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COVID-19 vaccine acceptance in the general population and under-resourced communities from high-income countries: realist review

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ABSTRACT

Objective To compare vaccination willingness before rollout and 1 year post-rollout uptake among the general population and under-resourced communities in high-income countries.

Design A realist review.

Data sources Embase, PubMed, Dimensions ai and Google Scholar.

Setting High-income countries.

Definitions We defined *vaccination willingness* as the proportion of participants willing or intending to receive vaccines prior to availability. We defined vaccine uptake as the real proportion of the population with complete vaccination as reported by each country until November 2021.

Results We included data from 62 studies and 18 high-income countries. For studies conducted among general populations, the proportion of vaccination willingness was 67% (95% CI 62% to 72%). In real-world settings, the overall proportion of vaccine uptake among those countries was 73% (95% CI 69% to 76%). 17 studies reported pre-rollout willingness for under-resourced communities. The summary proportion of vaccination willingness from studies reporting results among people from under-resourced communities was 52% (95% CI 0.46% to 0.57%). Real-world evidence about vaccine uptake after rollout among under-resourced communities was limited.

Conclusion Our review emphasises the importance of realist reviews for assessing vaccine acceptance. Limited real-world evidence about vaccine uptake among under-resourced communities in high-income countries is a call to context-specific actions and reporting.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ For country vaccination willingness, we included only studies with national representative samples.
⇒ For under-resourced communities' vaccination willingness, we included studies with purposive samples.
⇒ We compared countries' vaccination willingness with official country-level national reports.
⇒ Official country-level reports about uptake among under-resourced communities were limited.
⇒ We could not compare vaccination willingness with real-world vaccine uptake statistics among under-resourced communities.

INTRODUCTION

Cumulative excess death from the COVID-19 pandemic made it a leading global cause of death between 2020 and 2021.[1] Universal vaccination played a significant role transitioning into post-pandemic life.[2] COVID-19 vaccines were developed and authorised in record time; as of April 2023, 70% of the world population received at least one COVID-19 vaccine dose. However, vaccine uptake is complicated; it involves more than simply making vaccines available. For instance, inequitable vaccine distribution possibly contributes to the 2.8-fold difference in vaccine coverage between high-income countries (HICs) and low-income countries (LICs).[3] Whereas vaccine uptake in HICs was 81%, vaccine uptake in LICs was 29%.[4]

Countries with strong public health systems and economic resources achieved some early success vaccinating populations, yet people from historically, socially or economically under-resourced communities, such as people who experience homelessness, people from ethnic and racial minorities, as well as people with immigration or refugee experience, possibly remained unvaccinated for complex reasons. Regarding vaccination willingness and uptake among people from ethnic minority groups, Raizai *et al*[5 6] identified several structural aspects resulting from a mistrust of government and public health bodies: systemic racism and discrimination at societal and healthcare system levels, histories of unethical studies, as well as underrepresentation of people from ethnic and racial minority groups in health, drug and vaccine trials. Distrust in medical institutions

from inappropriate care and mistreatment also impacted vaccination willingness among people from socially or economically under-resourced communities, such as members of indigenous communities or racial minority groups as well as among incarcerated individuals.[7–9]

Additionally, local barriers to access vaccinations and individual vaccine hesitancy played roles explaining vaccine uptake differences within and among countries.[3] Nonetheless, structural access barriers and individual vaccine hesitancy possibly share common pathways, which complicate disentangling their effects in vaccination uptake.[10] For instance, in a systematic review of barriers, facilitators and vaccine hesitancy with included studies about mainly HICs, they found individuals from minority ethnic groups concurrently experience more access barriers along with higher vaccine hesitancy and lower vaccine uptake when compared with individuals from majority ethnic groups and non-migrants.[11] Therefore, a debate is ongoing about the true proportion of hesitancy and vaccine refusal among unvaccinated individuals in HICs. Although individual vaccination willingness is not under discussion, an understanding about vaccination willingness and vaccine uptake possibly informs health policies more reliably, identifies access barriers to vaccines, facilitates vaccination campaign planning and enhances uptake, eventually.

Generally, marginalisation and vaccine uptake in HICs has been scarcely described in the literature. We performed a realist synthesis to evaluate COVID-19 vaccine acceptance and its determinants among people from under-resourced communities in HICs. We compared data collected from a specific systematic review with real-world statistics to study the general evolution of vaccination rates—from hypothetical acceptance before the widespread rollout of vaccination programmes—until December 2021, 1 year after the first vaccine was available and when presumably, most HIC populations could be vaccinated. In addition, we compared hypothetical vaccination willingness between the general population and under-resourced communities in HICs.

METHODS

Study design and sources of data

We conducted a quantitative realist synthesis on the prevalence of vaccine acceptance among the general population from HICs. We followed the Realist And Meta-narrative Evidence Syntheses: Evolving Standards quality and publication standards and reporting guidelines.[12] We also report our findings according to the statement on Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[13] We defined *vaccination willingness* as the proportion of participants willing or intending to receive a vaccine before vaccines were available. We defined *vaccine uptake* as the real proportion of the population with complete vaccination as reported by each country until November 2021.

A medical information specialist searched three electronic databases: PubMed, Embase and Dimensions ai. For informal sources, and to add possibly relevant articles where the search terms only appear in the full text of an article, we also screened the first 200 hits of a Google Scholar search. The detailed search strategy is available in the section 1 of the online supplemental material. We sought peer-reviewed scientific literature published before 30 November 2022. Different descriptors were used for each component of the search, for surveys investigating COVID-19 vaccine attitudes among adult populations from HICs before COVID-19 vaccine rollout. We used the World Bank database to classify countries of origin according to income at the time of data collection (US$12 536 or more gross national income per capita in 2019). We defined the study to include surveys reporting quantitative data on populations willing to be vaccinated when vaccines became available. We included surveys meeting the following criteria: (1) conducted in 2020–2021 among adult populations before vaccine rollout campaigns; (2) reported prevalence of vaccination willingness via questionnaires; (3) peer-reviewed; (4) performed probabilistic sampling; and (5) reported results for general populations and/or under-resourced communities.

To mitigate the risk of bias, for country vaccination willingness, we included only studies with national representative samples. For under-resourced communities' vaccination willingness, we also included studies with purposive samples.

We excluded studies of unrepresentative participants from general populations, such as people with particular conditions or health statuses—like people with diabetes or pregnant people—or particular occupations—like healthcare workers or university students. We excluded articles with incomplete information, systematic reviews and meta-analyses, and reports from meetings or congresses.

We provide details for our study selection and data extraction methods in section 1 of the online supplemental material. When multiple records included data from the same country, we extracted data from all of them and calculated country-specific pooled prevalence and used the pooled prevalence as the value to compare further with real-world statistics of vaccine uptake.

Study outcomes

For each country, outcomes of interest included (1) the proportion of people willing to be vaccinated according to results of the systematic review (primary outcome: vaccination willingness/acceptance); and (2) the proportion of vaccinated people according to the real-world data statistics (secondary outcome: vaccine uptake).

Data selection and extraction

Two reviewers independently screened all records and verified included and excluded studies by using REDCap (Vanderbilt University, Nashville, Tennessee, USA). We

report identification, exclusion and inclusion of studies in the online supplemental figure 1. One reviewer extracted data using a pre-piloted extraction form, and a second reviewer verified the extracted data. Extracted variables were included, yet were not limited to sample size, study design, publication date, survey date, country and study population composition, community type, age, vaccine hesitancy, vaccine acceptance and vaccine refusal (section 1.d of the online supplemental material). We extracted all proportions as reported. For the realist synthesis, we obtained available country-specific data from multiple sources.[14 15] We provide sources of information and definitions for country-specific variables in section 1.d of the online supplemental material.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Potential bias assessment

Two independent reviewers assessed the risk of bias for each study using the checklist for prevalence studies from Hoy *et al*; we assessed each question independently and calculated scores, as recommended by checklist developers.[16] However, we did not use total scores in analyses. Instead, we grouped questions into categories according to the bias domain they addressed.[17] We analysed risk of selection bias and risk of non-response bias as potential sources of heterogeneity among studies. We provide potential bias assessment results in online supplemental table 1.

Statistical analysis

Data synthesis

We estimated the pooled prevalence of vaccination willingness and 95% CI using random-effects models. We used the 'metaprop' function from the 'meta' package in R (V.3.5.1) to synthesise and display findings from included studies in forest plots. For overall summary estimates, we calculated prediction intervals to represent the likely range of proportions obtained in subsequent studies conducted in similar settings.[18] We quantified statistical heterogeneity using the I^2 statistic. Heterogeneity was classified according to the most recent version of the Cochrane Handbook: 0–40% might not be important; 30–60% may represent moderate heterogeneity; 50–90% may represent substantial heterogeneity; 75–100% considerable heterogeneity. However, in meta-analyses of prevalence, heterogeneity according to the I^2 statistic is expected to be substantial and possibly not discriminative.[19] Therefore, we also calculated prediction intervals to describe the expected range of estimates.

Sensitivity analyses

We performed sensitivity analyses. First, we used the influence function in the 'metafor' package to compute outliers and influential case diagnostics, including externally standardised residuals and leave-one-out estimates of heterogeneity. Second, we investigated the impact of selection bias as a potential source of heterogeneity by means of meta-regression.

Real-world data analysis

After synthesising information from included studies, we compared results for each country with real-world data statistics concerning vaccination uptake. In addition, we identified how different country characteristics and policies (online supplemental table 2) in each country could be associated with vaccination uptake. Specifically, we selected four components to examine separately: percentage of populations older than 65 years; social spending as a percentage of gross domestic product (GDP); healthcare spending as a percentage of GDP; and stringency index (Oxford COVID-19 Government Response Tracker index) at the start date of vaccine rollout campaigns in each country since we thought them most likely associated with vaccine uptake among general populations.[14]

RESULTS

After deduplication, we identified 3349 potentially relevant citations. After initial screening based on titles and abstracts, we selected full texts of 214 articles for detailed evaluation (online supplemental figure 1). After full-text assessment, we excluded 152 citations. We provide the complete list of excluded references and reasons for exclusion in section 1c of the online supplemental material. We included the remaining 62 articles that reported vaccination willingness before vaccine rollout at the country level.

General characteristics of included studies

We provide detailed characteristics of included studies in table 1. Overall, studies included 299 769 individuals from 18 HICs. Among the 62 included references, 45 studies reported results for general populations and 17 studies reported results for at least one under-resourced community. We calculated the weighted average of exported mean ages from each study; the mean age was 47.5 years. The proportion of women ranged from 16% to 93% among studies including patients from both sexes. Two studies reported including only men.[20 21] Study sample sizes conducted among general populations ranged from 316 to 63 266 and study sample sizes conducted among under-resourced communities ranged from 83 to 18 474.

Since reporting vaccination willingness via questionnaire was an inclusion criterion, all studies used validated questionnaires or questionnaires developed specifically for studies.

General characteristics of the included countries

We present detailed characteristics of included countries in online supplemental table 2. Country populations ranged between 2.6 million (Qatar) and 332 million (USA). Median population was 11.1 million (IQR: 7.9–67). Median percentage of populations older than 65 years was 19 (IQR: 16.8–22.2), and median value for life

Table 1 General characteristics of included studies

Author	Country	Study design	Date of data collection	Population	Sample size	Female sex proportion	Mean age	Vaccine acceptance	Hesitancy	Refusal	Unwillingness
Attwell *et al*[22]	Australia	Cross-sectional survey	29 May 2020	General population	1316	60	58	65%	27%	8%	35%
Seale *et al*[23]	Australia	Cross-sectional survey	24 Mar 2020	General population	1420	52		80%	14%	6%	20%
Dietze *et al*[71]	Australia	Cross-sectional survey	22 Dec 2020	People who inject drugs at least monthly in the past 6 months	100	41	39	48%	37%	15%	52%
Enticott *et al*[24]	Australia	Cross-sectional survey	7 Mar 2021	General population	1166	49	51.7	78%	15%	7%	22%
Schernhammer *et al*[25]	Austria	Cross-sectional survey	3 Dec 2020	General population	1007	44	42	36%	23%	41%	64%
Kessels[50]	Belgium	Cross-sectional survey	16 Oct 2020	General population	2060			34%	57%	9%	66%
Lavoie *et al*[27]	Canada	Cross-sectional survey	29 Mar 2021	General population	15 019	50	48	58%	0%	0%	42%
Basta *et al*[26]	Canada	Cross-sectional survey	29 Dec 2020	General population	23 819	53		84%	12%	4%	16%
Abramovich *et al*[73]	Canada	Cross-sectional survey	30 Jan 2021	2SLGBTQ+ youth experiencing homelessness	139	61	20	64%	0%	0%	36%
Manca *et al*[9]	Canada	Cross-sectional survey	10 Dec 2020	Indigenous population	342	53		64%	17%	18%	35%
Bagic *et al*[28]	Croatia	Cross-sectional survey	11 Apr 2021	General population	765	52.4	49	64%	19%	17%	35%
Neumann-Böhme *et al*[29]	Denmark	Cross-sectional survey	15 Apr 2020	General population	7664			80%	12%	8%	20%
Detoc *et al*[30]	France	Cross-sectional survey	20 Apr 2020	General population	3656	89	67	78%	48%	0%	48%
Ward *et al*[32]	France	Cross-sectional survey	4 May 2020	General population	5018			76%	16%	8%	24%
Montagni *et al*[31]	France	Cross-sectional survey	10 May 2020	General population	1640	78.4		71%	11%	19%	30%
Ousseine *et al*[21]	France	Cross-sectional survey	11 Apr 2021	Men who have sex with men	18 474	0	34	61%	22%	18%	40%
Coulaud *et al*[33]	France	Cross-sectional survey	23- Dec 2020	General population	3204	38		60%	30%	10%	40%
Heyerdahl *et al*[34]	France	Cross-sectional survey	16 Dec 2020	General population	10 000			57%	19%	24%	43%
Bendau *et al*[35]	Germany	Cross-sectional survey	11 Jan 2021	General population	1779	77.6	41	65%	24%	11%	35%

Continued

Table 1 Continued

Author	Country	Study design	Date of data collection	Population	Sample size	Female sex proportion	Mean age	Vaccine acceptance	Hesitancy	Refusal	Unwillingness
Kourlaba *et al*[36]	Greece	Cross-sectional survey	3 May 2020	General population	1004	51	41	58%	16%	26%	42%
Murphy *et al*[37]	Ireland	Cross-sectional survey	5 Apr 2020	General population	1041	51.5		65%	26%	9%	35%
Maor and Caspi[38]	Israel	Cross-sectional survey	6 Sep 2020	General population	2024	52		76%	0%	24%	24%
Caserotti *et al*[39]	Italy	Survey with repeated measures	30 Jun 2020	General population	839	70.2	38	79%	0%	21%	21%
La Vecchia *et al*[40]	Italy	Cross-sectional survey	28 Sep 2020	General population	1055	51.7		54%	0%	46%	46%
Di Giuseppe *et al*[20]	Italy	Cross-sectional survey	28 Apr 2021	Incarcerated	685	0	42.4	64%	0%	36%	36%
Moscardino *et al*[41]	Italy	Cross-sectional survey	28 Jun 2021	General population	1200	49.2	29.8	73%	18%	8%	25%
Palamenghi *et al*[42]	Italy	Cross-sectional survey		General population	968			59%	0%	41%	41%
Iacoella *et al*[67]	Italy	Cross-sectional survey	15 Feb 2021	Persons experiencing homelessness	112	24.1	53.1	63%	4%	32%	36%
Yoda and Katsuyama[47]	Japan	Cross-sectional survey	30 Sep 2020	General population	1100	46.9	44.8	66%	22%	12%	34%
Ishimaru *et al*[43]	Japan	Cross-sectional survey	26 Dec 2020	General population	27 036	48.9		38%	0%	63%	63%
Machida *et al*[44]	Japan	Cross-sectional survey	18 Jan 2021	General population	2956	50.6		62%	0%	38%	38%
Kadoya *et al*[45]	Japan	Cross-sectional survey	25 Feb 2021	General population	4253	35	50.3	47%	31%	22%	53%
Sekizawa *et al*[46]	Japan	Cross-sectional survey	6 May 2021	General population	11 846	49.6	54	62%	30%	9%	38%
Soares *et al*[48]	Portugal	Cross-sectional survey	8 Jan 2021	General population	1943	67.7	47.7	35%	56%	9%	65%
Khaled *et al*[49]	Qatar	Cross-sectional survey	25 Jan 2021	General population	1912	31.7		43%	45%	12%	57%
Page *et al*[76]	Switzerland	Cross-sectional survey	31 May 2021	Undocumented migrants	812	60.9	39	41%	0%	59%	59%
Freeman *et al*[52]	UK	Cross-sectional survey	11 May 2020	General population	2501	51.4	46.6	48%	7%	5%	12%
Sethi *et al*[54]	UK	Cross-sectional survey	9 Oct 2020	General population	4884	69.9		79%	14%	7%	21%

Continued

Table 1 Continued

Author	Country	Study design	Date of data collection	Population	Sample size	Female sex proportion	Mean age	Vaccine acceptance	Hesitancy	Refusal	Unwillingness
Freeman *et al*[53]	UK	Cross-sectional survey	17 Oct 2020	General population	5114	49.2	46.9	72%	17%	12%	28%
Batty *et al*[51]	UK	Cross-sectional survey	31 Dec 2020	General population	11 955	56.4		85%	15%	0%	15%
Chaudhuri *et al*[55]	UK	Cross-sectional survey	31 Jan 2021	General population	22 421	58.5	55.4	89%	0%	11%	11%
Sherman *et al*[56]	UK	Cross-sectional survey	17 Jul 2020	General population	1494	51	46	64%	27%	9%	36%
Sherman *et al*[57]	UK	Cross-sectional survey	15 Jan 2021	General population	1500	51	45.6	74%	14%	9%	23%
Earnshaw *et al*[58]	USA	Cross-sectional survey	14 Apr 2020	General population	845	40.9	40	86%	0%	0%	14%
Fisher *et al*[59]	USA	Cross-sectional survey	20 Apr 2020	General population	991	51.5	18	58%	32%	11%	42%
Malik *et al*[60]	USA	Cross-sectional survey	1 May 2020	General population	672	57		67%	0%	0%	33%
Reiter *et al*[61]	USA	Cross-sectional survey	31 May 2020	General population	2006	56		48%	43%	9%	52%
Pogue *et al*[62]	USA	Cross-sectional survey		General population	316	49.4		68%	23%	9%	32%
Craig[63]	USA	Discrete choice experiment survey	11 Nov 2020	General population	1153	52.3		61%	0%	17%	17%
Kelly *et al*[66]	USA	Cross-sectional survey	30 Apr 2020	General population	2279	52		75%	0%	25%	25%
Christodoulou *et al*[74]	USA	Cross-sectional survey	30 Apr 2020	Youth aged 18–28 at risk of HIV	83	16	23	65%	0%	35%	35%
Sullivan *et al*[72]	USA	Cross-sectional survey	01 May 2020	People with opioid use disorder	234	56	46.8	32%	48%	20%	68%
Stern *et al*[75]	USA	Cross-sectional survey	12 Dec 2020	Incarcerated or detained persons	5110	17.6		45%	10%	45%	55%
Rogers *et al*[70]	USA	Cross-sectional survey	28 Feb 2021	Adult homeless shelter residents and staff	969	27.4	41	54%	18%	28%	46%
Crozier *et al*[78]	USA	Cross-sectional survey	31 Dec 2020	Rural, underserved and minority populations in Alabama	3721	56.5		39%	27%	24%	51%
Thunström *et al*[64]	USA	Cross-sectional survey	31 Mar 2020	General population	3133	52	46	80%	0%	20%	20%

Continued

Table 1 Continued

Author	Country	Study design	Date of data collection	Population	Sample size	Female sex proportion	Mean age	Vaccine acceptance	Hesitancy	Refusal	Unwillingness
Rane *et al*[65]	USA	Survey with repeated measures	01 Oct 2020	General population	4571	53		85%	9%	6%	15%
Scott *et al*[79]	USA	Cross-sectional survey	31 Jul 2020	Latino SNAP participants (food programme)	486	93	40	48%	39%	13%	52%
Bogart *et al*[7]	USA	Cross-sectional survey	31 Dec 2020	Black Americans	207	71	50.8	30%	38%	32%	70%
Tucker *et al*[68]	USA	Cross-sectional survey	1 Mar 2021	Young adults with recent experiences of homelessness	134	32		50%	0%	50%	50%
Shaw *et al*[77]	USA	Cross-sectional survey	1 Mar 2021	Refugees	244	55.3	38.5	57%	18%	25%	43%
Meehan *et al*[69]	USA	Cross-sectional survey	23 Feb 2021	Clients and staff of homeless shelters	106		44	58%	11%	31%	42%

2SLGBTQ+, Two-Spirit, Lesbian, Gay, Bisexual, Transgender, Queer or Questioning and additional sexual orientations and gender identities.; SNAP, Supplemental Nutrition Assistance Program (SNAP).

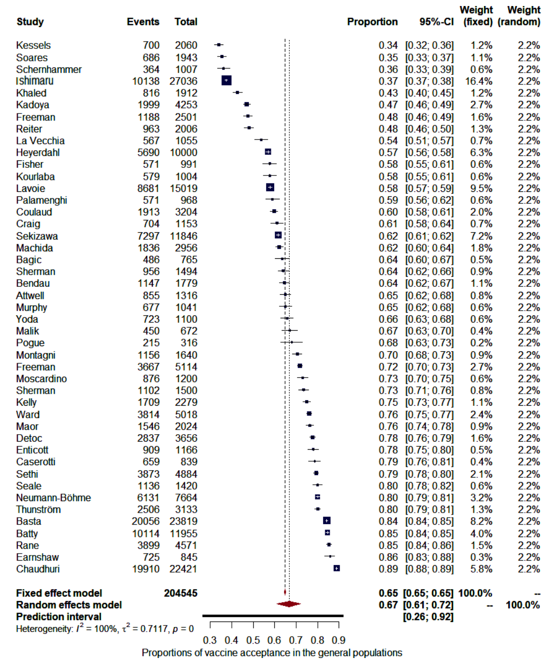

Figure 1 Random-effects meta-analysis of COVID-19 vaccine acceptance in the general population. For each study, boxes and horizontal lines correspond to the respective point estimate and accompanying 95% CI. The size of each box is proportional to the weight of that study result in the fixed-effects model. The red diamond represents the 95% CI of the summary pooled estimate of the effect and is centred on pooled prevalence of vaccine acceptance. Heterogeneity estimate of I^2 accompanies the summary estimate. Studies are ordered by the proportion of acceptance.

expectancy was 81.5 years (IQR: 81–83). With respect to economic indicators related to public policy, median social spending as a percentage of GDP was 25 (IQR: 18–29); median healthcare spending as a percentage of GDP was 10.3 (IQR: 8.7–11.3). We determined two median indicators of inequality: poverty gap 0.29 (IQR: 0.26–0.33) and gender wage gap 15 (IQR: 6–19), respectively.

Proportion of people from general populations reporting vaccination willingness before vaccine rollout

Among general populations, the summary proportion of vaccination willingness (figure 1) was estimated across all study settings as 67% (95% CI 61% to 72%, 45 studies). 45 studies reported vaccine acceptance among general populations: Australia (three studies)[22–24]; Austria (one study)[25]; Canada (two studies)[26 27]; Croatia (one study)[28]; Denmark (one study)[29]; France (five studies)[30–34]; Germany (one study)[35]; Greece (one study)[36]; Ireland (one study)[37]; Israel (one study)[38]; Italy (four studies)[39–42]; Japan (five studies)[43–47]; Portugal (one study)[48]; Qatar (one study)[49]; Belgium (one study)[50]; the UK (seven studies)[51–57]; and the USA (nine studies).[58–66]

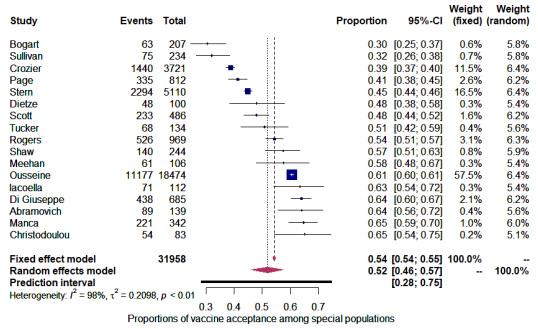

Figure 2 Random-effects meta-analysis of COVID-19 vaccine acceptance in special populations. For each study, boxes and horizontal lines correspond to the respective point estimate and accompanying 95% CI. The size of each box is proportional to the weight of that study result in the fixed-effects model. The red diamond represents the 95% CI of the summary pooled estimate of the effect and is centred on pooled prevalence of vaccine acceptance. Heterogeneity estimate of I^2 accompanies the summary estimate. Studies are ordered by the proportion of acceptance.

Proportion of people from under-resourced communities reporting vaccination willingness before vaccine rollout

The summary proportion of vaccination willingness for studies conducted among people from under-resourced communities (figure 2) was estimated as 52% (95% CI 0.46% to 0.57%, 17 studies). The 17 studies reporting vaccine acceptance in under-resourced communities included four studies among people experiencing homelessness[67–70]; two studies among people using illicit and unprescribed drugs[71 72]; three studies among lesbian, gay, bisexual and transgender populations[21 73 74]; two studies among incarcerated populations[20 75]; two studies among refugee and undocumented migrant populations[76 77]; and one study for each one of the following: indigenous population,[9] a rural community,[78] a Latino population[79] and a black American population.[7] In the cumulative meta-analysis from sensitivity analyses, we found a trend towards acceptance according to dates of data acquisition ranging from 32% in early pandemic stages to 52% during late pandemic stages before vaccine rollout (section 5c of the online supplemental material).

Proportion of vaccine uptake from real-world country statistics 1 year after vaccine rollout

The summary proportion of vaccine uptake from included countries was estimated as 73% (95% CI 0.69% to 0.76%, 18 countries). In general, the proportion of vaccine uptake for each country was higher than vaccination willingness before vaccine rollout (online supplemental table 3), except for Croatia (−15%), Denmark (−3%) and the USA (−8%). In the cumulative meta-analysis, we did not observe an effect from date of vaccine approval on vaccine uptake at the end of 2021 (section 6 of the online supplemental material). However, in meta-regression analyses (section 6 of the online supplemental material), vaccine uptake increased according to the proportion of the population older than 65 years (OR=1.8, 95% CI 1.04 to 3.1) and decreased at higher stringency index values (OR=0.8, 95% CI 0.69 to 0.94).

DISCUSSION

Main findings

Our realist synthesis involves data from 62 studies and 18 countries; we contribute to knowledge about the prevalence of vaccine acceptance among general populations and people from under-resourced communities. Additionally, we compared proportions of expected vaccine uptake from studies conducted before vaccines were available with the real uptake from the end of December 2021. To our knowledge, ours is the first systematic and realist review comparing vaccination willingness and vaccine uptake using real-world statistics among general populations with people from under-resourced communities in HICs.

The countries included in the study represented 70% of the HIC world population. Most countries showed higher vaccine uptake compared with the reported vaccination willingness in studies conducted before the vaccine rollout. For all studies among general populations, the proportion of vaccination willingness was 67% (95% CI 62% to 72%). In real-world settings, the overall proportion of vaccine uptake among countries was 73% (95% CI 69% to 76%). However, the scope of this study is limited in exploring possible explanations for lower-than-expected rates of vaccine uptake in Croatia, Denmark and the USA. For all the other countries, the real-world uptake was consistently higher than the reported willingness before rollout.

It is worth noting that some studies not included in our meta-analysis that evaluated the willingness to receive the vaccine when the vaccination rollout had already started in their country may have reported higher rates of willingness to receive the vaccine compared with the country's real uptake.[80] However, this should not be interpreted as an overestimation since such willingness was estimated on the unvaccinated fraction of the population instead of the total population of the country who was completely unvaccinated only before the rollout.

The pooled proportion from studies reporting vaccination willingness among under-resourced communities before rollout was 52% (95% CI 0.46% to 0.57%). Official country-level reports about vaccine uptake among under-resourced communities were too limited so we could not compare vaccination willingness before rollout with real-world uptake statistics among under-resourced communities after vaccine rollout.

Findings in context

The proportion of vaccination willingness among people from under-resourced communities was consistently lower than the proportion of vaccination willingness among people from populations in total. Existing evidence suggests people from ethnic minority groups[7] and indigenous communities reasonably distrust medical institutions

from experiences of differential care and mistreatment.[8 9] Mistrust of institutions and governments was reported as the most common reason to delay vaccine uptake among ethnic minority groups,[7] indigenous communities[8 9] and incarcerated people.[75] Experiences of discrimination, stigma and barriers to access were reported as possible explanations for lower prevalence of vaccine acceptance among people from sexual and gender minority groups.[81]

Despite the lack of official data on real-world uptake among under-resourced communities, some studies have reported lower vaccine uptake compared with the general population. For instance, a study among healthcare workers in the UK found that vaccine uptake was 58.5% among South Asian and 36.8% among black ethnic minority groups, compared with 70% in white healthcare workers.[82] Another analysis of patient primary care records in the UK found lower vaccine uptake among different ethnic groups (black 68%, white 96%) and to a lesser extent, among different levels of deprivation (most deprived 91%, least deprived 97%).[83]

Recent evidence provides initial insights about overcoming barriers to vaccination uptake. For instance, multicomponent interventions with tailored communication of risks of remaining unvaccinated and benefits of becoming vaccinated,[84] community-based action and engagement of religious and community leaders, dialogue to understand reasons for mistrust in government and public health bodies, as well as provision of access to convenient vaccination in collaboration with community-based and trusted health institutions.[85]

We suggest future studies compare trajectories of vaccination willingness with vaccine uptake among under-resourced communities. We also recommend future research link findings of trajectories with context-specific actions to address barriers to vaccine uptake among people from under-resourced communities. Ultimately, more research is needed to better understand vaccine uptake and the joint interactions among barriers, unwillingness, hesitancy, postponement or other unknown aspects driving vaccine uptake. The identification of necessary adjustments needed to improve vaccination uptake among different groups may inform future vaccination programmes.

Strengths and limitations

Studies reporting prevalence served as important sources of evidence during the COVID-19 pandemic and helped researchers understand factors related to the disease and inform policies. However, prevalence estimates from individual studies and pooled prevalence estimates from our meta-analyses may have been affected by selection and reporting biases.[17] Nevertheless, our inclusion criteria attempted to reduce such risks of bias, and we performed multiple sensitivity analyses that provided insights into possible sources of heterogeneity. A strength of the realist approach is the use of diverse sources of information. In the specific context of COVID-19 vaccine acceptance, the fact that countries have reporting systems in place to keep population-based statistics made it possible to assess the real-life counterpart of the studies.[86]

CONCLUSION

Our systematic and realist review highlights COVID-19 vaccine uptake in HICs generally exceeded expressed vaccination willingness before vaccine rollout and vaccination willingness tended to be lower among under-resourced communities, when compared with total populations living in HICs. Our review emphasises the importance of realist reviews for assessing vaccine acceptance and particularly the need for more specific real-world statistics on vaccine uptake among under-resourced communities as well as the importance of context-specific actions to promote vaccine uptake and reporting.

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Table of contents for the supplementary material

Supplementary material

1. Supplementary section 1: methods

a. Search strategy (concepts / block building approach)

Overview databases and results

Date last searched: 30.11.2022

PubMed

1 (((Coronaviridae[MeSH Terms] OR Coronavirus Infections[MeSH Terms] OR 2019 novel coronavirus disease[Title/Abstract] OR covid-19[Title/Abstract] OR sars-cov-2 infection[Title/Abstract] OR sars coronavirus[Title/Abstract] OR 2019 novel coronavirus infection[Title/Abstract] OR 2019-ncov infection[Title/Abstract] OR 2019-ncov disease[Title/Abstract]) AND (Vaccines[MeSH Terms] OR Immunization[MeSH Terms] OR vaccines[Title/Abstract]) AND (patient acceptance of health care[Title/Abstract] OR vaccination[Title/Abstract] OR attitude[Title/Abstract] OR willingness[Title/Abstract] OR readiness[Title/Abstract] OR preparedness[Title/Abstract] OR disposition[Title/Abstract] OR acceptance[Title/Abstract] OR acceptability[Title/Abstract] OR perception[Title/Abstract] OR receptivity[Title/Abstract] OR hesitancy[Title/Abstract] OR intention[Title/Abstract] OR attitudes[Title/Abstract])) AND ((Adult[MeSH Terms] OR Young Adult[MeSH Terms] OR Middle Aged[MeSH Terms] OR Aged[MeSH Terms] OR Aged, 80 and over[MeSH Terms]))) NOT (editorial/ or letter/ or case reports/ or comments/) Filters: Humans, Exclude preprints, from 2006 – 2022 (2600)

Embase

#	Concept	Search String	Results
1	COVID-19	'coronaviridae'/exp OR 'coronavirus infections' OR '2019 novel coronavirus disease':ti,ab OR 'covid-19':ti,ab OR 'sars-cov-2 infection':ti,ab OR 'sars coronavirus':ti,ab OR '2019 novel coronavirus infection':ti,ab OR '2019-ncov infection':ti,ab OR '2019-ncov disease':ti,ab	171,270
2	Vaccine acceptance	('patient acceptance of health care':ti,ab OR 'vaccination':ti,ab OR 'attitude':ti,ab OR willingness:ti,ab OR readiness:ti,ab OR preparedness:ti,ab OR disposition:ti,ab OR acceptance:ti,ab OR acceptability:ti,ab OR perception:ti,ab OR receptivity:ti,ab OR hesitancy:ti,ab OR intention:ti,ab OR attitudes:ti,ab)	376,320
3	COVID vaccine	'vaccines'/exp OR 'immunization'/exp OR vaccin*:ti,ab OR immun*:ti,ab OR 'vaccines':ti,ab OR (('covid-19 vaccin*' NEAR/3 'covid-19'):ti,ab)	1,385,897
4	Combine	#1 AND #2 AND #3	18,915
5	Filters	#4 NOT ('conference abstract'/it OR 'conference paper'/it OR 'conference review'/it OR 'editorial'/it OR 'letter'/it OR 'note'/it OR 'tombstone'/it)	10135
6	Population	([adult]/lim OR [young adult]/lim OR [middle aged]/lim OR [aged]/lim OR [very elderly]/lim)	3,660,406
7	Filters	'animal cell'/de OR 'animal experiment'/de OR 'animal model'/de OR 'animal tissue'/de OR 'case report'/de OR 'nonhuman'/de	2,971,939
8	Combine	(#5 AND #6) NOT #7	2,274

Dimensions ai

ID Search Hits

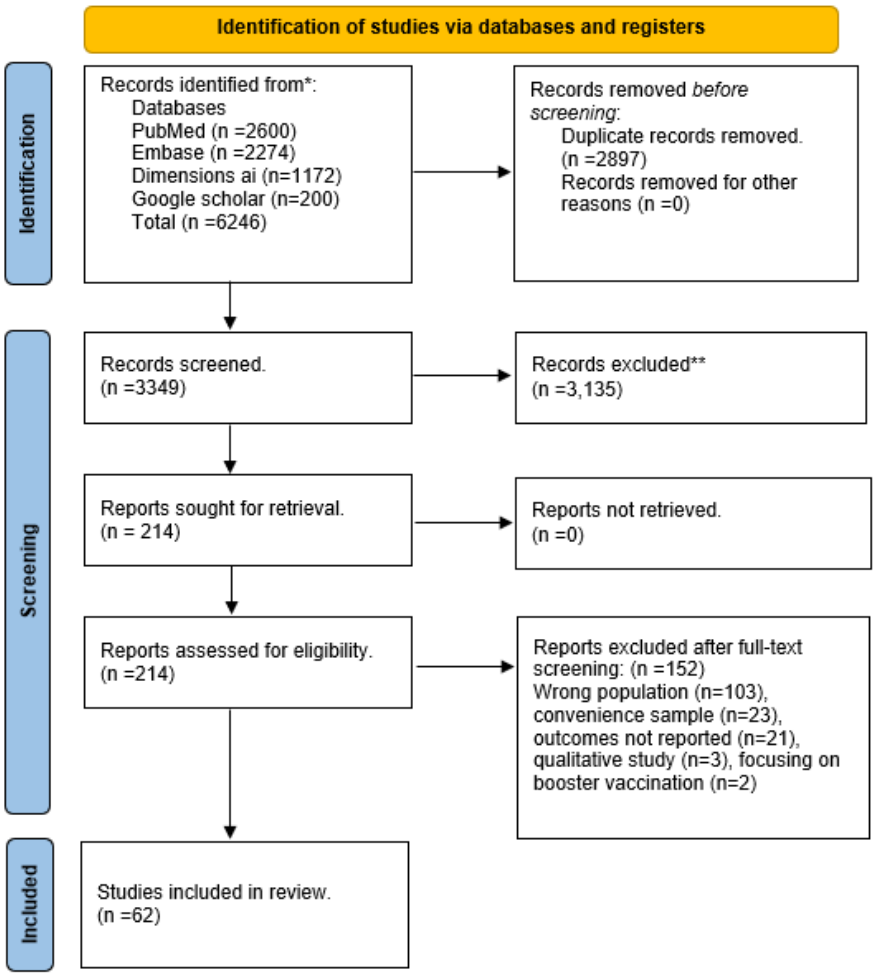
Vaccine acceptance covid free text in title and abstract (1172)

Google Scholar

"covid" "vaccine acceptance" -program: first 200

b. Figure S1 Flow diagram for selection of studies

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only.



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

c. List of excluded references after full-text screening

Exclusion reason	Reference
Wrong population (n=103)	1-103
Convenience sample (n=23)	104-126
Outcomes missing (n=21)	127-147
Qualitative study (n=3)	148-150
Focusing on booster vaccine (n=2)	151-152

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d. Definitions of variables and sources

For individual studies:

Items	Description
Study Identification	Authors, journal, and date of publication, doi
Study design	Quantitative, Qualitative, Other
Data Collection	Period of data collection
Geographic Context	Country, City/State, multi-country study
Sampling Method	Survey, Interviews, Other
Study size	Number of participants
Study population	General Population or marginalized, mean age, gender ratio, other characteristics if reported
Vaccine acceptability	Percentage of population accepting, being hesitant about, or refusing a Covid-19 vaccine
Promoters	Reasons for accepting a vaccine
Barriers	Reasons for refusing a vaccine
Demographic characteristics	Vaccine acceptance, hesitancy and refusal across demographic characteristics, as reported

Per country :

Data Sources : OECD, The World Bank, National Public Health Offices, Ourworldindata.org, US National Center for Education Statistics, Eurostat Database, Pew Research Center

Currency is current US dollars

Items	Description
Vaccination Data	
Vaccine approval	Date of first vaccine approval
Vaccination rates, past	Double, single and total vaccination rates as of 26.11.2021
General Demographic Data	
Population	Total population and percentage of foreign-born population
Gender ratio	Percentage of male population
Population, old	Population ages 65 and above, total
Life expectancy	Life expectancy at birth, total years
Religion and Ethnicity	
Religion and Ethnicity	Undenominational, Christians, Muslims, Hindus, Jews, Folk Religions, Buddhists, Others. Pew Research Center
Education	
Educational attainment	Educational attainment, primary to Doctoral or equivalent, population 25+ years. OECD
School enrollment	School enrollment, primary, % gross. OECD
Economical Indicators	
GDP	GDP per capita. OECD

Poverty Gap	Of total population. OECD
Poverty Rate	Of total population. OECD
Gender wage gap	Of total population. OECD
Unemployement Rate	Of total population. OECD
Gini Coefficient	OECD
Social Protection	
Social Spending	Cash-benefits, direct in-kind provision of goodds and services, and tax breaks with social purposes. OECD
Sociopolitical indicators of inequality	
Violence Against Women	Prevalence in the lifetime. OECD
Social Institutions and Gender	Discrimination in the family, Restricted access to resources and assets, restricted physical integrity, Restricted civil liberties. OECD, Index
Perceived Health	Of total population. OECD
People at Risk of Poverty or Social Exclusion	Index, Eurostat
Long Hours in Paid Work	Of total population. OECD
Well-Being	
Housing Overcrowding	Of total population. OECD
Social Connections	Social support and satisfaction with personal relationships, OECD
Housing Cost Overburden	Of total population. OECD
Subjective Well-Being	Of total population. OECD
Difficulty making ends meet	Of total population. OECD
Negative affect balance	Of total population. OECD
Work-life balance	Of total population. OECD
Quality of healthcare	
Universal healthcare	Yes/No
Health spendings	As share of GDP. The World Bank
Health coverage	Of total population. OECD
Consultations skipped due to cost	Per 100 patients. OECD
Medical Tests, treatment or follow-up skipped due to costs	Per 100 patients. OECD
Prescribed medicines skipped due to costs	Per 100 patients. OECD
Covid policy measures and downsides of not getting vaccine	
COVID-19 Stringency Index	Oxford Coronavirus Government Response Tracker (OxCGRT), Index

2. Supplementary section 2: Assessment of quality and risk of bias results

Table S1. Risk of bias assessment of included studies (Adapted from Hoy et al)

Author	Was the study´s target population representative?	Was the sample frame a close representation of the target population?	Was the sample randomly selected?	Was the likelihood of non-response bias minimal?	Were data collected directly from the subjects?	Was an acceptable case definition used?	Was the study instrument reliable?	Was the same mode of data collection used for all subjects?	Score
Attwell	No	No	No	Yes	Yes	Yes	Yes	Yes	1
Seale	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Dietze	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Enticott	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Schernhammer	Yes	No	No	Yes	Yes	Yes	Yes	Yes	2
Kessels	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Lavoie	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Basta	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Abramovich	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Manca	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Bagic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Neumann-Böhme	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Detoc	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	1
Ward	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Montagni	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Ousseine	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Coulaud	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Heyerdahl	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Bendau	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Kourlaba	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Murphy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Maor	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	1
Caserotti	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
La Vecchia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Di Giuseppe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Moscardino	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Palamenghi	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Iacoella	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Yoda	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Ihshimaru	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0

Machida	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Kadoya	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Sekizawa	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Soares	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Khaled	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Page	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Freeman	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Sethi	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Freeman	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Batty	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Chaudhuri	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Sherman	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Sherman	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Earnshaw	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	1
Fisher	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Malik	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	1
Reiter	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	1
Pogue	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	1
Craig	Yes	Yes	No	No	Yes	Yes	Yes	Yes	1
Kelly	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Christodoulou	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Sullivan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Stern	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Rogers	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Crozier	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Thunström	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Rane	Yes	Yes	No	No	Yes	Yes	Yes	Yes	2
Scott	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Bogart	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Tucker	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Shaw	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0
Meehan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0

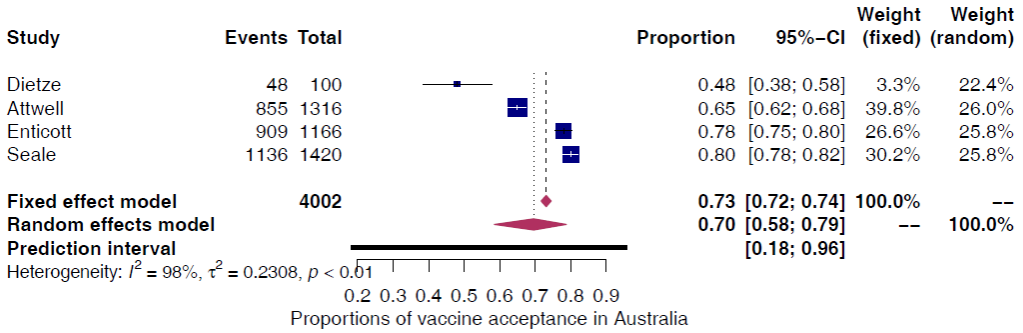
3. Supplementary section 3: Table S2.Country-specific real-world data

Country	Population	% of population over 65 years	Life expectancy	Date of first vaccine	% of population with complete vaccination as of 31st 2021	Poverty gap	Gender wage gap	% unemployment	% unemployment in migrants	Social spending, %of GDP 2021	Healthcare spending, %GDP	Healthcare coverage	Stringency index at the date of first vaccine
Australia	25690000	16	83.2	22-Feb-21	74								53.24
Austria	8956000	19	81.8	27-Dec-20	71	0.294	14.9	4.9	8.3	31	10.3	99.9	82.41
Belgium	11590000	19	81.7	28-Dec-20	76	0.233	3.4	5.7	10.4	29	10.3	98.6	60.19
Canada	38250000	18	82.0	14-Dec-20	76	0.303	18.5	6.5	6.3	18	10.8	100	72.69
Croatia	3900000	22	77.7	27-Dec-20	49								67.59
Denmark	5857000	20	81.2	27-Dec-20	77	0.289	4.9	5.1	8.4	28.3	10.1	100	51.85
France	67750000	21	82.6	27-Dec-20	73	0.261	11.8	7.9	13.1	33	11.3	100	63.89
Germany	83000000	22	80.9	26-Dec-20	71	0.256	13.9	3.2	5.6	28	11.4	89.5	82.41
Greece	10640000	23	81.9	27-Dec-20	68	0.331	5.9	13.3	28.6	26	7.8	100	84.26
Ireland	5000000	15	82.3	29-Dec-20	77	0.187	8.3	5.1	5.9	14	6.7	100	68.52
Israel	9364000	12	82.8	19-Dec-20	63	0.325	22.7	5	3.4	18	7.5	100	71.3
Italy	59110000	24	83.2	27-Dec-20	76	0.396	5.7	9	13.1	31	8.7	100	78.7
Japan	126000000	30	84.4	17-Feb-21	80	0.364	24.5	2.8	4.2	22.3	10.7	100	49.54
Portugal	10330000	23	80.9	27-Dec-20	83	0.266	22.7	5.9	8.4	25	9.4	100	63.89
Qatar	2660000	1	79.1	31-Jan-21	82								64.81
Switzerland	8703000	19	83.7	23-Dec-20	67	0.281	18	2.6	7,3	18	11.9	100	60.19
UK	67330000	18	81.2	08-Dec-20	70	0.326	16.3	3.9	4.3	22	10.2	100	63.89
USA	332000000	17	77.2	14-Dec-20	63	0.368	18.9	8.09	3.1	23	16.9	91.4	71.76

4. Supplementary section 4: Country-specific analyses

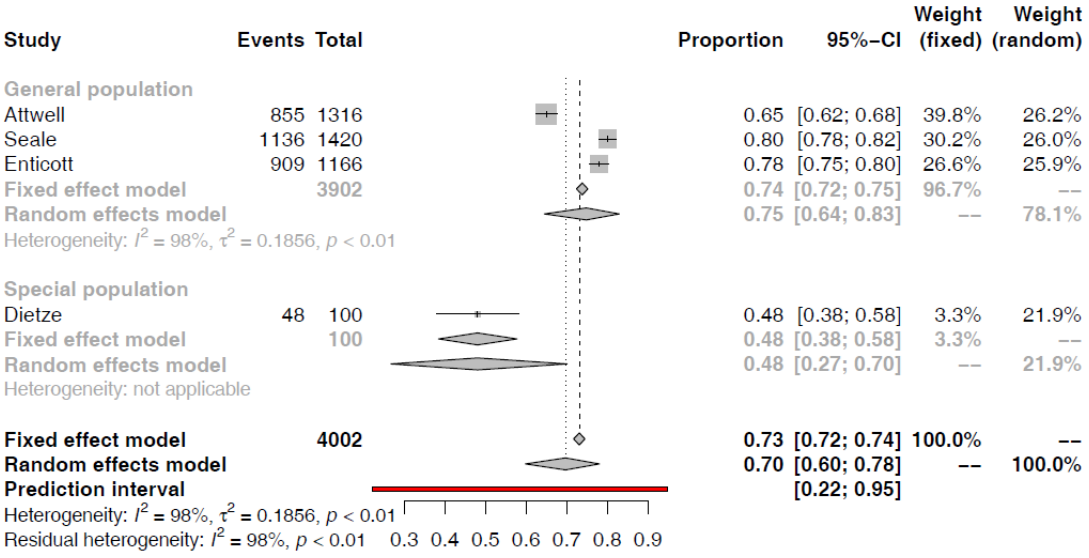
Random-effects meta-analysis of COVID-19 vaccine acceptance in Australia

a. All the studies from Australia



For each study, boxes and horizontal lines correspond to the respective point estimate and accompanying 95% confidence interval. The size of each box is proportional to the weight of that study result in the fixed effect model. The red diamond represents the 95% confidence interval of the summary pooled estimate of the effect and is centred on pooled prevalence of vaccine acceptance. Heterogeneity estimate of I^2 accompanies the summary estimate. Studies are ordered by the proportion of acceptance CI = confidence interval.

b. Subgroup analysis from Australia according to vaccine acceptance in the general population and among special populations

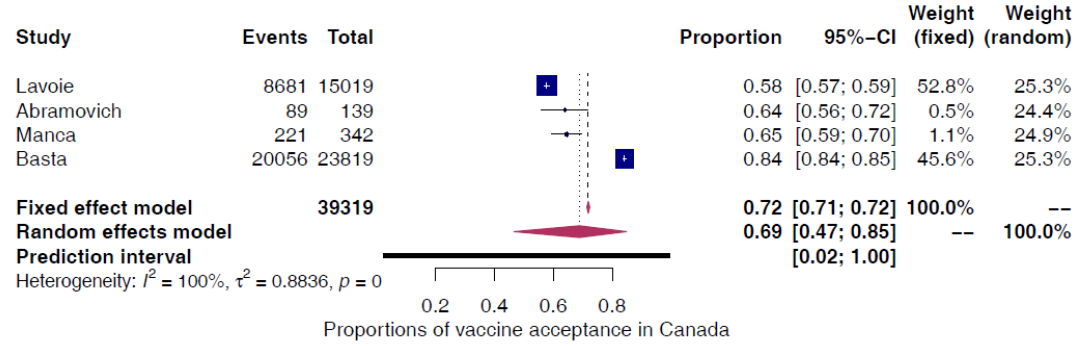


For each study, boxes and horizontal lines correspond to the respective point estimate and accompanying 95% confidence interval. The size of each box is proportional to the weight of that study result in the fixed effect model. The red diamond represents the 95% confidence interval of the summary pooled estimate of the effect and is

centred on pooled prevalence of vaccine acceptance. Heterogeneity estimate of I2 accompanies the summary estimate. Studies are ordered by the proportion of acceptance CI = confidence interval.

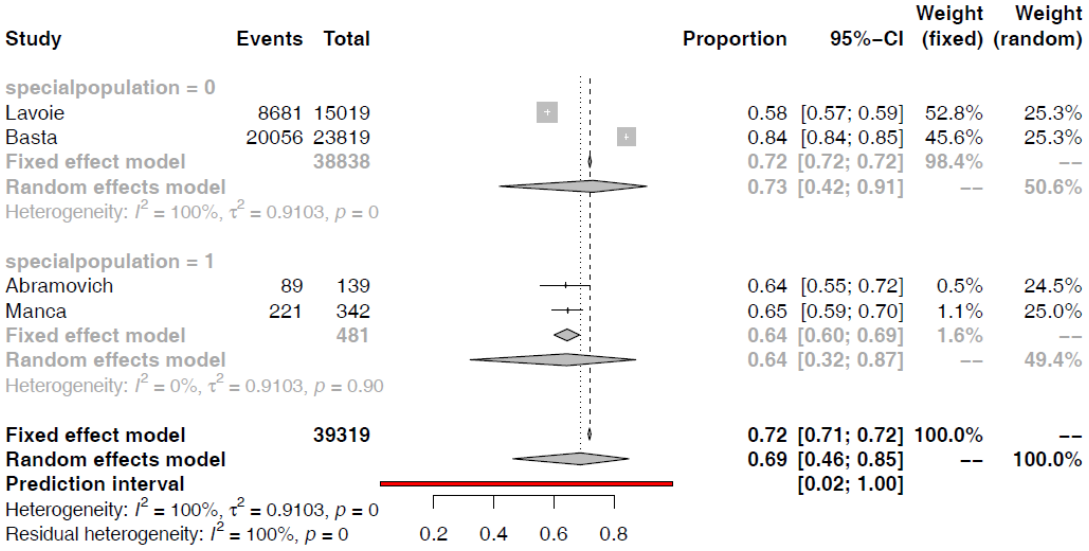
Random-effects meta-analysis of COVID-19 vaccine acceptance in Canada

a. All the studies from Canada



For each study, boxes and horizontal lines correspond to the respective point estimate and accompanying 95% confidence interval. The size of each box is proportional to the weight of that study result in the fixed effect model. The red diamond represents the 95% confidence interval of the summary pooled estimate of the effect and is centred on pooled prevalence of vaccine acceptance. Heterogeneity estimate of I^2 accompanies the summary estimate. Studies are ordered by the proportion of acceptance CI = confidence interval.

b. Subgroup analysis from Canada according to vaccine acceptance in the general population and among special populations



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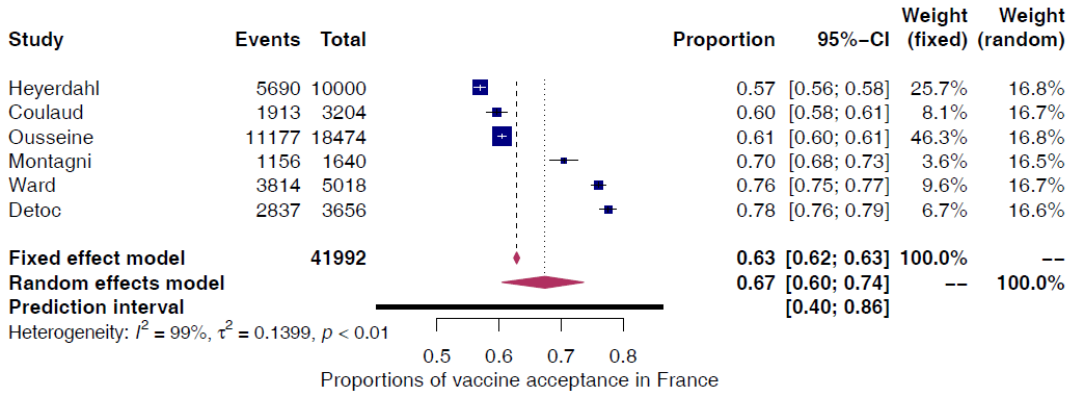
Random-effects meta-analysis of COVID-19 vaccine acceptance in France

a. All the studies from France



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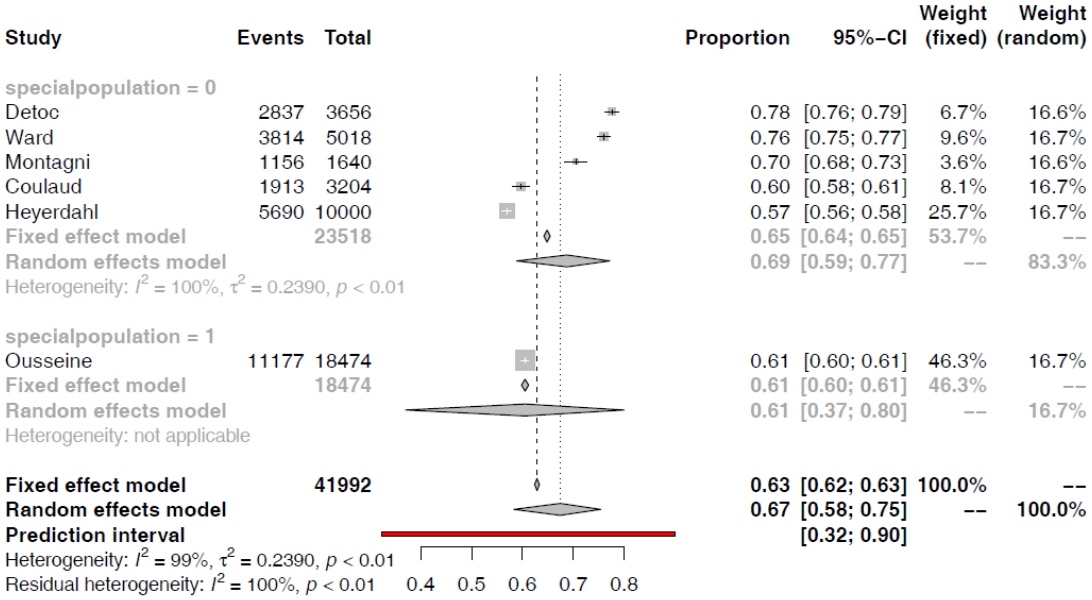
b. Subgroup analysis from France according to vaccine acceptance in the general population and among special populations



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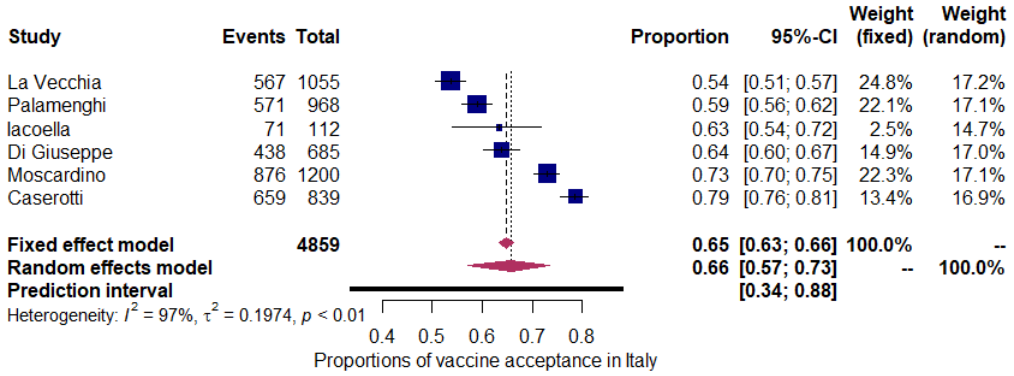
Random-effects meta-analysis of COVID-19 vaccine acceptance in Italy

a. All the studies from Italy



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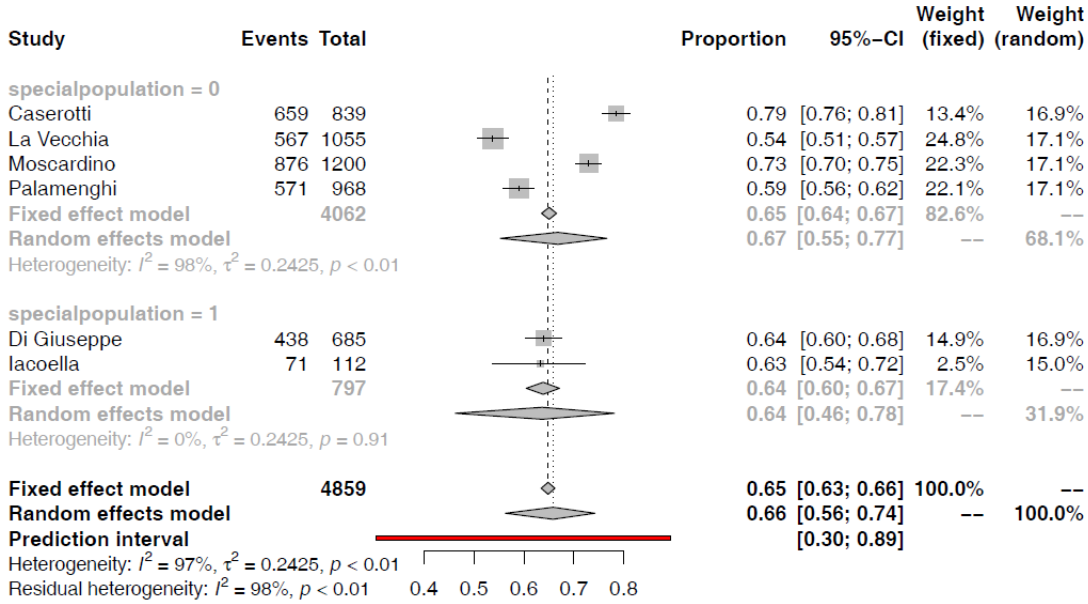
b. Subgroup analysis from Italy according to vaccine acceptance in the general population and among special populations



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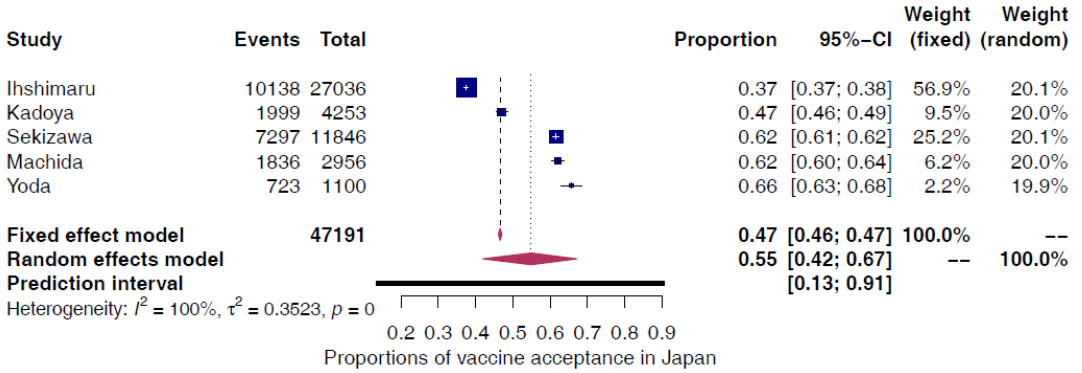
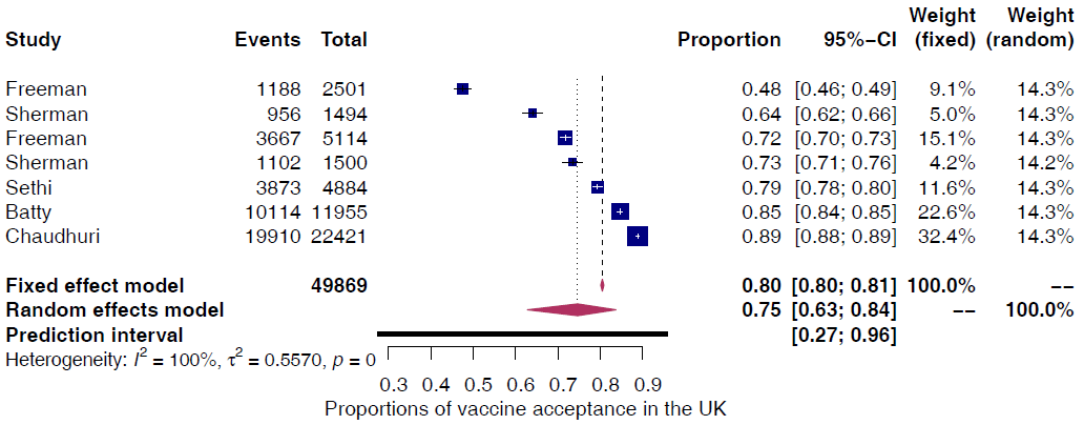
Random-effects meta-analysis of COVID-19 vaccine acceptance in Japan



For each study, boxes and horizontal lines correspond to the respective point estimate and accompanying 95% confidence interval. The size of each box is proportional to the weight of that study result in the fixed effect model. The red diamond represents the 95% confidence interval of the summary pooled estimate of the effect and is centred on pooled prevalence of vaccine acceptance. Heterogeneity estimate of I^2 accompanies the summary estimate. Studies are ordered by the proportion of acceptance CI = confidence interval.

Random-effects meta-analysis of COVID-19 vaccine acceptance in the United Kingdom



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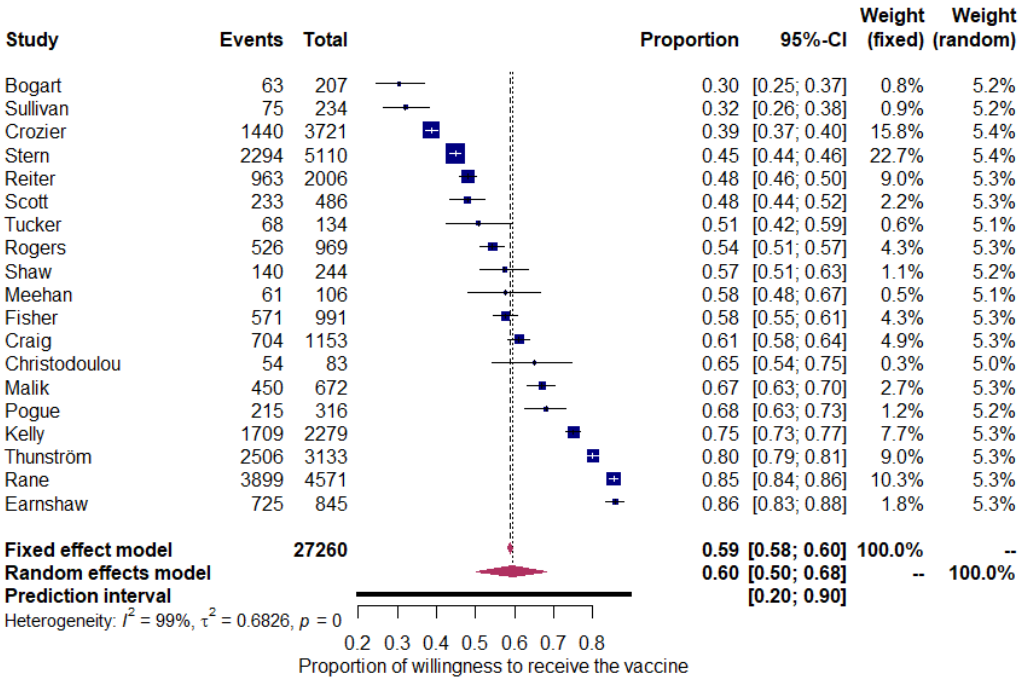
Random-effects meta-analysis of COVID-19 vaccine acceptance in the United States

a. All the studies from the U.S



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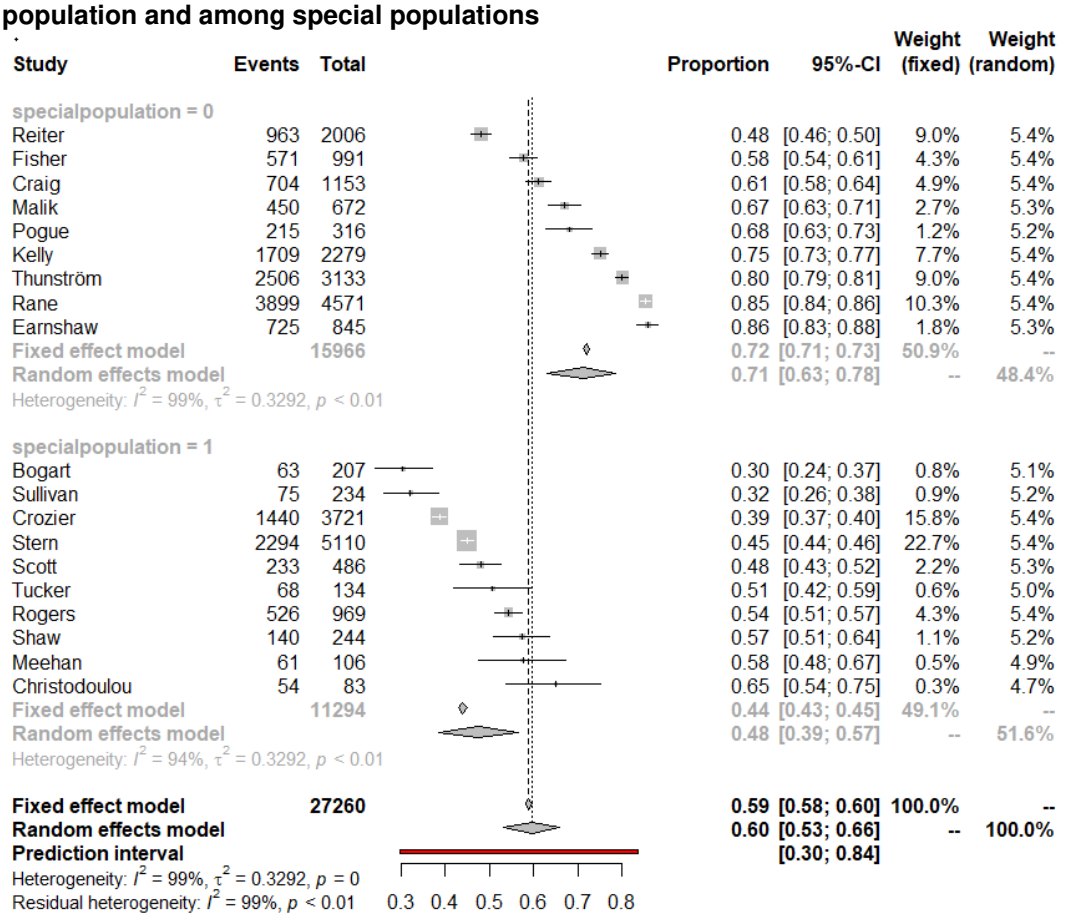
b. Subgroup analysis from the U.S according to vaccine acceptance in the general population and among special populations



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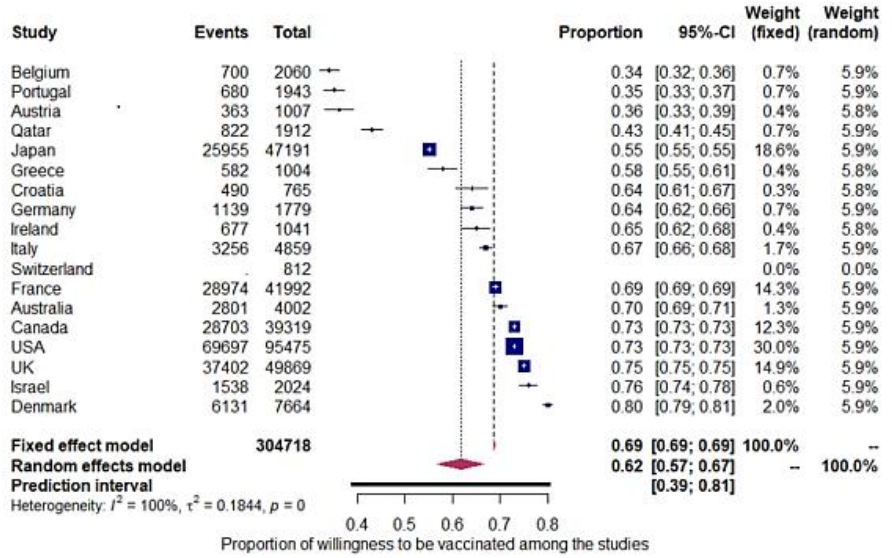
5. Supplementary section 5: Comparison between data from studies and real-world data

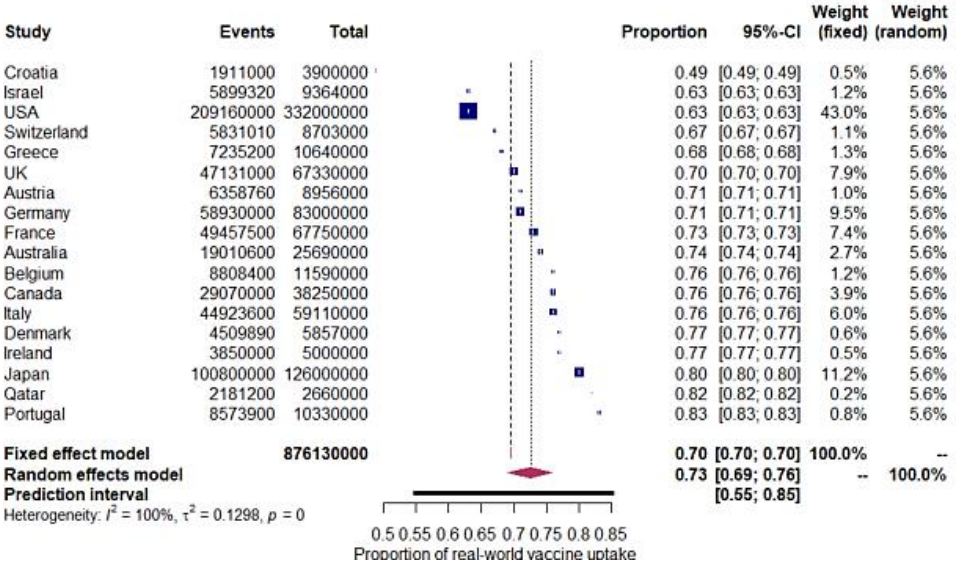
a. Table S3. Willingness to be vaccinated and real-world vaccine uptake

Country	% (CI 95%) of the general population willing to be vaccinated before vaccines rollout*	% (CI 95%) of special populations willing to be vaccinated before vaccines rollout*	% of the general population with complete vaccination as of 31st Dec 2021**	Difference between willingness and uptake
Australia	70 (58-79)	48 (27-70)	74	+4
Austria	36 (33-39)	-	71	+35
Belgium	34 (32-36)	-	76	+42
Canada	73 (42-91)	64 (32-87)	76	+3
Croatia	64 (60-67)		49	-15
Denmark	80 (79-81)	-	77	-3
France	69 (59-77)	61 (37-80)	73	+4
Germany	64 (62-67)	-	71	+7
Greece	58 (55-61)	-	68	+10
Ireland	65 (62-68)	-	77	+12
Israel	76 (74-78)	-	63	+7
Italy	67 (55-77)	64 (46-78)	76	+9
Japan	55 (42-67)	-	80	+25
Portugal	35 (33-37)	-	83	+48
Qatar	43 (40-45)		82	+39
Switzerland	-	41	67	-
UK	75 (63-84)	-	70	+5
USA	71 (63-78)	50 (39-61)	63	-8

*From the results of the systematic review.
**https://ourworldindata.org

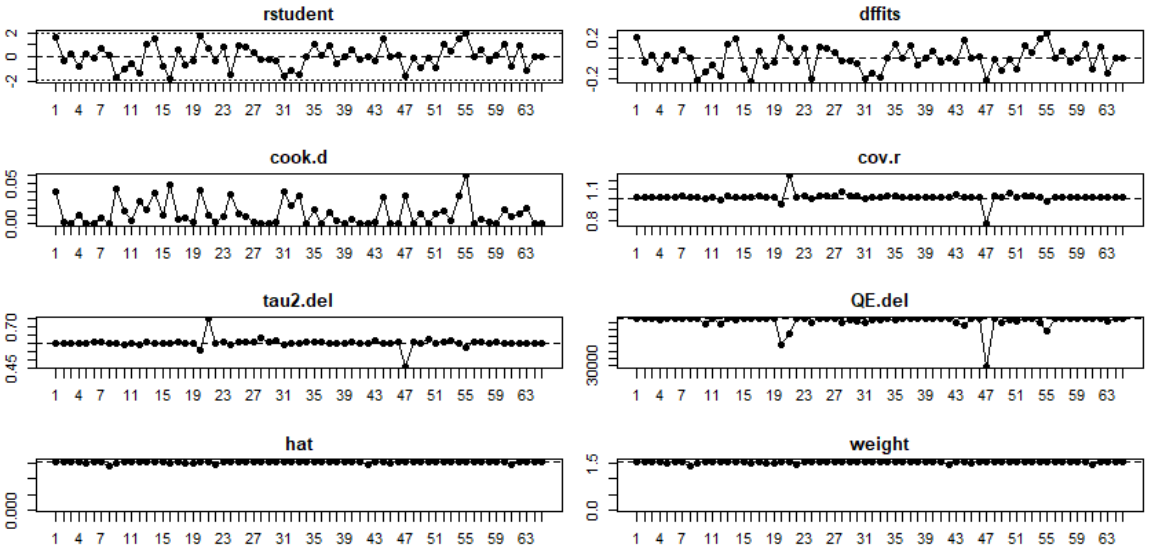
b. Consolidated country data from studies and country real-world statistics





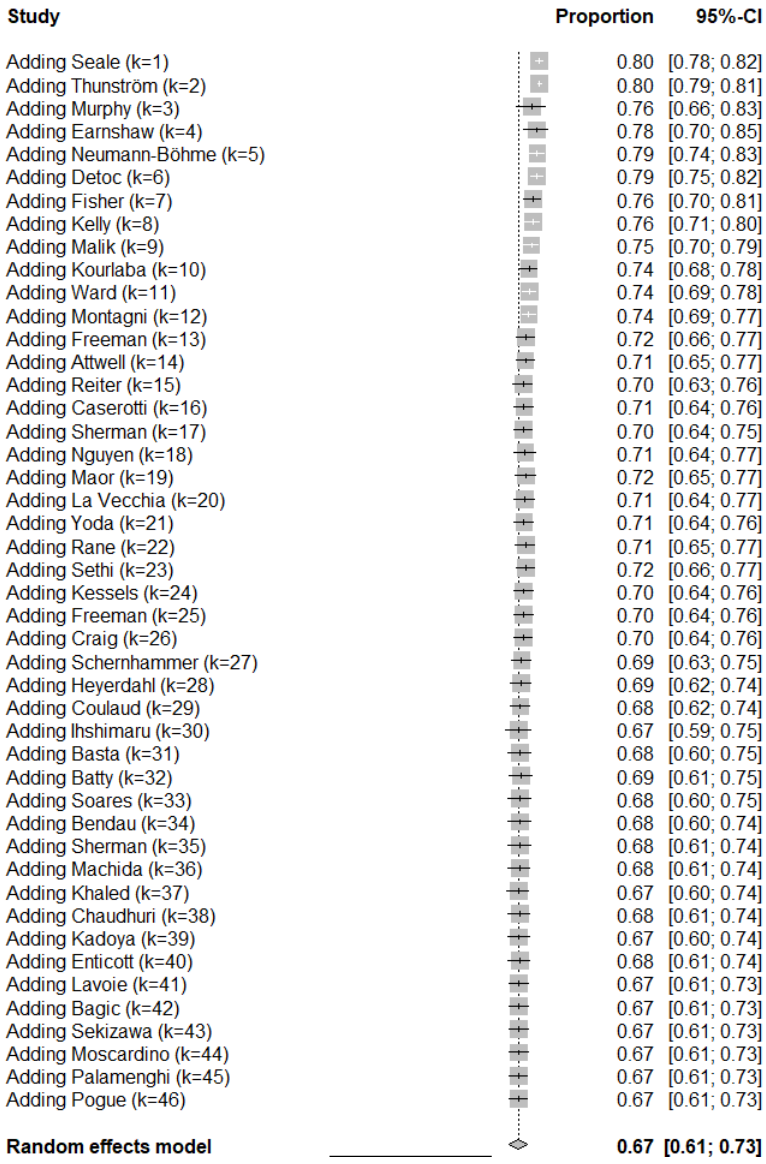
6. Supplementary section 6: Sensitivity analyses

a. Outlier and influential case diagnostics

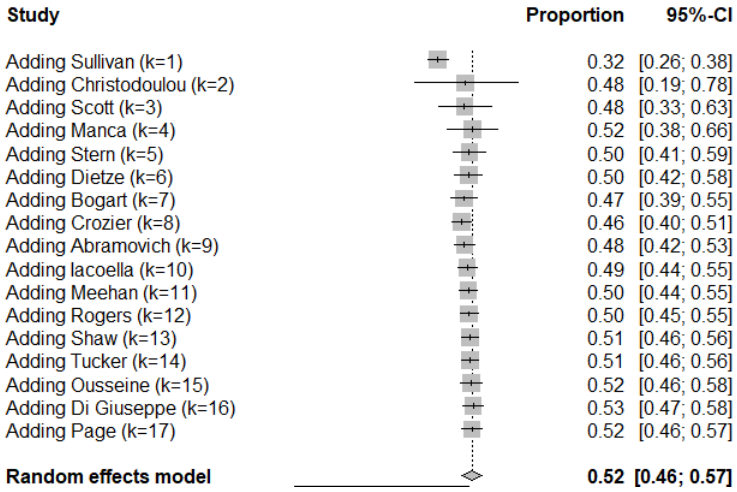


rstudent= externally standardized residuals, dffits= difference in fit values, cook.de=Cook's distances, cov.r= covariance ratios, tau2.del= leave-one-out estimates of the amount of heterogeneity, QE.del= leave-one-out values of the test statistics for heterogeneity, hat= hat values, weight= weights

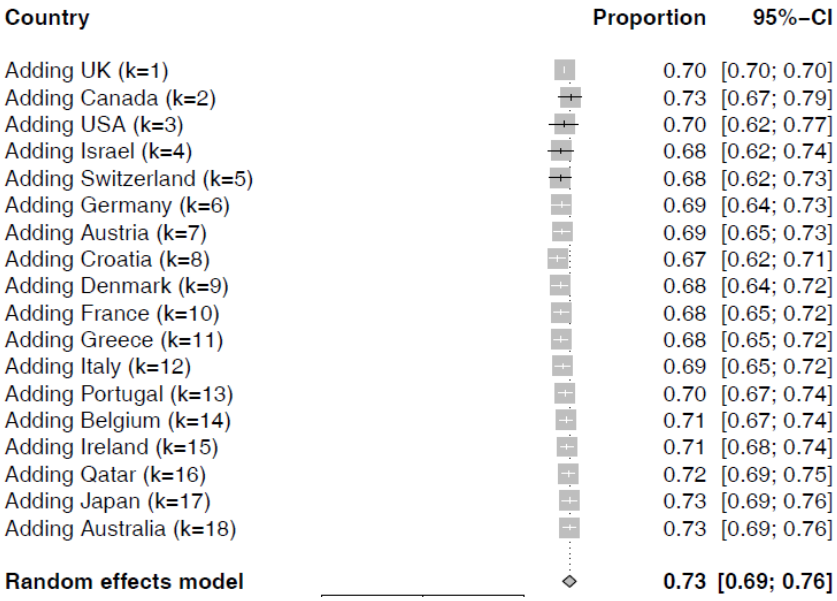
b. Cumulative meta-analysis of willingness to be vaccinated according to the date of data acquisition. General population.



c. Cumulative meta-analysis of willingness to be vaccinated according to the date of data acquisition. Special populations.



d. Cumulative real-world data meta-analysis according to the date of first COVID-19 vaccine administered in each country

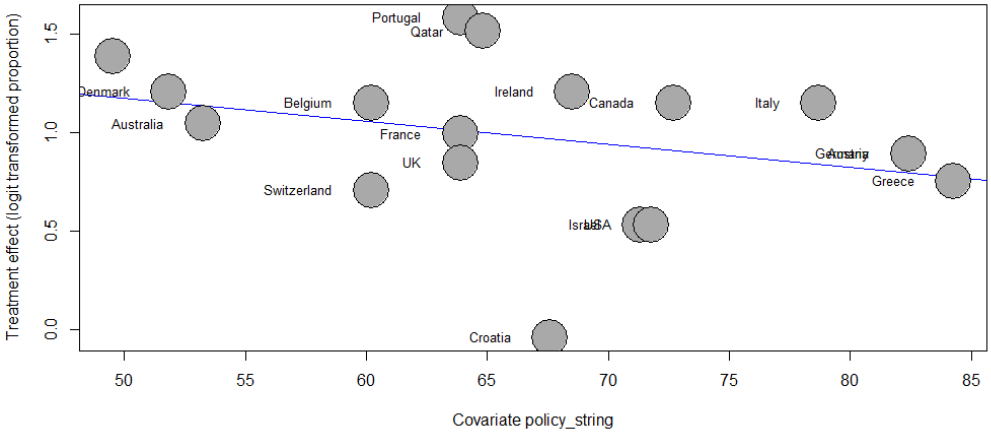


e. Results from the generalized linear models for vaccine uptake and country-level data

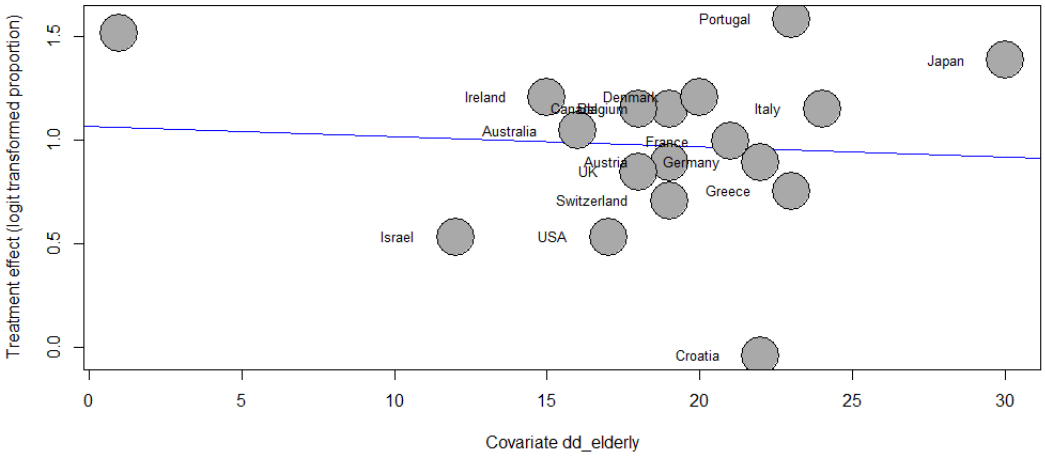
	B	Standard error	p-value	OR	95% CI
Intercept	80.683	10.35	.000		
Stringency index	-.206	.10	.04	.81	(0.69-0.94)
% of the population older than 65 years	.595	.28	.03	1.8	(1.04-3.1)
Healthcare spending as % of GDP	-.997	.46	.03	0.36	(0.14-0.91)
Social spending as % of GDP	.183	.21	.4	1.2	(0.78-1.84)

f. Bubble plots from meta-regressiosn analyses to explore associations of country-level data with vaccine uptake

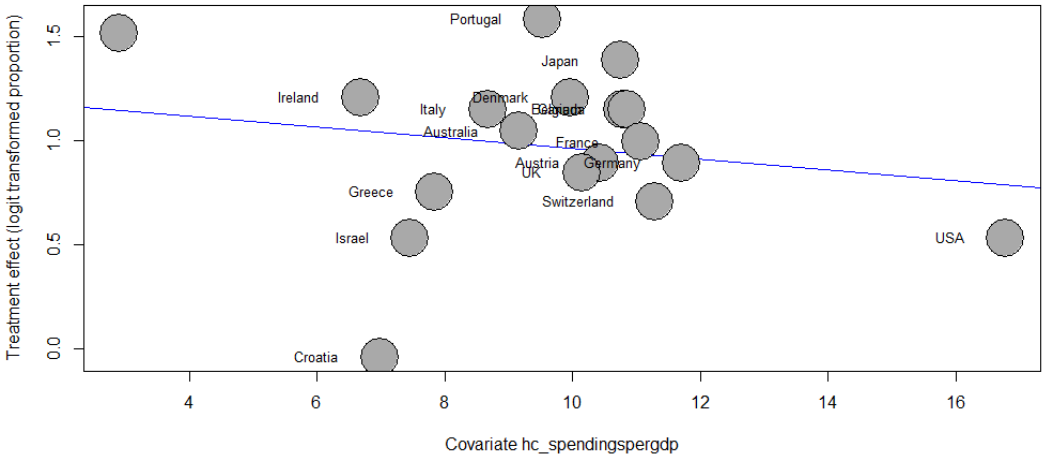
Stringency index



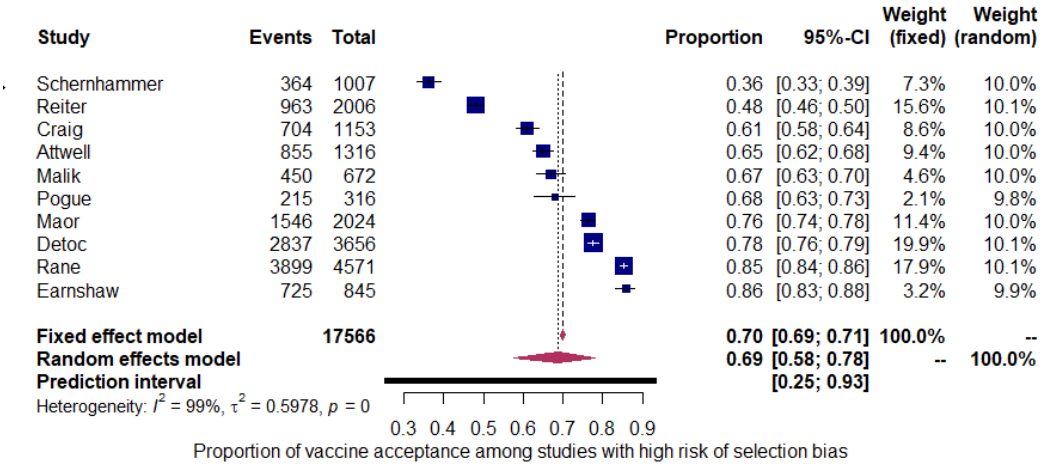
Percentage of the population older than 65 years



Healthcare spending as a percentage of GDP



g. Random-effects meta-analysis of COVID-19 vaccine acceptance in the general population for studies with high risk of selection bias



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7. Supplementary section. Checklists.

Prisma 2020 Checklist

Abstract checklist	Item #	Checklist item	Reported (Yes/No)
TITLE			
Title	1	Identify the report as a systematic review.	Yes
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	Yes
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	Yes
Information sources	4	Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched.	Yes
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	Yes
Synthesis of results	6	Specify the methods used to present and synthesise results.	Yes
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	Yes
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).	Yes
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision).	Yes
Interpretation	10	Provide a general interpretation of the results and important implications.	Yes
OTHER			
Funding	11	Specify the primary source of funding for the review.	No
Registration	12	Provide the register name and registration number.	

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1, title
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Abstract
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Methods section, pages 5,6
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Supplementary section 1
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplementary section 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Supplementary section 1|
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Supplementary section 1
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Methods section, page 6
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Supplementary section 1
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Supplementary section 1
Effect	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of	Data

Section and Topic	Item #	Checklist item	Location where item is reported
measures		results.	synthesis, page 7
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Data synthesis, page 7
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Sensitivity analyses, page 8
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Sensitivity analyses, page 8
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	NA
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Figure S1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Supplementary material, section 1c
Study characteristics	17	Cite each included study and present its characteristics.	Results section, page 8 and Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Table S1
Results of	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect	Figure 1,

Section and Topic	Item #	Checklist item	Location where item is reported
individual studies		estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Figure 2.
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Supplementary section 3,
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Results section, pages 8-11
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Results section, page 10. Supplementary section 6
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Supplementary section 6
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Main findings, page 11
	23b	Discuss any limitations of the evidence included in the review.	Study limitations, page 13
	23c	Discuss any limitations of the review processes used.	-
	23d	Discuss implications of the results for practice, policy, and future research.	Findings in context, page 13
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	The review was not registered because it was a realist review

Section and Topic	Item #	Checklist item	Location where item is reported
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	NA
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 1
Competing interests	26	Declare any competing interests of review authors.	Page 1
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Supplementary material

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For more information, visit: http://www.prisma-statement.org/

RAMESES II reporting standards for realist evaluations:

Title: Realist review of COVID-19 vaccine acceptance in the general population and marginalized communities from high income countries

		Reported in document Y/N/ Not applicable	Page no.	Comment
1	**TITLE** In the title, identify the document as a realist evaluation	Yes (refers to it as realist review)	Title	In the title, reference is made to "realist review"
SUMMARY OR ABSTRACT				
2	Journal articles will usually require an abstract, while reports and other forms of publication will usually benefit from a short summary. The abstract or summary should include brief details on: the policy, programme or initiative under evaluation; programme setting; purpose of the evaluation; evaluation question(s) and/or objective(s); evaluation strategy; data collection, documentation and analysis methods; key findings and conclusions. Where journals require it and the nature of the study is appropriate, brief details of respondents to the evaluation and recruitment and sampling processes may also be included. Sufficient detail should be provided to identify that a realist approach was used and that realist programme theory was developed and/or refined	Yes	Abstract	

			Reported in document Y/N/Not applicable	Page(s) in document	Comment
INTRODUCTION					
3	Rationale for evaluation	Explain the purpose of the evaluation and the implications for its focus and design	Yes	P. 4	
4	Programme theory	Describe the initial programme theory (or theories) that underpin the programme, policy or initiative	Yes	P. 4	
5	Evaluation questions, objectives and focus	State the evaluation question(s) and specify the objectives for the evaluation. Describe whether and how the programme theory was used to define the scope and focus of the evaluation	Yes	P. 4	
6	Ethical approval	State whether the realist evaluation required and has gained ethical approval from the relevant authorities, providing details as appropriate. If ethical approval was deemed unnecessary, explain why	Not applicable	-	No original data collected

			Reported in document Y/N/ Not applicable	Page(s) in document	Comment
METHODS					
7	Rationale for using realist evaluation	Explain why a realist evaluation approach was chosen and (if relevant) adapted	Yes	P. 4	
8	Environment surrounding the evaluation	Describe the environment in which the evaluation took place	Yes	Title	Title locates the study to high income countries.
9	Describe the programme policy, initiative or product evaluated	Provide relevant details on the programme, policy or initiative evaluated	Yes	Title p. 5	Title refers to COVID-19 vaccine acceptance
10	Describe and justify the evaluation design	A description and justification of the evaluation design should be included, at least in summary form or as an appendix, in the document which presents the main findings. If this is not done, the omission should be justified and a reference or link to the evaluation design given. It may also be useful to publish or make freely available any original evaluation design document or protocol, where they exist	Yes		
11	Data collection methods	Describe and justify the data collection methods – which ones were used, why and how they fed into developing, supporting, refuting or refining programme theory	Yes	S1	Supplementary section 1

		Provide details of the steps taken to enhance the trustworthiness of data collection and documentation	Yes	S1	Supplementary section 1
12	Recruitment process and sampling strategy	Describe how respondents to the evaluation were recruited or engaged and how the sample contributed to the development, support, refutation or refinement of programme theory	Yes	p. 5,6	No original empirical study but review of other studies Methods section describes inclusion and exclusion criteria Supplementary section 1 provides more details on databases and screening process
13	Data analysis	Describe in detail how data were analysed. This section should include information on the constructs that were identified, the process of analysis, how the programme theory was further developed, supported, refuted and refined, and (where relevant) how analysis changed as the evaluation unfolded	Yes	p. 7 p. 8	Data synthesis Sensitivity analyses, page 8

			Reported in document Y/N/Unclear/ Not applicable	Page(s) in document	Comment
RESULTS					
14	Details of participants	Report (if applicable) who took part in the evaluation, the details of the data they provided and how the data was used to develop, support, refute or refine programme theory	Yes	S1	Supplementary section 1
15	Main findings	Present the key findings, linking them to contexts, mechanisms and outcome configurations. Show how they were used to further develop, test or refine the programme theory	Yes	P. 8	Results section, and Table 1
DISCUSSION					
16	Summary of findings	Summarise the main findings with attention to the evaluation questions, purpose of the evaluation, programme theory and intended audience	Yes	P. 8-11	Figures 1 and 2 Results section,

			Reported in document Y/N/Unclear/ Not applicable	Page(s) in document	Comment
17	Strengths, limitations and future directions	Discuss both the strengths of the evaluation and its limitations. These should include (but need not be limited to): (1) consideration of all the steps in the evaluation processes; and (2) comment on the adequacy, trustworthiness and value of the explanatory insights which emerged In many evaluations, there will be an expectation to provide guidance on future directions for the programme, policy or initiative, its implementation and/or design. The particular implications arising from the realist nature of the findings should be reflected in these discussions	Yes	p. 13	

TITLE			Reported in document Y/N/Unclear/ Not applicable	Page(s) in document	Comment
18	Comparison with existing literature	Where appropriate, compare and contrast the evaluation's findings with the existing literature on similar programmes, policies or initiatives	Yes	P. 11	Main findings
19	Conclusion and recommendations	List the main conclusions that are justified by the analyses of the data. If appropriate, offer recommendations consistent with a realist approach	Yes	p. 13	Cf. "Findings in context" in the manuscript
20	Funding and conflict of interest	State the funding source (if any) for the evaluation, the role played by the funder (if any) and any conflicts of interests of the evaluators	Yes	P. 1	

Adapted from table 1 in:
Wong G, Westhorp G, Manzano A, *et al*. RAMESES II reporting standards for realist evaluations. *BMC Med* 2016; 14:96.