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.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
COVID-19 and missed or delayed vaccination in 26 middle- and high-income countries: An observational survey

Gilla K. Shapiro a,⁎, Nisha Gottfredson b, Julie Leask c,d, Kerrie Wiley c, Francine E. Ganter-Restrepo e, Sarah P. Jones f, Lisa Menning e, Noel T. Brewer b,g

⁎Department of Supportive Care, Princess Margaret Cancer Centre, University Health Network, Toronto, ON, Canada
bDepartment of Health Behavior, Gillings School of Global Public Health, University of North Carolina, Chapel Hill, NC, USA
cSchool of Public Health, Faculty of Medicine and Health, The University of Sydney, Sydney, NSW, Australia
dDepartment of Immunization, Vaccines and Biologicals, World Health Organization, Geneva, Switzerland
eInstitute of Global Health Innovation, Imperial College London, St Mary's Hospital, London, United Kingdom
gLineberger Comprehensive Cancer Center, University of North Carolina, Chapel Hill, NC, United States

A R T I C L E I N F O

Article history:
Received 4 March 2021
Received in revised form 14 December 2021
Accepted 15 December 2021
Available online 21 December 2021

Keywords:
Immunization
COVID-19
Cross-country analysis
Under-vaccination

A B S T R A C T

Background: The COVID-19 pandemic has disrupted vaccination services and raised the risk of a global resurgence of preventable diseases. We assessed the extent of and reasons for missed or delayed vaccinations (hereafter ‘missed’) in middle- and high-income countries in the early months of the pandemic.

Methods: From May to June 2020, participants completed an online survey on missed vaccination. Analyses separated missed childhood and adult vaccination in middle- and high-income countries.

Results: Respondents were 28,429 adults from 26 middle- and high-income countries. Overall, 9% of households had missed a vaccine, and 13% were unsure. More households in middle- than high-income countries reported missed childhood vaccination (7.6% vs. 3.0%) and missed adult vaccination (9.6% vs. 3.4%, both p < .05). Correlates of missed childhood vaccination in middle-income countries included COVID-19 risk factors (respiratory and cardiovascular diseases), younger age, male sex, employment, psychological distress, larger household size, and more children. In high-income countries, correlates of missed childhood vaccination also included immunosuppressive conditions, but did not include sex or household size. Fewer correlates were associated with missed adult vaccination other than COVID-19 risk factors and psychological distress. Common reasons for missed vaccinations were worry about getting COVID-19 at the vaccination clinic (15%) or when leaving the house (11%). Other reasons included no healthcare provider recommendation, clinic closure, and wanting to save services for others.

Interpretation: Missed vaccination was common and more prevalent in middle- than high-income countries. Missed vaccination could be mitigated by emphasizing COVID-19 safety measures in vaccination clinics, ensuring free and accessible immunization, and clear healthcare provider recommendations.

© 2022 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

The Coronavirus disease (COVID-19) pandemic has led to significant disruptions in immunization programs globally [1–6], alongside the disruption of other routine health services [7–9]. The World Health Organization (WHO) characterized COVID-19 as a pandemic on March 11, 2020 [10]. Fifteen days later, the organization issued guidance for the temporary suspension of mass vaccination campaigns [11]. The guidance advised countries to conduct individual risk-benefit assessments and continue vaccination programs where the operational capacity of adequate human resources and vaccine supply remained intact, while maintaining physical distancing and the necessary infection control precautionary measures [11]. By June 2020, over 68 countries had postponed approximately 125 mass vaccination campaigns [12]. This deferral is likely to affect an estimated 80 million children under age one [13]. Substantial missed or delayed routine vaccinations can trigger secondary outbreaks of vaccine-preventable diseases and associated mortality [2,3,14,15], similar to the Ebola outbreak in West Africa where reallocation of health resources decreased vaccination coverage and resulted in disease outbreaks [16].

To date, no comparable estimates are available for the prevalence and correlates of missed or delayed routine vaccination to

⁎ Corresponding author.
E-mail address: gilla.shapiro@uhnresearch.ca (G.K. Shapiro).

https://doi.org/10.1016/j.vaccine.2021.12.041
0264-410X/© 2022 The Authors. Published by Elsevier Ltd.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
inform a better understanding of the picture globally. However, effects on routine vaccination appear to be dramatic. One study of electronic health records in a high-income country, England, compared three weeks of routine measles-mumps-rubella vaccination after the introduction of physical distancing to the same period in 2019, and found that coverage was 20% lower in 2020 [17]. More recent examinations of weekly vaccination counts have found that rates recovered in 2021 in England; however, a cohort of children who missed routine vaccinations have not yet caught up. The effects may be even more pronounced in lower- and middle-income countries. For example, a study of electronic immunization registry data in Pakistan - a lower-middle income country - compared six weeks post COVID-19 lockdown to the six months previous and found daily immunization visits (for all antigens) in the capital city decreased by 53%, with steepest decreases in the earlier weeks of lockdown [19]. In the United States context, the deficit of missed adolescent vaccinations is projected to take up until 2031 to recover [20]. These reports of missed vaccination are dramatic, but further investigation is required to more broadly characterize the impact and examine reasons for missed childhood and adult vaccination [12,13,21,22]. Our study examined the prevalence, correlates, and reasons for missed or delayed vaccination (hereafter 'missed') due to COVID-19 in 26 middle- and high-income countries.

2. Methods

2.1. Participants

A polling company, YouGov, created national panels of adults who periodically completed surveys online, including demographic and lifestyle information [23]. As YouGov donated the country data to Imperial College London, countries were included based on feasibility and cost. The Imperial College London dataset included panels from 25 countries and Hong Kong (hereafter ‘countries’). Using the World Bank categorization [24], these countries were middle-income (Brazil; China; India; Indonesia; Malaysia; Mexico; Philippines; Thailand; and Vietnam) and high-income (Australia; Canada; Denmark; Finland; France; Germany; Hong Kong; Italy; Norway; Saudi Arabia; Singapore; Spain; Sweden; Taiwan; United Arab Emirates; United Kingdom; and United States of America). Participant recruitment sought a representative sample in each country based on a combination of factors including age, sex, and religion. We did not use country-specific survey weights in our analysis given these data were aggregated across countries.

2.2. Procedure

A generic email invitation was sent to participants and no reminders were sent. Participants completed the survey once between May 14 and June 9, 2020. They gave informed consent and then completed a survey, one portion of which concerned vaccination. Participants received a small payment as compensation. The wider survey included questions about protective behaviours, physical distancing, COVID-19 symptoms, among other aspects. These questions were developed by a large group of researchers from Imperial College London led by SPJ which included expertise in epidemiology, social science, public health, and health policy. Ethical approval for this study came from the Imperial College Research Ethics Committee (ICREC #20IC6020).

2.3. Measures

The World Health Organization working group for Measuring the Behavioural and Social Drivers of Vaccination developed three items to understand routine vaccinations missed due to the COVID-19 pandemic. The items assessed (1) whether anyone in the household had missed or delayed receiving vaccines because of the COVID-19 pandemic; (2) missed childhood vaccination (age 0–17) and missed adult vaccination (age 18+) for household members; and (3) the main reason for the missed vaccination (Supplementary Material).

The survey collected respondent characteristics including health conditions associated with increased risk of severe COVID-19 illness: respiratory disease (i.e., asthma, cystic fibrosis, and chronic obstructive pulmonary disease), cardiovascular diseases and related conditions (i.e., heart disease, high blood pressure, and high cholesterol), and immunosuppressive conditions (i.e., cancer, diabetes, and HIV/AIDS). Other characteristics included sex, age, employment status (currently working on full-time or part-time basis vs not working due to unemployment, retired, or students), and psychological distress. The survey assessed psychological distress using the four-item Patient Health Questionnaire-4 [25], which assesses symptoms of anxiety and depression and yields scores that range from 0 (no distress) to 12 (severe distress). Household characteristics included number of people (0–8+) and number of children (0–4+).

2.4. Statistical analyses

We report observed frequencies and percentages and adjusted odds ratios (AORs). To examine the correlates of missed vaccination, we used generalized linear mixed models, with a random intercept, and used full information maximum likelihood estimation. Random slopes were not supported empirically and so not included. The models nested individuals within country and treated the individual as the unit of analysis. Individual-level correlates were COVID-19 risk factors (i.e., respiratory disease, cardiovascular diseases and related conditions, and immunosuppressive conditions), respondent’s sex, age, employment status, psychological distress, household size, and number of children. The outcomes were missed childhood vaccines in middle- and high-income countries, and missed adult vaccines in middle- and high-income countries. Thus, we examined four models. To evaluate whether results were consistent across countries, we repeated the analysis for each country using logistic regression.

To examine differences in reasons for missing vaccination, we used independent samples t-tests for proportions with country as the unit of analysis. The comparisons were country income (middle vs. high) and age for missed vaccination (childhood vs. adult). The outcome was each country’s proportion for endorsement of the reasons. All analyses used a critical alpha of 0.05 and two-tailed tests.

3. Results

3.1. Sample characteristics

Respondents were 28,429 adults from 26 middle- and high-income countries, with 58% of participants from high-income countries (Table 1). The median age of the sample was 39, and 60% were working. Prevalence of diseases associated with higher risk of severe COVID-19 illness were 9% for respiratory diseases, 21% for cardiovascular diseases and related conditions, and 9% for immunosuppressive conditions (Supplementary Material, Table S1).

3.2. Prevalence of missed vaccinations

Overall, 9% of respondents reported that someone in their household missed a vaccine. An additional 13% overall were not
were moderately correlated, $r = 0.66$, $p < .05$ across countries, rates of childhood and adult missed vaccination ranged from 1.5% in Finland to 14.7% in Brazil. Looking from 1.0% in Hong Kong to 13.5% in Vietnam. Missed adult vaccination (9.6% (899/9,359) vs. 3.4% (499/14,886), $p < .05$). The same pattern held for middle-income countries (Fig. 1; Supplementary Material, Tables S2-3). In high-income countries, missed adult vaccination was more likely if the respondent had an immunosuppressive conditions (14% vs. 9%, AOR = 1.39, 95% CI: 1.09, 1.77), or reported higher levels of psychological distress, and in households with more children (all $p < .05$). The ICC for the model for children in high-income countries was 0.58.

Missed adult vaccination had few correlates beyond COVID-19 risk factors and psychological distress (Table 3). In middle-income countries, adults were more likely to miss a vaccine if the respondent had an immunosuppressive conditions (14% vs. 9%, AOR = 1.35, 95% CI: 1.04, 1.76) or reported higher levels of psychological distress (11% vs. 8%, AOR = 1.06, 95% CI: 1.03, 1.08). In high-income countries, missed adult vaccination was more likely if the respondent reported a respiratory disease (6% vs. 3%, AOR = 1.74, 95% CI: 1.35, 2.25), a cardiovascular disease and related condition (4% vs. 3%, AOR = 1.39, 95% CI: 1.09, 1.77), or higher levels of psychological distress (4% vs. 3%, AOR = 1.05, 95% CI: 1.02, 1.08). The ICC for the model for adults was 0.44 for middle-income countries and 0.47 for high-income countries. Stratified analyses for each country showed the same general pattern, with generally weaker associations that varied substantially across countries (Supplementary Material, Tables S2-S3).

### Table 1
Sample characteristics by country.

| Country              | N     | % Respiratory diseases | % Cardiovascular diseases | % Immunosuppressive conditions | % Male | Md age | % Working | Md psychological distress | Md household size | Md number of children |
|----------------------|-------|------------------------|---------------------------|-------------------------------|--------|--------|-----------|--------------------------|-------------------|-----------------------|
| Middle-income        |       |                        |                           |                               |        |        |           |                          |                   |                       |
| Brazil               | 3,944 | 8                      | 26                        | 8                             | 48.6   | 40     | 54        | 4                        | 3                 | 1                     |
| China                | 1,007 | 2                      | 7                         | 2                             | 56.2   | 30     | 64        | 4                        | 4                 | 1                     |
| India                | 1,006 | 5                      | 9                         | 8                             | 52.2   | 35     | 66        | 4                        | 4                 | 1                     |
| Indonesia            | 1,009 | 8                      | 9                         | 3                             | 55.2   | 28     | 64        | 4                        | 4                 | 1                     |
| Malaysia             | 1,014 | 9                      | 13                        | 6                             | 42.1   | 30     | 62        | 4                        | 4                 | 1                     |
| Mexico               | 1,001 | 6                      | 16                        | 9                             | 49.7   | 33     | 57        | 3                        | 4                 | 1                     |
| Philippines          | 1,002 | 12                     | 16                        | 6                             | 47.4   | 32     | 68        | 4                        | 4                 | 1                     |
| Thailand             | 1,001 | 5                      | 14                        | 5                             | 44.7   | 33     | 70        | 4                        | 4                 | 1                     |
| Vietnam              | 1,001 | 5                      | 12                        | 4                             | 52.4   | 29     | 68        | 3                        | 4                 | 1                     |
| High-income          | 16,434|                        |                           |                               |        |        |           |                          |                   |                       |
| Australia            | 1,008 | 15                     | 27                        | 12                            | 49.1   | 45     | 55        | 3                        | 2                 | 0                     |
| Canada               | 987   | 16                     | 32                        | 19                            | 44.2   | 53     | 40        | 3                        | 2                 | 0                     |
| Denmark              | 985   | 9                      | 26                        | 10                            | 49.1   | 49     | 73        | 2                        | 2                 | 0                     |
| Finland              | 992   | 13                     | 31                        | 15                            | 49.1   | 50     | 69        | 2                        | 2                 | 0                     |
| France               | 990   | 12                     | 20                        | 11                            | 41.7   | 51     | 51        | 3                        | 2                 | 0                     |
| Germany              | 955   | 13                     | 33                        | 15                            | 49.2   | 51     | 54        | 2                        | 2                 | 0                     |
| Hong Kong            | 497   | 3                      | 17                        | 6                             | 48.9   | 46     | 81        | 4                        | 3                 | 0                     |
| Italy                | 982   | 7                      | 29                        | 7                             | 47     | 51     | 52        | 4                        | 3                 | 0                     |
| Norway               | 977   | 14                     | 24                        | 11                            | 49.6   | 47     | 59        | 2                        | 2                 | 0                     |
| Saudi Arabia         | 998   | 9                      | 13                        | 9                             | 63.1   | 35     | 60        | 4                        | 2                 | 2                     |
| Singapore            | 1,007 | 6                      | 20                        | 7                             | 49.0   | 45     | 76        | 3                        | 4                 | 0                     |
| Spain                | 990   | 9                      | 28                        | 9                             | 48.6   | 48     | 52        | 4                        | 3                 | 0                     |
| Sweden               | 990   | 12                     | 25                        | 12                            | 49.2   | 49     | 70        | 2                        | 2                 | 1                     |
| Taiwan               | 1,001 | 6                      | 13                        | 4                             | 50.6   | 35     | 67        | 4                        | 4                 | 0                     |
| United Arab Emirates | 1,000 | 6                      | 12                        | 6                             | 68.3   | 33     | 82        | 4                        | 3                 | 1                     |
| United Kingdom       | 1,068 | 14                     | 22                        | 10                            | 45.3   | 48     | 47        | 3                        | 2                 | 0                     |
| United States        | 1,006 | 16                     | 12                        | 19                            | 43.5   | 52     | 42        | 3                        | 2                 | 0                     |
| Overall              | 28,429| 9                      | 21                        | 9                             | 50     | 39     | 60        | 4                        | 3                 | 0                     |

Missed childhood vaccination was more common if the respondent had a higher risk of severe COVID-19 illness (Table 3); such as among respondents reporting respiratory diseases (7% vs. 3%, AOR = 2.13, 95% CI: 1.61, 2.82), cardiovascular disease and related conditions (3% vs. 3%, AOR = 1.52, 95% CI: 1.12, 2.06), and individuals with immunosuppressive conditions (4% vs. 3%, AOR = 2.00, 95% CI: 1.42, 2.82). Missed childhood vaccination was less common for respondents who were older; and more common for working respondents, individuals who reported greater psychological distress, and in households with more children (all $p < .05$). The ICC for the model for children in high-income countries was 0.58.

Missed adult vaccination had few correlates beyond COVID-19 risk factors and psychological distress (Table 3). In middle-income countries, adults were more likely to miss a vaccine if the respondent had an immunosuppressive conditions (14% vs. 9%, AOR = 1.35, 95% CI: 1.04, 1.76) or reported higher levels of psychological distress (11% vs. 8%, AOR = 1.06, 95% CI: 1.03, 1.08). In high-income countries, missed adult vaccination was more likely if the respondent reported a respiratory disease (6% vs. 3%, AOR = 1.74, 95% CI: 1.35, 2.25), a cardiovascular disease and related condition (4% vs. 3%, AOR = 1.39, 95% CI: 1.09, 1.77), or higher levels of psychological distress (4% vs. 3%, AOR = 1.05, 95% CI: 1.02, 1.08). The ICC for the model for adults was 0.44 for middle-income countries and 0.47 for high-income countries. Stratified analyses for each country showed the same general pattern, with generally weaker associations that varied substantially across countries (Supplementary Material, Tables S2-S3).

### 3.4. Reasons for missed vaccination

The most commonly selected reason for missed childhood and adult vaccine was worry about getting COVID-19 at the vaccination clinic (15%), a finding that was consistent in middle- and high-income countries (Table 2). Other reasons for missed vaccination included worry about getting COVID-19 when leaving the house.
and adult vaccination by country appear in Fig. S2 (Supplementary present in high-income countries. Reasons for missed childhood who report any person (i.e., any child or adult) missed a vaccine. G.K. Shapiro, N. Gottfredson, J. Leask et al. Vaccine 40 (2022) 945–952

due to COVID-19, and worry about giving COVID-19 to others (all recommendation, challenges in getting an appointment, clinic closure (10%), or wanting to save services for people who most need them (11%).

Compared to middle-income countries, high-income countries more often had missed vaccination due to healthcare provider recommend, challenges in getting an appointment, clinic closure due to COVID-19, and worry about giving COVID-19 to others (all $p < .05$, Table 4). Conversely, middle-income countries were more likely to have missed vaccination due to cost, people being restricted to leaving their homes only for essential services, want,ing to save services for others who needed them, and worries about getting COVID-19 at the clinic, by leaving the house, or by using public transportation ($p < .05$).

In both middle- and high-income countries, children were more likely than adults to have missed a vaccine due to clinic closure or worry about giving COVID-19 to others; while adults were more likely than children to have missed a vaccine due to wanting to save services for those who need them (both $p < .05$, Table 4). In middle-income countries, respondents were more likely to identify cost as a reason for a missing an adult vaccine (8%) compared to missing a children's vaccine (4%, $p < .05$). This difference was not present in high-income countries. Reasons for missed childhood and adult vaccination by country appear in Fig. S2 (Supplementary Material).

4. Discussion

In 26 middle- and high-income countries, many households had someone who had missed a vaccine during the early months of the COVID-19 pandemic in 2020. Middle-income countries had a higher percentage of missed vaccination than high-income coun,tries, a pattern also found by previous studies conducted in England and Pakistan [2,17]. This suggests that COVID-19 and related lockdown measures may exacerbate existing global inequalities in vaccination. Countries also showed substantial vari,ation in the proportion of reported missed vaccination, suggesting unique country-specific factors. Inequities exist between countries as well as within countries. For example, an online cross-sectional survey in England conducted between April and May 2020 found that parents/guardians from ethnic minorities or households with lower income were more likely to report confusion about whether vaccination services were operating as usual during lockdown [26]. Vaccine coverage information during the COVID-19 pandemic is currently unavailable in many countries and regions. However, our findings of 9% missed vaccination is comparably lower than the limited available immunization registry estimates for select vacci,nes, which range from 20% to 53% [2,17]. It is plausible that many of the 13% of individuals who were unsure had someone in their household who missed a vaccination. This suggests an “awareness gap” where many respondents were unaware if someone in their household missed a vaccination. This challenge could be addressed by clearer messaging about vaccination schedules and appropriate prompts for under-vaccinated individuals. To improve equity in access to vaccines, it may also be beneficial to target and tailor informational campaigns to groups who report less awareness

Table 2
Vaccination item response frequencies, by country income.

| Vaccination Items | Middle-Income | | | High-income | | | Overall | | |
|-------------------|---------------|---|---|---------------|---|---|-----------|---|---|
| Has anyone in your household delayed or missed getting any vaccines because of COVID-19? This could be you or someone living in your home. | n | % of total | n | % of total | n | % of total |
| Yes | 1,636 | 14 | 997 | 6 | 2,633 | 9 |
| No | 7,723 | 64 | 13,889 | 85 | 21,612 | 76 |
| Not sure | 2,340 | 20 | 1,412 | 9 | 3,752 | 13 |
| Prefer not to answer | 296 | 2 | 136 | 1 | 432 | 2 |
| Total | 11,995 | – | 16,434 | – | 28,429 | – |

| If yes, who in your household delayed or missed getting vaccinated because of COVID-19? (Please tick all that apply) | Any child | 709 | 43 | 447 | 45 | 1,156 | 44 |
| Baby 0–23 months | 287 | 18 | 190 | 19 | 477 | 18 |
| Child 2–4 years | 246 | 15 | 147 | 15 | 393 | 15 |
| Child 5–17 years | 291 | 18 | 184 | 18 | 475 | 18 |
| Any adult | 899 | 55 | 499 | 50 | 1,398 | 53 |
| Me | 544 | 33 | 327 | 33 | 871 | 33 |
| Another adult | 546 | 33 | 237 | 24 | 783 | 30 |
| Prefer not to say | 199 | 12 | 105 | 11 | 304 | 12 |
| Total | 1,636 | – | 997 | – | 2,633 | – |

| If yes, what is the main reason that COVID-19 made you or someone in your household delay or miss getting vaccinated? (Choose only one answer) |
|-------------------|-------------------|-------------------|-------------------|
| Healthcare provider recommended delay | 137 | 8 | 116 | 12 | 253 | 10 |
| Cost | 104 | 6 | 36 | 4 | 140 | 5 |
| Hard to get appointment | 107 | 7 | 79 | 8 | 186 | 7 |
| Only allowed to leave for essential services | 153 | 9 | 68 | 7 | 221 | 8 |
| Clinic closed due to COVID-19 | 149 | 9 | 115 | 12 | 264 | 10 |
| Want to save services for people who most need them | 172 | 11 | 99 | 10 | 271 | 10 |
| Worry about giving COVID-19 to others | 90 | 6 | 65 | 7 | 155 | 6 |
| Nobody going out (do not need) | 60 | 4 | 47 | 5 | 107 | 4 |
| Worry about getting COVID-19 at clinic | 250 | 15 | 137 | 14 | 387 | 15 |
| Worry about getting COVID-19 leaving house | 193 | 12 | 87 | 9 | 280 | 11 |
| Worry about getting COVID-19 using public transportation | 125 | 8 | 65 | 7 | 190 | 8 |
| Something else | 96 | 6 | 83 | 8 | 179 | 7 |
| Total | 1,636 | – | 997 | – | 2,633 | – |

* As required by the European Union General Data Protection Regulation (GDPR), participants in this region were able to skip the first item. The first survey item also had the response option of ‘prefer not to answer’ for several countries (Hong Kong, Indonesia, Malaysia, Philippines, Saudi Arabia, Thailand, United Arab Emirates, and Vietnam).

b Respondents could report that more than one person missed a household vaccine; thus, summing over categories produced a value larger than the number of households who report any person (i.e., any child or adult) missed a vaccine. (11%), healthcare provider recommendations (10%), clinic closure (10%), or wanting to save services for people who most need them (10%).
with missed childhood vaccination in high-income countries. This suggests a strategy to increase confidence in those with such conditions taking their children to be vaccinated. This might include prioritization of COVID-19 vaccination for adults with COVID-19 risk factors to increase routine vaccination uptake. Once vaccinated, individuals with COVID-19 risk factors may have less fear of contracting COVID-19 and leaving their home to facilitate someone in their household getting a routine vaccination. However, another interpretation of this finding might alert COVID-19 service providers of the potential challenge of vaccinating adults with COVID-19 risk factors, as they report higher missed routine household vaccination.

Psychological distress was the most consistently associated factor with missed vaccination across children and adults. This highlights the potential effect of COVID-19 on exacerbating vulnerabilities that in turn might make routine vaccination harder to achieve. This study’s finding is in line with a study of almost 5,000 parents in Shenzhen, China, which found that parents reporting psychological distress were more likely to report less willingness to receive the COVID-19 vaccines [27]. Future mixed methods research is necessary to explore why respondents with COVID-19 risk factors or psychological distress reported greater missed household vaccine coverage. In so doing, it is necessary to clarify whether psychological symptoms are longstanding or caused by COVID-19. It would also be beneficial for further research that evaluates the correlates of missed vaccinations to include physical and psychological variables, which this study has shown to be associated with missed vaccination. Further qualitative research could also explore the relationship between psychological distress and missed vaccination and identify how this impact may be mitigated.

The most endorsed reasons for missed vaccination was worry about getting COVID-19 at the vaccination clinic (15%) or when leaving the house (11%). This finding is similar to an unpublished WHO study (May 2020) that surveyed 260 key informants from 82 countries and found the predominant reason for missed vaccination was the risk of exposure to COVID-19 [28]. The immediate worry of COVID-19 appears to be more worrisome than the threat of other vaccine-preventable diseases; however, a study modelled the risk of contracting COVID-19 associated with vaccination clinic visits and found that the deaths prevented by continuing routine childhood immunization in Africa outweighed the excess risk of COVID-19 deaths associated with vaccination clinic visits, especially for vaccinated children [16]. Other reasons for missed vaccinations during COVID-19 in our survey included healthcare provider recommendation to miss or delay vaccination, clinic closure, or wanting to save services for others. These findings suggest that missed vaccination during COVID-19 may be mitigated by emphasizing COVID-19 safety measures in the clinic, ensuring free and accessible vaccination, and communicating an explicit healthcare provider recommendation. Clear communication would also likely reassure individuals that it is important that they continue to receive vaccination per the immunization schedule and identify the measures in place at the clinic to mitigate risk of COVID-19.

4.1. Implications for practice

Addressing missed or delayed routine vaccination during COVID-19 requires an understanding of the determinants of the problem [2,29]. The current study has highlighted the need to address practical factors, such as providing access to clinics during COVID-19 and reducing the cost of vaccination, as well as factors...
that directly concern communities, such as reducing any ambivalence through locally tailored communications that include a recommendation of the importance of routine vaccination and emphasizing COVID-19 safety measures. Enhancing the accessibility of vaccines may include establishing vaccination centers at locations that are convenient to reach using public transport or by establishing mobile vaccination teams and using interpreters [30]. Approaches for emphasizing the importance of routine vaccination and COVID-19 safety measures may also include highlighting recommendations that those with symptoms of COVID-19 should delay attending routine vaccination clinics [30].

The message to governments and healthcare providers is clear: routine vaccination should be sustained and prioritized as far as is feasible [31,32]. As this study has shown, countries also need to now consider how to address missed vaccination due to COVID-19, and guidance is available [14,33]. Foresight and a comprehensive plan for rapidly closing this immunization gaps is crucial [12,34], including immediate planning for detecting individuals who have missed vaccination, instituting large-scale catch-up programs and campaigns, and bridging any delivery gaps [12,35,36].

Using shorter time periods to monitor vaccination uptake during the pandemic is advantageous [30]. The pandemic has also emphasized the importance of strong public health surveillance to track missed vaccination [21]. Not all countries have national immunization registries, and for these countries detecting individuals who have missed vaccination may be a particular challenge [36], especially given how many individuals this study found to be “unsure” if they have missed a vaccine during COVID-19. Countries will also need to plan for the possibility of increased vaccine-preventable

Table 3
Correlates of missed or delayed childhood and adult vaccination during the COVID-19 pandemic, by middle- (n = 11,995) and high- (n = 16,434) income countries.

| Respondent COVID-19 risk factors | Middle-income countries | High-income countries | Middle-income countries | High-income countries |
|----------------------------------|-------------------------|-----------------------|-------------------------|-----------------------|
|                                  | % Child Missed | AOR (95% CI) | % Child Missed | AOR (95% CI) | % Adult Missed | AOR (95% CI) | % Adult Missed | AOR (95% CI) |
| Respiratory diseases             | No 7            | 3           | 9           | 3           | Yes 18        | 2.58 (2.01,3.31) | 7           | 2.13 (1.61,2.82) | 13          | 1.19 (0.92,1.55) | 6           | 1.74 (1.35,2.25) |
|                                 | Yes 9          | 1.33 (1.05,1.67) | 3           | 1.52 (1.12,2.06) | 12          | 1.09 (0.90,1.33) | 4           | 1.39 (1.09,1.77) |
| Cardiovascular diseases          | No 7            | 3           | 9           | 3           | Yes 9        | 1.27 (0.92,1.75) | 4           | 2.00 (1.42,2.82) | 14          | 1.35 (1.04,1.76) | 3           | 1.26 (0.94,1.68) |
|                                  |               |             |             |             |             |               |             |               |             |               |             |               |
| Immunosuppressive conditions     | No 7            | 3           | 9           | 3           | Yes 9        | 1.38 (1.14,1.67) | 3           | 1.75 (1.36,2.25) | 10          | 1.09 (0.93,1.27) | 3           | 1.05 (0.85,1.29) |
| Other respondent characteristics  | Sex Female 7    | 3           | 10          | 3           | Yes 8        | 1.19 (1.00,1.41) | 3           | 1.18 (0.94,1.48) | 10          | 1.01 (0.87,1.18) | 3           | 1.06 (0.87,1.28) |
|                                  | Male 8         | 0.98 (0.97,0.99) | 3           | 0.95 (0.94,0.96) | 10          | 1.00 (0.99,1.00) | 3           | 0.99 (0.90,1.00) |             |               |             |               |
|                                  | Age           | 0.98 (0.97,0.99) | 3           | 0.95 (0.94,0.96) | 10          | 1.00 (0.99,1.00) | 3           | 0.99 (0.90,1.00) |             |               |             |               |
| Working                          | No 6           | 2           | 10          | 3           | Yes 8        | 1.38 (1.14,1.67) | 3           | 1.75 (1.36,2.25) | 10          | 1.09 (0.93,1.27) | 3           | 1.05 (0.85,1.29) |
| Psychological distress           | Below median 6  | 1           | 8           | 3           | Above median 9 | 1.04 (1.01,1.07) | 5           | 1.10 (1.06,1.13) | 11          | 1.06 (1.03,1.08) | 4           | 1.05 (1.02,1.08) |
| Household characteristics        | Household sizea | 1.07 (1.01,1.13) | 1.07 (0.99,1.16) | 1.02 (0.97,1.07) | 1.07 (0.99,1.15) |             |             |               |             |               |             |               |
|                                  | Number of childrena | 1.68 (1.56,1.82) | 1.90 (1.73,2.09) | 1.04 (0.96,1.12) | 1.09 (0.98,1.21) |             |             |               |             |               |             |               |

Note. % missed is based on observed data; AORs are based on estimates from generalized linear mixed models with random intercepts. Bold indicates statistically significant findings, p < .05.
a Continuous variable.

Table 4
Reason for missed or delayed childhood and adult vaccination, by country income.

| All ages | Middle-income | High-income |
|----------|---------------|-------------|
| Childhood | (n = 1,636) | (n = 997) |
| Adult | (n = 899) | (n = 499) |
| Worry about getting COVID-19 at clinic | 15 | 14 | 18 | 15 | 15 | 14 |
| Worry about getting COVID-19 leaving house | 12 | 9 | 12 | 12 | 9 | 8 |
| Want to save services for people most need them | 11 | 10 | 8 | 13** | 8 | 12* |
| Only allowed to leave for essential services | 9 | 7 | 9 | 9 | 7 | 7 |
| Clinic closed due to COVID-19 | 9 | 12 | 14 | 6 | 15 | 8 |
| Healthcare provider recommended delay | 8 | 12 | 9 | 8 | 13 | 12 |
| Worry about getting COVID-19 using public transportation | 8 | 7 | 8 | 7 | 7 | 7 |
| Cost | 6 | 3 | 4 | 8 | 3 | 4 |
| Hard to get appointment | 6 | 8 | 6 | 6 | 8 | 7 |
| Worry about giving COVID-19 to others | 6 | 7 | 6 | 5 | 8 | 5 |
| Nobody going out (do not need) | 4 | 5 | 4 | 3 | 4 | 5 |
| Something else | 6 | 8 | 3 | 9 | 4 | 12 |

*p < .05.
**p < .001.
diseases such as polio, measles, rubella, and maternal tetanus, and the necessary funding for secondary and tertiary prevention that may be required [37]. Lastly, to address the widening immunization gap between more and less wealthy countries [12], there will be a need for global players to assist in funding under-vaccinated and missed vaccination programs in the world’s poorest countries. In 2020, the WHO launched the Immunization Agenda 2030 strategy in 2020 to increase widespread and equitable access to vaccination [38]. It appears that addressing equitable “immunity gaps” will be even more pivotal as a result of the COVID-19 pandemic [39].

4.2. Study limitations

Limitations include use of self-reported vaccination data without the possibility for verification with immunization records. Items assessed the impact of the pandemic on ‘missed or delayed’ vaccination; however, this does not account for different processes that might be involved when vaccines are missed compared to when vaccines are delayed but later caught-up. Furthermore, the items developed to understand missed routine vaccinations were not validated survey items but were developed given the urgency to better understand the problem. We were not able to consider other sociodemographic characteristics (e.g., ethnicity or household income) and additional social and behavioural factors (e.g., trust, social norms including support of family and religious leaders) known to be associated with routine vaccination. The cross-sectional study design limits the causal inference. Most of the participants in the majority of high-income countries reported having no children and this may have resulted in an under-reporting of children who missed a vaccine in these countries.

The response rate of the survey was not computable given the sampling design to recruit participants for multiple surveys at one time and assign panelists to the most appropriate survey based on individual fit and survey needs at a given time. This study also did not use survey weights and our findings cannot be considered nationally representative. The generalizability of the study’s findings remains to be established for low-income countries, people without computer access, and in later periods in the COVID-19 pandemic when countries enacted new policies to control COVID-19 (e.g., mask requirements and lockdowns). In addition, countries had different contextual factors at the time of the survey, including varying COVID-19 cases and policy responses.

5. Conclusion

Immunization is a lifesaving and cost-effective public health intervention [40,41]. Achieving and sustaining high levels of vaccination coverage is crucial to the success of immunization programs. We present a global examination of self-reported experiences with and reasons for missed childhood and adult vaccinations during the COVID-19 pandemic. Disruptions affected the timeliness and use of vaccination services, with respondents in middle-income countries reporting higher rates of missed childhood and adult vaccinations. The correlates and reasons for missed vaccinations differed by country income and whether the vaccinee was a child or adult, indicating the need for tailored country approaches. To mitigate concurrent outbreaks of vaccine preventable diseases, routine vaccination should be prioritized in tandem with COVID-19 vaccination.

Declaration of Competing Interest

GKS, NG, JL, and KR report consulting fees from the World Health Organization during the conduct of the study. GKS is supported by a Canadian Institutes of Health Research 2019 Fellowship Award (CIHR MFE 171271) outside the submitted work. NB reports consulting fees for Merck, Novartis, Centers for Disease Control and Prevention, and World Health Organization. All other authors declare no conflict of interest. Pharmaceutical companies or other agencies were not involved in the funding of this article. The funders of this study played no role in the study design, data collection, data analysis, data interpretation, or writing of this manuscript.

Acknowledgements

We thank Melanie Leis, Roberto Fernandez Crespo, Hutan Ashrafian, Gavin Ellison and Marcus Roberts for their role in survey concept and design, data collection and preparation and clarifying the methodology that was used. We also thank Elena Altiери at the World Health Organization for facilitating the initial engagement with Imperial College London.

Data sharing and data accessibility

Data analyzed for the study, including deidentified individual participant data and a data dictionary defining each field in the set, is publicly available at: https://github.com/YouGov-Data/-covid-19-tracker.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2021.12.041.

References

[1] Santoli JM, Lindley MC, DeSilva MB, et al. Effects of the COVID-19 Pandemic on Routine Pediatric Vaccine Ordering and Administration - United States. MMWR Morb Mortal Wkly Rep 2020;69(19):591–3.
[2] Chandir S, Siddiqui DA, Mehmoood M, et al. Impact of COVID-19 pandemic response on uptake of routine immunizations in Sindh, Pakistan: An analysis of provincial electronic immunization registry data. Vaccine 2020;38 (45):7146–55.
[3] Ogundele OA, Omotoso AA. COVID-19 outbreak: a potential threat to routine vaccination programme activities in Nigeria. Hum Vacc Immunother 2020;29:1–3.
[4] Roberts L. Why measles deaths are surging—and coronavirus could make it worse. Nature 2020;580:446–7.
[5] World Health Organization. Eleventh meeting of the WHO South-East Asia Regional Immunization Technical Advisory Group: Regional Office for South-East Asia; 2020.
[6] World Health Organization. Special feature: Immunization and COVID-19; 2020. https://www.who.int/immunization/monitoring_surveillance/immunization-and-covid-19/en/ (accessed November 22 2020).
[7] Graham WJ, Afolabi B, Benova L, et al. Protecting hard-won gains for mothers and newborns in low-income and middle-income countries in the face of COVID-19: call for a service safety net. BMJ Glob Health 2020;5(6).
[8] Riley T, Sully E, Ahmed Z, Biddlecom A. Estimates of the potential impact of the COVID-19 pandemic on sexual and reproductive health in low- and middle-income countries. Int Perspect Sex Reprod Health 2020;46:73–6.
[9] Cash R, Patel V. Has COVID-19 subverted global health? The Lancet 2020;395 (10238):1687–8.
[10] World Health Organization. WHO Director-General’s opening remarks at the media briefing on COVID-19 – 11 March 2020; 11 March 2020. WHO Director-General’s opening remarks at the media briefing on COVID-19 – 11 March 2020 (accessed July 22 2020).
[11] World Health Organization. Guiding principles for immunization activities during the COVID-19 pandemic. March 26 2020. https://apps.who.int/iris/handle/10665/331590 (accessed November 19 2020).
[12] Centers for Disease Control and Prevention (CDC). Operational Considerations for Immunization Services During COVID-19 in Non-US Settings Focusing on Low-Middle Income Countries. Coronavirus Disease 2019 (COVID-19); 2020.
[13] World Health Organization. At least 80 million children under one at risk of COVID-19: call for a service safety net. BMJ Glob Health 2020;5(6).
[14] Olouonsunaye CZ, Yunus KR, Reinhardt K, Salihu HM. COVID-19 and Child Vaccination: A Systematic Approach to Closing the Immunization Gap. Int J MCH AIDS 2020;9(3):381–5.
[15] Blach S, Kondili LA, Aghemo A, et al. Impact of COVID-19 on global HCV elimination efforts. J Hepatol 2020. 50168-8278(20)30523-7.
Abbas K, Procter SR, van Zandvoort K, et al. Routine childhood immunisation during the COVID-19 pandemic in Africa: a benefit-risk analysis of health benefits versus excess risk of SARS-CoV-2 infection. Lancet Glob Health 2020;8(10):e1264–72.

McDonald HI, Tessier E, White JM, et al. Early impact of the coronavirus disease (COVID-19) pandemic and physical distancing measures on routine childhood vaccinations in England, January to April 2020. Euro Surveill 2020;25(19):2000848.

Public Health England. Impact of COVID-19 on childhood vaccination counts to week 13 in 2021, and vaccine coverage to February 2021 in England: interim analyses. London, England: Wellington House, 20 April 2021.

Chandir S, Siddiqi DA, Setayesh H, Khan AJ. Impact of COVID-19 lockdown on routine immunisation in Karachi, Pakistan. Lancet Global Health 2020;8(9):E1118–20.

Saxena K, Marden JR, Carias C, et al. Impact of the COVID-19 pandemic on adolescent vaccinations: projected time to reverse deficits in routine adolescent vaccination in the United States. Curr Med Res Opin 2021;1–11.

Saxena S, Skirrow H, Bedford H. Routine vaccination during covid-19 pandemic response. BMJ 2020;369.

World Health Organization. Special feature: immunization and COVID-19, 2020. https://www.who.int/immunization/monitoring_surveillance/immunization-and-covid-19/en/.

Jones SP, Imperial College London Big Data Analytical Unit and YouGov Plc, 2020. Imperial College London YouGov Covid Data Hub, v1.0, YouGov Plc, April 2020.

The World Bank Group. World Bank Country and Lending Groups. 2020. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-worldbank-country-and-lending-groups (accessed November 20 2020).

Kroenke K, Spitzer RL, Williams JB, Löwe B. An ultra-brief screening scale for anxiety and depression: the PHQ-4. Psychosomatics 2009;50(6):613–21.

Bell S, Clarke R, Paterson P, Mounier-Jack S. Parents’ and guardians’ views and experiences of accessing routine childhood vaccinations during the coronavirus (COVID-19) pandemic: A mixed methods study in England. PLoS ONE 2020;15(12).

Xu Y, Zhang R, Zhou Z, et al. Parental psychological distress and attitudes towards COVID-19 vaccination: A cross-sectional survey in Shenzhen, China. J Affect Disord 2021;292:552–8.

World Health Organization (WHO), Framework for decision-making: implementation of mass vaccination campaigns in the context of COVID-19, 2020. https://apps.who.int/iris/handle/10665/332159 (accessed November 22 2020).

Saso A, Skirrow H, Kampmann B. Impact of COVID-19 on Immunization Services for Maternal and Infant Vaccines: Results of a Survey Conducted by Imprint-The Immunising Pregnant Women and Infants Network. Vaccines 2020;8(3):556.

Jarchow-MacDonald AA, Burns R, Miller J, Kerr L, Willocks LJ. Keeping childhood immunisation rates stable during the COVID-19 pandemic. Lancet Infect Dis 2021;21(4):459–60.

Alsuhaibani M, Alaeeq A. Impact of the COVID-19 Pandemic on Routine Childhood Immunization in Saudi Arabia. Vaccines (Basel) 2020;8(4):E581.

Dinleyici EC, Borrow R, Safadi MAP, van Damme P, Munoz FM. Vaccines and routine immunization strategies during the COVID-19 pandemic. Hum Vaccin Immunother 2020;26:1–8.

World Health Organization (WHO). Global Routine Immunization Strategies and Practices (GRISP). Spain, 2016.

World Health Organization (WHO). Framework for decision-making: implementation of mass vaccination campaigns in the context of COVID-19, 2020. https://apps.who.int/iris/handle/10665/332159.

Mulholland K, Krestinger K, Wandwossen I, Crowcroft N. Action needed now to prevent further increases in measles and measles deaths in the coming years. The Lancet 2020;396:1782–4.

MacDonald NE, Comeau JL, Dubé É, Bucci LM. COVID-19 and missed routine immunizations: designing for effective catch-up in Canada. Can J Public Health 2020;111(4):469–72.

Malik AA, Safdar N, Chandir S, et al. Tuberculosis control and care in the era of COVID-19. Health Policy Plann 2020;1–3.

World Health Organization. Immunization Agenda 2030 A global strategy to leave no one behind, April 2020.

Salway S, Holman D, Lee C, et al. Transforming the health system for the UK’s multietnic population. BMJ 2020;368.

Ehreth J. The global value of vaccination. Vaccine 2003;21:596–600.

Wang X, Li Y, O'Brien KL, et al. Respiratory Virus Global Epidemiology Network. Global burden of respiratory infections associated with seasonal influenza in children under 5 years in 2018: a systematic review and modelling study. Lancet Glob. Health 2020;8(4):e497–510.