

# **Nudging the Needle: Using Behavioral Intervention to Reduce Vaccine Hesitancy Among Healthcare Providers**

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## **Abstract**

**Background:** Vaccine Hesitancy among healthcare workers (HCWs) remains a critical challenge to public health. These challenges are especially prevalent during periods of infectious disease outbreaks such as COVID-19, HPV, and Influenza. This meta-analysis investigates vaccine hesitancy among HCWs based on various factors, including race, age, and occupational hierarchy within the healthcare environment. This article brings findings from behavioral science, public health, medical ethics, and health systems research together to understand the effectiveness of nudging, a type of behavioral interventions, to improve vaccine uptake. Nudging involves using subtle changes to influence people's decisions in predicted ways, without removing autonomy from the decision-making process.

**Methods:** A systematic literature search was conducted, yielding a final sample of 10 articles consisting of large-scale surveys, randomized control

trials (RCT), and observational studies to understand the determinants of hesitancy and the impact of nudging strategies on mitigating this hesitancy. Nudging techniques analyzed included reminders, default option, social norms, emotional appeal, information framing, and education.

**Findings:** Our meta-analysis demonstrated significant prevalence of vaccine hesitancy among Black and Hispanic/Latino HCWs as well as ancillary or non-medical staff in the occupational hierarchy. Vaccine hesitancy among HCWs was mainly due to concern of potential side effects, distrust towards the effectiveness of vaccines, and misinformation about the vaccine. Evidence revealed that reminders, default-setting interventions, and social norm interventions were the most effective nudging techniques to increase vaccination. Overall, findings suggest that using situationally adapted behavioral intervention strategies can effectively reduce vaccine hesitancy among HCWs, encouraging an increase in the uptake of vaccines via a relatively inexpensive, scalable approach.

## **Introduction**

The World Health Organization (WHO) characterizes vaccine hesitancy as one of the top 10 threats to global health (Terrell et al., 2012). Vaccination behavior is often determined by three main factors: individual's views about

vaccines and disease, social networks, and interventions that directly impact behavior without altering an individual's beliefs (Bewer, 2021). Vaccine hesitancy is defined as not planning on, being unsure about, or planning to delay vaccination (Momplaisir et al., 2021). Research has found that reasons why individuals may delay or refuse vaccination include reduced vaccine availability or accessibility, poor health literacy, difficulty or inconvenience scheduling a vaccination appointment, fear of adverse effects to the vaccine, mistrust of health authorities and providers, and personal or religious beliefs (Terrell et al., 2012). Vaccine hesitancy poses threats to the success of vaccination programs since the effectiveness of vaccines is limited by the rate of vaccine uptake by populations (Terrell et al., 2012).

The Center for Disease Control (CDC) urges healthcare workers to get vaccinated to protect themselves, in addition to their family and patients (Hoven, 2020). In addition, WHO encourages healthcare workers to get vaccinated to minimize disease-generated mortalities, prevent nosocomial outbreaks, and limit absenteeism in the healthcare workplace (Cantarelli et al., 2021). In European nations, the average vaccination rate among healthcare workers is less than 30% (Hoven, 2020). Previous research also suggests that vaccine hesitancy differs based on the race of healthcare workers, with hesitancy being the greatest among Black and Hispanic/Latino healthcare workers (Momplaisir et al., 2021). Vaccination trends among healthcare

workers closely reflect those of the general public since healthcare workers are often seen as role models by society, thus, by increasing vaccination among healthcare workers, it is likely that this will also encourage an increase in vaccination among the general public (Hoven, 2020).

Behavioral intervention techniques have been used to combat vaccine hesitancy. Nudging is a form of behavioral intervention that alters people's behavior in a predictable manner without using direct persuasion or financial incentives (Barbaroux et al., 2021). Types of nudging tools include reminders, educational videos, incentives, and formatting a decision choice to appear to be the default option. This low-cost technique has been found to promote a variety of healthy behaviors, such as healthy eating and exercise in addition to vaccine uptake (Dai et al., 2021).

However, the effectiveness of nudging has been found to be limited by a person's preexisting desire to live a healthier lifestyle (Hoven, 2020). In addition, previous research has criticized nudging to be manipulative and disrespectful to the autonomy of decision-making individuals and can even be seen as a violation of personal liberty when the government employs this method (Hoven, 2020). Thus, research suggests that in order to maintain ethical uses of nudging, the nudgee (a person on which nudging techniques are used on) must be able to easily opt-out of decisions and be presented with transparent choices that are as least intrusive as possible (Hoven, 2020).

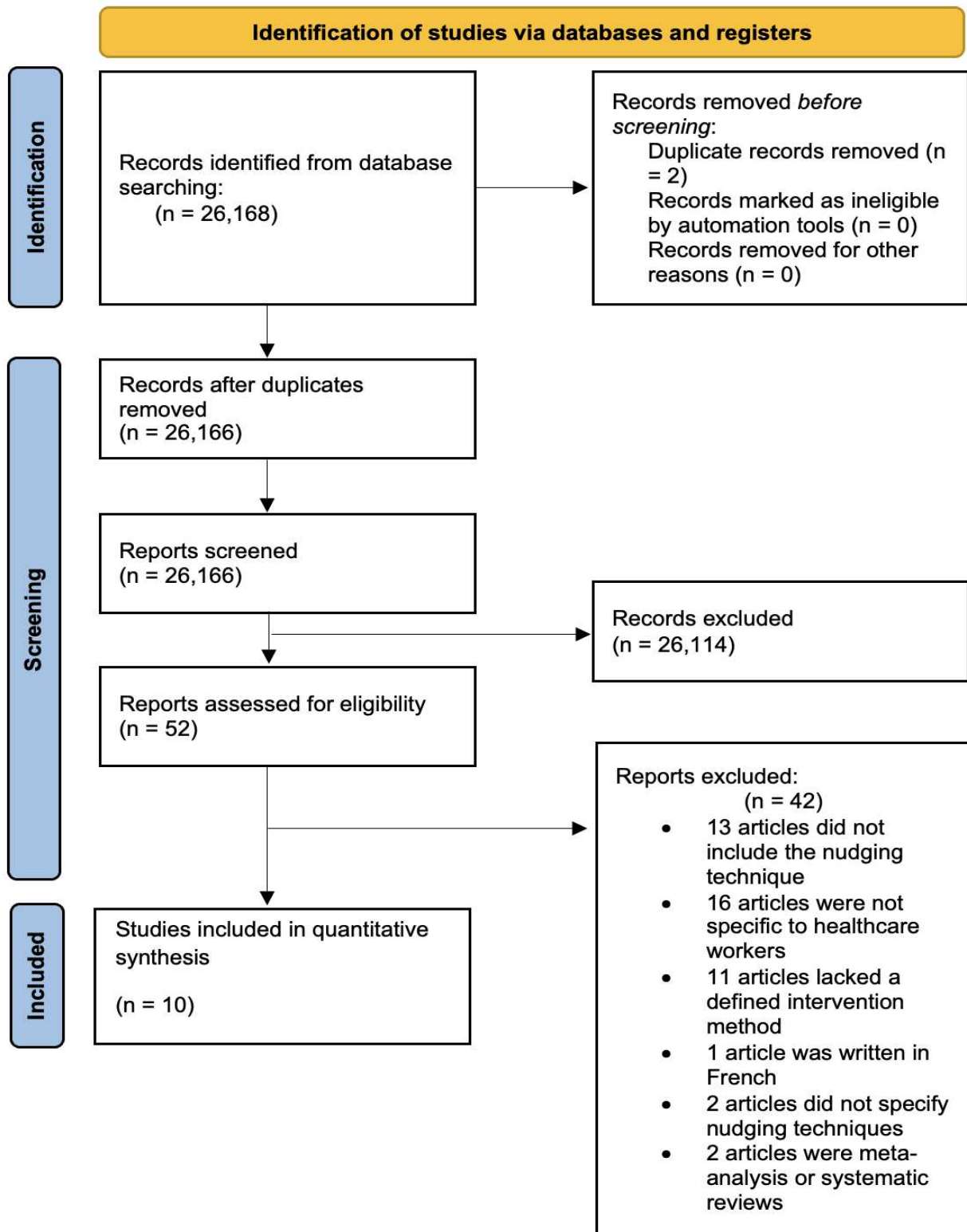
## **Methods**

In this meta-analysis, a systematic literature review was conducted to identify studies evaluating vaccine hesitancy among healthcare workers and the impact of behavioral interventions on reducing this hesitancy. Specifically, articles that included nudging strategies, a type of behavior intervention, on vaccine uptake were examined. Using the PubMed database in this search strategy, the usage of predefined keyword combinations such as “Vaccine Hesitancy,” “healthcare workers,” “vaccination,” “nudging intervention,” “behavioral nudges,” “racial/ethnic differences,” and “vaccine uptake” were used. We selected these key words based on prior research examining the patterns of vaccine hesitancy, adapting the key words by understanding the effectiveness of nudging techniques used in other studies.

Through further review, we assessed that studies were only eligible if they were published in English, peer-reviewed, and primarily focused on vaccination rates among the healthcare worker population. Articles that did not meet this specified criterion (i.e. editorials, non-healthcare populations, non-English language studies, and lack of measurable outcome on vaccine hesitancy) were excluded during the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) screening. Both randomized controlled trials (RCTs) and the non-RCTs were included to capture the

variations in intervention types (Bahar Madran et al., 2023; Cantarelli et al., 2021).

A total of 26,168 studies were identified using the search terms described. After eliminating two duplicate records, 26,166 studies underwent title and abstract screening. As a result of this screening process, 26,156 studies were excluded based on irrelevance primarily because sources excluded information relating to nudging techniques, limited emphasis on vaccine hesitancy intervention among healthcare workers specifically, or nondefinitive intervention techniques. This resulted in 10 studies being analyzed in this meta-analysis.



**Figure 1.** Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flowchart demonstrating the article selection process.

The risk of bias assessment for each study analyzed was conducted through the Cochrane Risk of Bias framework (RoB). This tool is used to check how reliable and trustworthy study results are by identifying possible sources of error. This helps highlight whether findings are affected by issues such as participant selection or lack of control over outside factors (Terrell et al., 2023). The randomized controlled trials (RCTs) were evaluated through RoB 2 (Barbaroux et al., 2021; Dai et al., 2021), as the randomization reduces the point of confounding variables. The non-randomized and observational studies were screened through ROBINS-I due to the fact that these designs are more prone to bias from voluntary participation and lack of random sampling.

		Risk of bias domains					
		D1	D2	D3	D4	D5	Overall
Study	Barbaroux et al., 2021						
	Belle & Cantarelli, 2024						
	Dai et al., 2021						
	Diaz et al., 2025						
	Santos et al., 2021						
	Schmidtke et al., 2019						
	Ugarte et al., 2022						

Domains:  
D1: Bias arising from the randomization process.  
D2: Bias due to deviations from intended intervention.  
D3: Bias due to missing outcome data.  
D4: Bias in measurement of the outcome.  
D5: Bias in selection of the reported result.

Judgement  
 Some concerns  
 Low

**Figure 2.** Assessment of risk of bias in RCTs using RoB 2. Green indicates a low risk, yellow indicates some concern, and red indicates a high risk of bias.

		Risk of bias domains							Overall
		D1	D2	D3	D4	D5	D6	D7	
Study	Bahar et al., 2023								
	Daicampi et al., 2025								
	de Vires et al., 2022								

Domains:  
D1: Bias due to confounding.  
D2: Bias due to selection of participants.  
D3: Bias in classification of interventions.  
D4: Bias due to deviations from intended interventions.  
D5: Bias due to missing data.  
D6: Bias in measurement of outcomes.  
D7: Bias in selection of the reported result.

Judgement  
 Serious  
 Moderate  
 Low

**Figure 3.** Assessment of risk of bias in observational studies using ROBINS-I. Green indicates a low risk, yellow indicates some concern, and red indicates a high risk of bias.

Data extraction include the study design, participant demographics, and the types of behavioral intervention strategies examined in each study. These elements were linked to primary outcomes such as vaccine hesitancy and

uptake. Studies focusing on vaccine hesitancy related to influenzas, HPV, and COVID-19 to name a few were included in this meta-analysis

## **Results**

Understanding the intervention studies, three of the primary nudging strategies that were most frequently implemented: 1. *Reminder and scheduling-based interventions*, 2. *Setting vaccination as the default option*, and 3. *Reframing information*. Reminder-based strategies such as automated messaging and simplified appointment scheduling was prevalent among two studies and assessed to produce the strongest behavioral shift. It resulted in a vaccination uptake increasing by 38.2%. Other peer endorsement campaigns like mentorship or leadership encouragement showed moderate effectiveness which was between a 15.6-21.4% increase. In contrast, educational prompts occupied two articles but had only a small portion of influence which was 13.9% of hesitant responses which showed limited standalone impact (Dai et al., 2021).

Further subgroup analysis revealed that the response varied based on the professional role. Among the nursing personnel, 47.8% indicated an increase in vaccination likelihood after reminder-based interventions compared to the 28.4% for peer-based strategies and 11.2% for informational measures (Bahar Madran et al., 2023). Physicians demonstrated a higher

responsiveness to education focused approaches compared to administrative staff which were most influenced by simplified access and scheduling support (Bahar Madran et al., 2023). A specific note goes to the Turkish mixed methods study which implemented multiple nudging strategies simultaneously. This helped prevent isolation of individual effects and had the highest uptake change of 52.6% of hesitant participants.

Reference	Method	Disease Discussed	Intervention Method Used	Outcome
<b>Bahar et al., 2023</b>	Mixed-methods observational study	COVID-19	Nudging: weekly PCR testing for unvaccinated staff every 2 days (default setting) Small group education seminars	Among the 156 vaccine hesitant individuals, 83.3% were vaccinated after weekly PCR 8.3% additionally vaccinated after intensified PCR and seminar phase Staff vaccination increased from 95.5% to 99.67% Key drivers were distrust, uncertainty, and media influence

<b>Barbaroux et al., 2021</b>	RCT	Influenza	Digital reminder nudges	Reminders were well accepted but did not lead to a significant increase in vaccination uptake  Concluded that acceptance of nudges does not guarantee behavioral impact
<b>Belle &amp; Cantarelli, 2024</b>	RCT	Influenza	Emotional appeal	No significant probability of getting vaccinated between medical doctors and administrative staff  Emotional appeal included the personal benefits of vaccination, protection for loved ones, and protection of HCWs' patients  Nurses were most likely to vaccinate to protect patients
<b>Dai et al., 2021</b>	RCT	COVID-19	Text-based reminders  Education  Reframing information	30% of American adults are unwilling/uncertain about getting vaccine in late June 2021  Findings suggest that the biggest barrier to increasing COVID-19 vaccinations is getting people to schedule an appointment for their first dose

<b>Daicampi et al., 2025</b>	Clustered quasi-experimental study	Influenza	Default settings	Vaccination rate increased as a result of nudging technique  Reasons why people still refused vaccination included that participants were already vaccinated (29%), concerns about potential adverse effects (14%), doubts about vaccine's efficacy and safety (11%), other doubts (4.8%)
<b>De Vries et al., 2022</b>	Cross-sectional survey	Influenza	Default settings (opt-out) Digital reminders Rewards Education	Most nudges were rated as acceptable  The peer vaccination and digital reminders were the most successful  Reward-based incentives were least successful  Nudge acceptability was positively associated with being vaccinated
<b>Diaz et al., 2025</b>	RCT	HPV	Text-message reminders Information framing Social norms	Significant increase in vaccination rates in all intervention groups compared to control  Calculates that for every dollar spent on intervention, \$3.6 to \$5.75 of economic benefit are generated  Digital nudges are a scalable, inexpensive strategy that can be implemented in healthcare settings with limited resources

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<b>Santos et al., 2021</b>	RCT	COVID-19	Information reframing Social norms	No significant difference between the nudging technique used Nudging technique led to a greater amount of vaccination among HCWs compared to the control
<b>Schmidtke et al., 2019</b>	RCT	Influenza	Education Social norms	Study found no statistically significant evidence that social norm nudges affected vaccination uptake Found that nudges work differently based on a person's profession within healthcare
<b>Ugarte et al., 2022</b>	RCT	COVID-19	Social norm	The methods used in this study increases requests for vaccine-related information, potentially reducing vaccine hesitancy While the intervention group showed greater information-seeking behavior, the study found that there is no statistically significant difference in vaccination rates between the intervention and control groups.

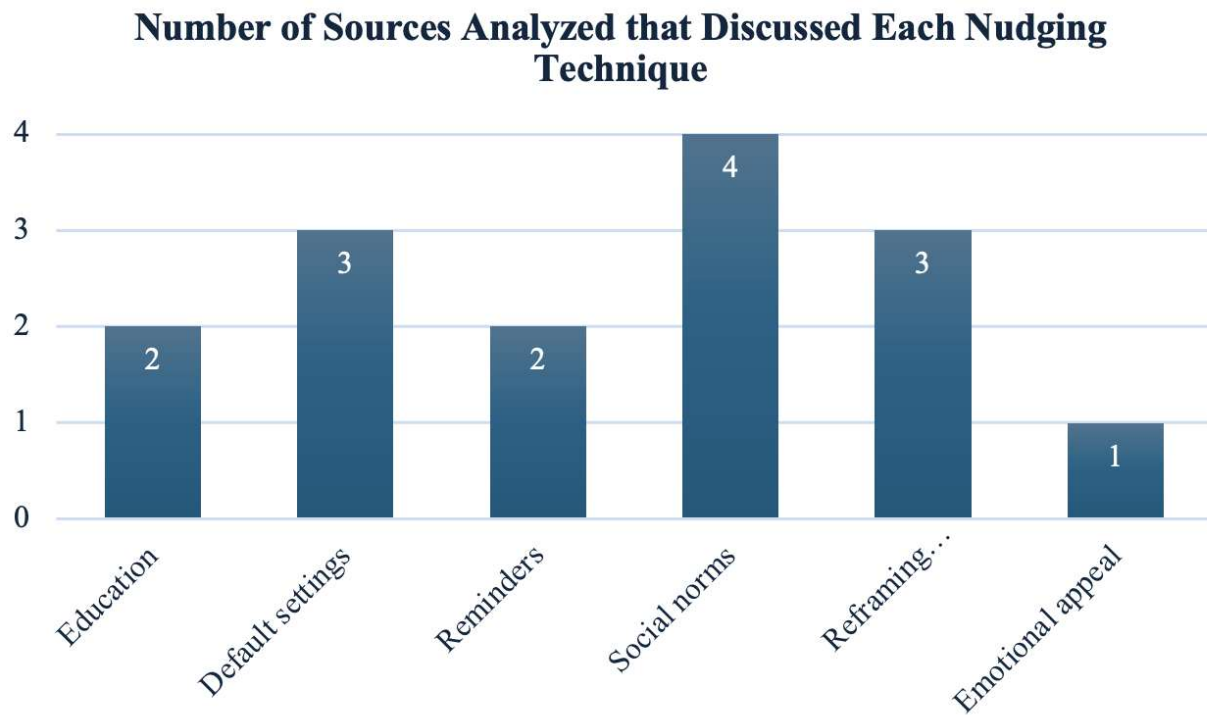
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**Figure 4.** Summary table discussing the study method, diseases discussed, intervention methods used, and outcomes of each study analyzed in this meta-analysis.

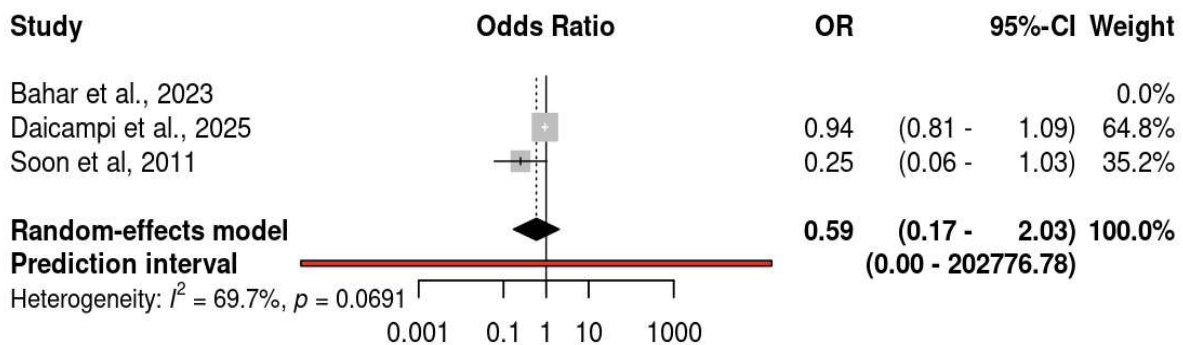
<b>NUDGING TECHNIQUE</b>	<b>STUDIES ANALYZED</b>	<b>TOTAL STUDIES</b>
<b>Education</b>	<ul style="list-style-type: none"> <li>• Bahar et al., 2023</li> <li>• Diaz et al., 2025</li> </ul>	2
<b>Default settings</b>	<ul style="list-style-type: none"> <li>• Bahar et al., 2023</li> <li>• Dai et al., 2021</li> <li>• Daicampi et al., 2025</li> </ul>	3
<b>Reminders</b>	<ul style="list-style-type: none"> <li>• Barbaroux et al., 2021</li> <li>• Dai et al., 2021</li> </ul>	2
<b>Social norms</b>	<ul style="list-style-type: none"> <li>• Diaz et al., 2025</li> <li>• Santos et al., 2021</li> <li>• Schmidtke et al., 2019</li> </ul>	4

	<ul style="list-style-type: none"> <li>• Ugarte et al., 2022</li> </ul>	
<b>Reframing information/outcomes</b>	<ul style="list-style-type: none"> <li>• Dai et al., 2021</li> <li>• Diaz et al., 2025</li> <li>• Santos et al., 2021</li> </ul>	3
<b>Emotional Appeal</b>	<ul style="list-style-type: none"> <li>• Belle &amp; Cantarelli, 2024</li> </ul>	1

**Figure 5.** Nudging techniques used in each study analyzed.



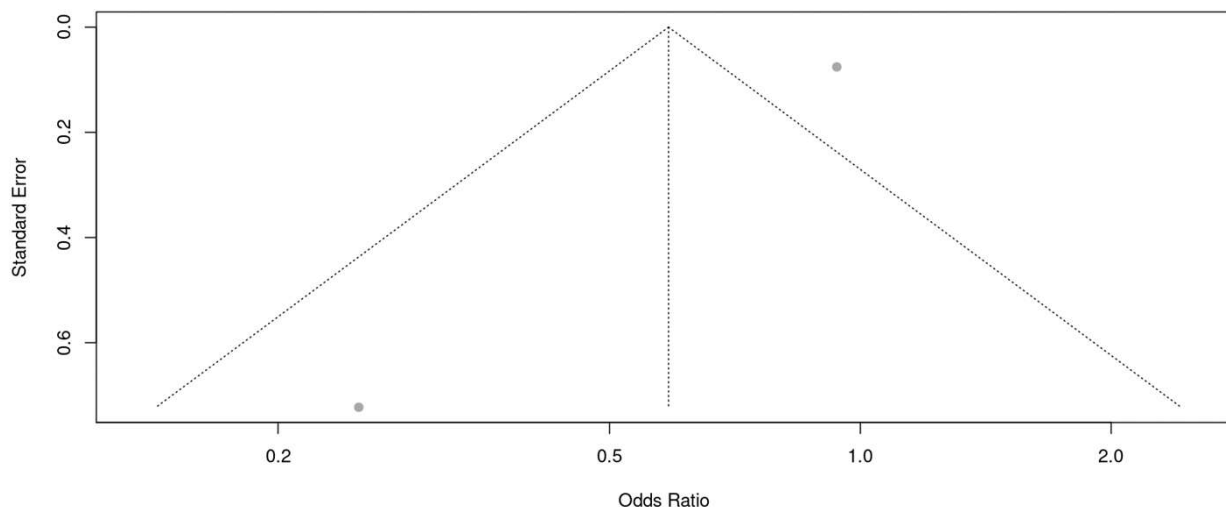
**Figure 6.** Number of times nudging techniques were mentioned in the studies analyzed to reduce vaccine hesitancy and instead increase vaccination uptake among healthcare workers.



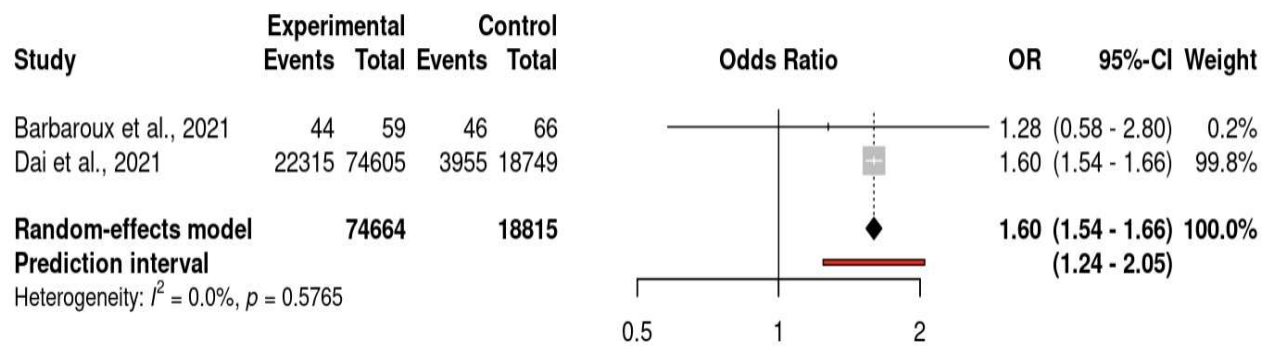
**Figure 7.** Forest plot for the observational studies analyzed in this study that discuss default settings as an intervention method to reduce vaccine hesitancy among HCWs.

According to Figure 7, the pooled OR of 0.59 with a 95% confidence interval of (0.00, 202776.78) for observational studies that analyzed default

settings demonstrates that this nudging technique resulted in lower odds of vaccine acceptance compared with the control condition by 41%. The large confidence interval provides substantial uncertainty about the true effect of default settings as a nudging technique in reducing vaccine hesitancy among HCWs. An  $I^2$  value of 69.7% represents substantial heterogeneity and that 69.7% of the variability in the observed effect sizes reflects true differences between studies rather than sampling error. The association did not reach statistical significance ( $p = 0.069$ ). There is a 6.91% probability of overserving an effect as large or larger than the one found by chance in terms of the odds of the outcome associate with the default settings intervention.

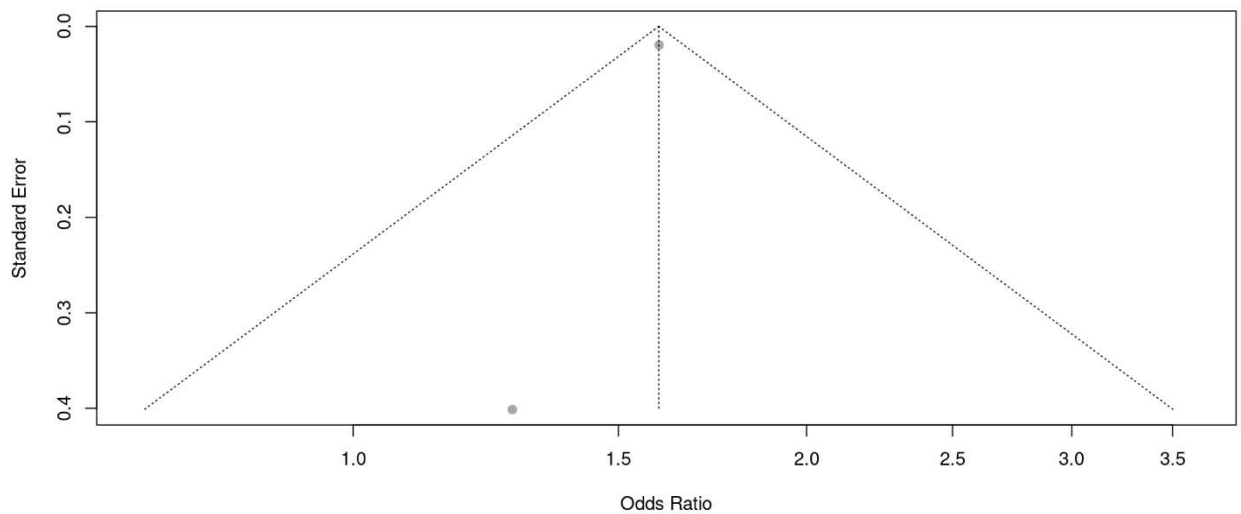


**Figure 8.** Funnel plot for the observational studies analyzed in this study that discuss default settings as an intervention method to reduce vaccine hesitancy among HCWs.

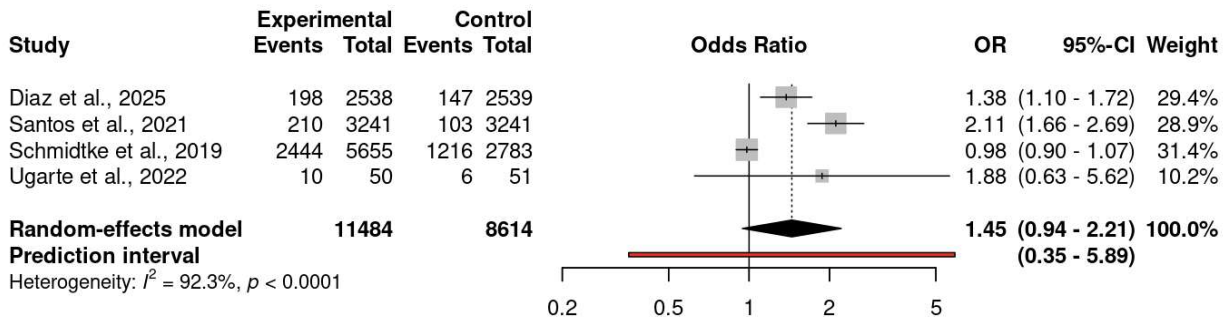


**Figure 9.** Forest plot for the RCTs analyzed in this study that discuss reminders as an intervention method to reduce vaccine hesitancy among HCWs.

According to Figure 9, the pooled OR of 1.60 with a 95% confidence interval of (1.24, 2.05) for RCTs that analyzed reminders demonstrates that this nudging technique resulted in higher odds of vaccine acceptance compared with the control condition. This value indicates that HCWs are 60% more likely to become vaccinated with the reminder nudge, highlighting the potential effectiveness of reminders as a behavioral intervention to improve vaccine uptake. An  $I^2$  value of 0.0% indicates no observed heterogeneity, meaning the effect of reminders as a nudging technique on vaccine hesitancy was consistent across all included studies. The association did not reach statistical significance ( $p = 0.5765$ ). There is a 57.65% probability of overserving an effect as large or larger than the one found by chance in terms of the odds of the outcome associate with the reminder intervention.



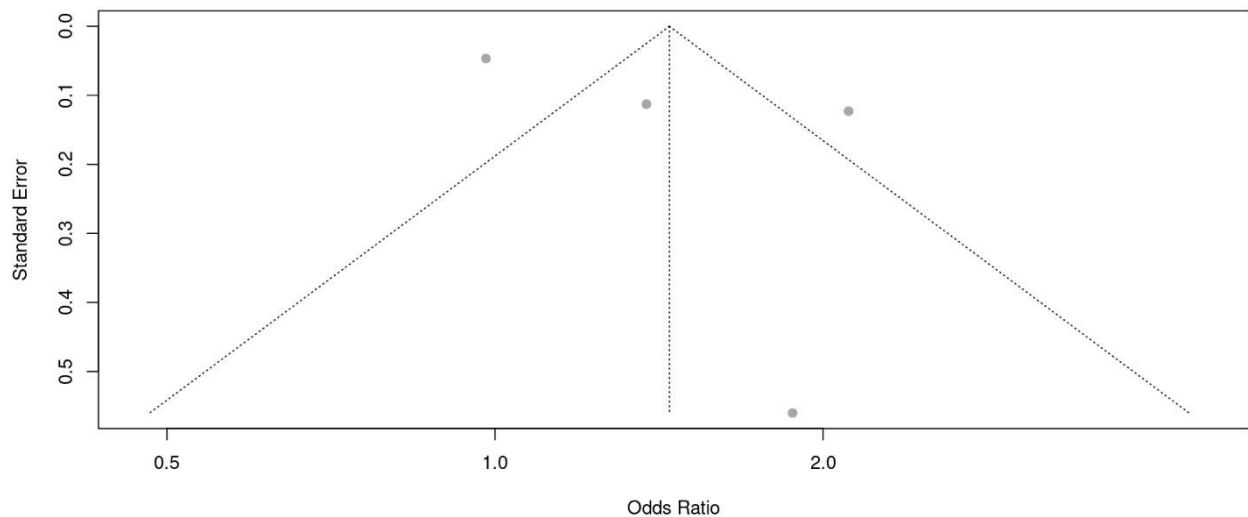
**Figure 10.** Funnel plot for the RCTs analyzed in this study that discuss reminders as an intervention method to reduce vaccine hesitancy among HCWs.



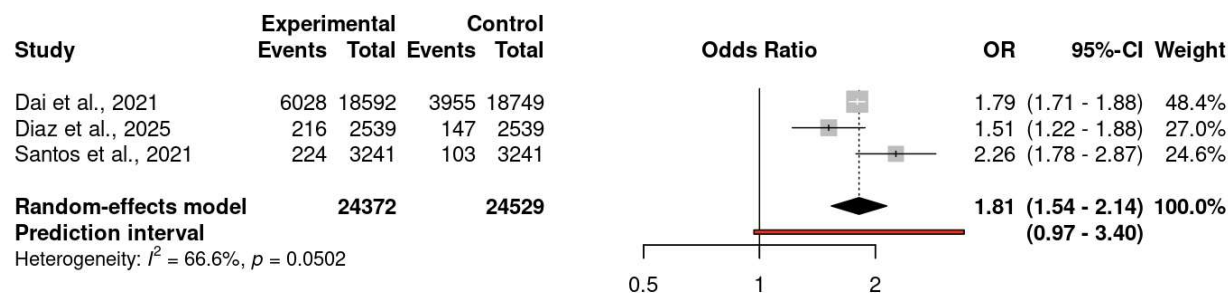
**Figure 11.** Forest plot for the RCTs analyzed in this study that discuss social norms as an intervention method to reduce vaccine hesitancy among HCWs.

According to Figure 11, the pooled OR of 1.45 with a 95% confidence interval of (0.35, 5.89) for RCTs that analyzed social norms demonstrates that this nudging technique resulted in higher odds of vaccine acceptance

compared with the control condition by 45%. Since the confidence interval contains 0, the effects of these studies are not statistically significant. An  $I^2$  value of 92.3% represents very high heterogeneity and that 92.3% of the variability in the observed effect sizes reflects true differences between studies rather than sampling error. The association reached statistical significance ( $p < 0.0001$ ). However, the wide confidence interval and very high heterogeneity indicate substantial variation in effect size across studies, suggesting that effectiveness of the social norms nudge may depend on study-specific factors such as implementation method or population.



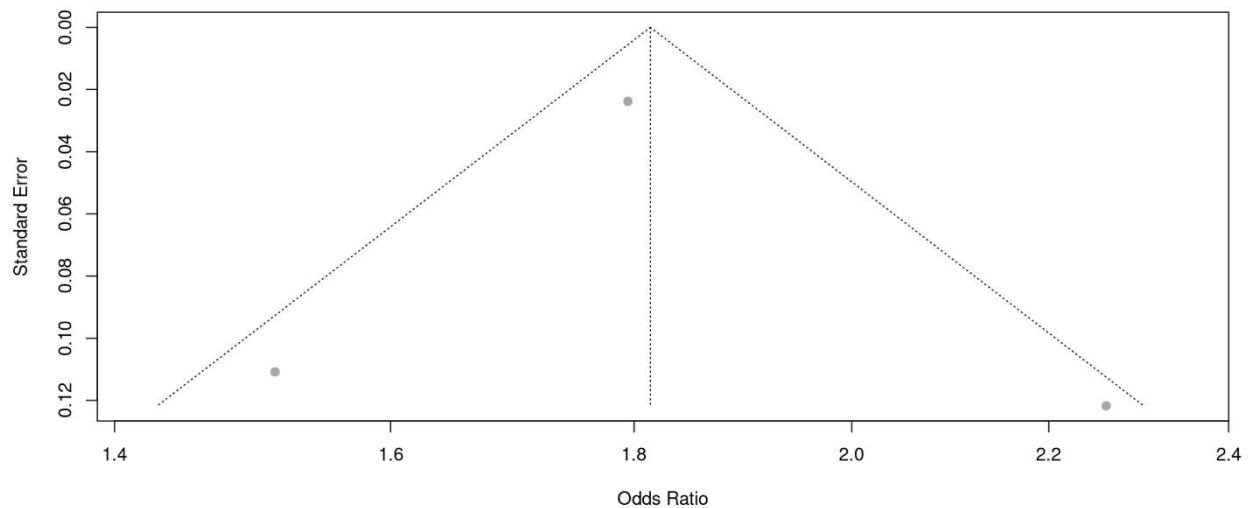
**Figure 12.** Funnel plot for the RCTs analyzed in this study that discuss social norms as an intervention method to reduce vaccine hesitancy among HCWs.



**Figure 13.** Forest plot for the RCTs analyzed in this study that discuss reframing as an intervention method to reduce vaccine hesitancy among HCWs

According to Figure 13, the pooled OR of 1.81 with a 95% confidence interval of (0.97, 3.40) for RCTs that analyzed reframing demonstrates that this nudging technique resulted in higher odds of vaccine acceptance compared with the control condition by 19%. The large confidence interval provides substantial uncertainty about the true effect of default settings as a nudging technique in reducing vaccine hesitancy among HCWs. An  $I^2$  value of 66.6% represents substantial heterogeneity and that 66.6% of the variability in the observed effect sizes reflects true differences between studies rather than sampling error. The association did not reach statistical significance ( $p = 0.0502$ ). There is a 5.02% probability of overserving an effect as large or larger than the one found by chance in terms of the odds of the outcome associate with the default settings intervention. Overall, this information

indicates that the effectiveness of nudging varies across studies and may be dependent on factors such as intervention type or study population.



**Figure 14.** Funnel plot for the RCTs analyzed in this study that discuss reframing as an intervention method to reduce vaccine hesitancy among HCWs.

## Discussion

The findings from this meta-analysis synthesizes current evidence on vaccine hesitancy among healthcare workers and highlights the effectiveness of low-cost nudging techniques as a behavioral intervention method to encourage vaccine uptake. Across these studies, a consistent pattern emerged, showing that even though HCWs who have high levels of medical knowledge

and experience direct exposure to vaccine-preventable diseases still express vaccine hesitancy. This hesitancy is shaped by the interactions between their professional role, perceived level of risk, cultural and ethnic background, and trust in vaccines. These findings reinforce the idea that information about vaccines alone is insufficient in influencing the vaccination behavior of HCWs, but also requires situationally adjusted behavioral intervention strategies.

Our analysis demonstrates that the nudging strategy, which includes default appointments, reminders, setting vaccination as a social norm, education, emotional appeal, and framing techniques, can effectively reduce hesitancy in diverse healthcare environments. Overall, our analysis found that interventions that minimize friction (e.g. simplifying vaccination appointments via reminders and automatic appointment scheduling) and emphasizing vaccination norms demonstrated some of the most consistent gains. These results align with previous behavioral science literature that suggest that small changes can create meaningful decision shifts without limiting the autonomy of the decision-making process, an important ethical responsibility in public health practices.

A key contribution of this review is that it uses a multidisciplinary lens, bringing findings from behavioral science, public health, medical ethics, and health systems research together. This approach highlights that the vaccine choices made by HCWs are shaped not only by clinical reasons, but also by

personal, institutional, societal, and cognitive biases. This idea explains why we conclude that nudging is most effective when situationally adjusted.

Despite these promising findings, there are several limitations to this meta-analysis. To start, many studies include an observational or quasi-experimental design, limiting the inferences that could be made. Similarly, most of the other studies used randomized controlled trials (RCTs), which are limited by their poor ability to be generalized and potential for bias. Additionally, the vast heterogeneity across the populations studied within the sources used for this meta-analysis, whether based on race and ethnicity, geolocation, cultural norms, occupational subgroups, vaccine types, and healthcare settings may influence the generalizability of the results of this meta-analysis.

Given this information, future research should prioritize evaluating randomized trials to evaluate the long-term sustainability of behavioral interventions similar to those identified in this study, exploring how nudges can be tailored to diverse HCW populations. In addition, gaps in research continue to exist when researching these effects in developing countries (Ellingson et al., 2019). Based on the results of this study, the most durable impact would likely be yielded if nudging was integrated with broader institutional strategies, such as transparent risk communication, to maintain ethical implementation of vaccine encouragement.

While the pooled log odds ratio provides an overall estimate of the effect of behavioral nudges as an intervention technique to increase vaccine uptake among HCWs, the high heterogeneity suggests that caution is advised when generalizing this average effect to any single context. Subgroup analyses by study design, vaccine type, and intervention method may help clarify sources of variability and identify conditions in which nudges are most effective.

Overall, this review supports the conclusion that nudging offers a practical and scalable approach to mitigate vaccine hesitancy among healthcare workers, encouraging the uptake of vaccines to promote public health and decrease future disease outbreaks. By understanding how to embed behavioral techniques into healthcare systems, institutions can better support the decision-making process of HCWs when it comes to confidence in vaccination, increasing resiliency among populations suffering from disease outbreaks.

## **Disclaimers and Declarations**

### **i. Funding**

External funding was not secured for this study.

### **ii. Financial Disclosure**

The authors have no financial relationships relevant to this article to disclose.

### **iii. Ethics**

This article does not involve primary data or human subjects; formal ethics approval was not applicable.

### **iv. Conflict of Interest**

The authors have no conflicts of interest relevant to this article to disclose.

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