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Review

Categorising interventions to enhance vaccine uptake or reduce vaccine hesitancy in the United Kingdom: A systematic review and *meta*-analysis

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A B S T R A C T

Background: Vaccination is one of the most important public health interventions to combat infectious disease. However, vaccine hesitancy prevents us reaching the global target of vaccine uptake (e.g., 75 % of influenza vaccination in at-risk groups). This review summarises all interventions designed to reduce vaccine hesitancy and increase vaccine uptake for all types of vaccines offered to adults (≥18 years) since 2000, in the United Kingdom (UK).
Methods: PubMed, Cochrane Reviews, CINAHL EBSCO, and Scopus were searched (September 19, 2023). The PRISMA Checklist 2020 was used for quality checking. Data from randomised-controlled trials (RCTs) were analysed with a *meta*-analysis and narrative analysis. In all included studies, a narrative synthesis was undertaken to summarise, evaluate and characterise the reported behaviour change interventions into four categories: organisational-level, public demand, provider-level, and multidimensional interventions. Findings are evaluated based on the MINDSPACE framework to understand the possible psychological mechanisms underpinning the interventions.
Findings: A total of 9,842 articles were identified, 50 met the inclusion criteria. Interventions aimed to boost vaccine uptake or reduce hesitancy of influenza (50 %), COVID-19 (32 %), hepatitis B (6 %), and other vaccines. A *meta*-analysis was conducted for nine RCTs evaluating various interventions impact on vaccine uptake. The pooled effect was statistically significant (OR with 95 % CI = 1.23 [1.07 to 1.41]). Providing certain and understandable information and using a reminder system with personal messages or letters were the most frequently documented and effective interventions to enhance public demand (enhance information salience). Organisational level interventions intended to make vaccinations more accessible (e.g., providing vaccination at alternative places or times). Provider-oriented interventions encouraged healthcare workers to focus on reducing vaccine hesitancy or enhancing vaccine uptake.
Interpretation: Among the main MINDSPACE techniques, enhancing the salience of vaccine information and priming vaccination by improving access were identified as the most applied and effective interventions in the UK.

1. Introduction

The last COVID-19 pandemic served as a reminder that vaccination is one of the most important public health interventions to combat epidemics or pandemics [1]. Vaccination averts an estimated 4.4 million deaths annually [2]. However, vaccine coverage for vaccine-preventable illnesses (e.g., polio and measles for children, pneumococcus for adults), is remaining constant or declining globally [3–6]. In England, the cumulative influenza vaccine uptake in General Practice (GP) registered patients aged 6 months to under 65 years in one or more clinical risk groups was 49.1 % compared with 52.9 % in 2021 to 2022 (a 3.8 %-point decrease compared with the previous season) [7].

Immunisation programmes tend to focus on childhood vaccination due to children disproportionally affected by vaccine-preventable diseases. However, the COVID-19 pandemic showed that infectious diseases can have significant effects on adult life quality, morbidity and mortality [8]. Additionally, aging populations have increased the importance of vaccination in older adults [8]. To optimise vaccination policy and programmes for adults and increase vaccination uptake, we will bring together all intervention studies implemented in the United Kingdom (UK, including England, Scotland, Wales and Northern Ireland). In the UK, influenza "flu" (every year), pneumococcal and shingles vaccines are routinely offered to all people aged 65 and over. In pregnancy, influenza and whooping cough (from 16 weeks pregnant) vaccines are offered. In addition, extra vaccines such as MenB, MenACWY, pneumococcal, influenza, shingles, Hepatitis A and B are offered at before 65 for at-risk people [9].Historically there has always been fear, scepticism, and refusal of vaccinations with multiple, complex reasons [10,11]. Some researchers publish studies using insufficient data or inappropriate methods is also an important factor in shaking the trust in vaccines. For example, the case series published by Andrew Wakefield and 12 of his colleagues in 1998 [12] caused people to believe that the measles, mumps, and rubella (MMR) vaccine caused autism in children, and vaccine uptake started to decrease. In February 2010, the

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article was completely retracted by the Lancet because it contained inaccurate information [13]. Hesitancy reasons may also differ depending on the vaccination type and purpose. For example, a person may accept their seasonal influenza vaccine, but reject the COVID-19 vaccine [14]. Interventions have been developed to increase vaccine intention, uptake or reduce hesitancy. These include communication, policy, and educational interventions. Also, incentives (both financial and non-financial), interventions that improve access, and multidimensional interventions [15].

To improve the effectiveness of interventions, we need to understand the theoretical mechanisms of behaviour change [16]. However, how different interventions work (or do not) remains uncertain [17]. For individuals to alter their behaviours, they must first comprehend basic facts about a specific health condition, adopt essential attitudes, learn a set of skills, and have access to required services [17]. Decision-making interventions applied to major health issues (such as providing information about health problems, adopting attitudes, and being given access to appropriate services), are usually relatively cheap and easy to apply. These approaches may deliver results within a relatively short time frame [17].

However, effective, and sustainable behaviour change strategies should include two important elements: 1) an evidence-based policy framework that provides a supportive environment; and 2) an opportunity for people to make decisions that may benefit their health [17]. In reality, interventions are often introduced with no formal analysis of either the target behaviour or the theoretically predicted mechanisms of action [18].

This systematic review aims to identify and examine the results of interventions that aim to promote vaccine intention, uptake and reduce hesitancy among adults (≥18 years) in the UK. The review will also suggest the underpinning psychological mechanism for each intervention using the MINDSPACE framework to establish which approach (or combination) works best [19]. The review focuses on the period since 2000, since that year saw the launch of a new policy to increase influenza vaccination uptake in England, UK [20].

This review will examine all implemented interventions that aim increase vaccine uptake or reduce vaccine hesitancy and examines the possible underpinning psychological mechanisms using the MINDSPACE framework. MINDSPACE is a mnemonic for a checklist for policymakers and stands for *Messenger*, *Incentives*, *Norms*, *Defaults*, *Salience*, *Priming*, *Affect*, *Commitments* and *Ego* (Supplementary Materials, Table 1) [19].

2. Methods

The systematic review was conducted in accordance with the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the PRISMA Checklist 2020 was used for quality checking of the systematic review (Supplementary File 1). Protocol registration (PROSPERO ID: CRD42023451472).

Table 1
Meta Analysis of Randomised Clinical Trials (RCTs) which aim to increase vaccine uptake.

Study	Study Type	Target group-Participants	Vaccine	Intervention	Uptake in intervention group (*n*)	Intervention group total participant (*n*)	Control	Uptake in control group (n)	Control group total participant (n)
Arthur 2002 [27]	RCT	75 years+	Influenza	Offer vaccination during health check administration	505	680	Invitation with personal letter	932	1372
Conner 2017 [28]	RCT	65 years+	Influenza	Beneficence + intention + attitude conditions (QBE survey + sticky note)	1293	1,678	No survey	1290	1,727
Dey 2001 [29]	RCT	HCWs	Influenza	Launch of campaign with posters and letters + visits by PHNs to promote vaccination for HCWs in PHCTs	100	457	Launch of campaign only with posters and letters	83	395
Herrett 2016 [30]	RCT	Aged 18–64 in 'at-risk' groups	Influenza	Posters, letters + text messages to remind vaccination	26,804	51,121	Campaign only with posters and letters (standard arm)	25,939	51,136
Hull 2002 [31]	RCT	Low risk patients aged 65 to 74 years	Influenza	Telephone appointments offered by GP receptionists	328	660	No intervention	288	658
Nuttall 2003 [32]	RCT	65 years+ patients in GP practices	Influenza	Invitation letter + home visits to discuss vaccination	12	30	Invitation letter	8	30
Siriwardena 2002 [33]	RCT	At risk groups aged 65 years+	Influenza	Educational outreach visit in primary care	8281	13,633	No intervention	8451	13,947
Mantzari 2015 [34]	RCT	17- to 18-year-old girls	HPV	Sent modified invitation letters + incentives (First-time invitees)	71	250	Sent standard invitation letters; no incentives	49	250
Weaver 2014 [35]	RCT	Individuals receiving OST	Hepatitis B	Financial incentives with fixed value contingency management (three £10 vouchers)	35	78	No financial incentives	6	67

RCT, Randomised Control Trial; DH, Department of Health; HCW; Healthcare workers; PHCT, Primary healthcare teams; NH, Nursing homes; OST, Opioid substitution therapy; HPV, Human papillomavirus.

2.1. Search strategy

Databases PubMed, Cochrane Reviews, CINAHL EBSCO, and Scopus were searched covering all published studies written in English from May 2000 to September 2023. Backward citation searching was undertaken on all included articles. Searches included keywords relating to vaccination, attitudes and behaviours, intervention, outcome, and country (See Supplementary File 2 for the search strategy). The inclusion and exclusion criteria are described in Supplementary Table 2.

2.2. Article selection

The results from the electronic search were imported into Rayyan [21]. Two researchers (AHK and SS) independently screened titles and abstracts for eligible articles. A third reviewer (KJ) resolved any study inclusion disagreements. The full text of all eligible articles was further assessed by AHK. Co-author SS was consulted for 20 % of the individual articles to double check their eligibility. The reference lists of all studies selected at the full text stage were double checked for missed studies. Finally, third reviewer KJ and co-author TD evaluated the eligibility of the included studies through discussions with AHK.

2.3. Data extraction and risk of bias assessment

Data extraction was conducted by AHK, SS independently evaluated the data extraction to 10 % of the included papers to determine eligibility and check for consistency. Information extracted included the lead author, year of publication, study design (including location), time (data collection), population characteristics, intervention, and outcomes. The final set of included studies underwent independent quality assessment by AHK. SS independently assessed the risk of bias of 10 % of the included papers.

2.4. Data synthesis and analysis

A *meta*-analysis was conducted using STATA version SE 18.0 studio for randomised control trial (RCT) interventions that aimed to increase vaccine uptake. The odds ratios (ORs) and corresponding standard errors (SEs) were computed to assess the differences between intervention and control groups. The *meta*-analysis was conducted using a random-effect model with REML (Restricted Maximum Likelihood) method to assess the effectiveness of intervention on outcome across different populations (e.g., people aged 65 + or healthcare workers). Funnel plots were used to evaluate publication bias and selective reporting bias. Heterogeneity between studies was assessed using T^2 and the I^2 statistics [22,23]. T^2 offers an assessment of absolute heterogeneity. As T^2 increases, it indicates a rise in observed variance or a decrease in variance within studies. I^2 is a measure of relative heterogeneity [22]. The I^2 test shows heterogeneity as low (I^2 was $\leq$ 40 %), moderate (I^2 > 40 % to < 60 %), and high (I^2 > 60 %) [23]. Sensitivity analyses were conducted to evaluate the robustness of the results to variations in age groups and vaccine types.

All included articles were categorised using the conceptual mapping model in four main groups based on the type of implemented intervention [24–26]; 1) organisational-level interventions (e.g., enhance access); 2) recipient-oriented interventions (aimed at increasing public demand); 3) provider-oriented interventions; and 4) multidimensional interventions (articles including a mixture of organisational-level, recipient, and provider-oriented interventions).

A narrative synthesis was undertaken to evaluate and characterise interventions based on those deemed most effective at promoting vaccine acceptance or reducing vaccine hesitancy. Intervention content was extracted from each study and summarised.

The MINDSPACE framework [19] was used by AHK (with consultation with KJ and TD) to categorise types of interventions and to identify underpinning mechanisms across the studies. The outcomes of each study were evaluated as to whether the intervention would have had an impact on vaccination behaviour, no impact on vaccination behaviour or no statistically significant change (Supplementary Tables 3 and 4). Interventions were also grouped according to vaccine types such as influenza, COVID-19, Hepatitis B (Supplementary Table 5).

3. Results

In total, 9,842 articles were identified from the electronic search. Title and abstract screening determined 98 individual articles for full text review. Of these, 44 were eligible for inclusion. In addition, we searched reference lists of published reviews and identified a further 6 eligible studies, making a total of 50 (See Fig. 1).

3.1. Characteristics of included studies

In order of frequency, studies examined vaccination for influenza (n = 25, 50 %), COVID-19 (n = 16, 32 %), hepatitis B (n = 3, 6 %), not specified vaccine (participants' future intention to vaccinate was examined after receiving financial incentives and information on the benefits of vaccination) (n = 2, 4 %), human papilloma virus (n = 1, 2 %), whooping cough (n = 1, 2 %), avian influenza (n = 1, 2 %), and multiple conditions (n = 1, 2 %). Thirty-nine studies focused on enhancing vaccine uptake [27–56,59,63,66,69–71,73–75], while ten studies aimed to increase vaccine intention [43,44,57,58,61,62,64,65,68,72]. One study aimed to improve vaccine confidence [67]. See Supplementary Tables 3 and 4 for detailed characteristics of the 50 included studies.

Supplementary Figure 1 shows the number of included studies to this review by vaccine types between 2000 and 2020. After the COVID-19 pandemic in 2020, promoting uptake of this vaccine became a more pressing public health problem than influenza.

3.2. Risk of bias

The Joanna Briggs Institute (JBI) critical appraisal tools for RCTs (n = 12), non-randomised experimental (n = 23), cohort (n = 6), cross-sectional (n = 6), and qualitative studies (n = 3) was used [76]. According to the summary score, four studies were rated as high (8 %), 38 as moderate (76 %), and eight as low quality (16 %) (See Supplementary File 3).

3.3. Main findings

A *meta*-analysis was conducted for nine RCTs evaluating the impact of different interventions on vaccine uptake [27–35] (Summarised in Table 1). The pooled effect was statistically significant (OR with 95 % CI = 1.23 [1.07 to 1.41]). However, high heterogeneity was observed across all the studies (T^2 = 0.03, I^2 = 94.90 %, p = 0.01). The forest plot is represented in Fig. 2. This study may exhibit potential publication bias due to the limited number of RCTs and heterogeneity among the included studies. This bias is indicated by the asymmetric results observed in the funnel plot (Supplementary Figure 2).

3.4. Sensitivity analysis

A sensitivity analysis highlighted the variable impact of interventions across different participant groups, emphasizing the importance of population-specific factors in vaccination strategies. Based on the sensitivity analysis conducted using a random-effects model for population groups, the estimated amount of total heterogeneity (τ^2) was 0.1388 (SE = 0.7933), indicating a moderate heterogeneity among the studies, with the low variability (I^2 = 6.10 %), suggesting that the results are robust across different population groups. Overall, the association between vaccine uptake and populations was statistically significant (OR = 0.9915; 95 % Cl [0.0619 to 1.9210],

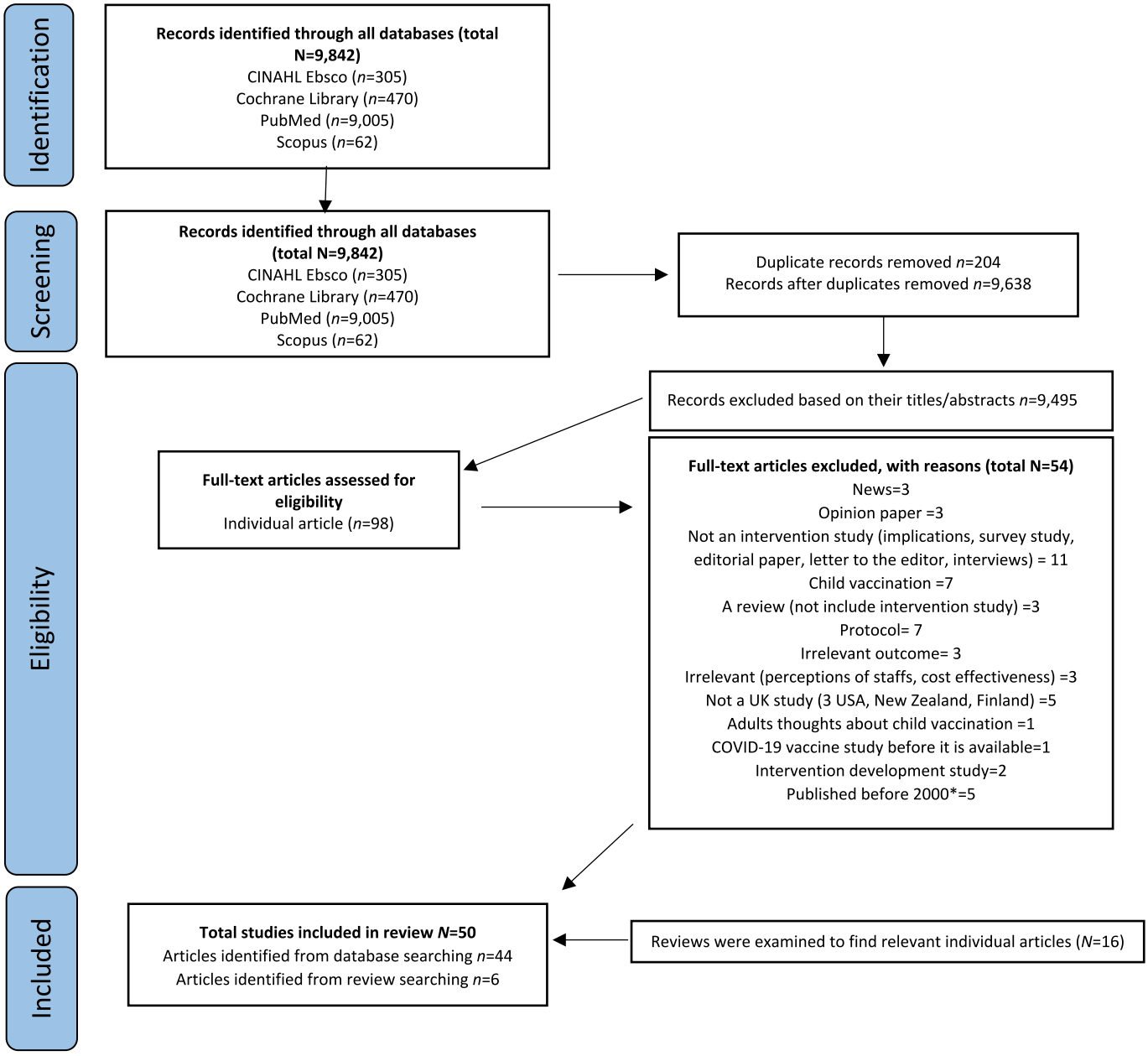

Fig. 1. Searches according to PRISMA 19.09.23 The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

$p = 0.0366$).

A significant increase in vaccine uptake was observed for individuals aged 75+ ($p < 0.0001$), 65+ ($p = 0.0100$), and 18 to 64 in 'at-risk' groups ($p < 0.0001$), low-risk patients aged 65 to 74 ($p = 0.0147$), 17- to 18-year-olds ($p = 0.0182$), and individuals receiving opioid substitution therapy ($p < 0.0001$). However, no significant effects were observed among healthcare workers ($p = 0.7525$) and at-risk groups aged 65+ ($p = 0.7506$).

Based on a sensitivity analysis using a random-effect model including data from the nine studies for vaccine types, substantial heterogeneity was observed among studies ($\tau\hat{}2 = 5.1584$ (SE = 2.6105), $I^2 = 99.97\,\%$), indicating significant variability. The overall effect size (OR = 2.0443, $p = 0.0073$) for vaccine types was statistically significant, suggesting a substantial impact of vaccine type on vaccine uptake.

3.5. Narrative synthesis

The included studies first were divided into two groups: studies that reduced vaccine hesitancy and studies that increased vaccine uptake. All studies were summarised into four main groups; 1) organisational-level (e.g., enhance access) ($n = 6$) [31,51–55]; 2) recipient-oriented (aimed at increasing public demand) ($n = 23$) [28–30,32,33,35,56–72]; 3) provider-oriented interventions ($n = 4$) [20,73–75] (Table 2); and 4) multidimensional (mix of organisational-level, recipient-oriented, and provider-oriented interventions) ($n = 17$, Table 3) [27,34,36–50]. All the interventions were assessed with the MINDSPACE Framework [Adapted from the Centers for Disease Control and Prevention (CDC)] [77].

3.6. Vaccine hesitancy

Ten non-RCT studies aimed to increase vaccine intention [43,44,57,58,61,62,64,65,68,72] and one increased confidence about vaccination [67]. In eight studies only recipient-oriented interventions were employed to increase vaccine intention [57,58,61,62,64,65,68,72]. Two multidimensional studies were

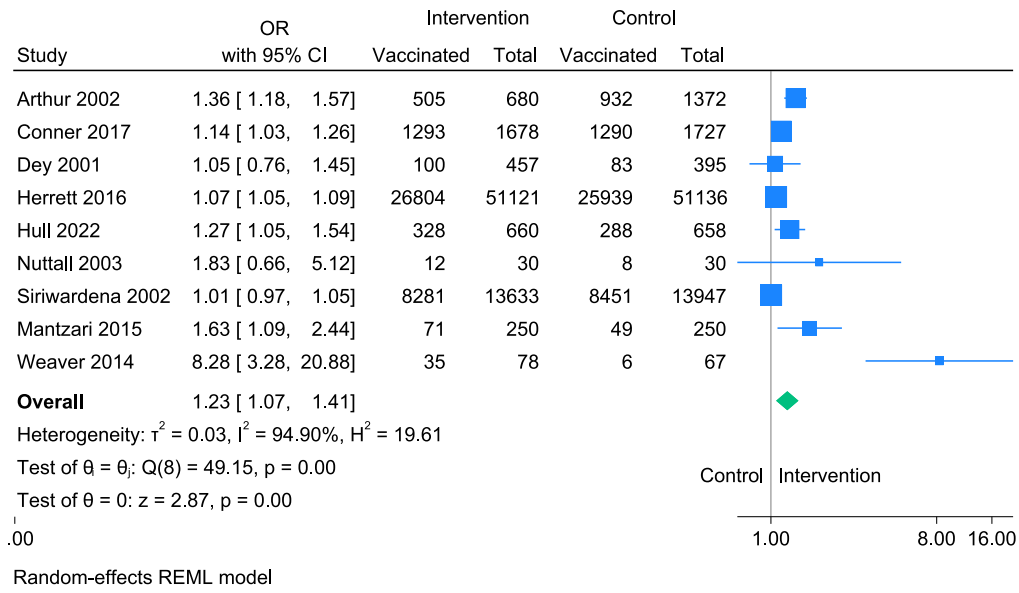

Fig. 2. Meta Analysis of Randomised Clinical Trials (RCTs) which aim to increase vaccine uptake.

implemented to reduce vaccine hesitancy [43,44]. One of them applied the organisational, recipient and provider-oriented interventions [44], and the other performed the recipient and provider-oriented interventions [43].

In total, twelve interventions were implemented to reduce vaccine hesitancy. Two interventions at the organisational level: Providing vaccination services at alternative, nontraditional sites [44] and setting targets and monitoring uptake [44]; six at the recipient-oriented level: Clinic-based HCW education [44], engagement and communication [43], providing community-wide information [64,65,67,68], information framing (negatively or positively) [61], providing non-financial incentives [72], and clinic-based population education [57,58,62]; and four at the provider-oriented level: Award the HCWs or services [44], personal motivators and attitudes of staff [43], choosing familiar HCWs for vaccination [43], and provider education and recommendation [44].

A study showed providing written information about the personal benefits of vaccination was the most effective in reducing COVID-19 vaccine hesitancy ($p = 0.0002$) [57]. Knowing the social benefits of vaccination (e.g., to provide herd immunity) significantly increased intention to have the COVID-19 vaccination ($p = 0.003$) [58]. Assigning healthcare professionals from minority ethnic and social groups to members of their respective communities reduced COVID-19 vaccine hesitancy [43].

Delivering vaccine-related information by trusted messengers such as expert scientists or vaccinated family members improved negative attitudes towards vaccination and reduced health inequalities as much as submitting clear messages to reduce vaccine hesitancy [44]. Additionally, whereas standard negative framing (e.g., the side effects may affect up to 1 in 10 people) appeared to increase intentions for familiar COVID-19 vaccines at low baseline intent, positive framing (e.g., 9 in 10 or fewer people may not be affected by side effects) was found to improve vaccine intention for unfamiliar COVID-19 vaccines but decreased intention for familiar vaccines [61].

3.7. Vaccination uptake

1. Organisational level interventions (Enhanced vaccine access)

In six studies only organisational-level interventions were employed to increase vaccine uptake [31,51–55], while in fourteen multidimensional studies implemented organisational-level interventions to enhance vaccine uptake [27,36–42,45–50]. Seven interventions were implemented to enhance vaccine access. Organisational level interventions included measures to ensure adequate vaccine supply, extending office hours, taking opportunities to give vaccines whenever possible, use of vaccine-only clinics or novel settings, setting and monitoring targets, and supporting vaccination providers.

The interventions primed vaccination uptake by enhancing accessibility and convenience and showed evidence of effectiveness by increasing vaccination rates [19]. Providing vaccination opportunistically at all visit types, to not miss people unable to visit the health facilities only for vaccination, was effective [27,39,45,51]. However, only in one study, it statistically significantly increased vaccine coverage from 67.9 % to 74.3 % in a local primary care area ($p = 0.003$) [27].

Providing vaccine-only clinics to target specific populations (e.g., women in antenatal clinics) was effective in raising the vaccination number higher than the national or regional average, yet it was not reported whether they were statistically significant [39,40,52]. Simple strategies such as providing organisations with new computers, and/or IT systems to support the vaccination process were found to be effective in two studies [48,49]. Notably, offering vaccination by community pharmacists (CPs) across Wales significantly enhanced influenza vaccine uptake in the under-65 age group ($p < 0.01$) [53]. Moreover, ad hoc services for prisoners [adjusted OR: 3.7 (95 % CI 3.2–4.3)] [54] and homeless drug users (versus hepatitis B) ($p < 0.0001$) [55] significantly increased vaccination rates.

2. Recipient-oriented interventions to increase public demand for vaccination

In 14 studies, only recipient-oriented interventions were employed to increase vaccine uptake [28–30,32,33,35,56,59,60,63,66,69–71]. Fifteen multidimensional studies implemented recipient-oriented interventions to enhance vaccine uptake [27,34,36–42,45–50]. Eight interventions were implemented to increase public demand for vaccination. Interventions included providing clinic-based education for public and healthcare workers, delivering certain, understandable, and reachable information, using vaccination reminder systems, providing incentives (financial or non-financial), increasing informative and honest communication with target groups, using positively (e.g., 9 in 10 or fewer people may not be affected by side effects) or negatively (e.g., the side effects may affect up to 1 in 10 people) framed information. The recipient-oriented interventions aimed to make vaccination information

Table 2
Interventions to increase intention or vaccination coverage with MINDSPACE Framework [.

Interventions to increase intention or vaccination coverage	Description	References	Author implications with the MINDSPACE Framework
Organisational level interventions (enhanced vaccine access)			
—Provide vaccine supply	Providing enough vaccines for the population targeted to be vaccinated	[36,40]	Priming
—Extend office hours	Increase or make more convenient the hours during which vaccination services are provided	[36,37]	Priming
—Vaccinate at all visit types "Immunise at Every Opportunity"	Assess patient need for vaccination at all types of healthcare visits, including routine visits, sick and follow-up visits, and during hospitalisation	[51]	Norms
—Vaccine-only clinics	Reduce waiting time/need to make an appointment to obtain vaccination through vaccination-only services	[52]	Priming
—Provide vaccination services at alternative, nontraditional sites	Deliver vaccinations in settings in which they were not previously provided including offering vaccination by CPs, accelerated schedules	[31,53–55]	Priming
—Setting target and monitoring uptake	Defining eligible people for vaccination and monitoring vaccine uptake including producing a written report to review vaccine uptake rates	[38,42]	Incentives Setting target and monitoring the outcome is crucial because of the reference points matter for HCWs and public to be transparent.
—Support vaccination organisations	Providing new computers, and IT systems to support vaccination process	[48,49]	Priming
Recipient-oriented interventions to increase public demand for vaccinations			
—Clinic-based population education	Provide information regarding vaccination to target patients served in a specific medical or public health clinical setting; techniques include mass mailings, workshops, posters, booklets, surveys, home visits	[28,29,32,33,56,57,58,62]	Salience
—Clinic-based HCW education	Provide information regarding vaccination to target HCWs worked in a specific medical or public health clinical setting; techniques include mass mailings, workshops, posters, booklets, surveys, and public health nurse visits	[44]	Salience
—Providing community-wide information	Deliver certain and understandable information regarding vaccination to a target population; techniques include media campaign (television, radio, newspapers, posters, leaflets, booklets, websites), and computer-based programs	[63–65,67,68]	Salience
—Engagement and communication	Communicating about social benefits, and herd immunity	[66]	Norms
—Framing	Positively or negatively frame information	[59,61]	Commitment/ Change the way outcomes are framed, show people the short-term benefits of vaccination rather than long term, e.g., positive framing, health-enhancing messages, negative framing, risk-reducing messages.
—Patient reminder/recall systems	Send alerts that vaccinations are due (reminders) or late (recall) to patients; delivery techniques include telephone calls, personal invitation letters, postcards, and e-mails	[30,32,69–71]	Salience
—Provide incentives	Provide financial incentives including reimbursement of vaccination, the cost of travel, lottery	[35]	Incentives
	Provide non-financial incentives including vaccine passport and vaccinate trusted people, choosing important people to offer vaccine (e.g., politicians, celebrities)	[60,72]	Incentives
—Assessment and feedback for vaccination process	Give chance to vaccinated people to assess vaccination processes	[49,50]	Norms
Provider-oriented interventions			
—Staffing	Have a lead member of staff for planning the practice's vaccination campaign	[40]	Priming
—Personal motivators and attitudes of staff	Assign staff who have positive attitudes and motivations towards being vaccinated (e.g., already vaccinated staff)	[43]	Messenger
—Incentives for vaccine providers	Provide incentives such as refreshments	[73,74]	Incentives
—Choosing familiar HCWs for vaccination	Perform vaccination by trusted HCWs for public or the other HCWs (i.e., peer vaccination)	[48]	Messenger
—Provider education and recommendation	Provide information to vaccination providers to increase their knowledge or change attitudes e.g., written materials, videos, lectures, continuing medical education programs, and computer-based learning programs	[20,75]	Salience
—Award the HCWs or services	Give championship, staff vaccination championships	[44]	Ego
—Encouragement for effective leadership	Encourage immediate line managers to lead in encouraging their staff to take the vaccines and arrange for them to get vaccinated; encourage managers to promote positive messages and encourage staff to attend clinics; have senior clinicians acting as champions; have 'respected' staff publicly immunised; and make sure the campaign was added to local Governance agendas.	[45]	Messenger

CP, Community pharmacist; HCW, healthcare worker; The MINDSPACE Framework [19].
Adapted from the Centers for Disease Control and Prevention (CDC)] [77]

Table 3
Multidimensional interventions with MINDSPACE Framework [.

Study	Organisational level interventions (enhanced vaccine access)	Recipient-oriented interventions to increase public demand for vaccinations	Provider-oriented interventions	Author implications with the MINDSPACE Framework
Arthur et al., 2002 [27]	—Vaccinate at all visit types"Immunise at Every Opportunity"	—Patient reminder/recall systems		Norms Salience
Aziz 2013 [36]	—Provide vaccine supply—Extend office hours—Provide vaccination services at alternative, nontraditional sites—Setting target and monitoring uptake	—Clinic-based HCW education—Providing community-wide information—Patient reminder/recall systems	—Provider education and recommendation—Award the HCWs or services—Encouragement for effective leadership	Messenger Incentives Salience Priming Ego
Berrou et al., 2022 [37]	—Extend office hours—Provide vaccination services at alternative, nontraditional sites	—Engagement and communication		Norms Priming
Blank et al., 2018 [38]	—Setting target and monitoring uptake	—Providing community-wide information—Framing—Provide incentives		Incentives Salience Commitment
Dalton 2022 [39]	—Vaccinate at all visit types"Immunise at Every Opportunity"—Provide vaccination services at alternative, nontraditional sites	—Engagement and communication		Norms Priming
Dexter et al., 2012 [40]	—Provide vaccine supply—Extend office hours—Vaccine-only clinics—Setting target and monitoring uptake	—Clinic-based population education—Patient reminder/recall systems—Provide incentives	—Staffing—Personal motivators and attitudes of staff	Messengers Incentives Salience Priming
Edelstein and Pebody 2014 [41]	—Extend office hours—Provide vaccination services at alternative, nontraditional sites	—Clinic-based population education—Patient reminder/recall systems	—Incentives for vaccine providers—Choosing familiar HCWs for vaccination—Award the HCWs or services	Messengers Incentives Salience Priming Ego
Giles et al., 2016 [42]	—Setting target and monitoring uptake	—Clinic-based population education	—Provide incentives	Incentives Salience
Hashim and Taha 2023 [43]		—Clinic-based population education—Engagement and communication	—Choosing familiar HCWs for vaccination—Personal motivators and attitudes of staff—Award the HCWs or services	Messengers Norms Salience Ego
Mantzari et al., 2015 [34]		—Patient reminder/recall systems—Provide incentives		Incentives Salience
Micallef et al., 2022 [44]	—Provide vaccination services at alternative, nontraditional sites—Setting target and monitoring uptake	—Clinic-based HCW education—Provide incentives	—Provider education and recommendation—Award the HCWs or services	Incentives Salience Priming Ego
Newby et al., 2016 [45]	—Vaccinate at all visit types"Immunise at Every Opportunity"—Setting target and monitoring uptake	—Engagement and communication—Patient reminder/recall systems	—Encouragement for effective leadership	Messenger Incentives Norms Salience
Poulikakos et al., 2022 [46]	—Extend office hours—Setting target and monitoring uptake	—Providing community-wide information—Patient reminder/recall systems		Incentives Salience Priming
Rai and Wood 2018 [47]	—Provide vaccination services at alternative, nontraditional sites—Setting target and monitoring uptake	—Engagement and communication		Messenger Incentives Priming
Stead et al., 2019 [48]	—Extend office hours—Support vaccination organisations	—Engagement and communication	—Incentives for vaccine providers—Choosing familiar HCWs for vaccination—Provider education and recommendation	Messenger Incentives Salience Priming
Taylor 2007 [49]	—Support vaccination organisations	—Clinic-based HCW education—Assessment and feedback for vaccination process	—Provider education and recommendation	Norms Salience Priming
Warner et al., 2013 [50]	—Extend office hours—Provide vaccination services at alternative, nontraditional sites	—Clinic-based population education—Assessment and feedback for vaccination process	—Incentives for vaccine providers	Incentives Norms Salience Priming

HCW, Healthcare workers. The MINDSPACE Framework [19].
Adapted from the Centers for Disease Control and Prevention (CDC) [77]

more salient and offered incentives to increase demand [19].

3. Provider-oriented interventions

In four studies, only provider-oriented interventions were employed to increase vaccine uptake [20,73–75], while in eight multidimensional studies implemented provider-oriented interventions to enhance vaccine uptake [36,40–42,45,48–50]. Seven interventions targeted vaccine

providers. Utilisation of personal motivators and attitudes of staff, incentives for vaccine providers, choosing familiar healthcare workers for vaccination, provider education, awarding healthcare workers and services, and encouraging effective leadership for rising vaccination were all strategies in this category. The interventions showed the importance of informed and motivated messengers in encouraging people to get vaccinated [19].

Interventions took creative and proactive approaches to target healthcare workers in a specific medical or public health settings. Strategies such as the use of innovative learning tools ("gamification") and pre-post survey assessment was found to significantly increase influenza vaccine knowledge ($p < 0.001$) [75]. Improvements in knowledge increased vaccine uptake in nursing students (36.7 % to 47.8 %) and increased the likelihood they recommended their patients to have the influenza vaccine [75]. Performance-based financial incentives in NHS frontline staff increased influenza vaccination rates from 43 % to 74 % (baseline rate 9 %–31 %) and produced significant threshold effects ($p < 0.001$) [74].

4. Multidimensional interventions

As mentioned above, fifteen studies examined the impact of multiple interventions on vaccination uptake [27,34,36–42,45–50]. The studies showed a significantly positive effect on vaccination behaviours by addressing various sides of behaviour change. For example, in one study, while enhancing vaccine access by providing adequate vaccine supply (priming), offering vaccinations during extended hours (priming), and at alternative, non-traditional sites (priming), and setting targets and monitoring vaccine uptake (incentives) [36], the study also included interventions to increase public demand through clinic-based population education (salience), reminders of vaccination due dates (salience), and incentives for the vaccinated public (incentives) [36]. Additionally, the study included interventions to increase the effectiveness of vaccine providers through education (salience), assigned personnel trained on vaccination (messenger), and awarded healthcare workers or services to increase vaccine uptake efforts (ego) [29]. Thus, studies on multidimensional interventions achieved increased vaccination by simultaneously targeting multiple elements included in the MINDSPACE Framework [19]. These studies highlighted the importance of a comprehensive, multidimensional approach to vaccination campaigns (Table 3).

4. Discussion

To the best of our knowledge, this is the first systematic review and *meta*-analysis to summarise the evidence for implemented interventions that aim to increase vaccine uptake and reduce hesitancy in a UK population. This is the first review to use the MINDSPACE framework [19] to understand how the interventions work. Interventions from 50 individual studies were summarised in this review. Meta-analytic results of nine RCTs showed mixed results. Interventions such as text message reminders significantly increased vaccine uptake [30]. However, educational outreach visits and financial incentives were not significant [33,35]. Multidimensional interventions combining organisational, provider, and recipient-focused strategies were the most effective for improving vaccination rates and reducing hesitancy. However, universal interventions may not be effective for all populations.

We found multidimensional intervention studies (organisational-level, recipient-oriented, and provider-oriented interventions) are frequently applied and effective in increasing vaccine uptake. This might be explained by Normalisation Process Theory [78]. NPT suggests all stakeholders (healthcare workers, public health professionals, public, patients, managers, and policymakers) should be included in the design and implementation processes of intervention programmes to help them become normalised into practice [78].

Some studies examined vaccination intention as the outcome measure. Though intention is important, the well-established "intention-behaviour gap" should be considered [79]. That is, although a person may intend to change a health behaviour, they may not make that change [79]. For example, a study comparing the association between influenza vaccine intention and completion found intention was translated into action approximately 51 % of the time [80]. Likewise, in studies exploring HPV vaccination intention and vaccination rate, only 38–57 % of parents who reported intention actually initiated vaccination [81,82].

Organisational-level interventions that enhanced vaccine access were crucial. Making vaccination available and convenient was associated with increased uptake. For example, involving community pharmacists into the vaccination process (after 2012) increased numbers of influenza vaccinations, which benefitted patients in all at-risk groups. This reinforces the valuable role of pharmacists in providing access to vaccination [53]. Providing services through vaccine-only clinics, extended office hours, and opportunistic vaccination at all healthcare visits nudged people to action, and removed barriers [36,37,51,52]. Supporting healthcare organisations through adequate vaccine supply, IT systems, and monitoring was also effective [48,49].

Monitoring systems help target under-vaccinated groups. We suggest these interventions prime people for vaccination by simplifying the process and making it 'default' [19]. However, opportunistic vaccination interventions may not always work because of socio-organisational reasons. For example, healthcare worker shortages, time constraints and patient preferences. Patients may only want to focus on their current issue rather than thinking about vaccination. Or they may need more time to decide. Therefore, public, patient, and policymakers' involvement to a project design process is crucial to make a programme effective and sustainable [78].

The most common type of intervention identified in this review (40 studies) aimed to increase public demand for vaccination. A simple intervention such as receiving a personalised vaccine invitation by letter may significantly increase vaccine coverage rate if the intervention targets a specific population (e.g., people with coeliac disease, or aged 18–64 in an 'at-risk' group) [30,70]. Although paper-based letters, posters, and flyers are still effective strategies to invite people to have a vaccination or increase their awareness [42,46,69,70], in the early 2000 s traditional methods such as letters and flyers were the only options [27,32,36,71]. Since 2010, there has been notable shift towards digital strategies such as text messages [30,34,41], websites [41,44,58], social media [41], and digital (animation) interventions [62]. This transition highlights the evolution in communication methods aimed at promoting vaccination. Taylor's (2007) study exemplifies how digitizing patient records and upgrading computer systems can boost the success of influenza vaccination programs [49].

Communicating personal benefits of vaccination and emphasising social benefits such as herd immunity for COVID-19 were linked to greater intention to get vaccinated [57]. Dealing with vaccine hesitancy can become even more complicated in vaccines that require multiple doses (i.e., a booster dose). For example, side effects from the first vaccination may cause people not to complete the course [10]. Providing clear and honest information through open communication about the possible side effects, the impact, and the effectiveness of the vaccine may be useful in preventing vaccine hesitancy in people who require a booster dose [83]. Underpinning mechanisms may be enhanced salience of information and presenting vaccination as the norm [19,57]. Invoking social norms (showing what others do and why) significantly increased intention to get vaccinated [57]. This is because people can be strongly influenced by others' decisions [19]. We found increasing community trust (through messengers) successfully helps reach underserved groups [19]. Reinforcing social benefits of vaccination may also shift commitments and norms [19,30,74].

Governments should be aware that people will be hesitant for different reasons [10,19]. For example, the vaccine hesitancy reasons of older people and pregnant women may not be the same. Unlike other

groups, interventions for pregnant women should explain the effect of the vaccine on the baby in an accessible way, and plan to administer the vaccination in the appropriate trimester [62]. We found tailored messaging from trusted sources reduced hesitancy, which highlights the importance of the messenger [19,40,60,72]. Meanwhile, governments should be careful to implement compulsory vaccination interventions such as requesting vaccine passports to travel, because mandatory interventions may have counterproductive effects [72,84]. For example, it was found that vaccine passports were perceived less positively in socio-demographic groups who live in large urban areas [72].

We have shown in this review that educating and engaging healthcare providers increases both provider and patient vaccination rates [50]. Findings are consistent with NPT, normalisation of a behaviour requires a whole system change rather than focusing only on the public or patients [78]. Incentives (financial and non-financial) can provide further motivation to promote and deliver vaccinations because people gain something [19]. However, there is a risk for that if the incentives are eliminated, vaccination providers may stop expending effort in increasing vaccine uptake. Additionally, giving championships or awards to healthcare workers or services for making effort to increase vaccination was significantly effective [36,41,44]. We suggest educating and incentivising healthcare providers can increase vaccination rate by leveraging behavioural science insights (salience and incentives). Incentives, feedback, and awards can boost the credibility of messengers, satisfy their ego, foster favourable vaccination norms, and elevate healthcare workers' motivation and capability in vaccine promotion [19].

In sum, findings highlight the complexity of vaccine decision-making and the need for multi-faceted approaches as well as the importance of patient and participant involvement work to deeply understand the reasons of health-behaviours in different groups (who may require tailored, not universal, intervention).

4.1. Gaps in knowledge and future directions

Only one study examined vaccination rates in mental health services, finding an influenza vaccination rate of 54.64 % in 2017 [48]. Additionally, one study aimed to reach underrepresented groups using tailored strategies to improve vaccination rates of the COVID-19 vaccine [37]. The study demonstrated that addressing vaccine access issues with pop-up clinics and mitigating any COVID-19 vaccine concerns with quality engagement and communication improved vaccination rates [37]. Moreover, public data for COVID-19 vaccination rate for vulnerable people such as people with dementia has not been calculated in England [85]. The knowledge gap at this point makes it difficult to determine targets and intervention strategies to combat vaccine hesitancy in people living with vulnerabilities including mental illnesses. Further high-quality studies evaluating optimal combinations and implementation strategies for different populations, including vulnerable populations would be beneficial.

If more interventions use text messaging and social media to reach people, we will need a better understanding of how conspiracy theories or myths spread via social media. There is a need to explore empirically if offer different types or brands of vaccines influences vaccine hesitancy or uptake. Finally, more studies need to involve patients and the public in the design of vaccination interventions, especially underrepresented and vulnerable groups. Policymakers should be engaged with the research process to embed successful interventions into the policy agenda. If these issues are not considered in the research design, there is a risk that effective interventions will never be properly implemented. While the World Health Organization influenza vaccination target (75 %) has been reached for last three years in a row in the UK (range from 82.3 % to 79.9 %), the vaccination rate is still well below this target in many countries, including some European countries such as Germany (43.3 %), Italy (58.1 %) and Finland (59.5 %) in the 2022–23 season [86,87]. If the interventions examined in this systematic review are applied in other under vaccinated countries, the vaccination rate can be reached to the desired level in the target populations.

Lastly, *meta*-analytic results show future research needs to address observed heterogeneity and improve vaccination coverage across different demographic groups. Future studies should focus on standardising intervention approaches and outcome measures to facilitate more meaningful comparisons across studies and enhance the generalisability of findings.

4.2. Strengths and Limitations

To our knowledge, this is the first comprehensive systematic review and *meta*-analysis summarising evidence for a wide range of vaccination interventions implemented in the UK. An extensive literature search across four databases was conducted with reference lists of defined reviews checked to identify relevant articles. Study screening, data extraction, and quality assessment were all conducted in duplicate, enhancing reliability. Validated frameworks were used to identify similarities and differences across strategies. This review provides a broad evidence base to inform selection of interventions to improve vaccine uptake in the UK population.

However, this systematic review did not search for factors of vaccine hesitancy. We evaluated studies across a range of interventions and vaccine types such as COVID-19, influenza, Hepatitis B, making comparisons across studies challenging. The heterogeneous interventions and study designs precluded a comprehensive *meta*-analysis, though we were able to pool nine RCTs. There was a potential publication bias due to several factors, including the limited number of RCTs, the heterogeneity among the included studies, and only published studies included. High heterogeneity among the RCTs and publication bias limited the interpretation of findings. To help contextualise findings, we restricted the review to UK only, limiting international generalisability. Finally, the systematic review did not include intervention studies aimed to increase childhood vaccine uptake. Future reviews could replicate our review protocol to examine interventions in other countries.

5. Conclusion

Key strategies to increase vaccine uptake include enhancing vaccine access through organisational-level interventions such as extended office hours and opportunistic vaccination, increasing public demand via recipient-oriented interventions like education and incentives, and improving provider effectiveness through motivators and training. Various intervention strategies, including providing personal and social benefit information, using trusted messengers, and framing messages positively, have proven effective in reducing vaccine hesitancy.

The review highlighted that even organisational-level pragmatic interventions might be adequate to increase vaccine coverage and change both vaccination intention and behaviours rather than applying complex psychological interventions. However, we suggest a combination of enhanced access, patient-focused communication, and strong provider engagement is needed to improve vaccine coverage, especially for vulnerable populations where there is low uptake. Targeted interventions are crucial for improving vaccine uptake, especially among older adults and healthcare workers, while considering the unique characteristics and needs of each population. Making vaccination readily available while promoting benefits to both individuals and society appears most likely to motivate uptake. Healthcare system buy in, and the use of a community approach may increase vaccine acceptance and coverage. However, further research is needed to explore potential underlying factors contributing to variability in vaccine uptake among different populations.

6. Authors' contributions

AHK developed the review protocol with critical input from KJ and

TD. AHK and SS independently screened titles and abstracts for eligible articles. As a third reviewer, KJ resolved any disagreement regarding study inclusion. Second, the full text of all eligible articles was further assessed by reading the full text to determine eligibility for inclusion by AHK. SS has been consulted for 20 % of the individual articles to double check the eligibility. The reference lists of all studies selected at the full text stage was double checked for missed studies by AHK. AHK produced the final manuscript, while KJ, SS and TD critically reviewed the drafts. All authors have read and approved the final manuscript.

CRediT authorship contribution statement

Aysegul Humeyra Kafadar: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Conceptualization. **Serena Sabatini:** Writing – review & editing, Formal analysis. **Katy A. Jones:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis. **Tom Dening:** Writing – review & editing, Writing – original draft, Supervision, Methodology.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Aysegul Humeyra Kafadar reports financial support was provided by Republic of Turkey Ministry of National Education. If there are other authors, they 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

This is a systematic review, the data were obtained from published articles.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2024.06.059.

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