Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Commentary

Decreasing routine vaccination rates in children in the COVID-19 era

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"*Ενός κακοῦ μύρια ἔπονται.*"

"*Misfortunes never come singly.*"

Sophocles, Greek tragedian (496–406 BCE)

In response to the coronavirus disease 2019 (COVID-19) pandemic, routine healthcare services, including delivery of vaccinations, were disrupted in many countries, while in some cases vaccination appointments were missed because of fear of attending healthcare facilities. Preliminary studies have demonstrated decreased routine vaccination rates in children in several countries [1–3]. On July 15, 2021 the World Health Organization (WHO) released global vaccination rates data for the year 2020 [4]. The global vaccination rate against tuberculosis [bacillus Calmette-Guérin (BCG) vaccine] dropped from 88% in 2019 to 85% in 2020, coverage with three doses of diphtheria-tetanus-pertussis (DTP3)-containing vaccines or poliomyelitis vaccine (polio3) dropped from 86% in 2019 to 83% in 2020 for both vaccines, rates against hepatitis B third dose (HepB3) dropped from 85% in 2019 to 83% in 2020, and measles-containing vaccine first-dose (MCV1) dropped from 86% in 2019 to 84% in 2020 [4]. While the percentage drop may seem small, these findings represent regressions to vaccination rates recorded more than a decade ago. Overall, an estimated 23 million infants younger than one year did not receive basic vaccines, which is the highest number since 2009 [5]. An analysis of pediatric vaccination trends for 204 countries from 1980 to 2019 found that after considerable increases in global coverage rates in most countries (e.g., DTP3 coverage raised from 39.9% in 1980 to 81.6% in 2019, and MCV1 from 38.5% to 83.6%, respectively), these gains remained stable or reversed over the last decade [6]. Overall, as of 2019 only 11 countries reached the target of at least 90% coverage set by the Global Vaccine Action Plan [6].

A thorough study of the 2020 WHO data reveals an alarming situation in many countries that were already facing fragile vaccination rates [5]. More than half of the African countries recorded a reduction of vaccination rates with polio3 (the largest reduction being 24% in Tanzania), DTP, Hep3, 3 doses of *Haemophilus influenzae* type b vaccine (Hib3), and 3 doses of pneumococcus conjugate vaccine (PCV3) (reductions up to 15% in Djibouti, each), MCV1 and MCV2 (reductions up to 21% in Djibouti, each) [5].

Although overall childhood vaccination coverage for most vaccines has gradually increased across Asia over the past five years, the COVID-19 pandemic led to a decline in pediatric vaccination coverage for almost all vaccinations. Compared to 2019, the overall BCG vaccination coverage decreased from 93% to 87% in 2020, with a larger decline (7%) observed in India [5]. The overall DTP3 coverage rate has decreased to 85% with the highest reduction in Nepal (9%). In Southeast Asia, MCV1 coverage fell from 94% in 2019 to 88% in 2020 with the most pronounced decline observed in Indonesia (12%). Southeast Asia also had a significant overall decline in vaccination rates for HepB3 (85% compared to 91% in 2019). Finally, the largest reduction in polio3 vaccination was recorded in the Democratic People's Republic of Korea (from 98% in 2019 to 70% in 2020) [5].

Significant changes were also noted in central Asia and in particular in Azerbaijan (Hib3 rates dropped from 94% in 2019 to 79% in 2020, polio3 from 96% to 85%, MCV1 from 98% to 82%, and MCV2 from 97% to 79%) and Georgia (polio3 from 94% in 2019 to 88% in 2020, MCV1 from 99% to 91%, and MCV2 from 97% to 77%) [5].

In Europe, significant reductions occurred in Bulgaria (MCV1 from 97% in 2019 to 87% in 2020, and MCV2 from 95% to 84%) and Ukraine (MCV1 from 93% to 85% and MCV2 from 92% to 82%). In Montenegro BCG coverage decreased from 80% in 2019 to 67% in 2020, HepB3 from 62% to 52%, MCV1 from 33% to 24%, and MCV2 from 80% to 76% [5]. Reductions in routine vaccination rates were also recorded in the Americas, as follows: from 83% to 68% for BCG, from 87% to 85% for MCV1, from 82% to 76% for PCV3, and from 87% to 80% for polio3 [4]. Finally, in Oceania reductions in vaccine coverage were noted in some countries with the most notable in Samoa (30% for MCV1) and Kiribati (34% for MCV2) [5].

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Historically, diseases whose prevention and treatment are highly dependent upon the continuity of healthcare services re-emerge during political, financial or humanitarian crises, even in countries with prior well-established healthcare services [7]. Recent examples include the dramatic increase of HIV-1 infections among injecting drug users in Athens, Greece in 2011 at the beginning of the financial crisis [8] and the re-emergence of poliomyelitis in Syria in 2013 during the devastating war [9]. Health crises can also disrupt vaccination services. During the peak of the Ebola epidemic in Liberia, measles vaccinations decreased by 67.3% [10]. The accumulation of susceptible individuals regardless of reason (e.g., vaccine hesitancy, inequalities in vaccination services, incomplete vaccination programs) below the threshold for herd immunity was the ideal substrate for the recent measles epidemics in Europe and the poliomyelitis outbreaks in Tajikistan in 2010 [11], Syria in 2013 [9], and Pakistan in 2019 [12]. Such epidemics may affect specific unvaccinated age-groups. This was the case in the poliomyelitis outbreaks in Tajikistan, Syria, and Pakistan which affected young pediatric cohorts [9,11,12]. In mid February 2022 the health authorities in Malawi detected a case of paralytic poliomyelitis in a three-year old child, which is the first wild poliovirus case in Africa since August 2016 [13]. The etiologic strain was linked to a strain that has been circulating in Pakistan [13]. Nonetheless, routine vaccinations have never been as massively disrupted as we are now seeing during the COVID-19 pandemic.

Modeling studies are important for understanding the dynamics of reduction of immunization rates. A modeling study estimated that a 50% reduction in routine immunizations against measles in six African and Asian countries during the COVID-19 pandemic, without catch-up vaccinations to reach unvaccinated children, was projected to increase the excess deaths in these countries and lead to large measles outbreaks in some countries [14]. Another model-based study found that a continuing reduction of measles vaccinations to children becoming one year old in 2020 in the United States could lead to projected vaccination rates below 80% [15]. The latter study also found that a 15% sustained catch-up vaccination rate may be needed to reach pre-pandemic vaccination rates in this cohort [15].

Although signs of recovery were observed in some countries during the past year, vaccination gaps are likely to persist over the coming years. National public health authorities should strengthen vaccination strategies and ensure the continuity of vaccination services, making this a critical public health priority. Nonetheless, more initiatives are needed to re-establish past vaccination coverage rates and to achieve higher rates over the next decade. We should remember however, that one solution does not fit all. Road maps with timelines and accountability metrics are needed to provide catch-up vaccinations targeting eligible age-groups and populations with higher immunity gaps and should be widely published [1,2,14]. Mobile vaccination teams and delivery of vaccinations along with other services (e.g., maternity healthcare, school-based vaccinations) may facilitate vaccinations in more deprived and remote communities, and have proven useful [7,10]. As an example, a multi-level intervention which consisted of healthcare training, distribution of educational materials and vaccination reminders increased by seven-fold the probability of scheduling an appointment for HPV vaccination in a rural healthcare facility in the United States during the COVID-19 pandemic [16]. Indeed, mobile clinics were successfully used to reach young children who missed vaccinations in the United States during summer of 2020 [17].

Currently COVID-19 is the leading cause of vaccine-preventable death [18]. COVID-19 vaccination facilities, which are widespread in many communities globally, could be re-purposed to provide catch-up routine vaccinations. Campaigns targeting parents and the general public are needed to address the benefits of routine vaccinations. Vaccination coverage rates should be available in real-time to inform public health actions, facilitated by vaccination registries. Finally, there is need to enhance active surveillance of vaccine-preventable diseases such that real-time detection and transparent reporting can inform public health strategies.

Vaccination programs are a key public health measure saving millions of lives every year. It is likely that in the coming years health authorities will need to address a difficult mixture of regressed routine vaccination rates, increased primary healthcare needs, gaps in vaccination registries, and vaccine hesitancy. For this reason, initiatives must be designed and implemented now at the local, state, and national levels to achieve high population-level rates of immunization. A return to normality cannot be achieved without high and sustainable routine vaccination coverage rates across the lifespan. Failing to do so simply invites further infectious disease outbreaks and continued morbidity and mortality from vaccine-preventable diseases. Together we have a responsibility to address this issue nationally and globally for the sake of us all.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Dr. Poland is the chair of a Safety Evaluation Committee for novel investigational vaccine trials being conducted by Merck Research Laboratories. Dr. Poland provides consultative advice on vaccine development to Merck & Co., Medicago, GlaxoSmithKline, Sanofi Pasteur, Johnson & Johnson/Janssen Global Services LLC, Emergent Biosolutions, Dynavax, Genentech, Eli Lilly and Company, Kentucky Bioprocessing, Bavarian Nordic, AstraZeneca, Exelixis, Regeneron, Janssen, Vyriad, Moderna, and Genevant Sciences, Inc. These activities have been reviewed by the Mayo Clinic Conflict of Interest Review Board and are conducted in compliance with Mayo Clinic Conflict of Interest policies. Dr. Poland holds patents related to vaccinia, influenza, and measles peptide vaccines. Dr. Poland has received grant funding from ICW Ventures for preclinical studies on a peptide based COVID-19 vaccine. This research has been reviewed by the Mayo Clinic Conflict of Interest Review Board and was conducted in compliance with Mayo Clinic Conflict of Interest policies.

Helena C. Maltezou, Snezana Medic, Evgnosia Effraimidou and Dimitrios Cassimos have no conflict of interest to declare.

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