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Review article

Social determinants of health and vaccine uptake during the first wave of the COVID-19 pandemic: A systematic review

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ABSTRACT

Social determinants of health significantly impact population health status. The aim of this systematic review was to examine which social vulnerability factors or determinants of health at the individual or county level affected vaccine uptake within the first phase of the vaccination program. We performed a systematic review of peer-reviewed literature published from January 2020 until September 2021 in Medline and Embase (Bagaria et al., 2022) and complemented the review with an assessment of pre-print literature within the same period. We restricted our criteria to studies performed in the EU/UK/EEA/US that report vaccine uptake in the general population as the primary outcome and included various social determinants of health as explanatory variables. This review provides evidence of significant associations between the early phases of vaccination uptake for SARS-CoV-2 and multiple socioeconomic factors including income, poverty, deprivation, race/ethnicity, education and health insurance. The identified associations should be taken into account to increase vaccine uptake in socially vulnerable groups, and to reduce disparities in uptake, in particular within the context of public health preparedness for future pandemics. While further corroboration is needed to explore the generalizability of these findings across the European setting, these results confirm the need to consider vulnerable groups and social determinants of health in the planning and roll-out of SARS-CoV-2 vaccination programs and within the context of future respiratory pandemics.

1. Introduction

The COVID-19 pandemic has had a vast and unprecedented impact on population health in terms of morbidity and mortality also in social and economic terms (Vardavas, 2022). Although age has been observed as the strongest factor related to adverse COVID-19 outcomes (Vardavas et al., 2022; Romero Starke et al., 2021), socially and economically disadvantaged groups have been severely affected by the pandemic, particularly during the first waves of the Alpha and Delta variants (Control, 2020). A large body of evidence describes how social determinants of health are associated with general health status and even play a more prominent role than lifestyle choices and medical care in affecting individual health (Braveman and Gottlieb, 1974). Furthermore, health disparities can be worsened by multiple factors, among which are infectious diseases that can disproportionately affect vulnerable groups (Semenza et al., 2010).

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Although the implementation of non-pharmaceutical interventions (NPI), applied across the European Union, European Economic Area, United Kingdom (EU/EEA/UK) and the United States (US), played an important role in mitigating the pandemic (Mendez-Brito et al., 2021), pharmaceutical measures, such as vaccines, are essential in reducing the risk of adverse outcomes and death (Xing, 2021). Previous research has identified variations in vaccine coverage between ethnic groups for other vaccinations (Ward et al., 2017; Loiacono, 2020; Jain et al., 2018) and in the intention to accept the SARS-CoV-2 vaccine (Omaduvie et al., 2021). Initial vaccination strategies focused on older adults, healthcare workers and those of high clinical vulnerability, and then expanded to the general population. Evidence shows that sociodemographic factors (Martin et al., 2021; Mena et al., 2021), which is consistent with the findings of studies examining immunization programs outside the context of global pandemics (Glatman-Freedman and Nichols, 2012; Yeung et al., 2016). Moreover, as described in the European Centre for Disease Prevention and Control (ECDC) series of reports on the SARS-CoV-2 vaccine deployment, EU/EEA countries face challenges in increasing uptake in different population groups, such as socially vulnerable populations (Control, 2021). Comprehending which factors are associated with vaccine uptake could be of importance for policy-makers when preparing a public health emergency plan for future respiratory pandemics. By exploring the first phase one can derive valuable information on what triggers or impedes vaccination uptake during the first phase of public health emergency preparedness, i.e. in the critical phase of the COVID-19 pandemic. With the above in mind, this systematic review aimed to examine which social determinants of health affected vaccine uptake during the first phase of the COVID-19 vaccination rollout in the EU/EEA, UK and the US.

2. Materials and methods

2.1. Search strategy and inclusion criteria

A systematic review was conducted from the 1st of January 2020 through the 22nd of September 2021 using the PRISMA framework (Preferred Reporting Items for Systematic Reviews and Meta-analyses) (Moher et al., 2009) within Medline and Embase (Bagaria et al., 2022) and the MedRxiv pre-print server. Subject headings relating to COVID-19, social determinants of health, and epidemiological study design terms were used to develop a comprehensive search strategy presented in the Online Supplementary Appendix A. Studies of all relevant analytical epidemiological designs were considered eligible provided: (i) they evaluated humans of all ages irrespective of health status, excluding healthcare workers given that this group was expected to have been included in the initial vaccination emergency response; (ii) they presented data on the association between a determinant of health and SARS-CoV-2 vaccine uptake as the outcome; (iii) they referred to actual vaccine uptake, not intention/willingness for vaccination or vaccine hesitancy; (iv) the full text was written in English. Reference lists of all included studies and relevant reviews were also screened to identify additional eligible studies.

2.2. Appraisal of methodological quality

The methodological quality of each included study was evaluated independently by two reviewers using the Joanna Briggs Institute (JBI) standardised critical appraisal tool for each appropriate study design (Moola, 2020). Disagreements were resolved through discussion and, when necessary, by a senior third reviewer. The results from the quality appraisal are presented in Online Supplementary Appendix B.

2.3. Data - extraction and synthesis

Studies identified from the searches were uploaded into Covidence, and duplicates were deleted. A two-stage screening process was used to identify eligible studies. Initially, a pilot training screening process was used where a random sample of 100 titles and abstracts was screened separately for eligibility by two reviewers to enable consistency in screening and identify areas for amendments in the inclusion criteria. Since a high measure of inter-rater agreement was achieved (percentage of agreement = 88.7%), the remaining titles and abstracts were shared between two reviewers. Full-text papers were screened independently with 89.3% inter-rater agreement. Disagreements or uncertainties in the screening stages were resolved through discussion and consensus with a third reviewer.

Data were extracted independently by two reviewers using a pre-defined data extraction sheet that included study characteristics (first author's name, year of publication), geographical context (country/area), study design, study population, recruitment date, vaccination data source, follow-up duration, and related quantitative or descriptive findings with regard to the social determinants of health and the primary outcome of interest (vaccine uptake, which was noted as percentages, prevalence ratios or odds ratios). The data were inversed where odds ratios were provided as the likelihood to decline vaccination. Where available, adjusted odds ratios (aOR) were extracted in preference to crude estimates.

3. Results

3.1. Study overview

Through the initial search, 2,932 peer-reviewed studies were identified, of which 2,485 passed onto the title/abstract review process after the removal of duplicates. Of the 118 studies that were found to meet the inclusion criteria through the title and abstract screening process, 16 met all inclusion criteria while 102 studies were excluded due to study design (n = 6), outcomes (n = 67 assessed the intention for vaccination, not actual vaccination), language (n = 1), irrelevancy to COVID-19 (n = 18), irrelevant region (n = 1), and irrelevant population (n = 9). An additional five studies were identified using the MedRxiv pre-print server. The flowchart of study selection and exclusion is presented in Fig. 1.

All 21 studies included in this systematic review (Agarwal et al., 2021; Barry et al., 2021; Brown et al., 2021; Dolby, 2021; Dryden-Peterson, et al., 2021; Gharpure et al., 2021; Glampson et al., 2021; Khubchandani et al., 2021; Kim, 2021; Lindemer, 2021; MacKenna, et al., 2021; Murthy et al., 2021; Nafilyan et al., 2021; Nguyen, 2021; Perry et al., 2021; Ryerson et al., 2021; Singh et al., 2021; Sun and Monnat, 2021; Tram, 2021; Wang et al., 2021; Whiteman et al., 2021) investigated the relationship between vaccination status and at least one social determinant of health (Table 1). The identified determinants included age and sex, ethnicity/minorities, deprivation and income, household composition and marital status, education, employment status, area of residence, household composition, housing type/tenure, health insurance, and disability. Indexes for measuring social vulnerability, such as the Social Vulnerability Index (SVI), the COVID-19 Community Vulnerability Index and the Index of Multiple Deprivation (IMD), were also extracted. Where available, information on demographics including age and gender was also extracted.

Concerning the geographical distribution, 15 were conducted in the US (Agarwal et al., 2021; Barry et al., 2021; Brown et al., 2021; Dryden-Peterson, et al., 2021; Gharpure et al., 2021; Khubchandani et al., 2021; Kim, 2021; Lindemer, 2021; Murthy et al., 2021; Ryerson et al., 2021; Singh et al., 2021; Sun and Monnat, 2021; Tram, 2021; Wang et al., 2021; Whiteman et al., 2021), five were performed in the UK (Dolby, 2021; Glampson et al., 2021; MacKenna, et al., 2021; Nafilyan et al., 2021; Perry et al., 2021) and one study combined data from the US and the UK (Nguyen, 2021). The overall recruitment timeframe of the included studies covered the period from December 2020 to August 2021, reflecting hence the initial rollout of vaccinations.

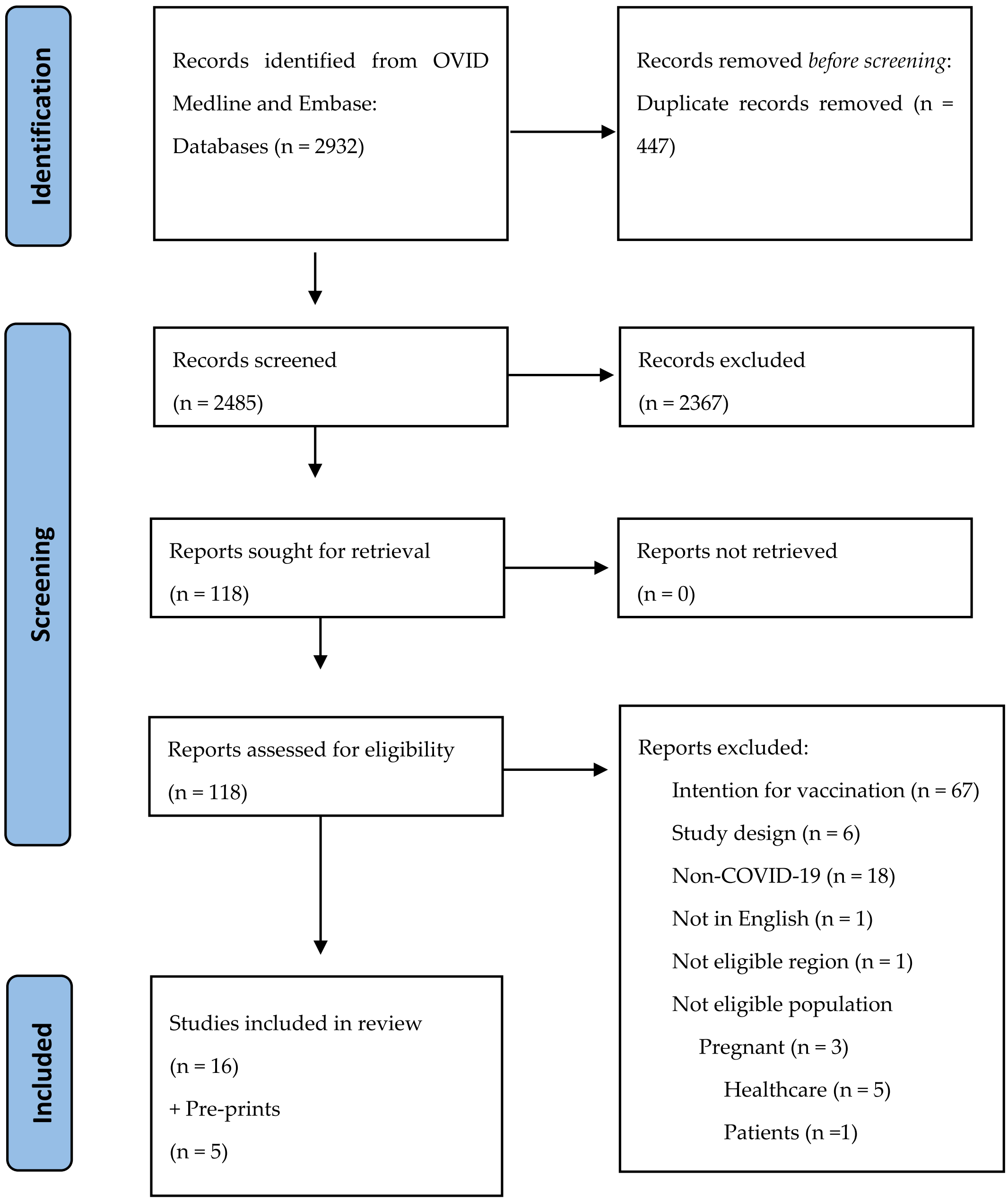

Fig. 1. PRISMA flowchart of the study selection on the social determinants of health and vaccine uptake during the first wave of the COVID-19 pandemic.

3.2. Vaccination coverage by age and gender

Among the determinants identified in the included studies of this review, age was reported in 13 studies (Barry et al., 2021; Dryden-Peterson, et al., 2021; Glampson et al., 2021; Khubchandani et al., 2021; Kim, 2021; Lindemer, 2021; Murthy et al., 2021; Nafilyan et al., 2021; Ryerson et al., 2021; Singh et al., 2021; Sun and Monnat, 2021; Tram, 2021; Whiteman et al., 2021), presented in Table 2. In all mentioned cases, vaccination coverage increased with age at either the participant or community level, reflecting the age-staggered prioritization of the vaccination. Gender was assessed as a possible contributing factor in vaccine uptake in most of the included studies (n = 11, Table 2) (Glampson et al., 2021; Khubchandani et al., 2021; Kim, 2021; MacKenna, et al., 2021; Murthy et al., 2021; Nafilyan et al., 2021; Perry et al., 2021; Ryerson et al., 2021; Singh et al., 2021; Tram, 2021; Whiteman et al., 2021). Among the seven studies conducted in the US (Khubchandani et al., 2021; Kim, 2021; Murthy et al., 2021; Ryerson et al., 2021; Singh et al., 2021; Tram, 2021; Whiteman et al., 2021), four studies estimated odds ratios (ORs) and found from self-reported data that women were more likely compared to men to have been vaccinated (Kim, 2021; Nafilyan et al., 2021; Perry et al., 2021; Singh et al., 2021), while six other studies with only descriptive results indicated higher vaccination proportions in men, without reporting the statistical significance of these differences (Glampson et al., 2021; Khubchandani et al., 2021; MacKenna, et al., 2021; Murthy et al., 2021; Ryerson et al., 2021; Tram, 2021; Whiteman et al., 2021). Two out of the four included UK studies agreed that women were slightly more likely to receive vaccination than men (Glampson et al., 2021; Nafilyan et al., 2021; Perry et al., 2021). With regard to older participants, vaccination rates were slightly higher among men within populations of UK adults 80 + years of age (Women: 94.5%, men: 94.9%) (MacKenna, et al., 2021) and among US adults 65 + years of age (women: 77.5%, men: 79.6%) (Whiteman et al., 2021).

Table 1
Descriptive characteristics of the studies included within this systematic review on the social determinants of health and vaccine uptake during the first wave of the COVID-19 pandemic.

Lead author, Year	Country	Population (n)	Study design	Timeframe	Vaccination data source	Outcome
(Agarwal et al., 2021)	US	General population, (n = 756 counties)	Cross-sectional	as of 19/4/2021	Official websites of Departments of Health in each state	Difference in rates with at least 1 dose
(Barry et al., 2021)	US	General population (n = 3,142 counties)	Cross-sectional	14/12/2020–1/5/2021	CDC COVID-19 data tracker	At least 1 dose
(Brown et al., 2021)	US	General population, (n = 2,415 counties)	Cross-sectional	as of 25/05/2021	CDC COVID-19 data tracker	Fully vaccinated[2]
(Dolby, 2021)	UK	General population (n = 35,223,466 adults – UK registrar)	Not mentioned	as of 15 September 2021	NHS Improvement's National Immunisation Management System	At least 1 dose
(Dryden-Peterson, et al., 2021)	US	General population, MA (n = 6,795,000, n = 291 communities)	Not mentioned	29/1/2020–9/4/2021	Massachusetts Department of Public Health and the Boston Public Health Commission	Vaccination-to-infection risk (VIR)[3]
(Gharpure et al., 2021)	US	Long term care residents and staff (n = 35,854 communities)	Cross-sectional	18/12/2020–21/04/2021	Partner pharmacies which reported to CDC	At least 1 dose
(Glampson et al., 2021)	UK	General population, London (n = 2,183,939)	Retrospective cohort	08/12/2020–15/2/2021	GP primary care records	Declining vaccination[4]
(Khubchandani et al., 2021)	US	General population, (n = 1,602)	Cross-sectional	as of 6/2021	Self-reported: Online survey via mTurk	At least 1 dose
(Kim, 2021)	US	General population, Household Pulse Survey (two waves, n = 68,348 and n = 80,567)	Cross-sectional	6–18/1/2021 17–29/3/2021	Self-reported: US Census Bureau's Household Pulse Survey	At least 1 dose
(Lindemer, 2021) (now published as Donadio)	US	General population (n = 1510 counties)	Not mentioned	as of 1/3/2021	CDC COVID Data Tracker	At least 1 dose
(MacKenna, et al., 2021)	UK	Primary care patients > 80 years old not resident in care homes (2,422,476)	Retrospective cohort	8/12/2020–25/3/2021	OpenSAFELY-TPP platform	At least 1 dose
(Murthy et al., 2021)	US	General population (n = 113,554,259)	Cross-sectional	14/12/2020–10/04/2021	CDC COVID-19 data tracker	At least 1 dose
(Nafilyan et al., 2021)	UK	Elderly adults > 70, (n = 6,829,643)	Cohort	as of 15/3/2021	National Immunisation Management System	Unvaccinated[5]
(Nguyen, 2021)	US & UK	General population (N = 1,341,682; US n = 87,388; UK n = 1254294)	Cohort study	24/3/2020–16/2/2021	Self-reported: COVID Symptom Study (CSS)	At least 1 dose
(Perry et al., 2021)	UK	General population (n = 1256412)	Cross-sectional	as of 25/4/2021	Wales Immunisation System (Wise, 2021)	At least 1 dose
(Ryerson et al., 2021)	US	General population (n = 56,749)	Cross-sectional	30/5/2021–26/6/2021	Self-reported: NIS-ACM Survey	At least 1 dose
(Singh et al., 2021)	US	General population (n = 224,458)	Cross-sectional	6/1–15/2/2021	Self-reported: US Census Bureau's Household Pulse Survey	At least 1 dose
(Sun and Monnat, 2021)	US	General population, (n = 2,869 counties)	Cross-sectional	as of 11/8/2021	CDC COVID-19 data tracker	At least 1 dose
(Tram, 2021)	US	General population (N = 459 235)	Cross-sectional	6/1–29/3/2021	Self-reported: US Census Bureau's Household Pulse Survey	At least 1 dose
(Wang et al., 2021)	US	General population, CT (n = 168 counties)	Cross-sectional	as of 8/3/2021	Connecticut Department of Public Health (CTDPH)	At least 1 dose
(Whiteman et al., 2021)	US	General population (n = 42,736,710)	Cross-sectional	14/12/2020–10/4/2021	CDC COVID-19 data tracker	At least 1 dose

1: Difference in rates with at least 1 dose1.
2 Fully vaccinated reported as having received both doses of a two dose vaccination series or a single dose of a one-dose series.
3: Vaccination-to-infection risk (VIR) VIR ratio was calculated for each community as the quotient of the number of fully vaccinated individuals divided by the cumulative number of confirmed SARS-CoV-2 infections.
4: declining a vaccine if they indicated that they did not want a vaccine to their GP and did not then receive a vaccine.
5: aOR have been reversed to indicate the likelihood of vaccine uptake.

3.3. Race/ethnicity/minorities

Sixteen studies focused on race and ethnicity (Table 2) (Agarwal et al., 2021; Barry et al., 2021; Brown et al., 2021; Dolby, 2021; Dryden-Peterson, et al., 2021; Gharpure et al., 2021; Glampson et al., 2021; Khubchandani et al., 2021; Kim, 2021; Lindemer, 2021; MacKenna, et al., 2021; Nafilyan et al., 2021; Nguyen, 2021; Perry et al., 2021; Ryerson et al., 2021; Singh et al., 2021; Sun and Monnat, 2021; Tram, 2021; Wang et al., 2021; Whiteman et al., 2021), of which 11 were set in the US (Agarwal et al., 2021; Barry et al., 2021; Brown et al., 2021; Dryden-Peterson, et al., 2021; Gharpure et al., 2021; Khubchandani et al., 2021; Kim, 2021; Lindemer, 2021; Nguyen, 2021; Ryerson et al., 2021; Singh et al., 2021; Sun and Monnat, 2021; Tram, 2021; Wang et al., 2021; Whiteman et al., 2021). In principle, the results showed an increased vaccination coverage in Asians and White, while Black people had lower odds of vaccination. Tram et al. (Tram, 2021), noted that Asians were found to have the highest vaccination proportion, followed by non-Hispanic and White individuals. The lowest proportions were noted in those declared ≥2 ethnic descents, Hispanic and Black. At the county level, US counties with a greater percentage of Hispanic and Black individuals were found to have lower vaccination coverage when compared to counties with higher shares of Asians, White, and

Table 2
Effect of Age, Sex and Ethnicity/minorities status on vaccine uptake during the first wave of the COVID-19 pandemic.

Author, Year	Age	Sex	Race/Ethnicity/ minorities
(Agarwal et al., 2021)			***Race*** White: 35.9% Black: 19.9% ***Percentage point change in vaccination disparity associated with one SD increase in the predictor*** Segregation index Coeff. = 1.43 (0.69)
(Barry et al., 2021)	***Percentage of the population ≥ 65*** Counties below median: 54.9% vaccinated Counties above median: 49.4% vaccinated ***Percentage of the population < 18*** Counties below median: 56.8% vaccinated Counties above median: 51.3% vaccinated		***Percentage of racial and ethnic minority residents:*** Counties below median: 48.5% vaccinated Counties at or above median: 55.1% vaccinated ***Percentage of persons speaking English less than well:*** Counties below median: 45.8% vaccinated Counties above median: 55.2% vaccinated
(Brown et al., 2021)			**COVID-19 Community Vulnerability Index**[1] Overall Community vulnerability index: Effect of a 10point increase = -1.2, p < 0.001 **Age: 18–65** Minority status and language: Effect of a 10point increase = 1.1, p < 0.001 Q1: 40.9% vaccinated Q2: 44.4% vaccinated Q3: 44.4% vaccinated Q4: 45.6% vaccinated Q5: 50.3% vaccinated **Age: >65** Minority status and language: Effect of a 10point increase = 0.2, p = 0.166 Community vulnerability index: Effect of a 10point increase = -1.2, p < 0.001 Q1: 67.4% vaccinated Q2: 70.5% vaccinated Q3: 71.1% vaccinated Q4: 71.3% vaccinated Q5: 72.0% vaccinated
(Dolby, 2021)			Vaccination rates were highest among White British and Indian ethnic groups, and lowest among Black Caribbean, Black African, Mixed, and Pakistani ethnic groups.

Table 2 (*continued*)

Author, Year	Age	Sex	Race/Ethnicity/ minorities
(Dryden-Peterson, et al., 2021)	***vaccination relative to infection risk***per 5% higher community proportion of residents aged 65+ (aRR 1.23,1.15–1.31, p < 0.001)		***vaccination relative to infection risk***> 20% of the community Black and/or Latinx (aRR 0.67, 95% CI 0.56 to 0.81, p < 0.001).
(Gharpure et al., 2021)			***Social Vulnerability Index*** Racial/Ethnic Minority and language: Residents in assisted living Q1: 72% vaccine uptake per 100beds Q2: 75% vaccine uptake per 100beds Q3: 75% vaccine uptake per 100beds Racial/Ethnic Minority and language: Residents in residential care Q1: 8/10 vaccine uptake per ten beds Q2: 9/10 vaccine uptake per ten beds Q3: 10/10 vaccine uptake per ten beds
(Glampson et al., 2021)	Male: 5.83% declining vaccination Female: 5.92% declining vaccination	Age:18–64 Male: 3.16% declining vaccination Female: 2.17% declining vaccination Age: ≥65 Male: 7.08% declining vaccination Female: 0.94% declining vaccination	Black/Black British: 16.14% declining vaccination Asian/Asian British: 3.21% declining vaccination White: 4.92% declining vaccination Mixed ethnicity groups: 10.39% declining vaccination Other ethnic groups: 9.95% declining vaccination Unrecorded ethnic groups: 8.52% declining vaccination
(Khubchandani et al., 2021)	18–25: 162/199 vaccinated (81%) 26–35: 558/704 vaccinated (79%) 36–45: 282/343 vaccinated (82%) 46–59: 185/243 vaccinated (76%)>=60: 77/95 vaccinated (81%)	Male: 830/ 1034 vaccinated (80.3%) Female: 435/ 552 vaccinated (78.8%)	White: 1040/1293 vaccinated (80.4%) African-American: 121/161 vaccinated (75.2%)Asian: 69/86 vaccinated (80.2%)Other: 47/62 vaccinated (75.8%) ***Ethnicity***Hispanic: 415/459 vaccinated (90.4%)Non-Hispanic: 850/1127 vaccinated (75.4%)
(Kim, 2021)	**6–18/1/2021** 18–29: Ref 30–39: aOR = **1.21** (1.00–1.46) 40–49: aOR = **1.34** (1.10–1.64) 50–64: aOR = **1.47** (1.20–1.80) 65–74: aOR = 0.95 (0.75–1.19) 75+: aOR = **1.55** (1.13–2.12)	**6–18/1/2021** Male: Ref Female: aOR = **1.69** (1.53–1.88) **17–29/3/ 2021** Male: Ref Female: aOR = **1.30** (1.22–1.39)	**6–18/1/2021** Non-Hispanic White: Ref Non-Hispanic Black: aOR = 0.92 (0.76–1.10) Non-Hispanic Asian: aOR = 1.79 (1.48–2.18) Non-Hispanic multiracial: aOR = 0.93 (0.74–1.17)

(continued on next page)

Table 2 (*continued*)

Author, Year	Age	Sex	Race/Ethnicity/ minorities
	17–29/3/2021 18–29: Ref 30–39: aOR = **1.42** (1.24–1.63) 40–49: aOR = **1.81** (1.57–2.07) 50–64: aOR = **3.04** (2.65–3.49) 65–74: aOR = **12.76** (10.81–15.05) 75+: aOR = **25.73** (20.29–32.67)		Hispanic: aOR = 1.06 (0.88–1.26) **17–29/3/2021** Non-Hispanic White: Ref Non-Hispanic Black: aOR = 1.07 (0.95–1.20) Non-Hispanic Asian: aOR = 1.28 (1.10–1.50) Non-Hispanic multiracial: aOR = 0.98 (0.81–1.18) Hispanic: aOR = 1.21 (1.08–1.36)
(Lindemer, 2021)	Difference in rate, by Quartile of vaccinated counties (Q1 vs. Q4) <18: RR = **0.87** (0.869, 0.87) ≥65: RR = **1.235** (1.234, 1.236)		Difference in rate, by Quartile of vaccinated counties (Q1 vs. Q4) %Black: RR = 0.635 (0.634–0.635) %Hispanic: RR = 0.642 (0.641–0.642) %American Indian: RR = 0.9 (0.896–0.904) %Hawaiian/Pacific Islander: RR = 1.045 (1.035–1.055) %Asian: RR = 1.198 (1.196–1.201) %White: RR = 1.228 (1.228–1.229)
(MacKenna, et al., 2021)		Female: 94.4% (1,400,532/ 1,481,970) Male: 94.9% (1,021,944/ 1,076,936)	***Among the 80 + population not resident in care homes***White: 96.2% (1,458,548/ 1,515,535)Mixed: 77.7% (6,650/8,554)South Asian: 84.6% (55,846/65,975) Black: 68.3% (23,590/34,517) Other: 78.3% (8,561/10,934) Unknown: 94.1% (869,260/923,363)
(Murthy et al., 2021)	18–64: 36.6% ≥65:74.7%	Female: 47.4% Male: 41.0%	
(Nafilyan et al., 2021)	70–74: Ref 75–79: aOR = 1.51 (1.51–1.53) 80–84: aOR = 2.22 (2.17—2.22) 85–89: aOR = 1.96 (1.92—1.96) 90–94: aOR = 1.56 (1.53—1.58) 95–99: aOR = 1.22 (1.19–1.25) ≥100: aOR = 0.62 (0.59—0.65)	Female: Reference Male: OR = 1.03 (1.02–1.03)	White British: Ref Bangladeshi: aOR = 0.39 (0.37–0.41) Black African: aOR = 0.19 (0.19–0.20) Black Caribbean: aOR = 0.20 (0.20–0.21) Chinese: aOR = 0.37 (0.36–0.39) Indian: aOR = 0.74 (0.72–0.75) Mixed: aOR = 0.45 (0.43–0.46) Other: aOR = 0.40 (0.4–0.41) Pakistani: aOR = 0.27 (0.27–0.28) White other: aOR = 0.51 (0.51–0.52)
(Nguyen, 2021)			**US** White: Ref Black: aOR = 0.71 (0.64 – 0.79) Hispanic: aOR = 0.93 (0.84–1.02) Asian: aOR = 1.00 (0.93–1.09) More than one/other: aOR = 0.94 (0.81–1.08) **UK** White: Ref Black: aOR = 0.98 (0.92–1.04) South Asian: aOR = 1.18 (1.13–1.23) Middle East/East Asian: aOR = 1.01 (0.94–1.08) More than one/other: aOR = 0.99 (0.93–1.04)
(Perry et al., 2021)		Male: Ref Female: aOR = **1.18** (1.16–1.19)	White: Ref Black: aOR = 0.22 (0.21–0.24) Asian: aOR = 0.41 (0.39–0.43) Mixed: aOR = 0.36 (0.34–0.38) Other: aOR = 0.24 (0.22–0.27) Unknown: aOR = 0.20 (0.19–0.20)
(Ryerson et al., 2021)	Age (No disability vs. disability) 18–24: 46.4% vs. 33.5% 25–29: 49.8% vs. 35.5% 30–39: 52.9% vs. 48.8% 40–49: 60.8% vs. 54.4% 50–64: 71.9% vs. 62.8%) 65–75: 88.6% vs. 82.7% 75+: 90.0% vs. 88.2%	Sex (No disability vs. disability) Male: 61.9% vs. 66.4% Female: 67% vs. 67.3%	Ethnicity (No disability vs. disability)White (Ref) : 66.6% vs. 69.0% Hispanic: 61.8% vs.67.2% Black: 56.3% vs 60.1% AI/AN: 39.2% vs. 38.2% Asian: 85.5% vs. 74.7% NHPI: 59.1% vs. 71.1% Multiple race/Other: 49.2
(Singh et al., 2021)	>= 75: Ref 64–74: aOR = 0.48 (0.44–0.53) 55–64: aOR = 0.25 (0.22–0.27) 45–54: aOR = 0.22 (0.20–0.24) 35–44: aOR = 0.20 (0.18–0.22) 25–34: aOR = 0.19 (0.17–0.21) 18–24: aOR = 0.14 (0.11–0.17)	Male: Ref Female: aOR = 1.54 (1.47–1.62)	Non-Hispanic White: Ref Non-Hispanic Black: aOR = 0.89 (0.82–0.98) Asian: aOR = 1.5 (1.36–1.67) Other & multiple race: aOR = 1.02 (0.89–1.17) Hispanic: aOR = 1.03 (0.95–1.12)
(Sun and Monnat, 2021)	% age 65+: Coefficient = **1.36**, p < 0.001		%Non-Hispanic Black (1st quartile) Ref% Non-Hispanic Black (2nd quartile) : Coeff. = -0.4, p = 0.425%Non-Hispanic Black (3rd quartile) : Coeff. = -0.5, p = 0.395%Non-Hispanic Black (4th quartile) : Coeff. = -4.18, <0.001%Hispanic (1st quartile) Ref%Hispanic (2nd quartile)

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Table 2 (*continued*)

Author, Year	Age	Sex	Race/Ethnicity/ minorities
			: Coeff. = 0.05, p = 0.927%Hispanic (3rd quartile) : Coeff. = 0.59, p = 0.276%Hispanic (4th quartile) : Coeff. = 1.96, p = 0.002
(Tram, 2021)	18–24 = 9.7% (9.0–10.4) 25–39 = 17.1% (16.8–17.4) 40–54 = 20.2% (19.9–20.6) 55–64 = 24.3% (23.8–24.8) ≥65 = 45.4% (44.9–45.9)	Female = 27.1% (26.8–27.3) male = 22.0% (21.7–22.3)	Black = 20.6% (20.0–21.1) White = 25.4% (25.2–25.6) Asian = 29.2% (28.3–30.1) ≥2 Races + other = 18.5% (17.7–19.3) Hispanic/Latino = 18.9% (18.3–19.5) Not Hispanic/Latino = 25.8% (25.6–26.0)
(Wang et al., 2021)			Minority aspect of the SVI Age: 65–74Q1: 78.81 (11.05)Q4: 70.18 (11.49)Diff: 8.63 (3.74–13.53) Age: >75Q1: 95.80 (17.39)Q4: 74.80 (10.88)Diff: 21.00 (14.70–27.30)
(Whiteman et al., 2021)	65–74: 79.6% vaccinated >=75: 78.3% vaccinated	Male: 79.6% vaccinated Female: 77.5% vaccinated	Average percentage of older adults indicating race/ethnicity other than White<50% vaccination rates (8.0%; 95% CI = 4.9%–11.1%)≥75% vaccination rates (9.3%; 95% CI = 6.4%–12.1%)

* The number of fully vaccinated individuals divided by the cumulative number of confirmed SARS-CoV-2 infections.

* The difference in the COVID-19 vaccination rate between White and Black residents in a county, where vaccination rates are based on the total population of a given race in a county.

** The number of fully vaccinated individuals divided by the cumulative number of confirmed SARS-CoV-2 infections.

1: CCVI is computed using 40 measures within 7 themes: socioeconomic status (SES); minority status and language; housing type, transportation, household composition, and disability ("housing type/composition" hereafter); epidemiological factors; healthcare system factors; high risk environments; and population density (Mendez-Brito et al., 2021).

Hawaiian/Pacific Islanders (Lindemer, 2021). Furthermore, significantly lower vaccination rates were noted in US counties with larger percentages of Black people (Sun and Monnat, 2021), findings that were corroborated by other studies (Agarwal et al., 2021; Nguyen, 2021; Singh et al., 2021), with the latter estimating that non-Hispanic Black people had lower odds of vaccination compared to non-Hispanic Whites, while Asians were more likely to be vaccinated. The minority status and language theme of the COVID-19 Community vulnerability index also indicated the US counties with lower levels of vulnerability had higher vaccination rates compared to those with the highest level of vulnerability (Brown et al., 2021), while the minority aspect of the SVI also was associated with significant differences in vaccine uptake (Wang et al., 2021).

In line with the findings of the preceding US studies, the included studies of this review which took place in the UK during the first four months of 2021 suggested that White people and Asians were more likely to have been vaccinated against COVID-19 when compared to Black and Black British (MacKenna, et al., 2021; Nguyen, 2021) while multivariable analyses also confirmed the above findings (Nafilyan et al., 2021; Perry et al., 2021). In the first study, White British at the age of ≥ 70 years old were found to have lower odds of being unvaccinated compared to White, Bangladeshi, and Pakistani, Black African/Caribbean, Chinese, Indian, mixed, and other ethnicity groups at the same age range (Nafilyan et al., 2021). In the second study, White individuals at 50 years of age or older were more likely to have been partially vaccinated than Black, Asian, mixed, other, and unknown ethnicity groups (Perry et al., 2021). Finally, in the Dolby et al. study (Dolby, 2021), vaccination rates were highest among White British and Indian ethnic groups and lowest among Black Caribbean, Black African, Mixed, and Pakistani ethnic groups.

3.4. Deprivation and, income

A key social determinant of health identified in this review is poverty/deprivation and overall socioeconomic status for which all studies noted significant associations and are presented in Table 3. In all studies that used the IMD as an indicator of deprivation, vaccination was lower for those within the most deprived communities compared to those within the most affluent (Government, 2015). Perry et al. (Perry et al., 2021), noted the odds of being vaccinated were significantly lower for deprived people compared to those least deprived (most deprived: OR = 0.59, 95% C.I: 0.57–0.60). These results are similar to those of Nafilyan et al. (Nafilyan et al., 2021) (most deprived: OR = 0.63; 95 %C.I: 0.62–0.64). Comparing vaccination rates between quintiles of the IMD, MacKenna et al. (MacKenna, et al., 2021) also indicated that the most deprived had lower rates of being vaccinated compared to the least deprived. Using the COVID-19 Community Vulnerability Index, Brown et al. (Brown et al., 2021), also noted that vaccination rates were lower among those more vulnerable while Wang et al., noted that the differences in vaccination rates were statistically significant between quartiles of the poverty SVIs (Wang et al., 2021).

Income was studied as a possible predictor and lower personal income, either at the individual or the county level, was associated with lower vaccination rates in all identified studies. Notably, two US studies reporting odds ratios of respondent level data, noted that participants with an income of <25,000$ had significantly lower odds of having been vaccinated with at least one vaccine dose (OR = 0.67, $p < 0.05$), (Kim, 2021; Singh et al., 2021). Lower odds were also noted for those within the 25,000–34,999$ (OR = 0.81, $p < 0.05$) and 35,000–49,999$ (OR = 0.87, $p < 0.05$) income range, while Tram et al. (Tram, 2021) found that as reported income increased, so did the proportion of people who received vaccination, ranging from 15.4% (14.6–16.2) among those with an income of < 25,000$ to 33.0% (32.2–33.8) for those with an income of ≥ 200,000$. Additionally, using county level data, rural and urban US counties with a higher median household income had significantly higher vaccination rates (Coeff. = 2.78, $p < 0.001$), while in the study by Barry et al. (Barry et al., 2021), those with a median income of <26,245$ had lower vaccination rates (42.7%) compared to those above the median income (56.7%). The study by Nguyen et al. (Nguyen, 2021), with data from the US and the UK, presented slightly higher vaccination rates in higher-income participants, while the median per capita income was also identified to be strongly associated with vaccine roll-out. According to Kim (Kim, 2021), the odds of being vaccinated were significantly lower for those experiencing very difficult financial hardship [OR = 0.76 (0.63–0.90), p = 0.002] and also for those experiencing somewhat difficult financial hardship [OR = 0.85 (0.73–0.99), p = 0.03].

3.5. Education

Ten studies aimed to examine the relationship between education level and vaccine uptake (Table 3), nine of which were based in the US, while one study included data both from the US and the UK. All studies indicated that increased vaccination rates were noted amongst those

Table 3
Effect of Education, income/deprivation, occupation/employment on vaccine uptake during the first wave of the COVID-19 pandemic.

Study	Education	Income/ Deprivation/ Poverty	Occupation/ Occupational setting/ Employment
(Agarwal et al., 2021)	***Percentage point change in vaccination disparity associated with one SD increase in the predictor*** County High school graduation rate: Coeff. = 1.22, p > 0.05 County High school disparity: Coeff. = **2.01**, p < 0.001	***Percentage point change in vaccination disparity associated with one SD increase in the predictor*** County Median income: Coeff. = **-2.2**, p < 0.05 County Median income disparity: Coeff. = 0.89, p > 0.05	
(Barry et al., 2021)	***No high school diploma*** Counties below median: 56.5% vaccinated Counties above median: 50.40% vaccinated	**Income per capita** Counties below median: 42.7% vaccinated Counties at or above median: 56.7% vaccinated **Percentage of people living in poverty** Counties below median: 57.4% vaccinated Counties at or above median: 49.8% vaccinated	***Unemployment:*** Counties below median: 56.6% vaccinated Counties at or above median: 51.9% vaccinated
(Brown et al., 2021)		**COVID-19 Community Vulnerability Index**[2] **Age: 18–65** Socioeconomical status: Effect of a 10point increase = -1.2, p < 0.001 Q1: 53.8% vaccinated Q2: 53.0% vaccinated Q3: 48.3% vaccinated Q4: 44.6% vaccinated Q5: 45.2% vaccinated **Age: >65** Socioeconomical status: Effect of a 10point increase = -1.4, p < 0.001 Q1: 76.7% vaccinated Q2: 76.0% vaccinated Q3: 72.7% vaccinated Q4: 69.0% vaccinated Q5: 66.9% vaccinated	
(Dryden-Peterson, et al., 2021)		Decreased VIR per Quartile increase aRR 0.82; 95 %C.I: (0.77–0.87)	

Table 3 (*continued*)

Study	Education	Income/ Deprivation/ Poverty	Occupation/ Occupational setting/ Employment
(Gharpure et al., 2021)		***Social Vulnerability Index Socioeconomical status Residents in assisted living*** Q1: 75% vaccine uptake per 100beds Q2: 74% vaccine uptake per 100beds Q3: 71% vaccine uptake per 100beds ***Socioeconomical status: Residents in residential care*** Q1: 10/10 vaccine uptake per ten beds Q2: 9/10 vaccine uptake per ten beds Q3: 8/10 vaccine uptake per ten beds	
(Glampson et al., 2021)		***Deprivation and rate of declining vaccination*** Overall association: r = –0.94; P = 0.002) ***By Postcodes***Most deprived 13.5% (1980/14,571) declining vaccinationLeast deprived 0.98% (869/9609) declining vaccination	
(Khubchandani et al., 2021)	High school or less: 44/90 (49%) College: 93/149 (62%)Bachelor's degree: 822/992 (83%)>=Master's degree: 306/355 (86%)		Full-time: 1121/1393 vaccinated (80.5%)Part-time: 91/116 vaccinated (78.4%)Not employed: 53/77 vaccinated (68.8%)
(Kim, 2021)	**6–18/1/2021** ≥College: Ref <High school: aOR = **0.41** (0.27–0.63) High school: aOR = **0.40** (0.34–0.48) Some college: aOR = **0.76** (0.69–0.85) **17–29/3/2021** ≥College: Reference <High school: aOR = **0.29** (0.24–0.36) High school: aOR = **0.41** (0.37–0.45) Some college: aOR = **0.58** (0.54–0.62)	**Income 6–18/1/2021** ≥$200,000: Ref $150,000-$199,999: aOR = 1.06 (0.83, 1.34) $100,000-$149,999: aOR = 0.96 (0.78, 1.17) $75,000-$99,999: aOR = 0.79 (0.63, 0.997) $50,000-$74,999: aOR = 0.78 (0.62, 0.98) $35,000-$49,999: aOR = 0.68 (0.51, 0.91) $25,000-$34,999: aOR = 0.63 (0.46, 0.87) <$25,000: aOR = 0.53 (0.36, 0.77) **17–29/3/2021** ≥$200,000: Ref $150,000-$199,999: aOR = 0.98 (0.82, 1.18)	

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Table 3 (*continued*)

Study	Education	Income/ Deprivation/ Poverty	Occupation/ Occupational setting/ Employment
		$100,000-$149,999: aOR = 1.00 (0.87, 1.16) $75,000-$99,999: aOR = 0.91 (0.77, 1.08) $50,000-$74,999: aOR = 0.91 (0.78, 1.07) $35,000-$49,999: aOR = 0.87 (0.73, 1.04) $25,000-$34,999: aOR = 0.86 (0.71, 1.04) <$25,000: aOR = **0.66** (0.54, 0.81) **Financial hardship: 6–18/1/2021** Not at all difficult: Ref A little difficult: aOR = **0.89** (0.78–1.00) Somewhat difficult: aOR = **0.69** (0.59–0.80) Very difficult: aOR = **0.56** (0.44–0.70) **17–29/3/2021** Not at all difficult: Ref A little difficult: aOR = 0.95 (0.87–1.03) Somewhat difficult: aOR = **0.85** (0.73–0.99) Very difficult: aOR = **0.76** (0.63–0.90)	
(Lindemer, 2021)	Difference in rate, by Quartile of vaccinated counties (Q1 vs. Q4) High school graduation: RR = **1.019** (1.017–1.021) Some college: RR = **1.143** (1.143–1.144)		Difference in rate, by Quartile of vaccinated counties (Q1 vs. Q4) Unemployment: RR = **0.87** (0.867–0.872)
(MacKenna, et al., 2021)		***Index of Multiple Deprivation***IMD: 5 (Least deprived): 612,731/634,340 (96.6%)IMD: 4: 564,410/588,546 (95.9%)IMD: 3: 514,682/541,737 (95%)IMD: 2: 402,836/433,622 (92.9%)IMD: 1 (Most deprived): 309,190/340,928 (90.7%)Unknown: 18,613/19,691 (94.5%)	
(Nafilyan et al., 2021)		IMD: 5 (least deprived): Ref IMD 4: OR = 0.92 (0.91 – 0.93) IMD 3: OR = 0.85 (0.85–0.86) IMD 2: OR = 0.75 (0.74 – 0.75)IMD 1 (most deprived) : OR = 0.63 (0.62–0.64)	
(Nguyen, 2021)	**US**Lower education (Quartile 1) : 3991/17936 vaccinatedWhite: 1.0 (ref.) Black: aOR = 0.65 (0.54 to 0.78) Hispanic: aOR = 1.06 (0.90 to 1.26) Asian: aOR = 1.10 (0.92 to 1.31) Other: aOR = 0.86 (0.64 to 1.14) Higher education (Quartile 4) : 4153/17851 vaccinatedWhite: 1.0 (ref.) Black: aOR = 0.93 (0.70 to 1.24) Hispanic: aOR = 0.95 (0.75 to 1.19) Asian: aOR = 1.19 (1.00 to 1.42) Other: aOR = 1.09 (0.80 to 1.50) **UK**Lower education (Quartile 1) : 40794/284004 vaccinatedWhite: 1.0 (ref.) Black: aOR = 1.08 (0.97 to 1.20) Hispanic: aOR = 1.06 (0.97 to 1.17) Asian: aOR = 1.09 (0.94 to 1.27) Other: aOR = 0.94 (0.83 to 1.05) Higher education (Quartile 4) : 37191/226383 vaccinatedWhite: 1.0 (ref.) Black: aOR = 0.96 (0.81 to 1.12) Hispanic: aOR = 1.13 (1.03 to 1.23) Asian: aOR = 0.93 (0.81 to 1.06) Other: aOR = 0.96 (0.86 to 1.07)	**US**Lower income (Quartile 1) : 4094/17865 vaccinatedWhite: 1.0 (ref.) Black: aOR = 0.73 (0.61 to 0.86) Hispanic: aOR = 0.94 (0.79 to 1.14) Asian: aOR = 0.90 (0.70 to 1.16) Other: aOR = 1.08 (0.81 to 1.44) Higher income (Quartile 4) : 4111/17845 vaccinatedWhite: 1.0 (ref.) Black: aOR = 0.83 (0.62 to 1.11) Hispanic: aOR = 1.05 (0.86 to 1.28) Asian: aOR = 0.97 (0.84 to 1.12) Other: aOR = 1.09 (0.81 to 1.45) **UK**Lower income (Quartile 1) : 43709/299277 vaccinatedWhite: 1.0 (ref.) Black: aOR = 0.97 (0.89 to 1.07) Hispanic: aOR = 1.12 (1.04 to 1.21) Asian: aOR = 1.05 (0.94 to 1.18) Other: aOR = 0.90 (0.82 to 0.99) Higher income (Quartile 4) : 30809/198904 vaccinatedWhite: 1.0 (ref.) Black: aOR = 1.08 (0.90 to 1.31) Hispanic: aOR = 1.19 (1.07 to 1.33) Asian: aOR = 0.91 (0.77 to 1.08) Other: aOR = 1.01 (0.88 to 1.15)	
(Perry et al., 2021)		IMD: 5 (least deprived): Ref IMD 4: aOR = **0.81** (0.79 – 0.83) IMD 3: aOR = **0.78** (0.76 – 0.79) IMD 2: aOR = **0.71**	

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Table 3 (*continued*)

Study	Education	Income/ Deprivation/ Poverty	Occupation/ Occupational setting/ Employment
		(0.70 – 0.73),IMD 1 (most deprived) : aOR = **0.59** (0.57–0.60)	
(Ryerson et al., 2021)		SVI (No disability vs. disability) Low: 69.9% vs. 68% Moderate: 65.1% vs. 68.6% High: 60.4% vs. 64.8% Poverty status and household income (No disability vs. disability) Above poverty > 75 K: 72.5% vs. 78.0% Above poverty < 75 K: 61.1% vs. 68.9% Below poverty: 48.6% vs. 55.5% Unknown: 64.3% vs. 66.6%	
(Singh et al., 2021)	Graduate degree or higher (>=17 y.o.): RefCollege degree, (16 y.o.) : aOR = 0.71 (0.68–0.75)Some college (13–15 y.o.): aOR = 0.59 (0.56–0.62) High school (12 y. o.) : aOR = 0.39 (0.36–0.42)High school (<12 y.o.): aOR = 0.36 (0.30–0.43)	>= 200,000 (in 2019): Ref 150,000–199,999 (in 2019): aOR = 1.07 (0.97–1.17) 100,000–149,999 (in 2019): aOR = 0.97 (0.90–1.04) 75,000–99,999 (in 2019): aOR = 0.95 (0.87–1.03) 50,000–74,999 (in 2019): aOR = 0.92 (0.84–1.00) 35,000–49,999 (in 2019): aOR = **0.87 (0.78–0.97)** 25,000–34,999 (in 2019): aOR = **0.81 (0.72–0.91)**< 25,000 (in 2019) : aOR = **0.67 (0.59–0.77)** Unknown: aOR = 0.98 (0.88–1.10)	Employed: Ref Unemployed: aOR = **0.5 (0.47–0.54)**
(Sun and Monnat, 2021)	Rural & urban % with Bachelor or higher: Coeff. = 0.13, p = 0.713 Urban % with Bachelor or higher: Coeff. = 2.33, p < 0.001	County Median household income: Coeff. = 2.78, p < 0.001	
(Tram, 2021)	High school or less = 18.8% (18.4—19.2) Some college or associate's degree = 23.1% (22.9–23.4) Bachelor's degree or higher = 33.6% (33.4–33.9)	**Income**<25,000$ =15.4% (14.6—16.2) 25,000–34,999$ = 20.3 (19.6–21.2) 35,000–49,999$ = 22.6% (22.0–23.2) 50,000–74,999$ =26.1% (25.4–26.8) 75,000–99,999$ =27.7% (26.9–28.5) 100,000–149,999$ = 29.4% (28.8–30.0) 150,000–199,999$ =32.0% (31.0–32.9)≥ 200,000$ = 33.0% (32.2–33.8)	
(Wang et al., 2021)	Without highschool diploma Age 65–74:Q1: 79.77 (8.19)Q4: 66.86 (10.14)Diff: 12.91 (8.91–16.92)	Below poverty Age: 65–74Q1: 79.58 (9.99)Q4: 69.12 (12.37)Diff: 10.46 (5.59–15.35)	Unemployed Age: 65–74Q1: 75.60 (9.39)Q4: 70.99 (12.43)Diff: 4.61 (0.14–9.36)
	Age > 75:Q1: 98.62 (13.53)Q4: 74.47 (14.91)Diff: 24.15 (17.97–30.33)	Age: >75Q1: 98.01 (14.92)Q4: 73.87 (13.70)Diff: 24.14 (17.92–30.35)	Age: >75Q1: 88.75 (15.64)Q4: 83.72 (19.24)Diff: 5.03 (2.54–12.58)
(Whiteman et al., 2021)		Counties with < 50% vaccination initiation rates:10.3% (95% CI = 9.2% – 11.4%) in poverty Counties with >=75% vaccination initiation rates:7.6% (95% CI = 7.0%– 8.2%) in poverty	

with higher education both within participant-level associations and county-level associations.

An increase in the vaccination rate as the educational level increased was noted in US counties in the self-reported survey by Khubchandani et al. (Khubchandani et al., 2021). Similarly in the US, Tram et al. (Tram, 2021) estimated a higher vaccine uptake among those with at least a bachelor's degree compared to individuals with a college or associate degree or those who had completed high school or less. Likewise, Sun et al. (Sun and Monnat, 2021) noted that US counties with a greater percentage of residents with Bachelor's degrees or higher were more likely to have better vaccine uptake. The disparity in high school graduation status was also associated with increased vaccination disparity (Agarwal et al., 2021), while at the county-level vaccination was lower in US counties with a higher percentage of residents with no high school diploma (Barry et al., 2021). Additional studies also indicated that higher levels of education were positively associated with vaccine coverage (Kim, 2021; Lindemer, 2021; Singh et al., 2021). Similarly, amongst those 65 + years old the lack of a high school diploma was negatively correlated with vaccination coverage (Wang et al., 2021). Finally, Nguyen et al. (Nguyen, 2021), who presented data both from the US and the UK for adults at the age of 18 and older, also confirmed that vaccination rates were higher in participants with higher education.

3.6. Employment status

The role of employment status in vaccine uptake was explored in five studies (Table 3), all of which took place in the US and which, in principle, indicated that unemployed individuals had a lower likelihood or lower percentages of vaccination either at the population level (Khubchandani et al., 2021; Lindemer, 2021; Singh et al., 2021) or through county-level unemployment rates (Barry et al., 2021).

3.7. Marital status

Four studies investigated marital status as a possible factor for vaccine uptake in the general population (n = 4). In three studies, married participants were found to have the highest vaccination rates (Khubchandani et al., 2021); (Tram, 2021); (Kim, 2021), while one (Singh et al., 2021) indicated that widowed people were more likely to have received vaccination than unmarried. With regard to household composition, findings differed based on the definition of composition across studies and on the associations between participant and county-level data.

3.8. Housing

Among the social determinants of health identified in this review, housing tenure was studied in three studies, two from the US adults (Lindemer, 2021; Singh et al., 2021) and one among adults > 70 years of age in the UK (Nafilyan et al., 2021). In all included studies, the odds of being vaccinated were higher for owners than for renters. With regard to housing type, we identified three studies (Barry et al., 2021; Gharpure et al., 2021; Wang et al., 2021); two of them reported data from the general US population and one from long-term care residents and staff in the US. Barry et al. (Barry et al., 2021), using the housing component of the SVI, indicated higher vaccination coverage in US counties with a higher percentage of housing structures with ≥ 10 units and lower coverage in counties with higher percentages of mobile homes. On the contrary, Gharpure et al. (Gharpure et al., 2021) reported increased vaccine uptake with decreasing SVI quartiles related to housing type among long-term care residents and Wang et al. (Wang et al., 2021) estimated higher rates of vaccination in mobile homes with residents aged 75 and older.

3.9. Urbanicity

The association between urbanicity and vaccination coverage in principle differed depending on whether the study was performed in the US or the UK. Data from the CDC COVID-19 data tracker suggested a better vaccination status in urban areas, with a lower likelihood of vaccination for the residents of rural US counties (RR = 0.96, 95 %CI: 0.96–0.97) (Lindemer, 2021), a direction of association similar to that reported by Murthy et al., also in the US (Murthy et al., 2021). On the contrary, two large studies with data from the UK reported higher vaccination rates in rural areas. According to Perry et al. (Perry et al., 2021), the odds of being vaccinated were lower for individuals over 50 years of age residing in urban areas compared to rural (OR = 0.86, 95% CI: 0.84–0.87), which is similar to the results of Nafilyan et al. for adults over 70 years old (OR = 0.89, 95 %CI: 0.88–0.89) (Nafilyan et al., 2021).

3.10. Disability

Disability was identified as a factor in five studies of this review with ambiguous results (Barry et al., 2021; MacKenna, et al., 2021; Nafilyan et al., 2021; Ryerson et al., 2021; Wang et al., 2021). The largest sample populations were from the UK, where people aged ≥ 70 years old were more likely to be vaccinated if they reported to be a little limited due to disability (OR = 1.08 (1.07–1.08) or a lot limited due to disability (OR = 1.29 (1.28–1.30) (Nafilyan et al., 2021), while among those > 80 years old, 93.6% of the participants with a learning disability were vaccinated (MacKenna, et al., 2021). On the contrary, a population-based study in the US (Ryerson et al., 2021) indicated that participants with disabilities were less likely to be vaccinated (PR = 0.88, p=<0.05), while studies assessing disability at the county level did not identify significant associations (Barry et al., 2021; Wang et al., 2021).

3.11. Health insurance

Among the social determinants of health identified in this review, health insurance was analysed in three US studies (Lindemer, 2021; Singh et al., 2021; Sun and Monnat, 2021) (Online Supplementary Appendix C). Based on the study of Singh et al. (Singh et al., 2021), the odds of being vaccinated were significantly lower for participants that didn't have insurance (OR = 0.59, p=<0.05). Similarly, Lindemer et al. (Lindemer, 2021) showed that the odds of being vaccinated were significantly lower for uninsured adults [OR = 0.74 (0.74–0.74), p=<0.001)] and children [OR = 0.79 (0.79–0.79), p=<0.001]. Finally, Sun et al. (Sun and Monnat, 2021) using county-level data did not identify a significant difference in vaccination status between insured and uninsured adults.

4. Discussion

This systematic review aimed to examine the relationship between social determinants of health and vaccine uptake for SARS-CoV-2 vaccines in the first phase of the vaccination programs. Our findings indicated significant differences in vaccine uptake by almost all factors assessed within the context of this review, including but not limited to age, ethnicity/minority status, income, indexes of social deprivation, marital status, health insurance, housing, employment, and disability. Notably, many of the groups with the lowest rates of COVID-19 vaccine uptake, are also the groups that have been disproportionately affected by the pandemic, with increased morbidity and mortality – further highlighting the significance of vaccine acceptance and uptake among these population subgroups (Mena et al., 2021; Elliott et al., 2021; Gross et al., 2020; Mackey et al., 2021).

With regard to age, most findings showed a high vaccination coverage in individuals at the age of ≥ 65 years compared to younger age groups, which reflects the age-based prioritization in the deployment strategies. The studies included in this current review mainly reflect the first 3–4 months after the initiation of the vaccination campaign in late December 2020, when most of the vaccination strategies initially targeted the rapid reduction of severe outcomes, hospitalizations, and deaths from SARS-COV-2 that were predominantly age dependent (Cilloniz et al.,). Hence, the initial phase focused on high-risk individuals, including older people, care home residents and staff, and front-line healthcare workers (Org 2020). With regard to gender, our results were ambiguous and indicated higher vaccine uptake by males in some studies and by females in others. Previous research on other diseases has indicated that among the general population women had higher odds of being vaccinated compared to men, which could be explained by the fact that women have an increased likelihood of seeking medical assistance, using preventive healthcare services, including other vaccinations, and having better health behaviours (Vaidya et al., 2012; Kopsidas et al.,). Studies also have shown that men are less compliant with personal protective measures for COVID-19 (Mahalik et al., 2022; Vardavas et al., 2020; Sultana et al., 2022; Boutsikari et al.,).

Consistent with our findings, prior analyses of COVID-19 vaccination coverage among the general population by county of residence identified lower vaccination coverage in counties with higher social vulnerability related to socioeconomic status (including income, employment status, and education level) and household composition/disability (including age, single-parent household status, and disability status) but higher vaccination coverage in counties with higher social vulnerability related to racial or ethnic minority status and limited English language fluency (Barry et al., 2021; Gharpure et al., 2021). In our review, indexes of social or community deprivation indicated a strong association between increased community deprivation and reduced vaccine uptake. As for income, lower income was associated with a lower likelihood of vaccination in all the included studies that assessed these parameters.

We also identified that ethnicity was strongly associated with disparities in vaccine uptake. According to the findings of the included studies in the current review, which were predominantly from the US, white individuals were more likely to have been vaccinated compared to other racial and ethnic groups. However, in addition to concerns regarding access to vaccination, an important barrier to vaccine uptake in different racial and ethnic groups was vaccine hesitancy (Hamel, 2020). The lack of diverse ethnical representation in clinical trials (Loomba et al., 2021) may have played a role in the hesitancy among these groups. Racial and ethnic disparities in COVID-19 vaccination shown here are mainly based on US and UK context, and are consistent with similar disparities in flu vaccine uptake showing significantly lower rates of flu vaccination among Hispanics, Black individuals, and American Indians/Alaska Natives compared to Asians and non-Hispanic Whites (Control, 2021).

It is important to note that, within the included studies, migrant status was not reported as a variable and hence ethnicity should be interpreted as the ethnicity of origin that does not necessarily reflect recent migratory status. Specifically for migrant populations in the EU/EEA, evidence shows that some migrant communities may be at increased risk of exposure to SARS-CoV-2, as well as infection with it, and are disproportionately represented in cases, hospitalisations, and deaths (Control, 2021). Also in Europe, some migrant sub-populations have lower coverage of routine vaccination, and higher rates of hesitancy towards vaccination compared with the general population (Control, 2021) (Crawshaw, et al., 2021). Region of birth has also shown to be significantly associated with vaccination coverage for COVID-19 (Martin et al., 2021; Folkhalsomyndigheten, 2022).

While the studies included in this systematic review report for vaccine uptake of at least one dose, it is interesting to note that these differences also persist with uptake of two doses of the vaccine. Notably, the COVID-19 health inequalities monitoring for England (CHIME) tool, including data up to March 2022, indicate a large gap uptake of two doses of the vaccine related to ethnic group, housing status and deprivation quintile (most deprived 78.9% vs. 92.7% for least deprived) (COVID-19 Health Inequalities Monitoring for England (CHIME) tool, 2022). Moreover, currently, there is a continued sub-optimal uptake of the second and subsequent booster doses in the European setting related to social determinants of health, as observed in the UK among elementary trade workers and manual workers (Office for National Statistics - Public Health Data Asset and Coronavirus, 2022) and to country of birth, as observed in Sweden. In Sweden, the uptake for non-Swedish-born citizens of all age categories increased more rapidly than for Swedish-born individuals in the later phases of the rollout, indicating a catch-up effect. However, the uptake of the second dose and of subsequent booster doses continued to be lower among non-Swedish born individuals of all ages indicating the importance of social determinants in all phases of the COVID-19 vaccine deployment (Folkhalsomyndigheten, 2022).

5. Strengths and limitations

Our systematic review has a number of strengths, including the systematic approach to study identification, data extraction, and quality appraisal. Some limitations should, however, be acknowledged. This systematic review mainly identified studies from the US, and hence the results here may not reflect the associations identified in other areas of the globe or be relevant to the European context. Moreover, included studies adjusted for important confounders such as age, yet there is a probability that not all factors related to priority groups for vaccination could be accounted for; hence associations require further assessment. Also, significant heterogeneity was noted with regard to population characteristics, sample sizes, methodology and outcomes which did not allow for a meaningful *meta*-analysis. As most of the included studies reflect the first months after the release of the COVID-19 vaccine, they reflect the prioritization strategies used at that time point that targeted specific population groups and thus impacted vaccine uptake (Control, 2022). Furthermore, due to the time lag between data extraction and manuscript publication, it is likely that additional studies have been published that may possibly alter the association of some of the identified analyses, although the addition of pre-print literature may have mitigated to some extent this time lag. Finally, as some of the studies used county-level estimates it is possible that these factors may vary within large counties and hence only ecological associations can be drawn. These limitations could have an impact on the generalisability of the findings. Future research could also focus on vaccination uptake within the later stages of the COVID-19 pandemic, so as to assess if the socioeconomical determinants that were associated with vaccination uptake differ between initial vaccination and vaccination later on within the COVID-19 pandemic. However, this review provides an overview of the factors associated with the initial vaccination uptake within the context of an emergency public health response and can be used by policymakers when designing roll out strategies in future respiratory pandemics.

6. Conclusion

This review provides evidence of the association between vaccine uptake for SARS-CoV-2 and multiple socioeconomic factors including income, poverty, deprivation, ethnicity, education, and health insurance. This evidence needs to be taken into account to protect socially and medically vulnerable groups and reduce disparities in vaccine uptake within the context of possible emerging variants of concern and future respiratory pandemics. The results of this analysis could provide healthcare professionals with guidance for addressing vaccination inequity among individuals as the significance of social variables in ensuring equitable healthcare delivery is increasingly recognised. While further corroboration is needed to explore the generalisability of these findings across the European setting, these results confirmed the need for an integrated approach to understand the drivers of sub-optimal vaccine acceptance and uptake in a given population and to develop targeted interventions to address these early on.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Contributions

CV, JLB, CD, and JES designed the study. KN and KA undertook the literature review and extracted the data with help from CV. JLB and RP developed the search code and performed the search. CV, KN, IL, VV, and KA analysed and interpreted the data. EF, CD, TN, and JES participated in data interpretation along with CV, JLB, RP, KN, KZ, KA, AK, ES, VV, VM and IL. CV and KN prepared the first draft of the manuscript with input from all authors with further revisions by VM. All authors reviewed and revised subsequent drafts and approved the final text.

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Data sharing statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2023.102319.

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