerpts of rules and regulations were taken from the Polish Journal of Laws.

Description of the state of knowledge

Epidemiology of infections among children

Children are likely to get infected by SARS-CoV-2 regardless of age.[9] The youngest are particularly vulnerable due to the immaturity of the immune system's defense mechanisms. Maternally-derived immunoglobulin G (IgG) antibodies are decreased in newborns. A lower reactivity of the complement system and a low number of B-cell co-receptors are responsible for a limited humoral immune response. In addition, cells of the immune system, such as T cells, only become immunocompetent when encountering foreign antigens over the years. The immune system does not reach maturity until around 12 years of age.[10]

In the initial phase of the pandemic (until January 30, 2020), out of nearly 25,000 cases reported in Wuhan, China, only 28 (0.11%) were among children.[11] During the following month, this percentage increased to approx. 1.34%. The youngest of the registered cases was a 28-day-old newborn.[11] The report prepared by the WHO indicated that a reliable epidemiological and clinical assessment of the disease among Chinese children was not possible due to the non-specificity of the presented symptoms and the small number of infected minors.[12] It is worth noting that most patients manifested mild cold-like symptoms, mainly cough and fever, that spontaneously resolved within 1–2 weeks. Only 0.20% of children were in critical condition.[12] It has been shown that the most common group among those infected up to 5 years of age were infants (50.0%) of the male sex (53.0%).[13] The presence of viral genetic material has also been documented by the polymerase chain reaction (PCR) testing in newborns (up to 30 h after delivery).[13] In the data from the first wave of the pandemic in England, 1.0% of the infected were children, with an average age of 6 years and the majority of infections observed among infants.[14] The data obtained in American studies was similar – 1.7% of pediatric patients in relation to the total number of infected people.[15] According to later studies, the percentage of juvenile patients fluctuated in the range of 1.0–5.0% in the general patient population.[16]

An increase in the rate of infections in the pediatric population was observed after the emergence of the Delta variant (B. 1.617.2), with a range of 10.0–24.0%.[9,17,18] Compared to the ancestral variants (19A/19B), the Delta variant is characterized by a shorter incubation period (4 days vs 5–6 days), a greater household attack rate (12–17% vs 80–100%) and a larger basic reproduction number (2.7 vs 5–6.5).[18] Currently (as of March, 2022), accumulating data from many countries indicates that this percentage reaches around 16.0%.[9]

Among the reasons for the low morbidity and the mild course of the disease in children is a low expression of renin-angiotensin-aldosterone system (RAAS) receptors (the gateway for SARS-CoV-2 to enter cells), lower angiotensin-converting enzyme activity, and a lower amount of interleukin (IL)-6 and IL-10 in comparison to adults.[16] The sources of infection among children may seem surprising. Children were shown to get infected more often in households from adults than from peers in schools.[17,18] The hospitalization rate remained at a low level (5.0–20.0%), with a significant increase (5–10 times) reported due to infections with the Delta (B.1.617.2) and Omicron (B.1.1.529) variants.[17,19,20] Infants up to 6 months of age were hospitalized most often.[20]

Many researchers, and medical practitioners in particular, point to the problem of underestimation of the data presented and the small number of studies conducted on pediatric patients.[5] Unfortunately, there is no official government data on infections among children in Poland. As of May 15, 2020, during the first wave of the pandemic, out of 17,921 diagnosed COVID-19 cases, only 1,191 (6.7%) of them were children.[21] These were mainly adolescents aged 15–19 years, representing 32.7% of the child population.[21] This result turned out to be surprisingly high, much higher than that reported for other European countries and the USA (0.6–2.0%), and comparable to the data obtained in Canada (5.7%).[21] This is likely due to the large number of tests conducted among children and fewer among adults.

In Poland, the highest proportion of pediatric patients was found in the Silesia Province (20.2%) and the lowest in the Lubuskie Province (3.0%).[21] Studies do not indicate the exact reasons for such a significant difference among provinces, but the authors mention as possible reasons the total number of tests performed, varying epidemic situation and differences in the SARS-CoV-2 transmission (e.g., epidemic outbreaks in healthcare facilities or nursing homes).[21] In September 2020, the proportion of children among those infected reached 7.6%.[22] Until then, no deaths in pediatric patients due to COVID-19 had been reported.[21,22]

COVID-19 symptoms in children

COVID-19 is characterized by a multitude of symptoms. Apart from respiratory tract involvement, the disease may significantly affect other systems (e.g., digestive, nervous, or muscular). In children, the symptoms of the disease are similar to those observed in adults, but they occur with different frequencies.[9] Most children are asymptomatic (15.0–42.0%) or have mild symptoms, to such an extent that children were initially thought not to be potential victims of the virus.[9,23] Most often, the asymptomatic course was observed in children aged 1–10 years (19.7%). Both asymptomatic and symptomatic patients were equally hospitalized.[24] The most

common indicators of infection were fever (64.2%), cough (34.8%) and a runny nose (16.1%).[24] Less common symptoms of respiratory tract infection included a sore throat (8.9%), sputum production (2.7%) and dyspnea (10.7%), which were most frequent in infants.[24] Gastrointestinal symptoms included diarrhea (13.4%) and vomiting (6.3%), specific to older children. Headaches affected approx. 5.5% of the examined children.[24] There were also reports of rash (10.7%), conjunctivitis (8.0%), peripheral edema (8.0%), oral lesions (6.3%), cervical lymphadenopathy (2.7%), and even shock (8.9%).[24] Feeding difficulties with accompanying fever were common in infants.[9] In addition, the aforementioned headaches and seizures played a major role among neurological symptoms.[25] The majority of these seizures were febrile seizures, sometimes with electroencephalography (EEG) changes.[26] However, it has not been demonstrated whether these seizures are SARS-CoV-2-induced epilepsy.[27] Non-febrile illness seizures may be immunologically mediated and stimulated by cytokine production.[27] All of them disappeared after appropriate treatment. Neurological symptoms were reported less frequently in children than in adults and were mainly non-specific.[26] Only 1.0% of them, apart from convulsions (0.3%), encephalopathy (0.6%), meningeal symptoms (0.41%), cranial nerve damage, and ataxia, were specific.[26] A loss of smell and taste, often accompanying infections in adults, was less frequent in children (1.0–10.0% of those infected).[9]

The clinical manifestation of COVID-19 in children and adults does not bypass the oral cavity (about 25% of patients), where blistering, ulceration and exfoliative stomatitis are most common,[7] with ulcerations primarily affecting the palate and tongue. They are painful (about 75%) but do not bleed.[7] Fungal infections are also very frequent, arising from stress and lowered immunity. The most serious oral complication is Kawasaki-like syndrome, the symptoms of which include erythema, dryness, cracking, and bleeding.[7] The above conditions are mainly associated with the aggravation of symptoms from pre-infection diseases. The specific symptoms of COVID-19 in the oral cavity are a loss of smell and taste.[7]

In Polish studies analyzing the clinical manifestations of SARS-CoV-2 infection in children in 2020, the most commonly observed symptom was fever (46.0%), mostly lasting for 1–2 days.[28,29] Additional 14.0% of patients had a subfebrile rise in temperature.[28] A loss of smell and taste occurred in only 8.0% of the general pediatric population, in 20.0% of adolescents, and never in those under 5 years of age. An asymptomatic course was found in 21.0% of children. Headache (22.0%) and sore throat (28.0%) were more common among adolescents. Younger children were more likely to have a runny nose, diarrhea, rash, and fever. Radiologically confirmed pneumonia was diagnosed in 12.0% of children. A total of 23.0% of patients presented at least one gastrointestinal symptom.[28] Among the aforementioned conditions, gastrointestinal symptoms, pneumonia and rash were associated with longer hospital stays in children.[29] It is also worth noting that during the second wave of the pandemic (September–December of 2020), there was a lower proportion of asymptomatic patients (13.0%) compared to the first wave (March–August of 2020; 36.0%).[28] However, pneumonia (14.0% vs 9.0%) and gastrointestinal symptoms (29.0% vs 12.0%) were more common.[28] The increase in cases of infected children in Poland in early 2022 due to the Delta and Omicron variants did not worsen the course of the disease, and most cases remained mild or moderate.[30] The most important symptoms of SARS-CoV-2 infection in children are presented in Table 1.

In addition to clinical symptoms, radiological and laboratory abnormalities have also been reported in children with COVID-19.[25] In more than one-third of pediatric patients after the X-ray examination, and in more than half of pediatric patients after the chest computed tomography (CT) examination, the "milk glass" image was seen, most often among adolescents aged 15–18 years.[25] This image was often observed bilaterally, with a predominance in the peripheral regions and lower lobes of the lungs.[28] Echocardiography revealed left ventricular dysfunction in approx. 47.4% of patients, with almost all cases (89.0%) resolving after 7 (5.0–8.3) days.[24] Laboratory tests have also shown significant discrepancies. Some researchers point to an absence of laboratory markers for the disease, with only a slight increase in C-reactive protein (CRP) and procalcitonin levels, while others describe key role for the latter measures and D-dimer levels as predictors of a patient's condition.[9,15,25] A significant percentage of pediatric patients had elevated levels of CRP (54.0%), ferritin (47.0%), lactate dehydrogenase (37.0%), D-dimers (35.0%), and procalcitonin (21.0%), as well as transaminases, creatine kinase MB (CK-MB), and the erythrocyte sedimentation rate (ESR).[31] Patients with pneumonia had higher leukocyte counts and CRP, D-dimer, IL-6, alanine transaminase (ALT), and aspartate transaminase (AST) levels than children without pneumonia.[28] The indicators of the severe course of COVID-19 in children include elevated levels of the abovementioned markers of inflammation, the occurrence of dyspnea with tachypnoea and hypoxia, and alimentary symptoms.[32] Risk factors for such a course and the need for hospitalization are primarily comorbidities, most commonly pulmonary (28.0%), metabolic (i.e., diabetes and obesity; 27.0%), neurological and developmental (22.0%) conditions.[31]

The variety of symptoms and the relatively mild course of infection in children have been common reasons for avoiding COVID-19 diagnosis and underestimating the impact of the infection in pediatric patients. However, concerns regarding the long-term complications of the pandemic in the current pediatric population are understandable.

Table 1. Key demographic aspects, clinical manifestations and effects of the coronavirus disease 2019 (COVID-19) pandemic among children

Topics covered	Study	Main findings
Epidemiology	Jackowska et al. 2021[19] Wei et al. 2020[11] Bhuiyan et al. 2021[13]	Children can get COVID-19 regardless of age. Newborns can also get infected.
	Wei et al. 2020[11] Ladhani et al. 2020[14] Alsohime et al. 2020[15] Koirala et al. 2021[17] Howard-Jones et al. 2022[18]	In the first wave of the pandemic worldwide, 0.29–1.7% of infected patients were children; during the Delta variant wave, the incidence rate in pediatric patients increased to 10.0–24.0%.
	Koirala et al. 2021[17] Patel 2020[19] Marks et al. 2022[20]	Hospitalization rate remained at a low level (5.0–20.0%); it increased during the Delta and Omicron variant waves.
	Jackowska et al. 2020[21]	The percentage of infected children in Poland was 6.7–7.6%.
Symptoms	Williams et al. 2020[23]	The most common course was asymptomatic (15.0–42.0%) or mild.
	Yasuhara et al. 2020[24] Paradowska-Stolarz 2021[17] Pokorska-Śpiewak et al. 2021[28] Mania et al. 2022[29]	The most common symptoms are fever, cough and a runny nose. Gastrointestinal (diarrhea, vomiting), neurological (convulsions, headache) and dental (blisters, ulcers, inflammation) symptoms have also been observed. A loss of smell and taste was less common compared to the adult population.
	Fernandes et al. 2021[32]	Indicators of severe COVID-19 in children include elevated levels of inflammatory markers (CRP, ESR, procalcitonin), the presence of dyspnea with tachypnea and hypoxia, and gastrointestinal symptoms.
PIMS/MIS-C syndrome	Jackowska et al. 2021[19] Radia et al. 2021[33] WHO 2020[35]	PIMS/MIS-C is a rare complication, appearing 4–8 weeks after the infection, manifesting with symptoms from the respiratory, cardiovascular, gastrointestinal, and oral systems, fatal in 1.5%.
Effects of the pandemic	Skolmowska et al. 2022[57]	The problem of compulsive overeating and weight gain has increased, especially in obese young women.
	Ezpeleta et al. 2020[58] Kolcakoglu and Yucel 2021[59] Chen et al. 2020[60]	The problem of mental disorders, caused by the occurrence of separation anxiety, uncertainty about the future and lack of the company of peers, has intensified to a mild or moderate degree. It manifested in tantrums, crying and aggression fits.
	Krywult-Albańska and Albański 2021[61]	The problem of deterioration in the quality of education and deepening of technological exclusion due to remote learning was noted, as observed by student's parents.
	Yum et al. 2021[62] Üstün et al. 2021[64]	There is a perceived problem of deteriorating eyesight (more frequent myopia) and reduced frequency of dental check-ups among children.

WHO – World Health Organization; CRP – C-reactive protein; ESR – erythrocyte sedimentation rate; PIMS – pediatric inflammatory multisystem syndrome; MIS-C – multisystem inflammatory syndrome in children.

PIMS/MIS-C syndrome

The multisystem inflammatory syndrome in children associated with COVID-19, known in Europe as pediatric inflammatory multisystem syndrome (PIMS) and in the USA as multisystem inflammatory syndrome in children (MIS-C), is a rare but very serious complication of SARS-CoV-2 infection.[9,33] The criteria for the diagnosis of this syndrome are presented in Table 2.[9,34,35]

Pediatric inflammatory multisystem syndrome occurs approx. 4–8 weeks after the SARS-CoV-2 infection.[9] Its course may resemble Kawasaki disease or toxic shock.[9] Patients diagnosed with this syndrome range in age from 3 months to 20 years, with a median age of 8.6–9.7 years.[33,35] This complication occurs in 1 in 3,000 children infected with the SARS-CoV-2 (approx. 0.03%).[9] Boys of African descent with obesity and respiratory dysfunction are more commonly affected.[33,35] Symptoms in these patients were mainly respiratory (80.0%; cough, dyspnea), cardiovascular (67–82%; hypotension, tachycardia) and gastrointestinal (71.0%; vomiting, diarrhea, abdominal pain). Rash and other skin symptoms were more common than in the course of COVID-19 without this syndrome (42.0%). The Kawasaki-like syndrome is also manifested by a number of symptoms in the oral cavity, including erythema, dryness, fissuring, peeling, cracking, and bleeding of mucosa and the lips, as well as strawberry tongue.[7] In Poland, 8.4% of children with this complication require care in an intensive care unit (ICU), while in other countries this percentage ranges from 40.0% to 60.0%.[9] In laboratory tests, the most common abnormalities were CRP elevated to approx. 150 mg/L (94.0%), neutrophilia (83.0%), lymphopenia (50.0%), elevated troponin T levels (68.0%), elevated N-terminal pro B-type natriuretic pep-

Table 2. Diagnostic criteria for PIMS/MIS-C syndrome according to WHO and Centers for Disease Control and Prevention (CDC)

Source	Description of the criteria
WHO criteria (all 6 must be met)	patient's age: 0–19 years
	fever for at least 3 days
	signs of multi-system activity (at least 2): – rash, bilateral non-suppurative conjunctivitis or symptoms of mucocutaneous inflammation (of the mouth, hands or feet) – hypotension or shock – heart dysfunction, pericarditis, valvulitis or coronary abnormalities (including echocardiograms or elevated troponin/BNP levels) – evidence of coagulopathy (prolonged PT or PTT; elevated D-dimers) – acute gastrointestinal symptoms (diarrhea, vomiting or abdominal pain)
	increased levels of inflammatory markers – CRP, ESR, procalcitonin
	exclusion of another infectious cause of the induced condition
	SARS-CoV-2 infection (positive PCR, antigen test or contact with an infected person)
CDC criteria (all 4 must be met)	age <21
	– documented fever >38.0°C for ≥24 h or reporting a subjective fever lasting ≥24 h – laboratory markers of inflammation
	no alternative diagnoses
	recent (up to 4 weeks) or current SARS-CoV-2 infection (PCR, antigen test, exposure)

BNP – B-type natriuretic peptide; PT – prothrombin time; PTT – partial thromboplastin time; SARS-CoV-2 – severe acute respiratory syndrome coronavirus 2; PCR – polymerase chain reaction.

tide (NT-proBNP) levels (77.0%), and thrombocytopenia (41.0%).[33,36] Abnormalities were also found in chest radiographs and echocardiography (59.0%), including mainly coronary aneurysms and pericardial effusions (41.0%).[36]

Among hospitalized patients, 1 in 10 required respiratory support in the ICU,[36] and 1.5% of children diagnosed with PIMS died.[32] A registry of patients with PIMS is kept in Poland, and by January 28, 2022, there were 500 children recorded.[37]

Pandemic calendar for children

The COVID-19 pandemic is now more than 2 years old. Like a child, the virus has developed and changed during the first 2 years of life, adapting to environmental conditions. Thus, if one were to plot the natural history of the pandemic on a numbered line, it would resemble a sine wave rather than a straight line.

On March 4, 2020, the first case of SARS-CoV-2 infection in Poland was detected in Zielona Góra.[38] Due to subsequent infections in other parts of the country, on March 10, a decision was taken to cancel all mass events, and a day later, schools, kindergartens and universities were closed until further notice. On March 15, the borders of Poland were closed, and on March 20, it was decided to impose an epidemic state throughout the country.[38] On March 23, the first case of COVID-19 was diagnosed in a Polish child – a 13-year-old girl hospitalized until April 13 in Kraków.[39] The closure of educational institutions was, therefore, one of the first government measures to curb the spread of coronavirus in the country. Schools were only allowed to perform a caretaking function. In the Act of March 2, 2020, on special solutions related to preventing, counteracting and combating COVID-19, other infectious diseases and emergencies caused by them, there was a provision on the possibility of remote work, which opened the way for further decisions concerning children.[40] On March 25, gatherings of more than 2 people were banned. Most institutions and service establishments remained closed. On April 1, a ban on the movement of people under the age of 18 without adult supervision was introduced. Parks, boulevards and beaches were closed.[40]

The first abolition of restrictions happened on April 20. The ban on moving without adult supervision was maintained only for children under 13 years of age. On May 4, nurseries and kindergartens were allowed to return to work under a sanitary regime, in accordance with the guidelines of the Chief Sanitary Inspectorate. On May 30, 2020, most of the restrictions in force were eased, but covering the mouth and nose remained mandatory in public spaces.[38] At that time, the first partially remote school year in Poland had ended. In May 2020, the first cases of PIMS in Poland were reported.

After the return to school, the pandemic situation began to deteriorate rapidly. On October 24, the decision was made to return to distance education for grades IV–VIII of primary school and the entire post-primary school.[38] From November 4, this procedure was extended to grades I–III. On November 28, the outside movement of people under the age of 16 was again restricted. On January 18, 2021, full-time education in grades I–III of primary schools and special schools was restored.[41] On March 25, nurseries and kindergartens were closed, and reopened on April 19. The students were learning remotely practically until the end of the school year. The new school year began in classrooms with a sanitary regime in place. On March 28, 2022, mouth and nose coverings and isolation were abolished.[42]

A large number of rapidly changing decisions issued by the authorities, combined with separation, rich misinformation and a fear of infection, made the COVID-19 pandemic a turning point in children's lives, and caused widespread changes in their health, both mentally and physically.

COVID-19 vaccinations in children

On March 31, 2022, the number of COVID-19 vaccinations administered in Poland was 53,924,321, and the number of fully (2 and more doses) vaccinated people amounted to 22,347,421 (59.0% of the population),[43] with 3.3 million vaccinations given to children aged 5–17 years.[43] These numbers are not optimistic, especially when compared to demographic statistics. The number of children aged 5–18 years in Poland in 2020 was 5,770,408.[44] Taking the uptake of 2 and 3 doses into account, the number of fully vaccinated children represents only a fraction of this population. A disturbing fact is also the lack of widely available vaccinations for children in some highly developed European countries, including Germany and England.

After the development of COVID-19 vaccines for adults, pharmaceutical companies started testing their products for safety in children.[45] These studies showed that the vaccines were safe for the youngest children, and mainly local reactions (pain, swelling, or redness) were reported.[45,46] Myocarditis or pericarditis were reported more frequently in young men than in other groups, but the vast majority of these cases were mild.[46] In addition, the risk of developing myocarditis after SARS-CoV-2 infection was 6–34 times higher than after getting the vaccine.[46] However, it was recognized that immunizing children was essential for a quicker end to the pandemic, and was beneficial for patients in terms of a lower risk of hospitalization and death.[45] Parents and patients themselves were also concerned. According to research results from all over the world, 40.0–70.0% of parents declared a willingness to vaccinate their children (44.0–75.0% in Poland).[47,48] Less enthusiasm was visible among the minors themselves. They expressed a willingness to vaccinate only in 49.6–61.4% of cases.[47] The main concerns were adverse reactions to the vaccines and doubts about their efficacy, often repeated in the media.[47]

Vaccination for those aged 16 years and older was introduced together with the program for adults on December 27, 2020. Teenagers aged 12–15 years old could register for vaccination from June 7, 2021, and children aged 5–11 years from December 14, 2021.[49,50] Currently (as of March, 2022), the following preparations are approved for vaccinating adolescents: Comirnaty by Pfizer (New York, USA)/BioNTech (Mainz, Germany) with a 21-day interval between doses and Spikevax by Moderna (Cambridge, USA) with a 28-day interval.[49] The youngest patients receive Comirnaty with an interval of 3 weeks.[50] It is also possible to be subjected to a three-dose vaccination, with intervals of 21 and 28 days between administrations, intended for children with immunodeficiencies, such as oncological patients, the immunosuppressed, transplant patients, or patients with human immunodeficiency virus (HIV).[50] From January 28, 2022, it is possible for adolescents to receive a booster dose of the Comirnaty vaccine.[51] The doses are not related to body weight and are only adjusted to the age of the vaccinated person. For adolescents, they are the same as the adult dose (30 μg), while children are given a lower dose of 12 μg.[52] This difference is due to the different physiology of the immune system in children and adults.

Arguments in favor of the vaccination of children include protection against infection, reducing the risk of developing PIMS syndrome, and ensuring greater population immunity.[53] Arguments against the vaccination include post-vaccination complications, the relatively mild course of COVID-19 in children and a low hospitalization rate, the limited vaccine supply in less affluent countries, and the higher costs of vaccination programs compared to treating pediatric patients in the ICU.[53] However, it is important to remember that each successive coronavirus variant was associated with a more severe course of the disease and more frequent hospitalization of children, and the long-term complications of the infection are unknown.[53] It is also extremely important during the COVID-19 pandemic to administer mandatory and recommended vaccinations to children in order to protect them from other infectious diseases. Unfortunately, there are reports of a decrease in their administration as early as 2020.[53–55]

Health and social consequences of the pandemic for children

Significantly fewer children than adults were infected with SARS-CoV-2. However, many more children have experienced the effects of isolation, repeated school closures, and prolonged negative mental and emotional states. Just over 2 years after the onset of the COVID-19 pandemic, another silent pandemic is beginning to emerge – obesity, depression and visual impairments.[56]

Children, like adults, were accompanied by permanent fear and uncertainty about the future. These feelings were compounded by isolation and the transfer of all social contacts to the Internet. A sedentary lifestyle, caused by prolonged time in front of the computer during remote activities, and the temporary inability to leave the house, contributed to weight gain and the intensification of compulsive overeating in many individuals.[57] These phenomena were particularly exacerbated in women and obese individuals.[57] Social problems of teenagers increased slightly to moderately during the pandemic.[58] A lack of companionship on weekdays and low activity increased depression and anxiety, especially among older adolescents.[59] They experienced significantly higher levels of separation anxiety and a fear of physical injury compared to other

types of anxiety.[60] Their manifestations were most often fits of crying (32.8%), anger (28.6%) and aggression (26.7%).[60] These symptoms became more frequent during the lockdown, when harmful oral health and hygiene habits (finger sucking, nail biting and lip biting) occurred at a lower frequency after the lockdown than before it.[60]

Educational inequalities related to differing access to technology (only 20.0% of rural households were connected to high-speed Internet in 2020) and students' different levels of motivation for self-education, ranging from 30.0% to 42.0%, also worsened the situation.[61] Eighty-nine percent of parents described the quality of distance learning as worse, including 62.0% who reported a much worse quality of distance learning than classroom education.[61] A long time spent in front of screens and low physical activity also contributed to visual impairments and a higher prevalence of myopia in children aged 5–10 years.[62] An increase in the incidence of pediatric trauma and self-harm has also been reported.[63]

A reduction in access to dental appointments should also be mentioned, which offers a worrying prospect for the coming years.[64] Due to the high risk of SARS-CoV-2 infection in the dental office, caused by direct face-to-face contact with patients and the presence of aerosols, alternative methods for dental visits were necessary during the pandemic.[65] Scheduled dental appointments and procedures had to be postponed, and only emergency treatments were implemented.[65] One of the alternatives that began to be more widely used is teledentistry.[65] With this method, it is possible to reduce the negative effects of the pandemic on the oral health of children and adults by providing adequate services without any risk of virus transmission. In addition, teledentistry, as a method with proven high efficiency, can be used in the future as one of the components of the healthcare system, enabling proper diagnosis and classification of patients, and thus reducing queues and the time to implement treatment.[65]

Among the positive changes, children's eating habits changed favorably, with more frequent consumption of fruits and vegetables, and an effort to reduce sugar and fat intake.[66]

In sum, the changes have concerned practically every sphere of children's lives and have not brought an optimistic prognosis for the future. The most important effects of the COVID-19 pandemic on children are shown in Table 1.

Conclusions

The COVID-19 pandemic has had an enormous impact on children. Even if they were not infected with the virus, their lives were changed by the nationwide quarantine and a sudden alteration of daily habits. The SARS-CoV-2 virus turned out to be relatively sparing in this age group, allowing children to pass through the disease mildly, often asymptomatically, with much lower hospitalization and mortality rates than those in adults. The main symptoms of the infection were respiratory, including fever, cough and a runny nose. In addition, children showed gastrointestinal and neurological symptoms, as well as dental problems (ulcers, blisters, inflammation of the oral cavity). Numerous uncertainties, isolation and significant changes in the education system have negatively affected the mental and physical health of the pediatric population. Weight changes, reduced physical activity, and increased social and emotional problems are bound to have a negative impact on their future lives. The deterioration of eyesight and dentition in the pediatric population seems worrying. Through remote learning, inequalities in children's education have widened, and the quality of their educational process has declined.

It should be remembered that the pandemic is not over yet, and currently (March 2022), a reduction in the level of precautions and the lifting of all sanitary restrictions have been implemented. Additionally, it is worth noting that all research results refer to a fairly short, two-year period. Currently, only the short-term effects of the pandemic among children are known, and concerns about the future remain in the realm of conjecture. In addition, due to the mostly benign and non-specific course of SARS-CoV-2 infections, not all cases of sick children were reported to doctors. Thus, the exact incidence statistics are not known, and a full qualitative and quantitative analysis of symptoms is impossible. The abovementioned facts are the limitations of the current study. In order to thoroughly analyze the condition of patients and assess complications of the COVID-19, it will be necessary to conduct further observations and research over a period of several years. Most of the negative effects of the COVID-19 pandemic on the pediatric population will not be observable until several years from now, but the fight against already identified problems and the prevention of foreseeable complications should begin immediately.

Ethics approval and consent to participate

Not applicable.

Data availability

All the data analyzed during the review process is included in this published article.

Consent for publication

Not applicable.

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