Navigating Barriers to Adequate Vaccination Coverage: Impact of the COVID-19 pandemic and Post-Pandemic Strategies

Layman's summary

The COVID-19 pandemic disrupted global vaccination programs through various measures that did not use drugs or vaccines, but instead lockdowns and social distancing. Additionally, the pandemic posed significant challenges to the administration of childhood vaccinations due to the high pressure it put on healthcare systems. This literature review describes the impact of the pandemic on the percentage of people that receive their vaccinations (coverage ratio), emphasizing the decline in the vaccine coverage ratios of various vaccines and the emergence of vaccine-preventable diseases like measles. It highlights the importance of addressing barriers to vaccination, including cultural, social, and economic factors. For example, while higher education and income levels correspond with greater vaccination acceptance, lower educational and income groups only show more vaccine hesitancy but not more refusal. Targeted education campaigns are essential to decrease vaccine hesitancy and improve vaccination uptake. These campaigns should not be limited to specific income or educational groups as there are people that have vaccine hesitancy in all groups.

This review also highlights the unequal recovery in vaccination coverage across regions and income groups, emphasizing the need for strategies that take everyone's situation into account to ensure that everyone who wants to be vaccinated has the chance to be.

Most regions returned to (almost) pre-COVID-19 pandemic levels of vaccination coverage ratios in 2022, however, when countries were grouped on the average income per citizen, the vaccination coverage ratio of low-income countries was still declining in 2022. Therefore, approaches that focus on the people in need and are customized to fit the local situation, such as those used by the GAVI vaccine alliance, offer potential solutions by identifying and addressing poorly vaccinated areas.

In the years after the COVID-19 pandemic, efforts to restore and strengthen vaccination programs are essential, especially with new outbreaks of vaccine-preventable diseases like measles. The year 2023, which is deemed "Big Catch-Up", together with the plans of the Immunization Agenda 2030, are important to reduce the pandemic's consequences and increase global vaccination coverage. The experiences of past outbreaks, such as the Ebola outbreak, underscore the urgency of these efforts. To achieve the Immunization Agenda 2030's aspiring goals and to ensure "no one is left behind", collective efforts should be made to increase vaccination coverage and tackle barriers to vaccine administration. These important steps are necessary to achieve the ultimate goal of adequately protecting the health of children worldwide against vaccine preventable diseases.

Abstract:
The COVID-19 pandemic disrupted global vaccination programs through various non-pharmacological interventions and posed significant challenges to the administration of childhood vaccinations. This literature review examines the impact of the pandemic on vaccination coverage, emphasizing the decline in coverage ratios and the emergence of vaccine-preventable diseases like measles. It accentuates the importance of addressing barriers to vaccination, including cultural, social, and socioeconomic factors. For example, while higher education and income levels correlate with greater vaccination acceptance, lower educational and income groups only show more vaccine hesitancy but not a higher rate of refusal. Targeted education campaigns are essential to mitigate vaccine hesitancy and improve coverage and should not be limited to specific income or educational groups.
This review also highlights the unequal recovery in vaccination coverage across regions and income groups, emphasizing the need for comprehensive strategies to ensure equity in immunization. Most regions returned to (almost) pre-COVID-19 levels of vaccination coverage ratio in 2022, however, when countries were grouped on gross national income, the vaccination coverage ratio of low-income countries was still declining in 2022. People-centred, locally tailored approaches, such as those employed by the GAVI vaccine alliance, offer potential solutions by identifying and addressing low-coverage areas.
In the post-pandemic years, efforts to restore and strengthen vaccination programs are crucial, especially with the resurgence of vaccine-preventable diseases. The year 2023, which is deemed "Big Catch-Up", is aligned with the Immunization Agenda 2030 and aims to mitigate the pandemic's consequences and accelerate universal vaccination coverage. The experiences of past outbreaks, such as the Ebola outbreak, underscore the urgency of these efforts. To achieve the Immunization Agenda 2030's ambitious goals and to ensure "no one is left behind", collaborative efforts should be made to increase vaccination coverage and address barriers to immunization uptake. These important steps are necessary to achieve the ultimate goal of adequately protecting the health of children worldwide against vaccine preventable diseases.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic is characterized by the extraordinary measures that were taken, such as nationwide lockdowns, curfews and social distancing, to reduce the spread and impact of the virus. With the global vaccination campaigns, the pandemic has quickly become a closed chapter, the disease has moved to an endemic phase and the COVID-19 non-pharmacological intervention measures (NPI) have been lifted across the world. However, these measures to combat the pandemic may have had unintended, far-reaching consequences, particularly on the administration of childhood vaccinations.
Childhood vaccinations are one of the most important measures to ensure public health[1]. The vaccinations protect the most vulnerable members of the society against a variety of vaccine preventable diseases (VPDs). Diseases like polio, with its irreversible paralysis, measles, causing high fever and other complications, diphtheria, leading to painful swelling, and tetanus, marked by severe muscle spasms, can be prevented with these vaccines[2,3,4]. Yet, the prevention of these diseases relies on achieving and maintaining a critical vaccination coverage ratio within a population[5].
Depending on the disease and its respective transmissibility, the minimum percentage of coverage differs. Measles for example, is the most contagious VPD and needs a routine vaccination coverage of between 92-95% to prevent large outbreaks[6]. Contrarily, a global average of 84% coverage of polio vaccines, was enough to prevent infections in all countries except for Afghanistan and Pakistan[7]. This underlines the necessity to prevent the spread of these high impact diseases, especially since the world has the means to do so in the form of

vaccines. This review is focussed on the overlap of these three topics, the administration of the childhood vaccines, maintaining the necessary vaccination coverage ratio (VCR) to prevent outbreaks and the COVID-19 pandemic. The measures taken during the pandemic like the lockdowns, and a possible increase in vaccine hesitancy may have inadvertently impacted the worldwide vaccination coverage of VPDs administered during childhood. I review this by delving into connections between pandemic measures and the preservation of childhood vaccination programs, with the aim to identify weaknesses and provide possible solutions to ensure adequate protection of the children in this world.

Stagnation in the vaccination coverage ratio in the years before the pandemic

Before going into the effects of the COVID-19 pandemic on childhood vaccinations, it is essential to assess the global situation of childhood vaccination coverage before the COVID-19 pandemic. Since the year 2000, there has been a substantial increase in VCR[8]. According to the World Health Organization (WHO), between the years 2000 and 2019, significant progress was made in extending the reach of essential vaccines, particularly for the first dose of measles-containing vaccines (MCV1) and the third dose of diphtheria-tetanus-pertussis vaccines (DTP3) [9]. Over this span of two decades, the global average coverage for MCV1 rose from 72% to 85%. The global average for the DTP3 vaccines also increased from 72% to 85% during this time period. However, the discrepancy between the WHO regions in the world, which are shown in figure 1, is quite large in both the increase and total vaccination coverage[9].

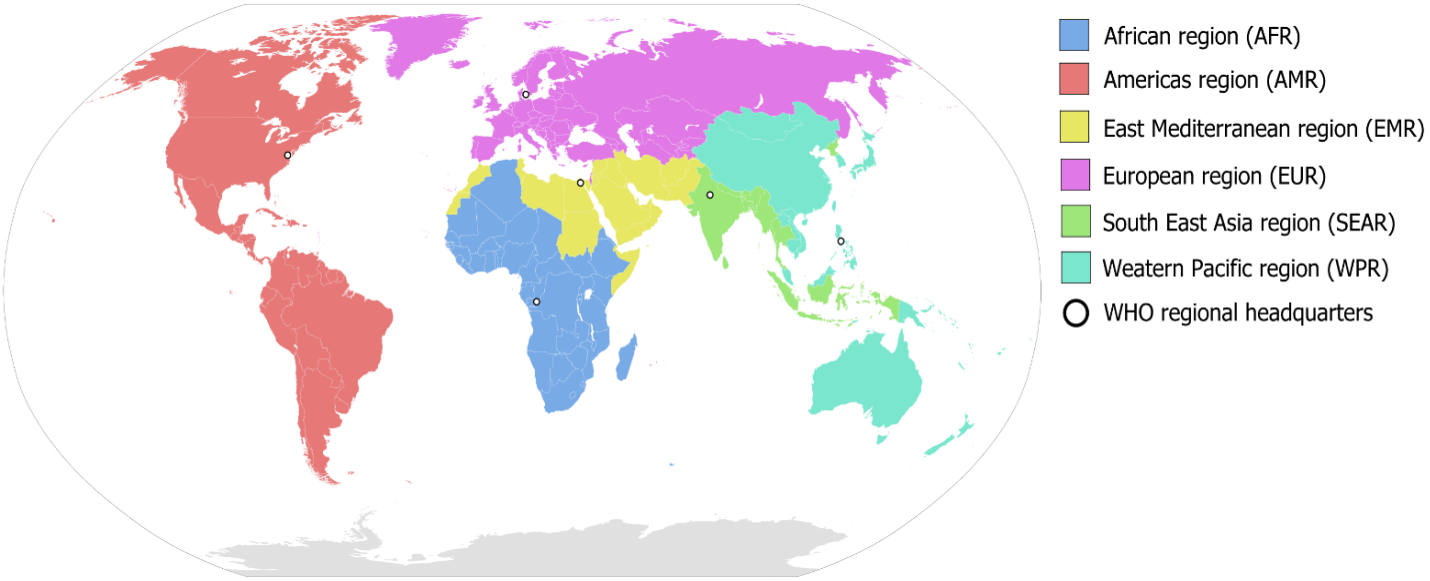

Figure 1. Overview of all WHO regions.
Coloured map of all WHO regions including their respective headquarters.

Image edited from public domain image.

For instance, the African (AFR) and South-East Asian (SEAR) regions exhibited the largest increase in coverage for MCV1, from 53% to 69% and 63% to 94% respectively. In contrast, the European (EUR) and American (AMR) regions, which had an already high coverage, showed more modest gains or even slight declines, from 91% to 96% and 91% to 88%, respectively[9]. These disparities in VCR progress underscore the complexities and challenges

faced by vaccination programs across the world.
When focusing on only the last 5 years before the COVID-19 pandemic (2015-2019), a troubling pattern emerges. Key vaccines, including the widely used bacillus Calmette-Guérin (BCG), the third dose of polio (Pol3), MCV1, and DTP3, all demonstrated a concerning stagnation in coverage across all regions, according to the published data by the WHO (fig. 2)[9]. It is important to note that there has been a shortage of BCG vaccines, especially in the America region, which may explain the sudden drop in coverage[10]. This stagnation in vaccination coverage raises concerns about the ability of vaccination programs to consistently reach their targeted populations, especially when challenges like pandemics are emerging. The stagnation in uptake of these vaccines can be attributed to a range of factors such as: difficult to reach and subpar healthcare systems, perceived low risk of VDP's due to low incidence, misperceptions about the benefits of vaccination and unfounded fears of vaccine side effects[11]. These factors, with the exception of poor healthcare systems, all contribute to the growth of the anti-vaccine movement potentially leading to more outbreaks of VDP's. For example, anti-vaccine movements in Italy caused the measles vaccine coverage to drop from 88% in 2013 to 85% in 2015, subsequently causing an increase in measles cases and deaths[12]. In summary, the years leading up to the COVID-19 pandemics showed great progress in extending the coverage of essential childhood vaccines. However, disparities between regions and stagnation in recent years are concerning, and show the challenges and opportunities in the vaccination systems. Hence, understanding the pre-pandemic situation is important to assess the potential impact of the pandemic on vaccination coverage and the prevention of vaccine-preventable diseases.

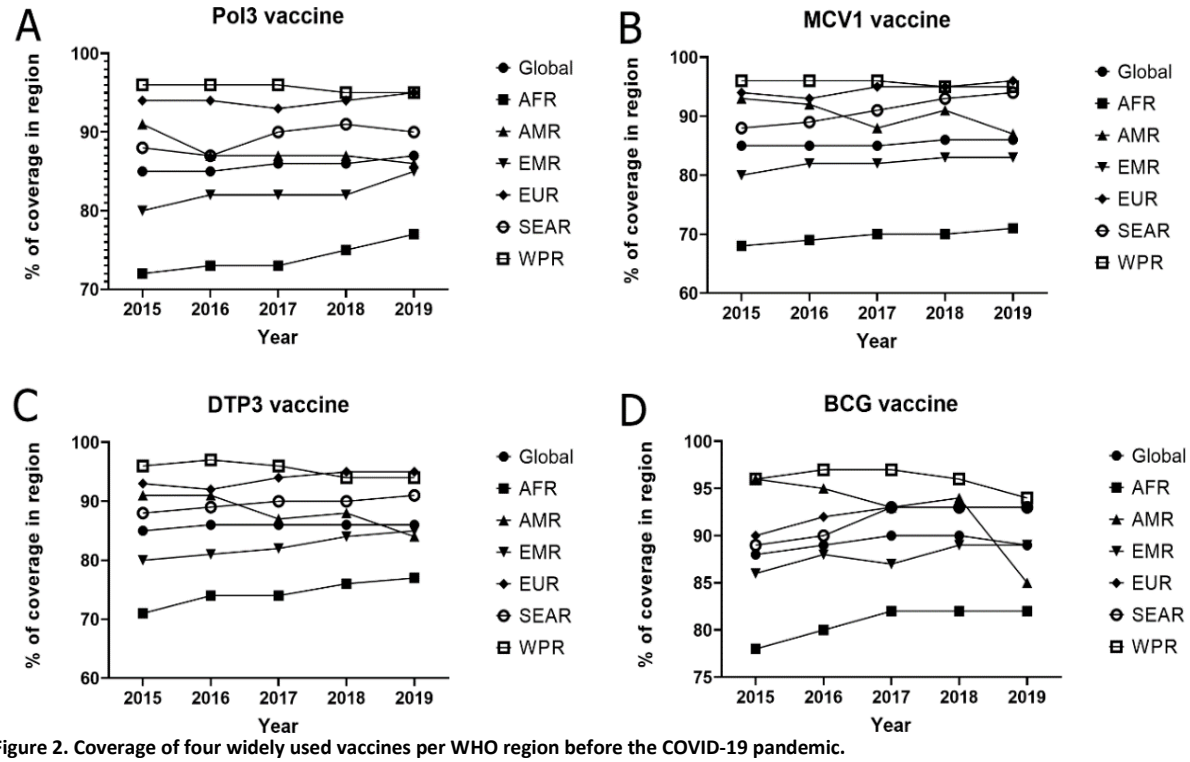

Figure 2. Coverage of four widely used vaccines per WHO region before the COVID-19 pandemic.
The average vaccination coverage ratio (VCR) for the global and WHO regions throughout the five years leading up to the COVID-19 pandemic (2015-2019). The VCR is shown for four of the most widely used childhood vaccines, 2A: third dose polio vaccine (Pol3), 2B: first dose measles-containing vaccine (MCV1), 2C: third dose diphtheria, pertussis, and tetanus vaccine (DTP3), 2D: Bacillus Calmette–Guérin vaccine (BCG).

Coverage data was collected from World Health Organization[9].
AFR = African Region; AMR =Americas Region; EMR = Eastern Mediterranean Region; EUR = European Region; SEAR = South-East Asia Region; WPR = Western Pacific Region.

An alternative for looking at the VCR by WHO-region is to categorize the countries based on their income level. This categorization provides a more detailed perspective, as economic differences among countries are taken into account. Countries were divided in three income levels based on their gross national income (GNI) for the respective year. These groups would for example be: low (≤ $1.135), middle (≥ $1.136 - ≤ $13.845) and high (≥ $12.846) in 2022[13]. Figure 3 shows that that higher GNI countries show correspondingly higher vaccination coverage. This correlation underlines the role of economic stability in access to vaccines and the infrastructure to administer them. However, despite the differences in VCR between the income levels, there is no considerable increase in vaccination coverage for any of the groups over the five years before the COVID-19 pandemic. This stagnation in coverage, regardless of income or region is concerning, especially for the countries with a suboptimal vaccination coverage ratio. The uneven vaccination coverage among WHO-member countries in the years leading up to the COVID-19 pandemic, coupled with the lack of consistent VCR improvement in lower coverage countries, indicates that possible additional disruptions caused by the pandemic could have far-reaching consequences.

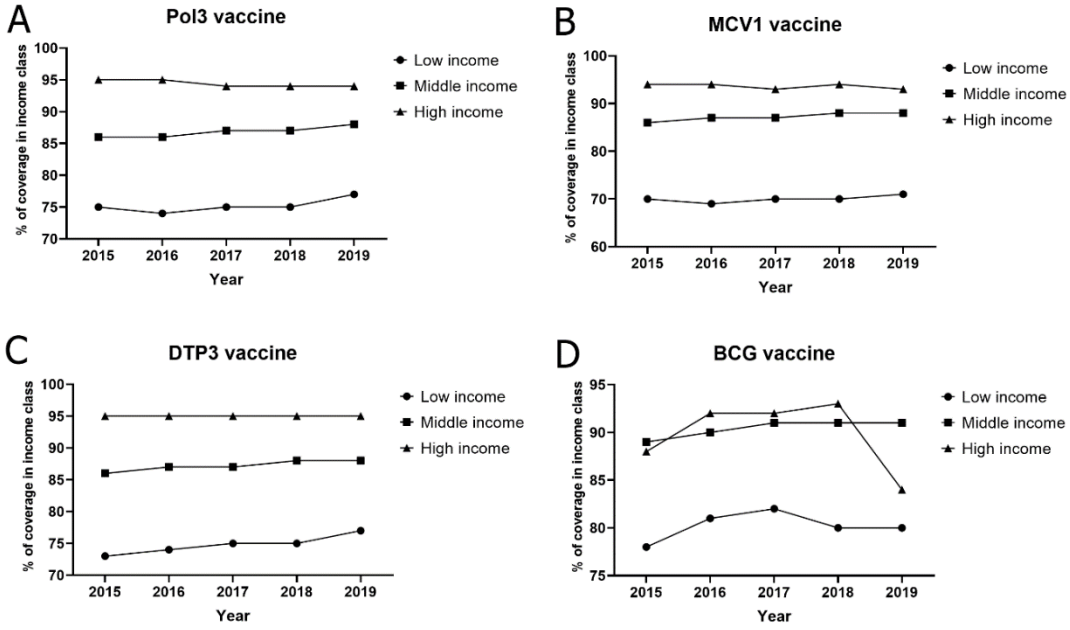

Figure 3. Coverage of four widely used vaccines per income-group before the COVID-19 pandemic.
The average vaccination coverage ratio (VCR) for countries grouped on gross national income* throughout the five years leading up to the COVID-19 pandemic (2015-2019). The VCR is shown for four of the most widely used childhood vaccines, 3A: third dose polio vaccine (Pol3), 3B: first dose measles-containing vaccine (MCV1), 3C: third dose diphtheria, pertussis, and tetanus vaccine (DTP3), 3D: Bacillus Calmette–Guérin vaccine (BCG).

Coverage data was collected from World Health Organization[9].
*World Bank income classification was used to determine income-group.
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COVID-19 pandemic negatively affected vaccination coverage in most regions

During the COVID-19 pandemic, almost all countries utilized the lockdown and social distancing measures to slow the upsurge of infections. Next to the NPI's, the pandemic also put very high pressure on the healthcare systems due to the large amount of COVID-19 hospitalization cases. The measures that were taken had unintended consequences on routine vaccination appointments, leading to a significant decline in vaccine administration. For instance, in Ontario, Canada a lockdown was declared on the 17th of March 2020. A survey conducted by Piché-Renaud et al. (2021) revealed that 45% of the responding paediatricians and family physicians, acknowledged a negative impact on their immunization services by the pandemic, leading in some cases to the stop of vaccination of an age group or even the

stoppage of all vaccination administration[14]. Furthermore, in the city of Calgary in March and April 2020, a 20% decline has been reported in overall vaccinations. Similar declines in vaccine administration were described in various other parts of the world. In the Netherlands, a 6-14% reduction in the administration of the first measles-mumps rubella (MMR1) vaccination was reported between the first lockdown on March 16, 2019, and September 2019 [15]. Furthermore, a study conducted by Harris et al. (2021) on the SEAR and Western Pacific (WPR) regions showed that a median of 91% of the antigens in a total of 19 countries in the regions were adversely affected during the pandemic[16]. This translates to around 15 antigens per country, most of which are administered during (early-)infancy or school-entry age. The DTP, MMR and polio vaccines, which are for highly contagious and/or impactful diseases and are administered during childhood, were negatively impacted in 17 out of the 19 countries. As for the direct effect on the VCR, changes were publicly reported in eight countries. Taiwan, Australia, Korea and Australia used publicly reported data while Hong Kong, Myanmar, India and China used estimates based on sales data, press releases and clinician interactions. A 6% median VCR decrease was estimated based on the information of the publicly reported data, and when the estimates were included, the decrease further extended to 18%. Figure 4 depicts a similar pattern in the VCR of the four previously mentioned vaccines aligning with the findings in existing literature. According to data of the WHO, the years 2020 and 2021, which were most impacted from COVID-19 measures like lockdowns, show a clear decrease in VCR when compared to 2019 in nearly every region[9]. The Eastern Mediterranean (EMR) and EUR regions displayed the most stable VCR throughout the pandemic. Interestingly, only the WPR, SEAR and AFR regions showed a substantial decrease in VCR in 2021 while the AMR, EMR and EUR regions remained stable compared to 2020. An explanation could be the longer lockdowns in the WPR region (e.g. China and Australia) compared to other regions and the lack of a robust universal healthcare systems which lead to vulnerability to disruptions in the AFR and SEAR regions[17,18]. This vulnerability correlated with the GNI of a country as low- and middle-income countries were most affected by the pandemic's impact as depicted in figure 5[9].

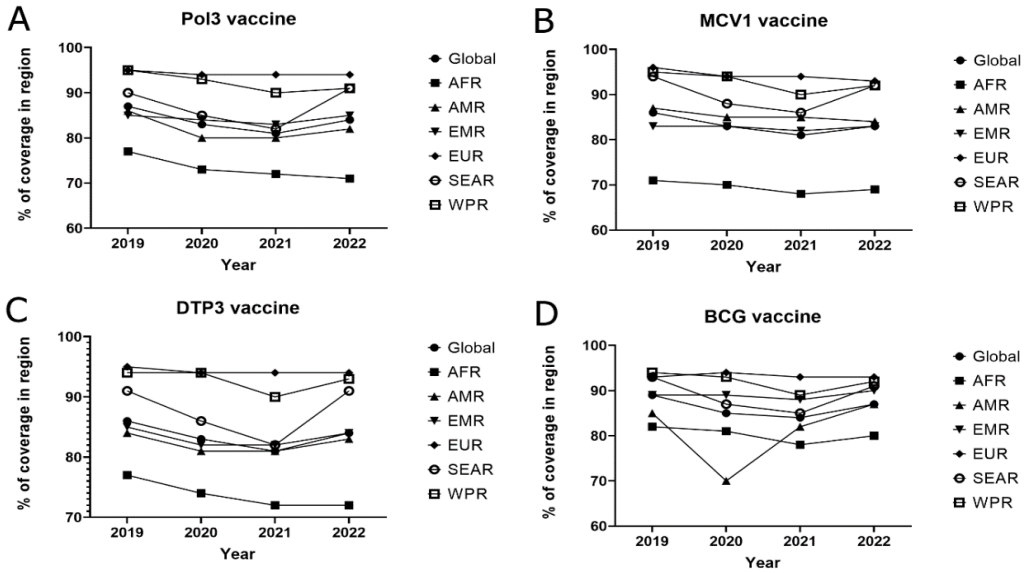

Figure 4. Coverage of four widely used vaccines per WHO region before, during and after the COVID-19 pandemic.
The average vaccination coverage ratio (VCR) for the global and WHO regions in the year before to the COVID-19 pandemic (2019), during the pandemic (2020, 2021) and the first year post-pandemic (2022). The VCR is shown for four of the most widely used childhood vaccines, 4A: third dose polio vaccine (Pol3), 4B: first dose measles-containing vaccine (MCV1), 4C: third dose diphtheria, pertussis, and tetanus vaccine (DTP3), 4D: Bacillus Calmette–Guérin vaccine (BCG).

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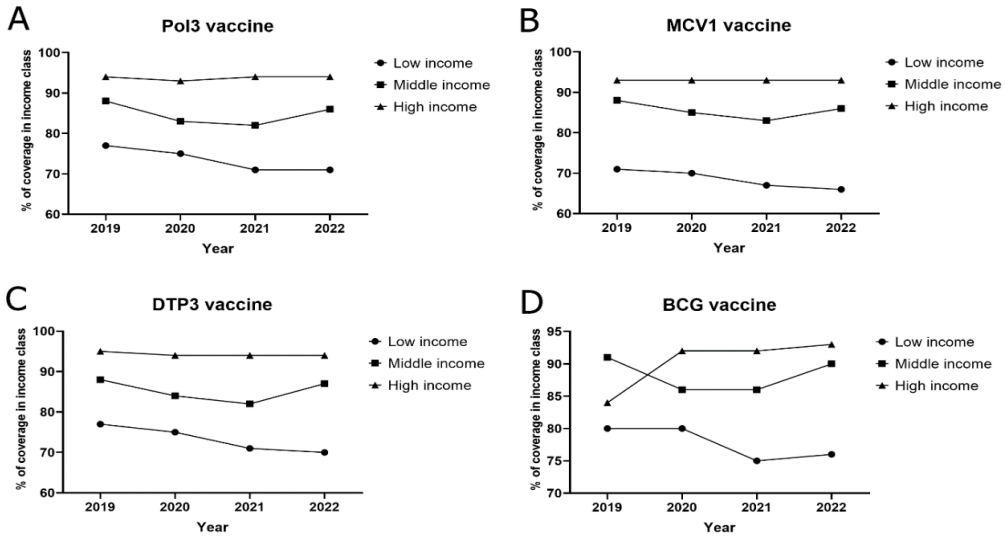

Figure 5. Coverage of four widely used vaccines per income-group before, during and after the COVID-19 pandemic.
The average vaccination coverage ratio (VCR) for countries grouped on gross national income* in the year before to the COVID-19 pandemic (2019), during the pandemic (2020, 2021) and the first year post-pandemic (2022). The VCR is shown for four of the most widely used childhood vaccines, 5A: third dose polio vaccine (Pol3), 5B: first dose measles-containing vaccine (MCV1), 5C: third dose diphtheria, pertussis, and tetanus vaccine (DTP3), 5D: Bacillus Calmette–Guérin vaccine (BCG).

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Uneven recovery after the COVID-19 pandemic

As most countries began lifting their COVID-19 measures around Q1-Q2 of 2022, it was evident that a catch-up was needed to combat the loss in VCR. Additionally, the goal of the Immunization Agenda 2030 (IA2030) set by the WHO will be even more difficult to achieve if the recovery of the VCR is slow[19]. The IA2030 was set by all WHO member states with the goal to halve the number of zero-dose children (no DTP1 vaccine), as well as 'leaving no one behind' by making vaccines available to everyone by 2030. The number of zero-dose children was steadily decreasing in most regions before the COVID-19 pandemic as seen in figure 6A[9]. This is mainly attributed to the in low-income countries, as the VCR of DTP1 is increasing in those countries while remaining relatively stable in the middle- and high-income countries (fig.6B). Similar to the other four previously shown vaccines, the coverage of DTP1 took a significant hit during the pandemic (2020-2021) in most regions. In 2022 there was again good recovery of the VCR to (almost) pre-pandemic levels, except for the African region (fig. 6C). The low-income countries however showed poor recovery, similar to the other four vaccines, undoing the steady increase of DTP1 vaccine coverage in the years before the pandemic.

The urgent need to increase the VCR across all regions that show suboptimal coverage is shared by multiple large international organizations like the Vaccine Alliance, IA2030, WHO and UNICEF, and Gavi as they coined 2023 'The Big Catch-Up'[20]. The plan is to restore immunization practices to pre-COVID-19 levels and further strengthen them while addressing the backlog of missed vaccinations during the pandemic in pursuit of the IA2030 objectives. The most recent data, published by the WHO on the vaccination coverage for the year 2022, offers a moderately optimistic perspective. When examining the VCR of the WHO regions, almost every region shows an increase in VCR for all four vaccines compared to 2021 (Fig. 4). DTP3 shows the best recovery, as every region records either a 0% or -1% change in VCR relative to pre-pandemic levels in 2019 except for the African region. The slow recovery and even a decline in VCR for the four vaccines in the African region is an omen of a bigger problem: the recovery is uneven. High income countries stayed mostly consistent in VCR during the pandemic, however, there was no increase after the restrictions

were lifted in 2022, which were a total of 56 out 194 WHO members. Middle income countries showed a decrease in both 2020 and 2021 compared to the previous year yet showed a great recovery in 2022 to be almost on pre-COVID-19 levels, totalling 107 out 194 WHO members. The low-income countries struggled to recover after the pandemic, with only the BCG vaccine coverage slightly increasing while the three other vaccines' coverage further decreased in 2022, affecting 31 out of 194 WHO members.

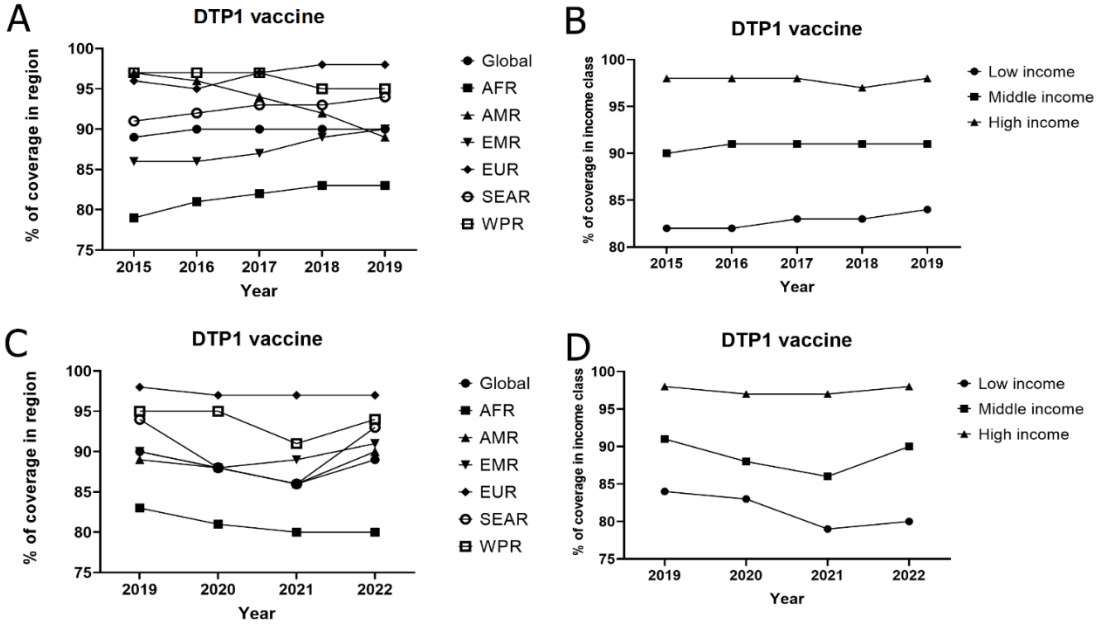

Figure 6. Coverage of DTP1 vaccines showing zero-dose children, before during and after the COVID-19 pandemic.
The average vaccination coverage ratio (VCR) of DTP1 vaccination, children not receiving the DTP1 vaccination are considered zero-dose children. Countries are grouped on WHO region in the five years before the COVID-19 pandemic in 6A, and also when the countries are grouped on gross national income* in 6B. 6C and 6D, show this the same information but in the year before to the COVID-19 pandemic (2019), during the pandemic (2020, 2021) and the first year post-pandemic (2022), respectively.

Coverage data was collected from World Health Organization[9].
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Outbreaks of VPDs across various countries after the pandemic

The aftermath of the pandemic has already revealed the worrisome effects of the decrease and uneven recovery in VCR. Of all the vaccine preventable diseases that are targeted with the childhood vaccinations, the measles virus is the most contagious[21]. Consequently, this disease would be the first to cause outbreaks when the coverage ratios of VPDs drop. As expected, numerous new measles outbreaks have been reported in various countries after the COVID-19 pandemic. For example, in Zimbabwe there was a measles outbreak in August 2022 where there were more than 2000 confirmed cases and 173 deaths [22]. Meanwhile in Mumbai, India various outbreaks were reported in November 2022 totalling 233 confirmed cases, 13 deaths and thousands of suspected cases[23]. The situation in India has not improved since, in January till August 2023 there were a total of 61.555 cases of measles in India alone [24]. Not only India but other countries are struggling with an increase in measles cases. In the year 2023, up to August, the global measles cases have already surpassed that of the entire previous year in number, with 176,051 cases in 2023 compared to 171,296 cases in 2022[24].
The Ebola outbreak of 2014 and 2015 across Africa is the closest resemblance to the COVID-19 pandemic in terms of used NPIs, as curfews, border closures and movement restrictions were used. Additionally, like in the COVID-19 pandemic, the healthcare system focussed

more on the Ebola outbreak by opening specialised treatment centres and re-deploying healthcare workers to these centres. These changes caused closure of healthcare facilities as well as suspension of vaccination administration[25]. Lastly, there was avoidance of healthcare facilities for the fear of infection. Compared to COVID-19, Ebola has lower transmissibility, therefore the chances of infection in everyday life were significantly lower. Instead the chance of infection was higher in healthcare facilities where infected individuals would go to, to seek aid. Similarly, to what is currently seen after the COVID-19 pandemic, there was a resurgence of various VPDs in the years after the Ebola outbreak. In Liberia for instance, the MCV1 coverage dropped 16% compared to the two years before the outbreak, resulting in an upsurge of measles cases from 0 in 2013 and 2014 to 108.5 per million inhabitants in 2015[26]. In Sierra Leone, measles cases increased by over 2.5-fold to 18 per million in 2015 compared to 2014 and remained high in the subsequent years. In Guinea, coverage of the MCV1, Yellow fever and DTP3 vaccines dropped between 5-10% during the Ebola outbreak and failed to return to pre-outbreak levels in the two subsequent years after the outbreak was over. Again, there was an increase in measles cases post outbreak, increasing from 2.5 to 11.5 cases per million. Thus, after both the Ebola outbreak and the COVID-19 pandemic an increase in VPDs were noted after a drop in VCR due to an outbreak of a disease where NPIs were used. However, in the case the COVID-19 pandemic happened on a much larger scale than the Ebola outbreak, thus consequences can be more severe.

Barriers that prevent vaccination uptake and solutions

Uniform recovery and subsequently achieving sufficiently high base level in VCR across all regions and income groups is important. This necessitates a well-devised and comprehensive strategy, with a specific focus on critical areas like zero-dose children and under-immunized children and communities. Firstly, it is valuable to identify the barriers that lead to reduced vaccination uptake. There are various variables that should be taken into account like: cultural and social factors, age, gender, and location[19]. A cultural factor could be religion, in the Netherlands for example, there is a region nicknamed the 'Bible Belt' with the highest concentration of conservative reformed Protestants. In this region the vaccination coverage is significantly below the rest of the Netherlands, due to conflicts with religious beliefs and restrictions, but for other people also due to reduced trust in vaccination and in the state-run vaccination programmes[27]. Socioeconomic and education levels also influence the acceptance of vaccination. The uptake of COVID-19 vaccinations demonstrated this issue, regardless of the income class of the country. Individuals with higher education had a higher percentage vaccine uptake compared to those with secondary education which in turn had a higher uptake compared to individuals with no or primary education[28]. High-income countries had slightly less vaccine hesitancy compared to the middle- and low-income countries among unvaccinated people. Contrarily, the percentage of unvaccinated people that completely refused vaccination was almost twice as high in high-income countries compared to the middle- and low-income countries regardless of education level. It is important to note is that because of the percentually higher vaccine uptake in the high-income countries and higher educational groups, the absolute numbers of individuals with vaccine hesitancy and refusal are smaller in these groups compared to the lower income and educational groups.

Addressing the disadvantaged individuals and communities, whether it is because of poor education, geographical location or another reason, is important. As these areas show, when looking at absolute numbers, the most room for improvement. Developing the right strategy to identify and address these groups is important, and perhaps one disease can act as a marker for measuring overall trends in vaccine coverage. By tracking measles cases and outbreaks, areas with low immunization can be identified and the immunization programme should then

be adjusted accordingly to help raise the VCR. As shown by the COVID-19 vaccination, groups with low income and education do not refuse vaccination more often than individuals with high income or education, however they do show hesitancy and face structural barriers more often[28]. Structural barriers that they face could be that no vaccines are available, inability to travel to vaccination sites or unclear/insufficient information. People-centred and locally tailored approaches should be developed to address low coverage, like the GAVI vaccine alliance that provides most vaccines to the African region but also invests in the manufacturing of vaccines on the African continent[29]. Currently only 0.1% of the worldwide vaccines are produced in the African region, furthermore only 1% of the vaccines used in Africa are produced there[30]. This highlights the importance of not only providing help through donations but also investing to develop the local immunization programme to be more self-sufficient. Making efforts to educate these individuals or communities is the most obvious and most likely way to decrease their hesitancy towards vaccines.

However, it should be stressed that this education should not be limited to only low and/or middle-income countries, as there is vaccine hesitancy regardless of education and income[28]. The uptake of the vaccinations and the confidence in the health benefits provided by them is based on trust. Because of the large news coverage of the rushed COVID-19 vaccination approval, many individuals all over the world were for the first time introduced to the drug acceptance processes of health agencies like the FDA and EMA. In the United States for example, concern was caused among Americans because of the realization that the approval process of the COVID-19 could be influenced by politics[31]. This caused nearly a quarter of the Americans to have little to no trust in recommendations by the FDA in May 2021[32]. When the distrust in the government combines with the ease of spreading misinformation through social media, it becomes a significant threat to the uptake of vaccinations. Because of the algorithms that are used in social media, users will often see other posts similar to the ones that they have viewed, which could prove to be a downward spiral when it comes to posts with misinformation about vaccines[33]. Moderating the spread of misinformation is a very difficult task, for example, determining where something is not the right of free speech anymore is a difficult. Therefore, it is best to educate individuals with facts backed information about vaccines to restore trust. However, it is important that this is done on the right difficulty level. There will of course be a part of a society that will refuse vaccination regardless, yet a large part of those that do not participate in vaccination programs, describe that a lack information is the main reason[34,35]. The parents that are open for discussion and education about the vaccines, show to be more agreeable and willing with vaccination afterwards[36].

An example of targeted education on the audiences' level and vaccine hesitancy/refusal, is the recent human papillomavirus (HPV) vaccine campaign ran by the Dutch government[37]. In the Netherlands, the two doses of the HPV vaccine used to be only available without cost for girls around the age of 12. HPV is widely known to cause cervical and vaginal cancer, however, can also cause other types of cancer that also affects males, like throat, anal and penile cancer[38]. Therefore, the Dutch government started to vaccinate boys as well and lowered the age from 12 to 10. To compensate the boys that did not receive a vaccine during the old policy, a large catch-up campaign was started where men that were born between 1996 and 2003 could receive their vaccinations for free[37]. The biggest challenge was not the availability of the vaccines or the infrastructure to administer them, but to inform and attract the young adults of this age group to take the HPV vaccine. The government invested heavily in advertising through social media and flyers with similarly aged people on the covers as the target audience and stating what types of cancer could be prevented. Appointments were

easily made online, and the vaccination locations were abundant throughout the Netherlands. However, despite all these favourable conditions, only 21% of the 1.3 million eligible young adults collected at least one of the two doses of the HPV vaccine so far[39]. It is important to note though, that this target group is very difficult to reach compared to parents, as disinterest and a feeling of 'invincibility' to diseases are prevalent around this age. This underlines the challenges of reaching the target audience if they show hesitancy and the need of constant improvement in strategy, even in a well-developed country with good infrastructure and health care.

Conclusion

So, to conclude, the COVID-19 pandemic introduced significant challenges to the administration of childhood vaccines by disrupting immunization programs. This revealed vulnerabilities in the global public health system. From the collected data from the WHO and various studies on the effects of the pandemic on childhood vaccination efforts, several key themes stand out.

First, the pandemic's impact on childhood vaccination coverage was substantial, with lockdowns, vaccine hesitancy, and the strain on healthcare systems leading to a decline in immunization ratios. Measles, a highly contagious vaccine-preventable disease, became a strong indicator of this decline, with outbreaks reported in various countries post-pandemic. Moreover, by underlining the importance of addressing barriers to vaccination uptake, including cultural, social, and socioeconomic factors. Higher education and income levels show a positive correlation in vaccination acceptance; however, vaccine hesitancy and rejection are found regardless of education and income levels. Targeted education campaigns can help mitigate vaccine hesitancy and help raise the vaccine coverage. This insight calls for strategies that are not limited to specific income or educational groups but rather tailored to meet the unique needs of different populations.

The vaccination coverage for the year 2022, offers a moderately optimistic perspective. Most regions returned to (almost) pre-COVD-19 levels of vaccination coverage ratio in 2022. However, the uneven recovery in vaccination coverage across regions and income groups is a matter of concern, emphasizing the need for a comprehensive approach to ensure equity in immunization. Localized and people-centred strategies, similar to those employed by the GAVI vaccine alliance, offer potential solutions by identifying low-coverage areas and adapting immunization programs accordingly, even in difficult to reach areas.

In the years after the COVID-19 pandemic, the imperative of restoring and strengthening vaccination programs is evident. The global "Big Catch-Up" initiative, aligned with the Immunization Agenda 2030, aims to mitigate the consequences of the pandemic and accelerate efforts to achieve universal vaccination coverage. Especially now more outbreaks are appearing of VPDs, similar to the situation after the Ebola outbreak in 2014 and 2015 on the African continent where measles cases surged after the outbreak.

Thus, this literature review highlights the various challenges posed by the pandemic to the administration of childhood vaccinations and the importance of targeted strategies for recovery. To achieve the Immunization Agenda 2030's ambitious goals and to ensure "no one is left behind," collaborative efforts are required to bridge gaps in vaccination coverage and address barriers to immunization uptake. These important steps are necessary to achieve the ultimate goal of adequately protecting the health of children worldwide against vaccine preventable diseases.

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