Global declines in vaccine confidence from 2015 to 2022: a large-scale retrospective analysis

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Abstract

The latest WHO/UNICEF estimates of national childhood immunisation coverage have revealed the largest declines in routine immunisation uptake globally in three decades. Although the COVID-19 pandemic has contributed to these falls via supply-side disruptions impacting vaccine availability, the extent to which the COVID-19 pandemic has impacted demand-side barriers, such as vaccine confidence, is not yet well understood. Through a large-scale retrospective modelling study, we investigate the extent to which vaccine confidence has changed globally using pre- and post-pandemic data. A total of 165,729 individual interviews across 55 countries as part of nationally representative surveys were conducted between 2015 and 2022. Vaccine confidence is measured using three items that probe perceptions towards the importance, safety, and effectiveness of vaccines. Changes in national-level confidence are evaluated for the sampled populations and within age and sex subgroups via nonparametric tests and a Bonferroni correction is used to adjust study-wide *p*-values to account for multiple hypotheses. Since the pandemic, perceptions towards the importance of vaccines for children have seen significant decreases in 46 of 55 countries studied, with significant increases found only in China, India, and Mexico. Vaccines are perceived to be less safe in 24 countries, less effective in 28, with only four countries reporting increases in confidence around vaccine safety and five for effectiveness. Among demographic subgroups, a widening gap between older and younger groups is found, with younger groups becoming less confident over time. Declining global confidence in vaccines, particularly among younger age groups, may be contributing to the backslide in routine childhood immunisation uptake. Growing hesitancy among younger age groups should be investigated as a public health priority to better understand confidence among parents.

Keywords Vaccine confidence, vaccine hesitancy, determinants of health, COVID-19, vaccine confidence age-gap.

Introduction

Supply-side vaccination barriers during the Covid-19 pandemic have disrupted progress towards childhood immunisation goals. Supply chain disruptions, resource diversions, and lockdown measures have all contributed to the global downtick in uptake of childhood immunisations between 2020 and 2022.[1] During this period, the percentage of children who received three-doses of the diphtheria, tetanus, and pertussis (DTP3) vaccine, a marker for immunisation system strength, has fallen five percentage points, the largest sustained decline in approximately 30 years.[2] 2021 was predicted to be a year of recovery; instead, DTP3 coverage continued its backslide and coverage hit a 30-year low. Declines in coverage for other vaccines have resulted in outbreaks, such as measles and the re-emergence of polio in a number of countries where it had previously been eliminated.[3,4]

While vaccine confidence can be interpreted narrowly to trust in vaccines, there are much broader systemic factors at play. Vaccine confidence also reflects trust in people that deliver vaccines, the systems that recommend them, as well as the policymakers who enact vaccination policies[5]. Multi-component community-led strategies including raising awareness and community outreach have been consistently shown to improve levels of vaccine confidence and uptake.[6,7]

The rapid development and rollout of COVID-19 vaccines since late 2020 saw vaccine confidence issues rise to the forefront of public consciousness. Many studies have examined COVID-19 vaccine confidence in a range of settings and have found multifaceted barriers to vaccine acceptance that include trust in the safety and efficacy of the vaccines (and concerns around the speed of vaccine development)[8,9], trust in institutions and policymakers[10,11], susceptibility to misinformation[12], and concerns around vaccination policies[13,14]. Barriers have often fallen strongly along socio-demographic lines, with younger age groups[11,15] and minority and historically marginalised groups[16] typically holding lower levels of vaccine confidence driving vaccination inequity.

Much less is known, however, about how the COVID-19 pandemic has shifted perceptions towards other vaccines and the consequences that any loss in confidence may have on routine immunisation uptake. The recent State of Vaccine Confidence in the EU 2022 report reveals a worrying decline in vaccine confidence among young people across the EU and an increasing 'gap' in vaccine confidence between old and young[17]. While the introduction of a mandatory vaccination policy in France likely led to short-term increases in vaccine acceptance[18], there is also evidence to suggest an increasing polarisation of sentiment, with increases both in the proportions of French adults feeling relieved and others feeling angry to have been vaccinated[19]. A recent study among a predominately UK-based population reveals a decline in vaccine confidence since the onset of the pandemic, with younger groups experiencing a noticeable decline[20].

Understanding how the pandemic has shaped vaccine confidence, particularly among younger people, is a crucial question. There is precedent for confidence losses in one vaccine to precipitate

system-wide confidence losses, leading to refusal of unrelated vaccines[21]. To better understand how vaccine confidence has shifted since before the pandemic, we harness data reporting individual vaccine confidence levels from over 100 nationally representative cross-sectional surveys collected between 2015 and 2022 and across 55 countries. We thus extend the scope of the State of Vaccine Confidence in the EU 2022 report[17] to an additional 28 countries. Vaccine confidence is measured through a three-item battery that captures agreement in the importance of vaccines for children, the safety of vaccines, and the effectiveness of vaccines. These items are vaccine agnostic, enabling us to understand temporal shifts in confidence over time. We treat the Covid-19 pandemic as an exposure and pool all survey data collected before 1 January 2020 as a pre-exposure cohort and data collected after 31 December 2020 as the post-exposure cohort.

We find a concerning overall trend of declines in vaccine confidence. Only three countries—China, Mexico, and India—report significantly higher levels of vaccine confidence than before the pandemic. This effect of declining confidence appears to be heightened in younger participants, who showed a more pronounced loss in vaccine confidence across most countries.

Methods

Data

The Vaccine Confidence Project (VCP) has been collecting vaccine confidence data since 2015 in over 140 countries and territories via over 400 nationally representative surveys. All surveys include a three-item vaccine confidence battery that explores perceptions towards the importance of vaccines for children, the safety of vaccines, and the effectiveness of vaccines: "I think vaccines are important for children to have"; "I think vaccines are safe"; and "I think vaccines are effective" (a large subset of the surveys contain the additional question "I think vaccines are compatible with my religious beliefs" but due to a rewording of the question to "I think vaccines are compatible with my religious or philosophical beliefs" in more recent surveys, this item is not considered in this survey, which compares temporal trends in these items). Except for one global study that included a five-point Likert scale[22], all responses to these items are collected on a four-point scale ranging from 'strongly agree' to 'strongly disagree' with an additional response option allowing respondents to report that they 'do not know'.

Data are included in the study if they include the four-point Likert scale, facilitating a direct temporal comparison over time. This criterion resulted in the exclusion of 144 surveys[22]. Further, data are included if they contain at least one pre- and post-exposure survey, with the exposure period defined as January 1, 2020, and December 31, 2020. This additional inclusion criterion resulted in the exclusion of an additional 106 surveys. The exclusion of 2020 data removes data in the early stages of the pandemic: we aim to record baseline vaccination beliefs in the pre- and post-exposure groups, a distinction that may be complicated due to the circulation of a novel virus. Where more than one survey exists for a country in either the pre- or post-exposure groups, the data are combined into a single pre- or post-exposure dataset, respectively. Each individual survey

is collected through online surveys (which use opt-in panels), face-to-face interviews, or through computer-assisted telephone interviews (both of which use probability-based sampling).

The final dataset comprises 159 nationally representative surveys (representing over 160,000 individuals) across 55 countries, each with at least one pre- and post-exposure survey and with comparable response scales. A demographic breakdown of respondents in the pre- and post-exposure cohorts is provided in table 1. A summary of data used in this study is found in supplementary table S1. The 55 countries are: Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Croatia, Cyprus, Czech Republic, Denmark, Democratic Republic of the Congo (DRC), Estonia, Finland, France, Germany, Ghana, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malaysia, Mali, Malta, Mexico, Mongolia, Netherlands, Niger, Nigeria, Pakistan, Papua New Guinea, Peru, Philippines, Poland, Portugal, Romania, Russia, Senegal, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Syria, Turkey, USA, and Vietnam.

Changes in confidence over time

To test for changes in pre- and post-exposure vaccine confidence for each country and item, we use the weighted Wilcoxon rank-sum test (WRS)[23], a nonparametric test for shifts in location. For each country, a pre- and post-exposure sample is obtained by mapping Likert responses to a numeric scale: 'strongly agree' → 1, 'tend to agree' → 2, 'do not know / prefer not to say' → 3, 'tend to disagree' → 4, and 'strongly disagree' → 5. Individuals who do not provide a response are removed from the analysis. If data for a given country and item is represented as $(Y_i,\ G_i)$ where Y_i represents the numeric Likert response of the i-th individual and $G_i \in \{0,1\}$ denotes the pre- (0) or post-exposure (1) group, then the WRS tests the null hypothesis that Y is independent of G, assuming that Y is generated independently from some distribution F_Y. The WRS test is implemented using the 'svyranktest' function in the 'survey' package in R[24]. Weights have been calculated by market researchers to align sample survey populations with national census data. Specifically, quotas are set by market researchers for age, sex, and sub-national administrative regions according to marginal distributions from census or official data and weights are applied when sample distributions do not align with these population-level marginal distributions. Application of weights via weighted WRS tests enables us to account for imbalances in relevant characteristics in the sample cohorts.

To measure changes in confidence over time – rather than assess significance – the weighted percentage of respondents agreeing that vaccines are important for children, safe, or effective is calculated and associated with the corresponding WRS significance test.

Changes in vaccine confidence between males and females and between under 35s and over 55s are calculated for each country and item using WRS as described above. The choice of these age strata is to assess changes in vaccine confidence among a predominately birth-giving age cohort.

A demographic breakdown of respondents in the pre- and post-exposure cohorts is provided in table 1.

Multiple hypothesis correction

A statistical test is performed for each country and each item, resulting in the generation of 165 *p*-values for the main analysis. A further 162 *p*-values are calculated for each of the age sub-strata temporal comparison and 165 *p*-values for each of the sex sub-strata temporal comparison. In total, therefore, there are 819 *p*-values computed across the main analysis of the study. (We note that there is no age sub-strata data for Australia which removes one *p*-value for each item.) To control for multiple hypotheses, we perform Bonferroni correction by multiplying each *p*-value calculated by 819. A change in vaccine confidence over time is then determined to be significant if the Bonferroni-adjusted *p*-value is less than 0.05. This Bonferroni correction can be interpreted as a strict study-wide control.

Sensitivity analysis

To assess the impact of assigning respondents who answer 'do not know / no response' the middle Likert value (3), a sensitivity analysis is performed to remove these individuals from the analysis and the following recoding is instead used: 'strongly agree' → 1, 'tend to agree' → 2, 'tend to disagree' → 3 and 'strongly disagree' → 4. This recoding of responses made no difference to the results of the WRS tests throughout the study, though the confidence values were higher for any country with at least one individual who reported a 'do not know' response or who did not provide a response as this caused a decrease in the country's denominator.

Results

Global trends in national vaccine confidence

The percentage of respondents agreeing that vaccines are important for children in the post-pandemic cohort is shown in Figure 1A, while percentage point changes in agreement between the post- and pre-pandemic cohorts are shown in Figure 1B. The percentage of respondents agreeing that vaccines are safe in the post-pandemic cohort is shown in Figure 2A with the corresponding percentage point changes in confidence over the pandemic in Figure 2B. The percentage of respondents agreeing that vaccines are effective in the post-pandemic cohort is shown in Figure 3A with the percentage point change over the pandemic shown in Figure 3B. For each of Figure 1B, 2B, and 3B, countries with significant changes in confidence are highlighted, with no significant change in confidence coloured grey.

Agreement that vaccines are important for children has increased in only three countries between the pre- and post-pandemic cohorts: India (3.9% increase between the pre- and post-pandemic cohorts), Mexico (+4.7%), and China (+8.9%). There are decreases in 46 countries and no significant change detected in six (Italy, Peru, Poland, Sweden, Turkey, and Vietnam). Of the 46 countries with decreases in confidence detected, the three with the largest falls are South Korea (45.6 percentage point [pp] decrease between pre- and post-pandemic cohorts), Papua New Guinea

(45.6pp), and Ghana (36.4pp). There are also large falls exceeding 25% in Japan (-30.9pp), Senegal (-29.7pp), Croatia (-28.8pp), Philippines (-26.7pp), South Africa (-26.7pp), Latvia (-26.5pp), and Russia (-26.4pp) (Figure 1B).

Agreement that vaccines are safe has increased in four countries: France (11.9%), China (11.9%), Vietnam (10.3%), and Mexico (7.6%). Agreement that vaccines are safe has decreased in 24 countries, while there is no change detected in 27. Of the 24 countries with decreases in confidence detected, the three with the largest falls are again South Korea (-34.9pp), Papua New Guinea (-33.0pp), and Ghana (-25.2pp). Other large falls in the levels of agreement that vaccines are safe are found in Syria (-22.9pp), Pakistan (-21.0pp), Democratic Republic of Congo (-18.8pp), Slovakia (-14.9pp), South Africa (-13.7pp), and Senegal (-13.7pp) (Figure 2B).

Agreement that vaccines are effective has increased in five countries: China (10.2%), India (6.7%), Mexico (6.6%), Italy (4.0%), and Vietnam (3.3%). Agreement that vaccines are effective has decreased in 22 countries, while there is no change detected in 28. Of the 22 countries with decreases in confidence detected, the three with the largest falls are Papua New Guinea (-34.7pp), South Korea (-34.9pp), and Democratic Republic of the Congo (-24.2pp).

Across all three items, the highest levels of agreement in the post-pandemic cohort are in India, Vietnam, and China while the lowest levels are in Russia, South Korea, and Papua New Guinea (Figure 1A, 2A, and 3A).

Strata analysis: sex

The percentage point change in the percentage of males and females agreeing that vaccines are important for children, safe, and effective is shown in Figure 4.

There are losses in confidence in the importance of vaccines for children among females in 40 countries and in males in 39 countries, with 36 countries having a loss in confidence among both males and females. The largest falls in confidence are among females in South Korea (-48.1pp) and Papua New Guinea (-46.1pp). The largest increases in confidence are among females in China (7.2pp) and Mexico (5.7pp).

There are losses in confidence in the safety of vaccines in 20 countries for both females and males, with 18 countries reporting a loss in confidence for both sexes. Confidence losses in the effectiveness of vaccines is found in 26 countries for females, 18 for males, and 18 for both. The largest falls in confidence are among females in South Korea (-35.6pp) and Papua New Guinea (-35.5pp). The largest increases in confidence are among females in China (12.3pp) and France (12.0pp).

Confidence losses in the effectiveness of vaccines is found in 26 countries for females, 18 for males, and 18 for both. The largest falls in confidence are among females and males in Papua New

Guinea (35.7pp and 33.8pp, respectively) with the largest increases among females in Mexico (9.0pp) and China (8.5pp).

Strata analysis: age

The percentage point change in the percentage of under 35s and 55-and-overs agreeing that vaccines are important for children, safe, and effective are shown in Figure 5. There are consistently larger falls in confidence among the under 35s cohort compared to the 55-and-over cohort.

Among under 35s, confidence in the importance of vaccines for children has increased in three countries but decreased in 19, while among 55-and-over cohort, confidence has increased in only one (Mexico) but decreased in 22. Perceptions towards the safety of vaccines have increased in three countries in under 35s but decreased in 40, while among 55-and-overs perceptions have increased in five but fallen in 11. With regards to perceptions towards vaccine effectiveness, views have increased in three countries among the younger cohort but fallen in 21 countries in the same age group. Among 555-and-overs, perceptions have increased in seven countries but fallen in 22. In 21 countries, confidence in the importance of vaccines for children has fallen for both under 35s and 55-and-overs. For vaccine safety and effectiveness perceptions vaccine confidence has fallen in five countries (Argentina, Niger, USA, South Korea, Hungary for safety perceptions and Democratic Republic of the Congo, Croatia, Niger, South Korea, and USA for effectiveness).

In the Netherlands there is a significant increase in vaccine confidence for 55-and-overs and a corresponding decrease in confidence for 35-and-unders on the vaccine safety and effectiveness items. In Denmark, there is a significant increase in confidence for 55-and-overs with a corresponding decrease in confidence for 35-and-unders for the vaccine effectiveness item.

	Pre-pandemic group					Post-pandemic group				
	total	<35	>= 55	female	male	total	< 35	>= 55	female	male
Argentina	1524	487	395	811	713	1000	463	166	473	527
Australia	1190	252	558	595	595	1000	-	-	505	493
Austria	2935	831	1022	1502	1433	1000	271	380	515	483
Belgium	2000	461	835	1024	976	1000	282	376	511	488
Brazil	1985	771	457	1039	946	1000	644	30	500	500
Bulgaria	3035	732	1163	1548	1487	1000	301	260	526	473
Canada	1010	227	397	481	529	1003	236	451	554	449
China	1150	450	194	575	575	2000	972	74	1000	1000
Croatia	1001	253	387	526	475	1000	314	303	488	500
Cyprus	1010	202	370	522	488	251	129	11	126	124
Czech Republic	3047	832	1037	1537	1510	1000	265	334	505	488
Denmark	1526	371	636	807	719	1001	275	407	507	490
DRC	1000	471	194	500	500	2160	1305	185	1060	1099
Estonia	1016	275	392	517	499	1000	312	289	539	454
Finland	3373	734	1657	1724	1649	1000	290	370	505	488
France	2924	812	1022	1514	1410	1001	256	403	517	482
Germany	2908	820	1011	1455	1453	1001	227	459	512	486
Ghana	995	687	40	500	495	2164	1555	118	551	1049
Greece	2009	737	363	1064	945	1000	297	276	499	498
Hungary	1003	253	362	539	464	1000	263	365	531	468
India	2123	1066	175	919	1204	1000	495	115	461	539
Indonesia	1533	760	153	759	774	1000	431	137	500	500
Ireland	3035	899	997	1561	1474	1000	292	288	507	491
Italy	3115	666	1224	1611	1504	1000	212	431	533	465
Japan	2310	529	973	1171	1139	1066	273	464	510	487
Latvia	2020	583	671	1117	903	1001	313	289	534	458
Lithuania	1018	272	372	516	502	1000	302	336	529	458
Luxembourg	530	162	146	256	274	500	143	167	250	250
Malaysia	808	515	60	304	504	1000	574	42	496	504
Mali	1856	1054	458	933	923	1190	509	207	592	598
Malta	500	150	190	253	247	500	325	17	286	206
Mexico	1502	660	299	752	750	1000	617	86	500	500
Mongolia	1000	480	140	513	487	1000	429	176	513	487
Netherlands	2077	482	905	1024	1053	1000	281	379	510	489
Niger	1957	1166	434	975	982	1219	572	235	610	609
Nigeria	5837	4230	594	2922	2915	2038	1346	79	1031	1007

Pakistan	2000	1140	125	1027	973	1110	632	96	188	922
Papua New Guinea	597	410	22	195	402	513	272	27	250	263
Peru	2000	1027	214	1061	939	1000	655	100	410	590
Philippines	2000	781	349	1000	1000	1000	484	139	499	501
Poland	3023	915	1031	1563	1460	1000	272	348	523	474
Portugal	2000	547	647	1011	989	1000	278	309	534	466
Romania	2772	801	940	1499	1273	1000	302	259	513	486
Russia	2500	1022	508	1346	1154	1016	197	386	525	491
Senegal	2384	1512	488	1195	1189	2153	1178	286	1063	1090
Slovakia	1047	288	337	544	503	1000	290	304	511	484
Slovenia	2102	555	753	1050	1052	1000	283	322	474	514
South Africa	1157	308	374	753	404	2014	930	263	1040	974
South Korea	3000	868	891	1504	1496	1155	414	369	472	519
Spain	2955	827	878	1467	1488	1000	242	348	511	485
Sweden	2031	535	768	1019	1012	1000	268	400	505	494
Syria	686	345	44	354	332	2047	982	282	1023	1024
Turkey	1027	412	212	502	525	1200	737	51	549	651
USA	2006	549	729	1065	941	1204	394	470	643	561
Vietnam	1070	516	121	546	524	1003	380	220	509	494

Table 1 ***Overall respondent counts in the pre- and post-pandemic cohorts and among the age and sex strata.*** *The number of surveyed respondents in pre- and post-pandemic cohorts and the number of respondents in the sex and age cohorts. The number of males and females may not add to the total count as some respondents do not provide their sex. There are also no age data for the post-pandemic age cohort for Australia as these data were not collected.*

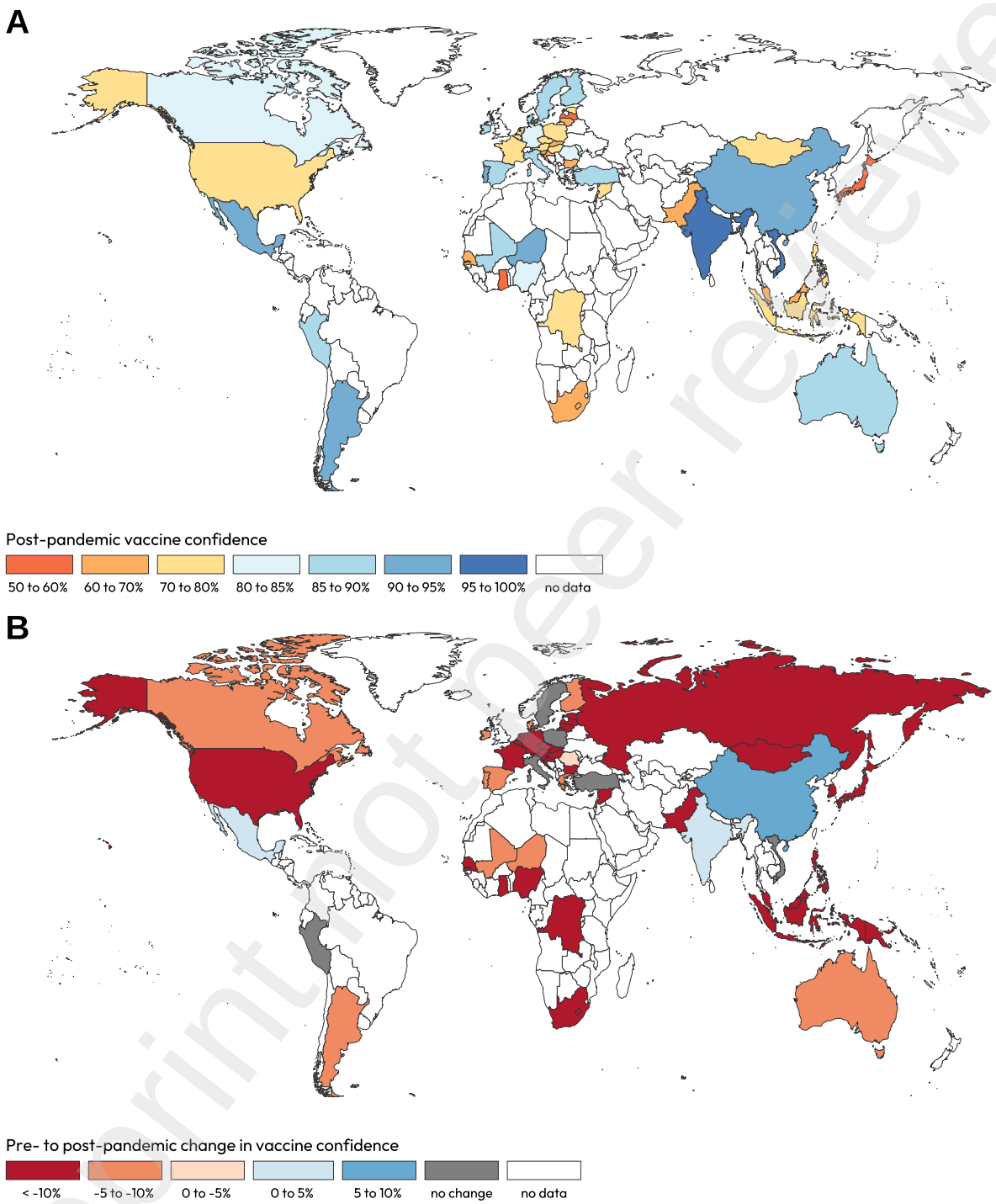

Figure 1 ***Confidence in the importance of vaccines for children*** *(A) The percentage of respondents in the post-pandemic cohort (2021 onwards) agreeing that vaccines are important for children. (B) The percentage point change in the percentage of respondents agreeing that vaccines are important for children from the pre- to post-pandemic cohorts. Countries coloured grey have no significant change detected.*

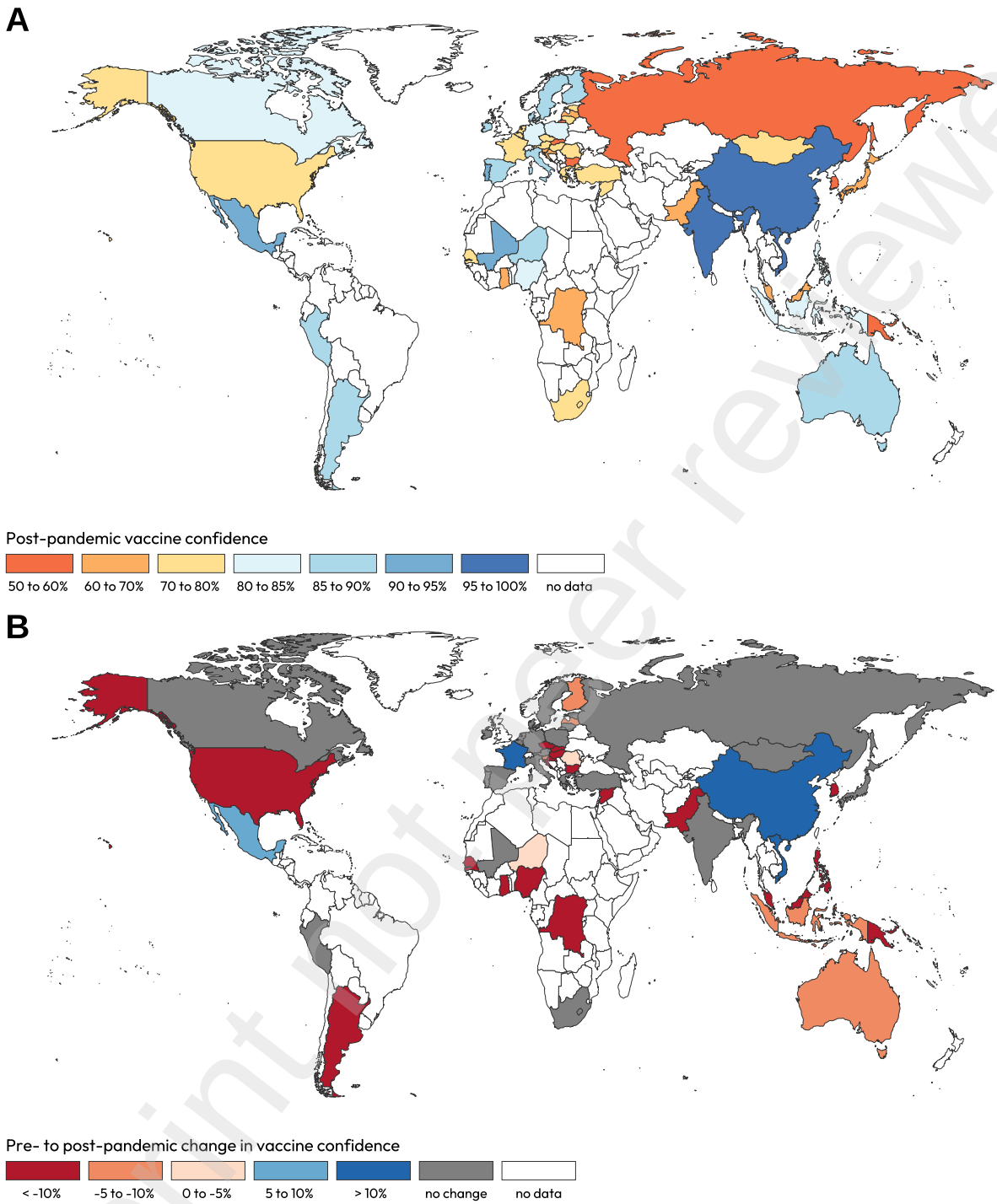

Figure 2 ***Confidence in the safety of vaccines*** *(A) The percentage of respondents in the post-pandemic cohort (2021 onwards) agreeing that vaccines are safe. (B) The percentage point change in the percentage of respondents agreeing that vaccines are safe from the pre- to post-pandemic cohorts. Countries coloured grey have no significant change detected.*

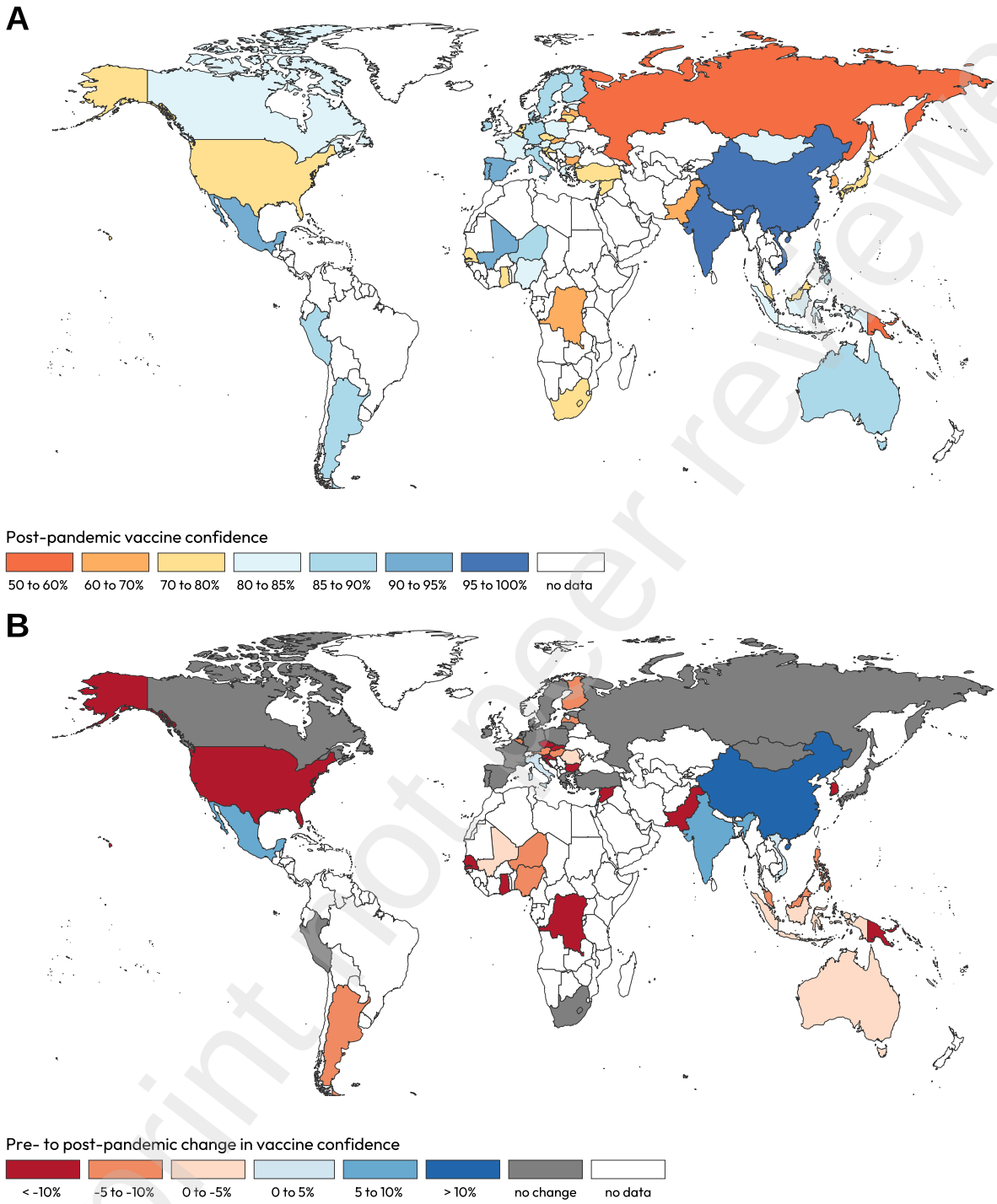

Figure 3 ***Confidence in the effectiveness of vaccines*** *(A) The percentage of respondents in the post-pandemic cohort (2021 onwards) agreeing that vaccines are effective. (B) The percentage point change in the percentage of respondents agreeing that vaccines are effective from the pre- to post-pandemic cohorts. Countries coloured grey have no significant change detected.*

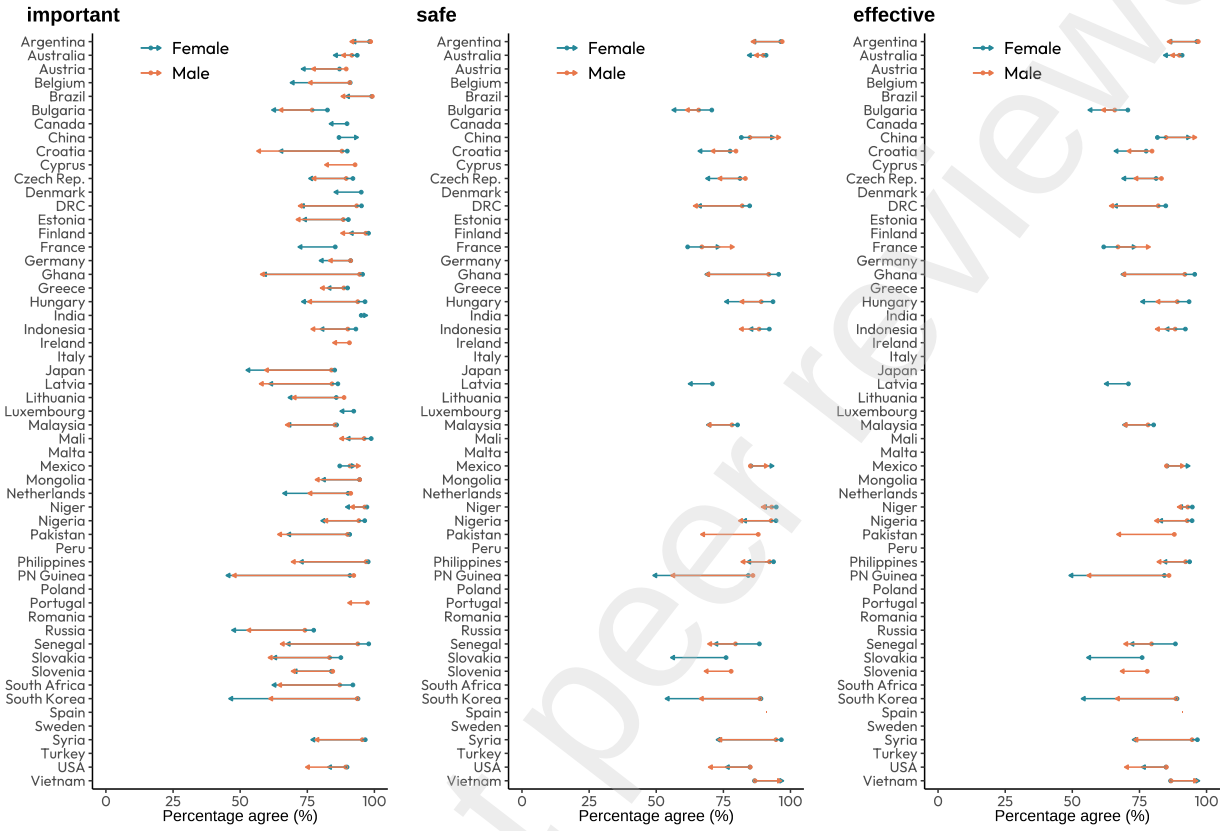

Figure 4 ***Changes in vaccine confidence between males and females*** *The percentage of males (red) and females (blue) agreeing that vaccines are important for children (important), safe, and effective between the pre-pandemic cohort (dotted end) and the post-pandemic cohort (arrowed end). Arrows pointing to the left (right) denote that vaccine confidence has decreased (increased) over time. Non-significant results are not highlighted.*

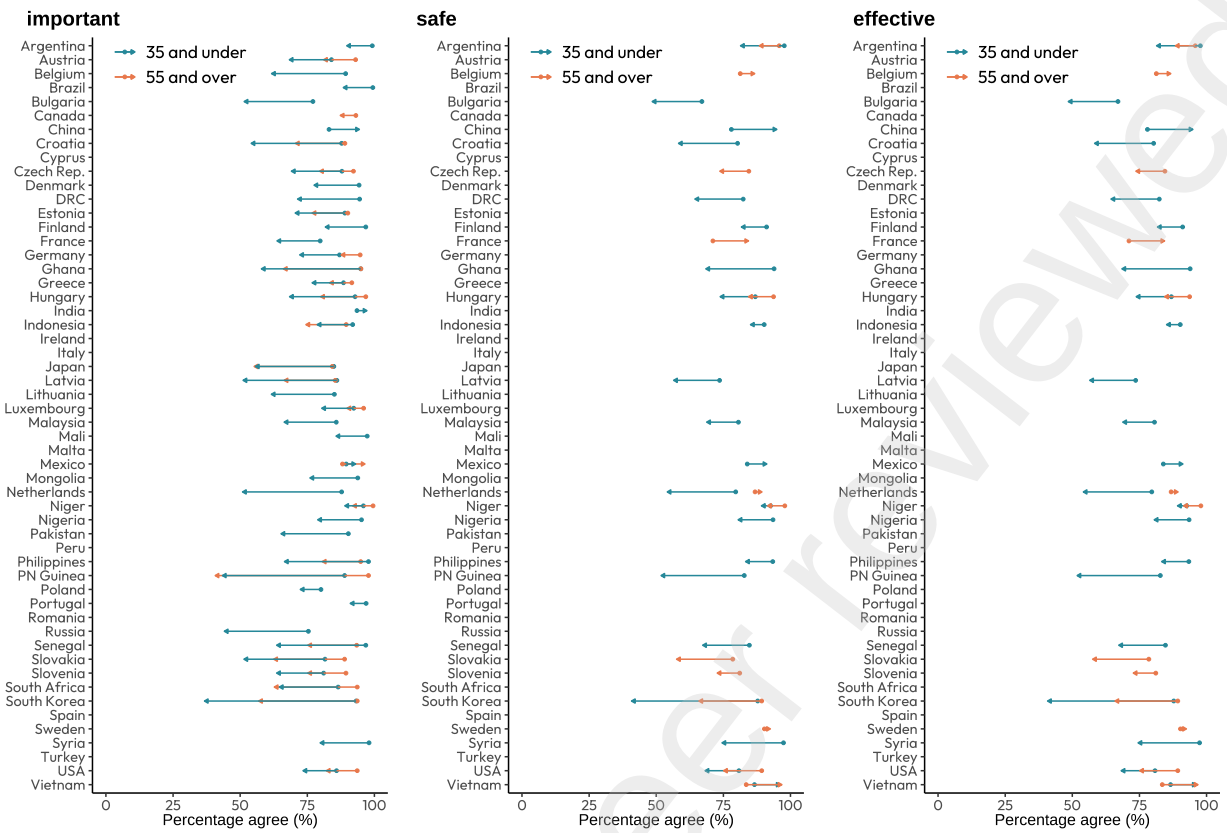

Figure 5 ***Changes in vaccine confidence between 35-and-unders and 55-and-overs.*** *The percentage of respondents aged 35 and under (blue) and 55 and over (red) agreeing that vaccines are important for children (important), safe, and effective between the pre-pandemic cohort (dotted end) and the post-pandemic cohort (arrowed end). Arrows pointing to the left (right) denote that vaccine confidence has decreased (increased) over time. Non-significant results are not highlighted.*

Discussion

To our knowledge, this is the first study assessing general perceptions towards vaccines across the globe since before the COVID-19 pandemic to 2021 onwards. Vaccine confidence was estimated and mapped for 55 countries who had pre- and post-pandemic survey data and key temporal trends were revealed. Results from our study can inform further research, in particular the decline in vaccine confidence in under 35s, the most important demographic group for the uptake of routine childhood immunisations. Below, we discuss countries findings in-depth: these countries are candidates for nuanced follow-up to understand the precise drivers of vaccine confidence among younger age groups and how the pandemic – and its associated policies – impacted vaccine confidence.

Confidence remains low in Europe as has been found by previous studies relating to vaccine confidence[25,26] generally as well as for COVID-19 specifically[10,27]. Many Eastern European countries and the Baltic states have experienced large losses in confidence. The Netherlands also appears to be undergoing large vaccine confidence losses among younger groups, but with confidence rising among 55-and-overs. This is a surprising finding, especially given marked increases in intent to receive a COVID-19 between 2020 and 2021 across all age groups[28]. Although there were decreases in uptake of childhood immunizations preceding the pandemic in the Netherlands, these were relatively small[29]. There were hostilities towards COVID-19 restrictions and curfews in Netherlands that generated large protests[30] and that may have had lasting impact on governmental trust. Our finding, perhaps, presents an early-warning signal of significant vaccine confidence losses in the Netherlands among younger age groups and should be monitored closely.

All African countries surveyed in this study experienced declines across at least one vaccine confidence item. Some of the largest falls in confidence were seen in the Democratic Republic of Congo, Ghana, and Senegal, for which we cannot find explanations for in the current literature and so which thus warrant further investigation. Vaccine confidence losses were also seen in Nigeria, which has had historic concerns over the safety of the polio vaccine.[31]

In Asia, China and India buck the global trend of declining vaccine confidence. India consistently ranks among the highest countries in the world for vaccine confidence[26], including COVID-19 vaccine confidence[32]. Shaped by a collectivist cultural background, Chinese citizens often display a pronounced sense of nationalistic expression, which may have been amplified due the Government's COVID suppression[33]. Upon the initial release of Chinese-made COVID-19 vaccines in January 2021, health authorities in China have rigorously addressed and provided information about vaccine side effects. Specifically, clinics have taken measures to exclude people susceptible to adverse reactions from vaccines, encompassing the elderly and individuals with underlying medical conditions[34]. Furthermore, heightened vaccine confidence in China is likely closely related to government communication and the presence of notable public figures. The Chinese president, state leaders, and public health scientists have been proactive in official

information channels to mitigate public anxiety and promote vaccination strategies[35,36]. It is worth noting, however, that data for China in the post-pandemic cohort was collected prior to China's lifting of COVID-19 restrictions and subsequent increase in the number of COVID-19 cases and deaths[37]. It is unclear whether these increases may have altered vaccine confidence in China.

However, Asia also reports some countries with the largest global falls in vaccine confidence including Papua New Guinea, Philippines, Japan, and South Korea. The significant decline in South Korea's vaccine acceptance may have resulted from a high baseline prior to the COVID-19 pandemic and the peak of negative sentiment towards the COVID-19 vaccine in early 2021. Historically, South Korea has had high vaccine acceptance rates. However, with the introduction of COVID-19 vaccines, concerns about their safety and efficacy began to rise and spread rapidly on social media[38,39]. Negative sentiment increased significantly after reports of emerging side effects surfaced in early 2021. At that time, approximately 33% of South Korean citizens refused to be vaccinated, regardless of their eligibility[40] with high hesitancy rates also reported elsewhere[41]. A sentiment analysis study discovered that about 71% of negative opinions on South Korean social media platforms were associated with the AstraZeneca vaccine, as several individuals reported thrombocytopenia after receiving it[40]. South Korea also has a very low proportion of parents who were willing to vaccinate their children against COVID-19 as a priority[42].

Vaccine confidence remains low in Japan, in line with earlier surveys. COVID-19 vaccine hesitancy in Japan has roots in MMR scepticism in the 1990s as well as the human papillomavirus (HPV) vaccine scandal in 2013, when HPV vaccine recommendations were suspended by the Ministry of Health, Labour and Welfare and resulted in HPV coverage falling below 1%.[50] While the government decision to suspend active recommendation of the HPV vaccine has now been reversed, lingering anxieties persist. These events led to widespread public concern, media scrutiny, and lawsuits, which fostered a cautious and hesitant attitude towards new vaccines, including the COVID-19 vaccine.[43]

In Papua New Guinea, childhood immunization rates have undergone substantial declines since the mid 2000s. Uptake of first-dose measles-containing vaccine, for example, fell from 82% in 2005 to 37% in 2019 according to the WHO-UNICEF estimates of national immunization coverage[44]. COVID-19 vaccination uptake in Papua New Guinea is one of the lowest in the world, with only half a million COVID-19 vaccine doses administered as of April 2023, a low rate for a population exceeding nine million[45]. Fears over vaccine safety and low vaccine confidence among healthcare workers, as well as a fragmented political landscape and distrust in central government present significant barriers[46,47]. Low vaccine confidence in Papua New Guinea is combining with a weak healthcare system and hard-to-reach populations to present a significant public health challenge. These factors have led to a recent WHO Outbreak and Crisis Response appeal in early 2023[48].

Philippines still appears to be suffering from the impact Dengvaxia vaccine safety crisis around a new reported risk to individuals who had not been previously exposed to the dengue virus[21]. Pre-pandemic studies already found large losses in vaccine confidence in the aftermath of the already political controversy and public panic around the dengue vaccine introduction [49]. Although there is some indication that confidence has increased in recent years[21], this study finds that perceptions have still not yet fully recovered to pre-Dengvaxia levels, highlighting lingering public distrust of authorities.

In the Americas, the USA and Argentina reported vaccine confidence falls across all three items, while Mexico reported increases. In the US, politicisation of the COVID-19 vaccine[51], the introduction of vaccine mandates[13], as well as the impact of misinformation[12,52] all appear to influence COVID-19 vaccine acceptance, though it is currently unknown whether these have driven losses in perceptions towards vaccines more broadly.

While there appear to be no notable differences in vaccine confidence declines between the sexes, there are alarming falls in vaccine confidence reported among under 35s. This vaccine confidence 'age gap' has already been reported recently across the European Union[17] (we note that data from 2018 and 2022 in that report is used in this study) as well as in a recent study by Siani and Tranter, who found younger groups becoming less confident than older groups over the course of the pandemic[20]. This present study extends this finding to a broader set of countries across the globe.

There are various reasons for declining vaccine confidence among under 35s including restrictive pandemic policies – such as vaccine requirements, from passports to mandates – as well as lockdowns, school, and university closures, and employment losses. Many studies have highlighted psychological reactance effects from their introduction[13,14,53], though these studies – conducted in the US and UK – do not provide strong evidence for the role of age and would largely not be applicable in many of the countries in this study that did not introduce vaccine-based requirements COVID-19 vaccine misinformation may also have played a role in the declining confidence among young people [12,54], impacting views towards vaccines more broadly.

There are study limitations to note. Firstly, the three-item question set was often included as part of a larger questionnaire that explored other vaccination attitudes, including confidence in specific vaccines[17]. It is therefore possible that when answering these three vaccine-agnostic questions, respondents either had a specific vaccine in mind or were judging beliefs against a wider vaccination set, given the introduction of the COVID-19 vaccines in late 2020. The detection of confidence backslides in countries with known recent confidence issues (for example, the Philippines or Papua New Guinea) does provide some reassurance that the observed effects do reflect genuine views towards vaccines in general. Secondly, while we explore the relationship between sex and age and vaccine confidence, a large range of other contextual factors drive confidence concerns. Nonetheless, the large falls in confidence among younger age groups provide a key signpost to policymakers and other researchers seeking to explore precise vaccine confidence

drivers among this cohort. Thirdly, as our three survey items are vaccine-agnostic, we can make no direct claims about changes in confidence among specific vaccines over time; nor is it clear how losses in vaccine confidence measured through these items will affect acceptance of childhood immunizations.

Further research is needed to identify the precise drivers of declining global confidence and to establish the extent to which decreases in confidence among younger age groups may translate into decreases in uptake of routine immunisations. Research should also consider the specific role of the pandemic on attitudes to non-COVID vaccines to identify possible unintended consequences of COVID-19 policies.

References

1. WHO. COVID-19 pandemic fuels largest continued backslide in vaccinations in three decades. https://www.who.int/news/item/15-07-2022-covid-19-pandemic-fuels-largest-continued-backslide-in-vaccinations-in-three-decades (2022).
2. World Health Organization. Progress and challenges with Achieving Universal Immunization Coverage: Technical document. https://www.who.int/publications/m/item/progress-and-challenges (2022).
3. Russo, G. B., Goyal, T., Tyler, K. & Thakur, K. T. Re-Emergence of Poliovirus in the United States: Considerations and Implications. *Annals of Neurology* (2022) doi:10.1002/ana.26504.
4. Shaheen, N., Mohamed, A., Ramadan, A. & Nashwan, A. J. The poliovirus reemergence: Did concentrated efforts against COVID-19 open the door? *J. Virus Erad.* (2023) doi:10.1016/j.jve.2023.100321.
5. World Health Organization. Understanding the behavioural and social drivers of vaccine uptake WHO position paper – May 2022. *Wkly. Epidemiol. Rec.* **97**, 209–224 (2022).
6. Jarrett, C. *et al.* Strategies for addressing vaccine hesitancy - A systematic review. *Vaccine* (2015) doi:10.1016/j.vaccine.2015.04.040.
7. Crocker-Buque, T., Mindra, G., Duncan, R. & Mounier-Jack, S. Immunization, urbanization and slums - A systematic review of factors and interventions. *BMC Public Health* (2017) doi:10.1186/s12889-017-4473-7.
8. Wong, L. P. *et al.* COVID-19 vaccination intention and vaccine characteristics influencing vaccination acceptance: a global survey of 17 countries. *Infect. Dis. Poverty* (2021) doi:10.1186/s40249-021-00900-w.
9. Bono, S. A. *et al.* Factors affecting COVID-19 vaccine acceptance: an international survey among low-and middle-income countries. *Vaccines* (2021) doi:10.3390/vaccines9050515.
10. Lazarus, J. V. *et al.* A global survey of potential acceptance of a COVID-19 vaccine. *Nat. Med.* (2020) doi:10.1038/s41591-020-1124-9.
11. de Figueiredo, A. & Larson, H. J. Exploratory study of the global intent to accept COVID-19 vaccinations. *Commun. Med.* (2021) doi:10.1038/s43856-021-00027-x.

12. Loomba, S., de Figueiredo, A., Piatek, S. J., de Graaf, K. & Larson, H. J. Measuring the Impact of Exposure to COVID-19 Vaccine Misinformation on Vaccine Intent in the UK and US. *Nat. Hum. Behav.* 2020.10.22.20217513 (2021) doi:10.1101/2020.10.22.20217513.

13. Eshun-Wilson, I. *et al.* Preferences for COVID-19 vaccine distribution strategies in the US: A discrete choice survey. *PLoS One* (2021) doi:10.1371/journal.pone.0256394.

14. de Figueiredo, Alexandre; Larson, Heidi J; Reicher, S. D. The potential impact of vaccine passports on inclination to accept COVID-19 vaccinations in the United Kingdom: evidence from a large cross-sectional survey and modelling study. *EClinicalMedicine* **40**, (2021).

15. Lazarus, J.V., Ratzan, S., Palayew, A., Billari, F.C., Binagwaho, A., Kimball, S., Larson, H.J., Melegaro, A., Rabin, K., White, T.M. and El-Mohandes, A. COVID-SCORE: A global survey to assess public perceptions of government responses to COVID-19 (COVID-SCORE-10). *PLoS One* **15**, p.e0240011 (2020).

16. de Figueiredo, A. Forecasting sub-national trends in COVID-19 vaccine uptake in the UK before vaccine rollout. *Sci. Rep.* (2022) doi:10.1038/s41598-022-25354-4.

17. de Figueiredo, A; Eagan, RL; Hendricks, G; Karafillakis, E; van Damme, P; Larson, H. *State of Vaccine Confidence in the EU 2022*. (2022).

18. Mills, M. C., & Rüttenauer, T. The effect of mandatory COVID-19 certificates on vaccine uptake: synthetic-control modelling of six countries. *Lancet Public Heal.* **7**, e15–e20 (2022).

19. Ward, J. K. *et al.* The French health pass holds lessons for mandatory COVID-19 vaccination. *Nature Medicine* (2022) doi:10.1038/s41591-021-01661-7.

20. Siani, A. & Tranter, A. Is vaccine confidence an unexpected victim of the COVID-19 pandemic? *Vaccine* (2022) doi:10.1016/j.vaccine.2022.10.061.

21. Reyes, M. S. G. L., Dee, E. C. & Ho, B. L. Vaccination in the Philippines: experiences from history and lessons for the future. *Hum. Vaccines Immunother.* (2021) doi:10.1080/21645515.2020.1841541.

22. Wellcome Trust. *Wellcome Global Monitor 2018*. https://wellcome.org/reports/wellcome-global-monitor/2018 (2019).

23. Lumley, T. & Scott, A. J. Two-sample rank tests under complex sampling. *Biometrika* (2013) doi:10.1093/biomet/ast027.

24. Lumley, A. T. Package 'survey': analysis of complex survey samples. R package version 3.31-5. *R Doc.* (2016).

25. Larson, H. J. *et al.* The State of Vaccine Confidence 2016: Global Insights Through a 67-Country Survey. *EBioMedicine* (2016) doi:10.1016/j.ebiom.2016.08.042.

26. de Figueiredo, A., Simas, C., Karafillakis, E., Paterson, P. & Larson, H. J. Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: a large-scale retrospective temporal modelling study. *Lancet* (2020) doi:10.1016/s0140-6736(20)31558-0.

27. Salomoni, M. G. *et al.* Hesitant or not hesitant? A systematic review on global covid-19

vaccine acceptance in different populations. *Vaccines* (2021) doi:10.3390/vaccines9080873.

28. Sanders, J. G. *et al.* Understanding a national increase in COVID-19 vaccination intention, the Netherlands, November 2020-March 2021. *Eurosurveillance* (2021) doi:10.2807/1560-7917.ES.2021.26.36.2100792.

29. WHO. Netherlands: WHO and UNICEF estimates of immunization coverage: 2021 revision. *WUENIC estimates of immunization coverage* https://cdn.who.int/media/docs/default-source/country-profiles/immunization/2022-country-profiles/immunization_nld_2022.pdf?sfvrsn=49e4b851_3&download=true (2021).

30. van der Zwet, K., Barros, A. I., van Engers, T. M. & Sloot, P. M. A. Emergence of protests during the COVID-19 pandemic: quantitative models to explore the contributions of societal conditions. *Humanit. Soc. Sci. Commun.* (2022) doi:10.1057/s41599-022-01082-y.

31. Ghinai, I., Willott, C., Dadari, I. & Larson, H. J. Listening to the rumours: What the northern Nigeria polio vaccine boycott can tell us ten years on. *Glob. Public Health* (2013) doi:10.1080/17441692.2013.859720.

32. Lazarus, J. V. *et al.* Revisiting COVID-19 vaccine hesitancy around the world using data from 23 countries in 2021. *Nat. Commun.* (2022) doi:10.1038/s41467-022-31441-x.

33. Su, L., Du, J. & Du, Z. Government Communication, Perceptions of COVID-19, and Vaccination Intention: A Multi-Group Comparison in China. *Front. Psychol.* (2022) doi:10.3389/fpsyg.2021.783374.

34. Wang, G. *et al.* Determinants of COVID-19 vaccination status and hesitancy among older adults in China. *Nat. Med.* (2023) doi:10.1038/s41591-023-02241-7.

35. BBC News. Covid in China: Xi Jinping and other leaders given domestic vaccine. https://www.bbc.com/news/world-asia-china-62279377 (2022).

36. Liu, J. From social drama to political performance: China's multi-front combat with the Covid-19 epidemic. *Crit. Asian Stud.* (2020) doi:10.1080/14672715.2020.1803094.

37. Dyer, O. Covid-19: China stops counting cases as models predict a million or more deaths. *BMJ* (2023) doi:10.1136/bmj.p2.

38. Cho, H.-K. *et al.* Parental concerns on COVID-19 vaccine safety and hesitancy in Korea: Implications for vaccine communication. *Epidemiol. Health* (2022) doi:10.4178/epih.e2023004.

39. Choi, Y. J., Lee, J. & Paek, S. Y. Public Awareness and Sentiment toward COVID-19 Vaccination in South Korea: Findings from Big Data Analytics. *Int. J. Environ. Res. Public Health* (2022) doi:10.3390/ijerph19169914.

40. Lee, H. *et al.* COvid-19 vaccine perception in south korea:web crawling approach. *JMIR Public Heal. Surveill.* (2021) doi:10.2196/31409.

41. Hwang, S. E., Kim, W. H. & Heo, J. Socio-demographic, psychological, and experiential predictors of COVID-19 vaccine hesitancy in South Korea, October-December 2020. *Hum. Vaccines Immunother.* (2022) doi:10.1080/21645515.2021.1983389.

42. Lee, M. *et al.* Parental Acceptance of COVID-19 Vaccination for Children and Its Association with Information Sufficiency and Credibility in South Korea. *JAMA Netw. Open* (2022) doi:10.1001/jamanetworkopen.2022.46624.

43. Tanaka, Y., Ueda, Y., Yoshino, K. & Kimura, T. History repeats itself in Japan: Failure to learn from rubella epidemic leads to failure to provide the HPV vaccine. *Human Vaccines and Immunotherapeutics* (2017) doi:10.1080/21645515.2017.1327929.

44. World Health Organization. WHO-UNICEF estimates of national immunisation coverage. https://www.who.int/docs/default-source/immunization/immunization-coverage/wuenic_notes.pdf?sfvrsn=88ff590d_6 (2020).

45. World Health Organization. WHO COVID-19 Dashboard. https://covid19.who.int/region/wpro/country/pg (2022).

46. Hoy, C., Wood, T. & Moscoe, E. Addressing vaccine hesitancy in developing countries: Survey and experimental evidence. *PLoS One* (2022) doi:10.1371/journal.pone.0277493.

47. Ball, P. & Maxmen, A. The epic battle against coronavirus misinformation and conspiracy theories. *Nature* **581**, 371–374 (2020).

48. World Health Organization. Outbreak and Crisis Response Appeal 2023. https://www.who.int/emergencies/funding/outbreak-and-crisis-response-appeal/2023/2023-appeals/appeal-papua-new-guinea (2023).

49. Larson, H. J., Hartigan-Go, K. & de Figueiredo, A. Vaccine confidence plummets in the Philippines following dengue vaccine scare: why it matters to pandemic preparedness. *Human Vaccines and Immunotherapeutics* (2019) doi:10.1080/21645515.2018.1522468.

50. Yagi, A. *et al.* Change of HPV vaccination rates in Japan: the effect of individual notifications implemented by local governments. *Int. J. Clin. Oncol.* (2022) doi:10.1007/s10147-022-02213-w.

51. Bolsen, T. & Palm, R. Politicization and COVID-19 vaccine resistance in the U.S. in *Progress in Molecular Biology and Translational Science* (2022). doi:10.1016/bs.pmbts.2021.10.002.

52. Pierri, F. *et al.* Online misinformation is linked to early COVID-19 vaccination hesitancy and refusal. *Sci. Rep.* (2022) doi:10.1038/s41598-022-10070-w.

53. Porat, T. *et al.* "Vaccine Passports" May Backfire: Findings from a Cross-Sectional Study in the UK and Israel on Willingness to Get Vaccinated against COVID-19. *Vaccines* (2021) doi:10.3390/vaccines9080902.

54. Caceres, M. M. F. *et al.* The impact of misinformation on the COVID-19 pandemic. *AIMS Public Health* (2022) doi:10.3934/PUBLICHEALTH.2022018.

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Data and materials availability: All raw data for this study is freely available at https://www.vaccineconfidence.org/vci/data-and-methodology/.

Supplementary materials

Survey year	Region	Countries	Fieldwork partner	Study in data first appeared	Methodology
2015	Global	67	WIN/Gallup International Association	The state of vaccine confidence 2016: global insights through a 67-country survey. *EBioMedicine* 12. 2016	Online, CATI, face-to-face
2016	Sahel	6	WIN/Gallup International Association	Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: a large-scale retrospective temporal modelling study. *Lancet* 396 (10255).	Face-to-face
2018	EU	28	ORB International	State of Vaccine Confidence in the EU 2018. *European Commission*. 2018	Online & face-to-face
2018	Global	41	ORB International	Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: a large-scale retrospective temporal modelling study. *Lancet* 396 (10255).	Online, CATI, face-to-face
2022	Africa	14	ORB International	-	Face-to-face
2022	EU	27	ORB International	State of Vaccine Confidence in the EU 2012. *European Commission*. 2012	Online
2022	Asia	9	ORB International	-	Online & CATI
2022	Africa	7	ORB International	-	Face-to-face
2022	Global	14	ORB International	-	Online & CATI

Table S1. ***Data collection and summary.*** Summary of data used in this study and data collection methodology. Only a single methodology is used for a single country. Each survey comprises roughly 1,000 interviews with some exceptions, for example Cyprus in Europe. Only countries with a pre- and post-pandemic cohort are used.