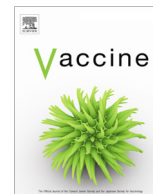




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COVID-19 and missed or delayed vaccination in 26 middle- and high-income countries: An observational survey



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ABSTRACT

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.

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1. Introduction

The Coronavirus disease (COVID-19) pandemic has led to significant interruptions 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 vaccina-

tion 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

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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; [18] 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

Table 1
Sample characteristics by country.

	N	% Respiratory diseases	% Cardiovascular diseases	Immuno-suppressive conditions	% Male	Md age	% Working	Md psychological distress	Md household size	Md number of children
Middle-income	11,995									
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	38	57	3	4	1
Philippines	1,002	12	16	6	47.4	32	68	4	5	1
Thailand	1,001	5	14	5	44.7	33	70	4	4	1
Vietnam	1,011	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	999	8	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

sure if someone in the household had missed a vaccine and 2% preferred not to answer (Table 2; Supplementary Material, Fig. S1). About half (53%) missed vaccinations were for an adult, and 44% were for a child.

Missed vaccination was generally higher in middle- than high-income countries (Fig. 1; Supplementary Material, Tables S2-3). In middle-income countries, 7.6% (709/9,359) of children had missed a vaccination due to COVID-19, while in high-income countries this rate was lower at 3.0% (447/14,886; $p < .05$). The same pattern held for adult vaccination (9.6% (899/9,359) vs. 3.4% (499/14,886), $p < .05$) (Tables S2-3). Reported missed childhood vaccination ranged from 1.0% in Hong Kong to 13.5% in Vietnam. Missed adult vaccination ranged from 1.5% in Finland to 14.7% in Brazil. Looking across countries, rates of childhood and adult missed vaccination were moderately correlated, $r = 0.66$, $p < .05$.

3.3. Correlates of missed vaccination

In middle-income countries, missed childhood vaccination was more common if the respondent had a higher risk of severe COVID-19 illness (Table 3). Missed childhood vaccination was more common for respondents with respiratory diseases (18% vs. 7%, AOR = 2.58, 95% CI: 2.01, 3.31) and cardiovascular diseases and related conditions (9% vs. 7%, AOR = 1.33, 95% CI: 1.05, 1.67). The same pattern held for individuals with immunosuppressive conditions but was not statistically significant. Missed childhood vaccination was less common for respondents who were older; and more common for respondents who were male, who worked, and who reported greater psychological distress (all $p < .05$). Missed childhood vaccination was more common in larger households and in households with more children (both $p < .05$). The ICC for the model for children in middle-income countries was 0.42.

In high-income countries, missed childhood vaccination was also more common in respondents with increased 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

Table 2
Vaccination item response frequencies, by country income.

Vaccination Items	Middle-Income		High-Income		Overall	
	n	% of total	n	% of total	n	% of total
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.^a						
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)^b						
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	–

^a 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%).

Compared to middle-income countries, high-income countries more often had missed vaccination due to healthcare provider recommendation, 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, wanting 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 (all $p < .05$).

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 countries, 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 variation 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 vaccines, 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 about the availability of routine vaccination services.

Health conditions that elevate risk of severe COVID-19 illness were associated with missed vaccination. Specifically, having a respiratory or cardiovascular disease was associated with missed childhood vaccination in both middle- and high-income countries, while immunosuppressive conditions were additionally associated

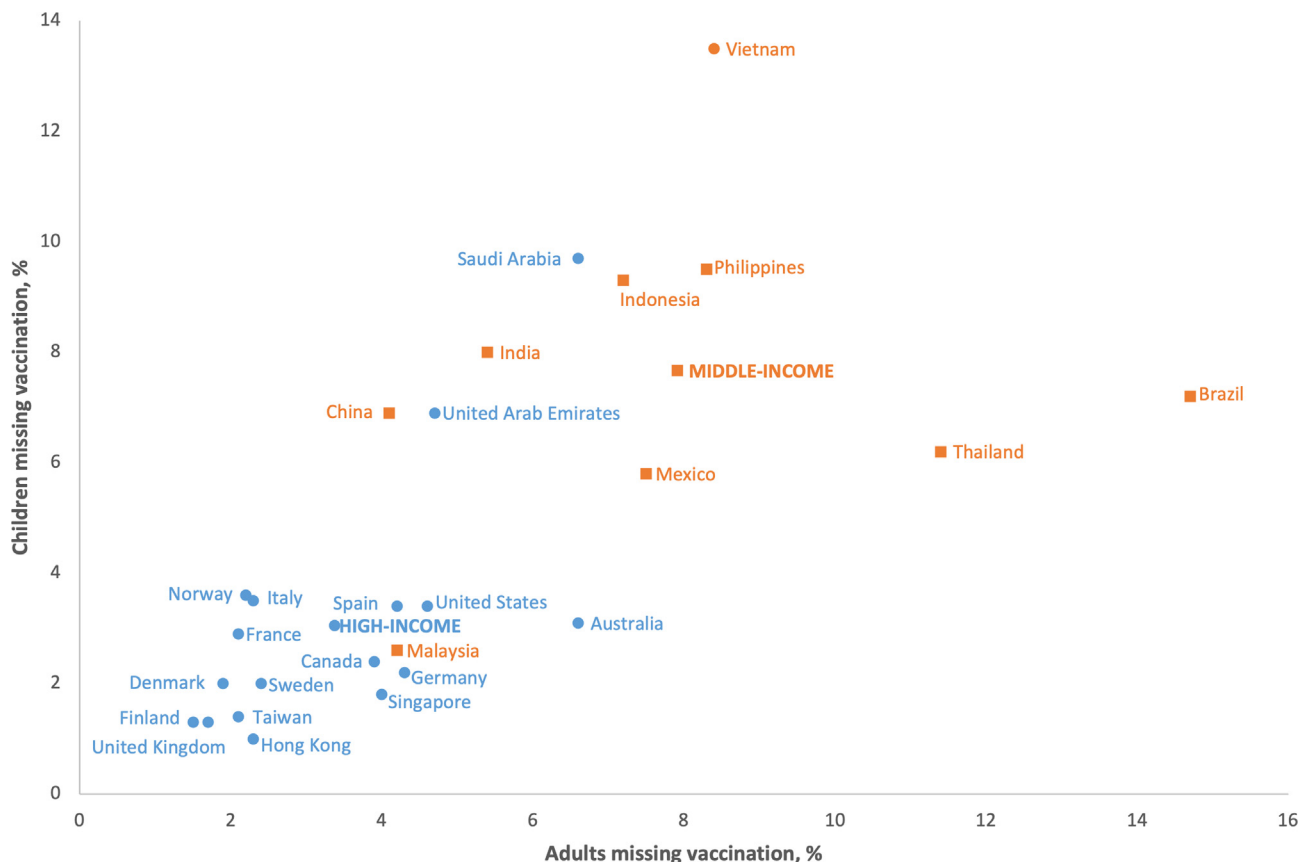


Fig. 1. Missed or delayed childhood and adult vaccination during COVID-19, by country.

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

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.

	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)
Respondent COVID-19 risk factors								
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)
Cardiovascular diseases								
No	7		3		9		3	
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)
Immunosuppressive conditions								
No	7		3		9		4	
Yes	10	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)
Other respondent characteristics								
Sex								
Female	7		3		10		3	
Male	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)
Age ^a		0.98 (0.97,0.99)		0.95 (0.94,0.96)		1.00 (0.99,1.00)		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 size ^a		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 children ^a		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	
	Middle-income (<i>n</i> = 1,636) %	High-income (<i>n</i> = 997) %	Childhood (<i>n</i> = 709) %	Adult (<i>n</i> = 899) %	Childhood (<i>n</i> = 447) %	Adult (<i>n</i> = 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.

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 as required [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

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 panellists 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

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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>.

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