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REVIEW

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Increasing vaccine uptake among employees within the non-health related critical infrastructure sectors: A review

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ABSTRACT

This review aimed to identify barriers to employee vaccination, motivators for vaccination, and vaccine uptake strategies within the critical infrastructure sectors. We focused on non-healthcare-related sectors, including food and agriculture, manufacturing, and education where employee vaccination is rarely mandated. We conducted a search for literature published from 2012 to 2022 from MEDLINE-PubMed, PsycINFO, and Web of Science Core Collection, which resulted in 22 studies that met the inclusion criteria. We found that 1) barriers to vaccination differ by infectious disease and population; 2) common motivators for vaccination were about protecting self, family, and community; and 3) common uptake strategies for influenza (which accounted for 83% of uptake strategies in reviewed studies) addressed convenience and confidence barriers such as vaccination cost and education. Our review highlights the need for employers, policymakers, and researchers to identify infectious disease and population-specific barriers to vaccination and implement strategies aimed at addressing the identified barriers.

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Critical infrastructure sectors; vaccine hesitancy; barriers to vaccination; motivators for vaccination; vaccine uptake strategies

Introduction

The current COVID-19 pandemic has demonstrated that a low vaccination uptake and vaccination hesitancy among employees in the critical infrastructure sectors may represent a vulnerability to the functioning of the whole society.[1–5] Research shows that employees within these sectors, especially those who hold service-related jobs (retail, manufacturing, food service, construction), are less likely to be vaccinated than non-critical infrastructure-sector employees.[1–5] By definition, the critical infrastructure sector includes vital sectors whose incapacitation would have negative effects on national economic security, public health, or safety.[6] These sectors include food and agriculture, manufacturing, and government facility sectors such as education.[6] Employees within these sectors are also commonly referred to as essential workers, frontline workers (a subcategory of essential workers who cannot feasibly work from home), and essential critical infrastructure workers.[7] For example, the spread of COVID-19 among employees within the food and agricultural sector led to the forced shutdown of facilities, such as meat facilities, leading to the eventual reduction of production, processing, and distribution of meat products.[8,9] This reduction of services led to labor shortages, economic losses expected to reach 13.6 billion US dollars for the beef cattle industry alone, and an increase in food prices that in turn places people at risk for poverty and food insecurity.[9–11] Other sectors like the transportation sector experienced high unemployment rates due to the reduction in transportation service use; employees within this sector were 20.6% more likely to experience unemployment when compared to other critical infrastructure sectors.[12] To reduce the critical infrastructure sectors' vulnerability to infectious diseases and eventual incapacitation, employers, researchers, policymakers, and other stakeholders need an understanding of the causes of vaccine hesitancy.

Multiple studies and reviews have reported on the barriers to vaccination, motivators for vaccination, and vaccine uptake strategies for varying infectious diseases within populations such as healthcare employees, patients, and children. Factors such as individual's social circle, susceptibility to disease, perceived vaccine effectiveness, lack of time, transportation, and lack of health insurance have been shown to influence decisions to get vaccinated among individuals in the general population.[13] Because these contributors to vaccination were studied across different populations, the generalizability of the results to non-healthcare-related critical infrastructure sectors may be limited. Therefore, it is necessary to outline the barriers contributing to low vaccination, the motivators to leverage to increase vaccine uptake, and the effective vaccine uptake strategies for employees within the critical infrastructure sectors. Studies continue to show that individuals within non-health critical infrastructure sectors are less likely to be vaccinated.[4,14] For the critical infrastructure-sector employees specifically, the reported factors influencing their vaccination decisions are the cost of vaccination, lack of access to vaccines, vaccine side-effect concerns, and needle fear.[14] Low vaccination among these employees hinders progress made toward disease control and has the potential to debilitate the functioning of our society because of the critical role that these employees play in ensuring societal function. Thus, our review aims to identify the

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concerns/barriers that employees within various critical infrastructure sectors have toward vaccination. In addition to identifying these barriers, our review also illustrates how the World Health Organization's (WHO) 3C model of vaccine hesitancy (comprised of confidence, convenience, complacency) can be used to understand which factors contribute the most to hesitancy within our target population.[15] Vaccine confidence relates to trusting vaccine safety and effectiveness, vaccine delivery systems, and their reliability, while complacency is when individuals' perceived risk and necessity to be vaccinated is low.[15] Lastly, convenience is any factor that impedes individuals' ability to access vaccines including availability, affordability, geographic accessibility, and literacy.[15]

Besides identifying the barriers to employee vaccination, our review also aimed to identify the key motivators for vaccination among employees within the critical infrastructure sector. These motivators play a vital role in increasing vaccine uptake because if identified, leveraging the motivators can form the foundation of vaccine uptake strategies. Literature suggests that the most common motivator for vaccination is protecting one's family, friends, and community from vaccine-preventable diseases (VPDs).[16,17] Whether this finding within the literature applies to non-healthcare related critical infrastructure sectors is still a gap in the knowledge.

In addition to understanding employee barriers to vaccination, and motivators for vaccination, our review also identifies strategies that have been effective at increasing vaccine uptake within the critical infrastructure sector. For example, to mitigate the risk of low vaccination within the critical infrastructure sectors, employers are encouraged to become messengers of accurate and reliable information.[18] This measure is especially important because it aims to minimize the impact of misinformation that contributes to vaccine hesitancy.[19] Additionally, to improve vaccine uptake, employers are also encouraged to consider providing vaccine access options for their employees (on-site vaccination or off-site vaccination), building confidence in vaccines, and providing incentives and benefits for vaccinated employees.[20] There is a consensus in the literature that the most effective way to increase vaccine uptake is by implementing multicomponent strategies.[21–24] Furthermore, strategies that were tailored to specific populations and addressed the vaccination concerns of target groups were most effective at increasing vaccine uptake.[21] Despite the existence of these recommendations, reviews on non-healthcare critical infrastructure sectors vaccine uptake strategies are still lacking as compared to the healthcare sector.[25–28] In summary, the objectives of this review were to fill gaps in the knowledge by 1) identifying barriers to vaccination of employees in the non-health critical infrastructure sectors, 2) identifying motivators for employee vaccination, and 3) identifying strategies that have been effective at increasing vaccine uptake within those sectors.

Methods

Eligibility criteria

A rapid review strategy, as defined by Grant and Booth, was implemented.[29] The rapid review was based on published studies that assessed vaccination barriers and motivators, as well as studies that evaluated the effectiveness of vaccine uptake strategies. Studies eligible for inclusion were original studies, in English, and published between January 1, 2012, and February 28, 2022. Eligible studies reported on vaccination of working adults within critical infrastructure sectors, the effectiveness of vaccine uptake strategies, barriers to vaccination, and motivators to vaccination. Studies that focused on the vaccination of children and pregnant women were not eligible. In addition, studies that assessed uptake strategies in the healthcare sector were outside the scope of this study and were excluded from the search because of differences in vaccination requirements between this and the other critical infrastructure sectors.[30,31]

Literature search strategy

The literature databases MEDLINE/PubMed, PsycINFO (EBSCO), and Web of Science Core Collection (Web of Science) were used for identifying the studies included in the rapid review. The review team consulted with a Cornell University library expert (Matthew R. Kibbee) with professional experience in research and evidence synthesis. With the help of the librarian, we determined appropriate search databases based on our topic of interest and the organization of our search strategy procedure into tables. Boolean operators were used during the search to obtain results on critical infrastructure employees. The final searches were conducted from February 11, 2022, to February 28, 2022. A total of six steps were performed on each database to obtain studies to be included in the review. Step 1 was a literature search for studies on critical infrastructure employees. Step 2 was a search for studies on intervention concepts (any activity carried out to increase vaccination rates such as vaccine access, promotion, etc.). Step 3 was a literature search of synonyms for vaccination to retrieve any studies with vaccination or immunization as a topic. Step 4 was about vaccine acceptance or refusal. Step 5 was a combination of Boolean operators for steps 3 and 4. Step 6 was a combination of Boolean operators for steps 1, 2, and 5. In consultation with our librarian, we combined the steps of the search strategy to increase the precision of our literature search results. The search strategy is provided in the Supplement material.

Screening and selection procedure

Study analysis/selection was conducted using Covidence.[32] Covidence allows reviewers to import citations into its online tool, automatically deduplicates citations, and assigns study IDs to imported citations. The two-stage screening process was performed by L.K. and Z.C. independently, including title and abstract screening (which does not require reviewers to provide explanations for study exclusion), and full-text screening (which requires an explanation for study exclusion). During the full-text screening, a study was excluded if (i) it did not evaluate vaccine attitudes or (ii) it evaluated attitudes toward hypothetical vaccines. E.B. and R.I. resolved conflicts during both stages.

Data extraction

Data extraction was completed using Excel and conducted by L.K. Extracted data was inputted into two different Excel sheets, one about employee vaccination attitudes (i.e., barriers and motivators), and the other about strategies to increase vaccine uptake. Both Excel worksheets comprised author and study published data, Covidence-assigned study ID, location, target population, study aims/objectives, study design, sampling method, sample size, study duration, and disease of interest. In addition, the attitudes worksheet contained information on motivators for vaccination and barriers to vaccination, while the strategy worksheet contained information on strategy type (single/multi-component), the strategy used, outcome, and conclusion. A meta-analysis could not be conducted due to data heterogeneity.

Data organization

The extracted data on barriers, motivators, and uptake strategies in Excel sheets were synthesized into tables of results and further grouped by infectious disease. We categorized barriers to vaccination by convenience (cost, no time, vaccine access, administrative barriers, and vaccine availability), confidence (vaccine safety concerns and side effects), and complacency (low perceived risk, not receiving a vaccine because it was not employer-mandated) as recommended by WHO-Strategic Advisory Group of Experts on Immunization (SAGE).[15] Studies were further visually summarized by study location, population, and infectious disease.

Results

Overview of included studies

A total of 240 articles were identified in the literature databases and screened. Of those, 51 were duplicates among different databases and removing them resulted in 189 studies. Furthermore, 189 studies were assessed for the title and abstract eligibility, resulting in the full-text assessment of 31 studies. Of these, 22 met the eligibility criteria (Figure 1).

Study characteristics

A summary of the extracted data and included study characteristics are shown in Tables 1 and 2. The 22 studies included in this rapid review consist of 14 cross-sectional studies, 2 prospective case–control studies, 2 prospective cohort study, 1 intervention trial, 1 retrospective observational study, 1 qualitative study, and 1 comparative descriptive study (as stated by the authors of the study) which we classified as a prospective cohort study as per the definition.[33] The total number of participants within the cross-sectional studies ranged between 14 and 1,450. Within the comparative descriptive study, 170 employees participated in the intervention, while 82 and 88 participated in the pre- and post-cross-sectional survey, respectively. The prospective cohort studies had a total of 517 participants. The qualitative study included 52 participants.

Included studies were conducted in the United States, Italy, Australia, and China (Figure 2). These studies focused primarily on assessing vaccination for six infectious diseases (influenza, measles, mumps, and rubella (MMR), Q fever, tetanus, COVID-19, and tick-borne encephalitis (TBE)). Additionally, these studies assessed vaccination barriers and motivators for vaccination among employees within critical infrastructure sectors such as education, food and agriculture, manufacturing, construction, and financial group workers (Figure 3). Lastly, studies assessing vaccine uptake strategies focused on influenza and tetanus among food and agriculture, finance, and industrial workers (Figure 4).

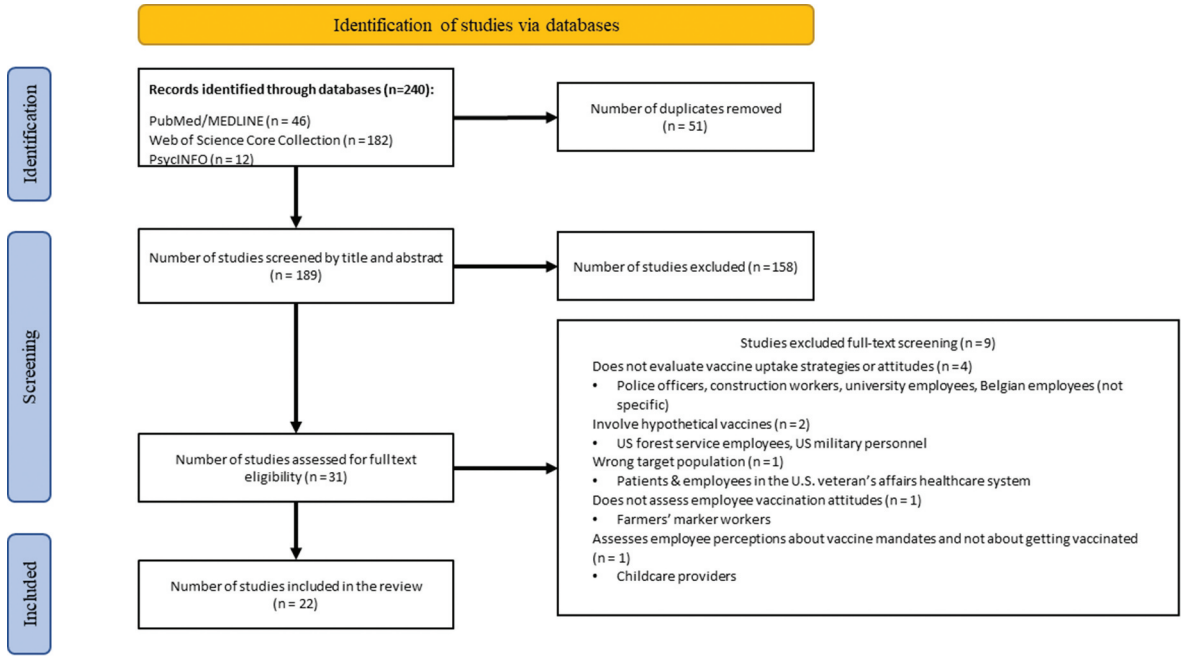

Figure 1. Flow chart of included studies and exclusion reasons.

Table 1. Characteristics of included studies and barriers and motivators to vaccination (N = 18).

Author/ year	Location	Study period	Population	Disease	Sample size	Study design	Barriers	Motivators	Conclusion
de Perio 2014[34]	Ohio, United Sates	Mar. 5– Mar. 26, 2014	School employees (bus drivers, teachers, food services, custodial)	Influenza	412	Cross-sectional survey	N = 172 (Participants who had not received the vaccine) *32% Believe that the vaccine is not needed *21% Vaccine not effective *17% No time get the vaccine *11% Vaccine not safe *20% other (never get the flu & got very sick from flu vaccine)	N = 238 (Participants who received the vaccine) *87% To protect themselves and their family *5% read/heard that getting a flu shot is recommended *4% doctor recommendation *5% Other (Not specified)	*There is a need to emphasize the benefits, safety, and effectiveness of vaccination, and to make the vaccine more available in the workplace
McKiernan 2016[35]	United States	Not mentioned	Manufacturing & Daycare	Influenza	17 – Manufacturing plant workers 14 – Daycare workers	Cross-sectional survey	Not assessed	*61.2% To protect self *48.3% To protect friends and family *48.3% Easy and convenient *29% Protect community *19.4% Vaccine was effective in the past in preventing flu *9.6% Suggested by health care provider	*Implemented educational programs to increase influenza should emphasize the benefits of vaccinations
Li 2014[36]	Guangzhou, China	Jun. 17– 24, 2013	Food production workers	Influenza A (H7N9)	1450	Cross-sectional survey	* 58.19% Had vaccine safety concerns * 24.57% Think vaccination is not necessary and cannot be infected with the virus * 14.22% Costly, but will get vaccinated if free * 6% Refused to get vaccinated	*Worry/fear of being infected was the strongest predictor of vaccine uptake * 84% Said they would accept the vaccine if available	* Participants who received an influenza vaccine in the past three years were two times more likely to accept the new vaccine compared to those who had not received it
Parrish 2015[37]	Washington, United States	2012	Restaurant employees	Influenza	428	Cross-sectional survey	*86% Vaccinated &74% of unvaccinated employees are worried about vaccine side effects *90% Vaccinated & 75% unvaccinated explained that vaccination is painful or uncomfortable *91% Vaccinated & 88% unvaccinated stated that the flu shot costs too much money	*40% of Vaccinated & 20% unvaccinated employees believe flu vaccination is relevant for people their age *65% Vaccinated & 34% unvaccinated believe vaccination will protect them against the flu *72% Vaccinated & 43% unvaccinated believe vaccination will protect their families against the flu *62% Vaccinated &46% unvaccinated stated that getting the flu shot is convenient	*Interventions should be aimed at highlighting vaccine relevance and effectiveness among restaurant employees

(*Continued*)

Table 1. (Continued).

Author/ year	Location	Study period	Population	Disease	Sample size	Study design	Barriers	Motivators	Conclusion
Ofstead 2013[38]	Mid West region (United States)	Sept. 2010–Feb. 2011	Industrial workers	Influenza	"Baseline survey * Site A = 497 * Site B = 503 Follow-up survey * Site A = 250 * Site B = 517 * Site C = 493 (control site)"	Prospective case-control	Barriers for Sites A & B *Vaccines could make me ill (A – 67%, B – 56%) *Healthy/don't need it (A – 45%, B – 52%) *Vaccines don't work (A – 35%, B – 37%) *Don't like injections (A – 35%, B – 33%) *Don't like vaccines in the nose (A – 32%, B – 32%) *Doctor doesn't recommend (A – 18%, B – 25%)	Motivators for Sites A & B *Free or low cost (A – 86%, B – 81%) *Avoid missing work (A – 82%, B – 82%) *Convenient (A – 84%, B – 76%) *Not to transmit the flu (A – 75%, B – 66%) *Could have gotten ill (A – 66%, B – 58%) *Doctor advice (A – 45%, B – 42%)	*Economic reasons (free vaccines, convenience of getting vaccinated, and not wanting to miss work), therefore interventions could include making vaccination easier for employees by providing on-site vaccination and multiple vaccination opportunities and offering free vaccines.
Landwehr 2021[14]	United States	Oct. 2019–Dec. 2019	Financial group workers	Influenza	82 – pre survey 88 – post survey	Comparative descriptive study (as stated by authors) We classified this as a prospective cohort study	Pre & Post survey barriers: *Lack of access to vaccine (32% pre, 27% post) *Side effect concerns (28% pre, 32% post) *Vaccine cost (26% pre, 17% post) *Injection fear (10% pre, 15% post) *Other (not specified 4% pre, 9% post)	Not assessed	*Barriers to flu vaccination can be reduced by providing education in the workplace
Luthy 2013 (pilot study)[39]	Utah, United States	Non mentioned	School employees	Seasonal influenza & MMR	277	Cross-sectional survey	* 20.8% (31) Vaccine is not effective at protecting against influenza * 14.8% (22) No time to be vaccinated/ forgot * 12.1% (18) Worried about vaccine side effects * 10.1 (15) Worry about getting sick from the vaccine * 9.4% (14) Not sure of the need for vaccination * 6.7% (10) Vaccination not mandated by the employer * 5.4% (8) Concerned about vaccine cost	Not assessed	*Education provided by school nurses to promote and encourage employee vaccination could increase vaccine uptake and control vaccine-preventable diseases in schools

(*Continued*)

Table 1. (Continued).

Author/ year	Location	Study period	Population	Disease	Sample size	Study design	Barriers	Motivators	Conclusion
Luthy 2013 (developed from previous pilot study)[40]	Utah, United States	Not mentioned	School employees	Seasonal influenza & MMR	835	Cross-sectional survey	*Lack of knowledge regarding adult vaccinations *Needed vaccinations administered during childhood *Concerns about cost of adult vaccination (insurance doesn't cover for vaccination or too costly, can't afford health insurance *11% Unsure of what to believe about vaccine safety	*Support mandatory vaccination requirements because "if children have to, why not the adults too?" To protect self and coworkers	*School nurses might be instrumental in providing school employee vaccination information and educating policymakers on vaccine mandates and disease containment plans
Luthy 2015 (adapted from 2013 pilot study and main study (Luthy 2013))[41]	Utah, United States	Not mentioned	School employees	Seasonal influenza & MMR	852	Cross-sectional survey	*Little knowledge about needed boosters	*39.9% and 53.0% Strongly agreed and agreed that vaccines are safe respectively	*Regular assessment of school employee vaccination status and recommendations could improve vaccination uptake
Macintosh 2016[42]	Utah, United States		School employees	Seasonal influenza & MMR	1259	Cross-sectional survey	*62.2% Had not received the influenza vaccine *20.5% Did not believe the flu vaccine would help *16.1% Did not have time/ forgot *15.9% Did not need the vaccine because they are in good health 15.7% Vaccines make them sick *14.2% Worried about side effects *6.7% Not required by employer *10.2% (Not sure about need to get one, cost, vaccination caused pain, allergic)	Not assessed	*Gaps in knowledge about adult vaccination requirements *Need for education about required vaccinations for adults

(*Continued*)

Table 1. (Continued).

Author/ year	Location	Study period	Population	Disease	Sample size	Study design	Barriers	Motivators	Conclusion
Macintosh 2014[43]	Utah, United States		School employees	Seasonal influenza & MMR	835	Cross-sectional survey	*20.5% Don't believe vaccines help *16.1% Don't have time and forgot *15.9% I have good health & don't need it *15.7% Vaccines make me sick *14.2% Worried about vaccine side effects *6.7% Not required by employer *10.2% Not sure if I needed to get one, cost, vaccination-caused pain, allergic	Not assessed	*Public health professionals should focus addressing vaccine knowledge gaps and misconceptions about adult boosting and regular vaccination
Ricco 2016[44]	Italy	Jan. 2010–Jan 2012	Construction	Tetanus	554	Cross-sectional survey	Foreign-born workers(fbw) (N = 64), Italian-born workers (ibw)(N = 176) *Forgot about booster (fbw = 6.1%, ibw = 20.6%) *Useless: pediatric doses sufficient (fbw = 3.8%, ibw = 8.7%) *Fear of side effects (fbw = 2.0%, ibw = 4.1%) *Personal/religious beliefs (fbw = 3.6%, ibw = 4.0%)	Foreign-born workers(fbw) (N = 92), Italian-born workers (ibw)(N = 222) *Protection against tetanus (fbw = 4.7%, ibw = 22.7%) *Recommended by physician (fbw = 4.7%, ibw = 12.3%) *Required on workplace (fbw = 4.7%, ibw = 12.1%) *Mandatory on workplace (fbw = 7.0%, ibw = 19.7%) *Recommended by public health services (fbw = 5.4%, ibw = 4.9%)	*There is an opportunity for general practitioners and occupational practitioners to promote vaccination
Ricco 2017[45]	Italy	Jan.–Jun. 2016	Agricultural workers	Tetanus	707	Cross-sectional survey	n = 171 * 58.2% Forgot about boosting *11.6% Not enough time * 9.2% Don't require boosting because initial childhood dose was sufficient *12.2% Fear of side effects* 8.2% Fear of shots *4.8% personal/religious beliefs *1.0% Known allergy to vaccine components	Not assessed	*Individuals who had a better understanding of vaccination and risks associated with tetanus infection were more likely to have positive attitude toward vaccination *Communication strategies could be beneficial for vaccine acceptance

(*Continued*)

Table 1. (Continued).

Author/ year	Location	Study period	Population	Disease	Sample size	Study design	Barriers	Motivators	Conclusion
Rahaman 2022[46]	Australia	Mar. 21–Jun. 10, 2019	Farmers	Q fever	154	Cross-sectional survey	* Know importance of vaccination, but time/ cost are barriers * Unable to access appropriate vaccine programs * Few providers of Q fever vaccination in rural areas * Takes several weeks to get appointment	* To protect self, family, and community * Subsidized vaccinationMandatory vaccination * Availability of trained providers who offer Q fever vaccination	*Importance of industry and sector-wide awareness programs and vaccine subsidies could increase vaccine uptake
Lower 2017[47]	New South Wales, Australia		Farmers	Q fever	52	Qualitative study (interview, focus groups, community meetings)	* Time, Cost, Access to vaccination	Not assessed	* Vaccine subsidies likely to increase coverage *Extend vaccine promotion and availability in the community to increase coverage
Rahaman 2021[48]	Australia	Mar. 21–Jun. 10, 2019	Livestock farmers	Q fever	351	Cross-sectional survey	* 55%–66.8% Listed the following as barriers to vaccination * Belief that Q fever is not a serious illness * Cost, time, and access to an accredited vaccine provider	*≥89.5% To protect self, spouses, workers *≥90.6% Suggested that subsidized vaccination, improved access to trained doctor could increase vaccine uptake	*Consider famers' understanding and risk perceptions about Q fever as potential enablers of vaccination
Ricco 2020[49]	Italy	Dec. 2016–Mar. 2017	Farmers	Tick-borne Encephalitis (TBE)	106	Cross-sectional survey	* 43.8% Did not know about TBE vaccine * 23.6% I'm not at risk * 21.3% Knew about vaccine but not enough time *16.3% Have doubts about vaccines * 16.3% Fears about vaccine side effects * 11.3% Too expensive * 10% Vaccine was not available	* 56.6% Knowledge of TBE vaccine * 24.5% Previously vaccinated against TBE	*Public health communication on TBD in farmers should, therefore, target understanding of health issues and appropriate preventive measures.
Chicas 2022[50]	Florida, United States	June 2020 & July 2021	Agricultural workers	COVID-19	92 – Initial study (vaccine unavailable in June 2020) 81 – Follow-up study (July 2021)	Descriptive study	N = 81 *26% of Vaccine mistrust *11% No time to get vaccinated *32% Concerned about side effects (getting sick after shot) *11% Vaccine not necessary *21% Other	Not assessed	*Worksite vaccination could address vaccine hesitancy that arises due to lack of time, transportation, or fear of contact with public officials *Education campaigns to address vaccine side effect misinformation *Targeted community campaigns are essential to increase vaccine rates

Table 2. Characteristics of the included studies and strategies to improve vaccine uptake (N = 6).

Author/ Year (reference notation)	Location	Study period	Population	Disease	Sample size	Study design	Strategy type	Strategy	Category	Outcome	Conclusion
Montejo 2017[51]	Durham, NC (United States)	Aug. – Dec (2015–2016 flu season)	Retail	Influenza	201 – Intervention site 245 – Comparison site	Prospective case-control	Multicomponent	*Health professional led education *program promotion (posters and flyers) *On-site vaccination clinic *No-cost immunizations *Choice of immunization delivery *Incentives (gift cards and bags, free restaurant entrée, company swag) *Free vaccines-Vaccine receipt stickers	*Communication *Education *Vaccine policies *Vaccine access	*Intervention sites had greater immunization rates compared to comparison sites. *Post-intervention uptake increased from 35 to 37% during the 2015–2016 flu season.	*Multicomponent interventions led by nurse practitioners in retail settings increase influenza immunization rates.
Graves 2016[52]	Seattle, WA (United States)	Fall 2012	Restaurant	Influenza	428 – preintervention 305 – post-intervention	Prospective cohort study	Multicomponent	*Program promotion (posters, flyers, model emails? text messages) *Free influenza vaccines for employees *On-site vaccine clinic	*Communication *Vaccine access	Self-reported vaccination rate increases post-intervention ranged from 26% to 46% at five sites whereas six sites had a smaller increase ranging from 2% to 14%.	*Workplace-based vaccine programs can be successfully implemented in restaurant settings.
Ofstead 2013[38]	Mid West region (United States)	Sept. 2010 – Feb. 2011	Industrial workers	Influenza	**Baseline** "Baseline survey * Site A = 497 * Site B = 503 Follow-up survey * Site A = 250 * Site B = 517 * Site C = 493 (control site)"	Prospective case-control	Multicomponent	*Incentives ($25 deposit into employee or spouse health savings account) *Free vaccination at worksite clinic) *Program promotion (CDC materials posted in factories) *Customized education messages *Health coach allocation *Recruitment of employees with artist skills to develop cartoons for posters & newsletters	*Communication *Education *Community mobilization *Vaccine policies *Vaccine access	*Vaccine uptake increased by 6% and 14% at site A and B, respectively during the intervention year. *>90% Of vaccinated employees received the vaccine at worksite event 70% Of vaccinated spouses and dependents at one site received the vaccine at an employer event.	*Immunization rates did not increase as much as expected. *Worksite programs can increase vaccination rates among industrial employees and families.

(*Continued*)

Table 2. (Continued).

Author/ Year (reference notation)	Location	Study period	Population	Disease	Sample size	Study design	Strategy type	Strategy	Category	Outcome	Conclusion
Sparkman 2017[53]	Virginia, United States	July 1 – Sept. 30 (2015)	Supermarket	Influenza	252	Retrospective observational study	Single	*Implemented immunization checkups as part of an employee health screening	Education	*Pharmacist-led influenza recommendations had a 50% (higher than national average of 38%) acceptance rate. *More vaccines were administered during the employee health screening than other times of the year.	*Immunization checkups performed at a pharmacist-provided employee health screening can lead to patient acceptance of recommendations and receipt of needed immunizations.
Landwehr 2021[14]	United States	Oct. 14 – Oct. 25	Financial group workers	Influenza	170	Comparative descriptive study (as stated by authors)	Multicomponent	*Onsite vaccination *Free employee vaccination *Educational handouts	*Vaccine access *Education *Communication	*There was an 8% increase in employee vaccine uptake compared to the previous flu season (45% employees received their vaccine through the onsite vaccination clinic)	*Offering education and multiple onsite and no-cost vaccination clinics can increase vaccine uptake
Main 2014[54]	Kentucky, United States	Oct. – Apr.	Farmers	Tetanus	280	Intervention trial	Single	*Used trusted and respected community members (academic faculty) who understood farmer culture *Identification of points of contact from in 10 counties with interest in promoting farmer health *Shared project idea with point of contact in each county	*Community mobilization	*The farmers (does not specify how many) received the Tdap vaccine. *Participants who were current with their tetanus immunization chose to receive Tdap vaccine.	*Tetanus immunization rates among farmers increased because of the community-based participatory intervention.

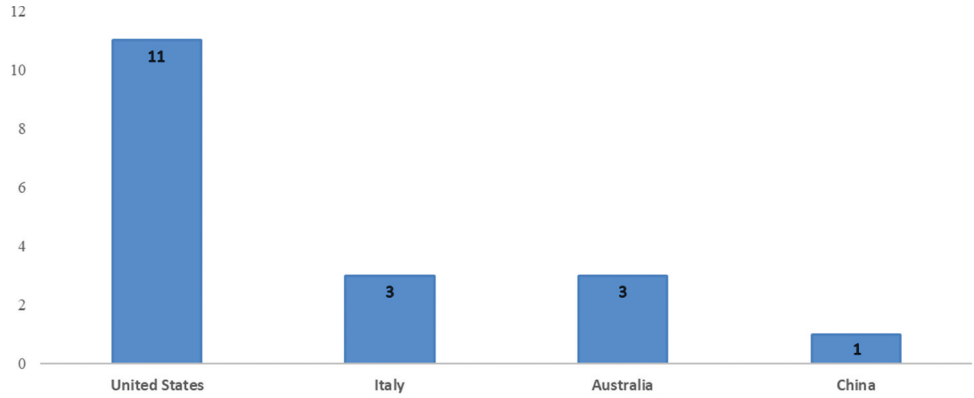

Figure 2. Study representation by location for barriers to vaccination (N = 18).

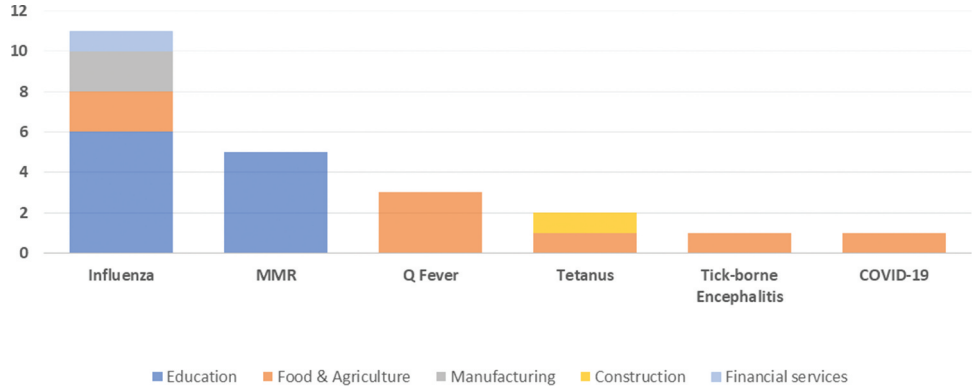

Figure 3. Included studies by infectious disease and population for barriers to vaccination (N = 18).

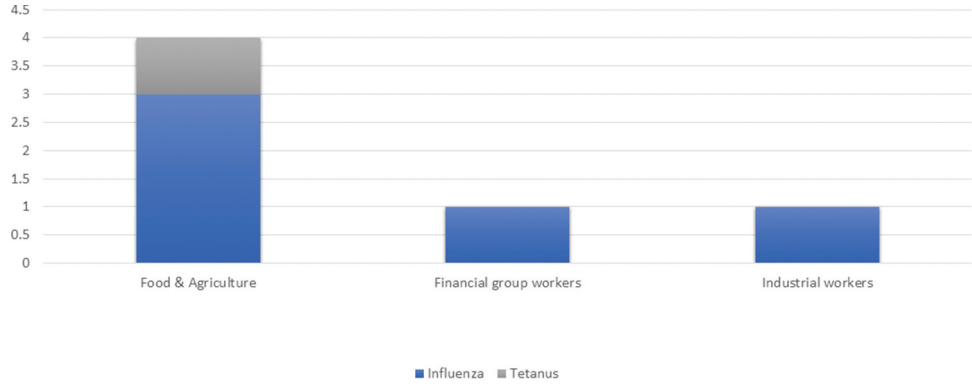

Figure 4. Included studies by infectious disease and population for vaccine uptake strategies (N = 6).

Barriers to vaccination by infectious disease

Our rapid review identified 18 studies that assessed barriers to vaccination as shown in Table 1. Two of these studies assessed both employee barriers to vaccination and vaccine uptake strategies.[14,38] By frequency, we found that the most common barriers to vaccination for all studies were convenience-related barriers such as employees not having time to get vaccinated, and the cost of vaccination (Table 3), while the most frequently stated barriers for influenza specifically were confidence and complacency related (Table 4). Conversely, when analyzed by employee response percentage variation, the barriers to employee vaccination varied by infectious disease. For influenza vaccination, about 8.6–86% participating employees were concerned about vaccine side effect, 2.4–91% were concerned about vaccination cost, and 33–90% expressed fear/dislike of injections.[14,34,36–43] Conversely, the common barriers to MMR vaccination were employee uncertainty about adult boosting requirements which accounted for approximately 30–69% of participating employees, while the percentage of participants who perceived that vaccination was unnecessary ranged from 5.3% to 16.8%.[39,40,42,43]

Table 3. Reasons for vaccine hesitancy categorized by WHO's 3C model of hesitancy (N = 17).

			Author/Year															
Factors	Barriers	Frequency	Landwehr 2021 et al	de Perio 2014 et al	Chicas 2022 et al	Rahaman 2021 et al	Ricco 2016 et al	Ricco 2017 et al	Luthy 2013* et al	Luthy 2013 et al	Luthy 2015 et al	Macintosh 2016 et al	Li 2014 et al	Parrish 2015 et al	Macintosh 2014 et al	Rahaman 2022 et al	Ricco 2020 et al	Lower 2017 et al	Ofstead 2013 et al
Convenience	No time to get vaccinated	10		x	x	x		x	x			x			x	x	x	x	
	Cost of vaccination	11	x			x			x	x		x	x	x	x	x	x	x	
	Vaccine access	4	x			x										x		x	
	Administrative barriers	1														x			
	Vaccine availability	2														x	x		
Complacency	Low perceived risk of disease	7		x		x						x			x	x	x		x
	Forgot to get the vaccine	5					x	x	x			x			x				
	Not mandatory	3							x			x			x				
	Unsure about vaccine need	3							x			x			x				
	Vaccines not necessary	5		x	x							x	x		x				
	Childhood vaccines are enough	3					x	x		x									
Confidence	Vaccine side effect concerns	9	x		x			x	x			x		x	x		x		x
	Not effective	5		x					x			x			x				x
	Needle fear	4	x					x						x					x
	Vaccine safety concerns	8		x			x		x	x		x	x		x				x
	Vaccine mistrust/ doubts	2			x												x		
Other	Religious/personal beliefs	2					x	x											
	Known vaccine allergy	2						x							x				
	Lack of knowledge about vaccination	3								x	x						x		

Table 4. Barriers to influenza vaccination uptake (N = 9).

			Author/Year								
Factors	Barriers	Frequency	de Perio 2014 et al	Ofstead 2013 et al	Li 2014 et al	Parrish 2015 et al	Luthy 2013 et al*	Luthy 2013 et al	Luthy 2015 et al	Macintosh 2014 et al	Macintosh 2016 et al
Convenience	No time to get vaccinated	4	x				x			x	x
	Cost of vaccination	6			x	x	x	x		x	x
Complacency	Low perceived risk of disease	4	x		x					x	x
	Forgot to get the vaccine	2								x	x
	Not mandatory	3					x			x	x
	Unsure about vaccine need	2					x				x
	Vaccines not necessary	3	x	x	x						
	Childhood vaccines are enough	1						x			
Confidence	Vaccine side effect concerns	5		x		x	x			x	x
	Not effective	6	x	x			x	x		x	x
	Needle fear	3		x		x				x	
	Vaccine safety concerns	4	x		x		x	x			
Other	Known vaccine allergy	2								x	x
	Lack of knowledge about vaccination	2						x	x		

For tetanus, common barriers included forgetting to get vaccinated, not having time to get vaccinated, and side effect concerns. Participant responses for forgetting to receive a booster ranged widely from 6.2% to 58.2%, while not having enough time to get vaccinated accounted for 11.6% of the responses. Additionally, responses about side effect concerns ranged from 2% to 12.2%.[44,45] For Q fever, approximately 55–66.8% of the study participants said that cost, time, access to providers, and peoples' perceived risk were barriers to vaccination.[48] The most common barriers to TBE vaccination were a lack of knowledge about the TBE vaccine and a low perceived risk, while the most common barriers to COVID-19 vaccination were side effect concerns and vaccine mistrust as shown in Table 1.[49,50]

Barriers to vaccination by most represented population

The two most represented sectors in this review were the food and agriculture and education sectors as shown in Figures 3 and 4. Overall, the most common barriers to vaccination in the identified food and agricultural sectors were vaccination cost, not having enough time to get vaccinated, vaccine accessibility issues including vaccine unavailability, and lack of vaccine providers in rural areas.[36,37,45–50] Conversely, the most common barriers to vaccination within the education sector include vaccine side effect concerns, the belief that vaccines were neither effective nor necessary, and employees not having time to get vaccinated.[39–43]

Motivators to vaccination

Table 1 provides employee motivations for vaccination assessed by 11 studies. The most common motivator for vaccination across all the represented critical infrastructure sectors and infectious diseases was protecting (self/family/friends). Recommendations made by healthcare professionals and social/peer influence also contributed to participating employees' decision to get vaccinated. Additionally, the ease/convenience of getting vaccinated were other common motivators for employee vaccination.

Strategies for increasing vaccine uptake by infectious disease

Vaccine uptake strategies for influenza focused on addressing convenience and confidence-related barriers among employees. These strategies included the provision of on-site vaccination, vaccination at no cost to employees, education programs that explained the importance and benefits of vaccination, and program promotion by using posters and flyers.[14,38,51–53] Other strategies included incentives (gift cards, $25 deposit into employee or spouse health savings account), health professional-led education sessions that addressed immunization benefits, customized education, and choice of immunization route (injectable or intranasal).[38,51] Vaccine uptake increase for the three studies that utilized multicomponent strategies ranged from 2% to 46%.

The single-component strategies included pharmacist-led immunization checkups to ensure that employees were up-to-date with their immunizations.[53] The other single-component strategy utilized a community-based participatory research frame in which key agricultural stakeholders participated in the selection of the site of the immunization program events, and recruitment activities.[54] Both these strategies led to vaccine uptake as illustrated in Table 2.

Discussion

Barriers to vaccination

As stated earlier, this rapid review was conducted to identify barriers to vaccination, motivators for vaccination, and vaccine uptake strategies within the non-health critical infrastructure

sectors. We found that barriers to employee vaccination varied by infectious disease and critical infrastructure sectors. For example, barriers to influenza and COVID-19 vaccination consisted of employee concerns about vaccine side effects, cost of vaccination, and vaccine mistrust. This finding is consistent with prior literature that found that the barriers to influenza vaccination include the fear of side effects and doubts about vaccine effectiveness.[17] For example, one study found that approximately 78% of their unvaccinated study population did not try to make a vaccination appointment largely because of concerns about vaccine side effects.[55] These concerns often originate from a fear of missing work without the possibility of paid time off or compensation if vaccination resulted in adverse side effects.[55,56] This is an important consideration for planning vaccine uptake strategies not only for influenza vaccination but also for other vaccinations like for COVID-19.

Unlike influenza and COVID-19, we found that barriers to MMR and tetanus vaccination consisted of employees' uncertainty about the need to be vaccinated, the perception that vaccination was unnecessary, and forgetting or not having time to obtain the needed booster. Similarly, a recent study found that 13% of American adults did not get a COVID-19 booster because they thought that the initial dose was enough.[57] Overall, these results suggest a need for different uptake strategies for vaccines requiring adult boosting like tetanus versus those not requiring adult boosting. We can therefore increase vaccine uptake and reduce vaccine hesitancy within the critical infrastructure sectors by identifying and eliminating disease-specific barriers.

Furthermore, we found differences in barriers to vaccination between the two most represented critical infrastructure sectors (food production and education). For influenza, tetanus, TBE, COVID-19, and Q-fever, employees within the food production sectors experienced barriers such as the cost of vaccination, not having enough time to get vaccinated, and difficulties with accessing vaccines. Studies show that employees within the frontline sectors are more likely to experience low incomes, less opportunities for paid leave, job insecurity, and unstable work schedules that can represent as barriers to vaccination.[55,58] Therefore, a revision of work policies (e.g., by incorporating vaccination time off policies) that make the choice to be vaccinated easy and convenient for employees in these sectors can increase vaccine uptake. Additionally, providing good incentives such as cash bonuses for vaccinated employees can increase vaccination.[20,56] For the education sector, it was no surprise that the identified barriers were synonymous with barriers to MMR vaccination. This was because the studies that assessed barriers to MMR vaccination were all focused on employees within the education sector. To recap, the most common barriers to MMR vaccination for employees within the education sector were uncertainty about adult boosting requirements or the perception that vaccination was unnecessary. Since the studies in the food production and education sectors focused on vaccination for different infectious diseases, a fair comparison between these two sectors is not possible. Because many critical infrastructure sectors were not represented among the reviewed studies, we still do not know the factors that influence vaccination behaviors for employees within those unrepresented critical sectors like the transportation and energy sectors. Without this knowledge, there is the danger that low vaccination and vaccine hesitancy in these sectors will result in infectious disease spread and service disruptions, as mentioned earlier.[12] Therefore, additional sector-specific studies need to be conducted to understand the barriers, motivators, and vaccine uptake strategies for employees within these unrepresented sectors. Our review found that the number of studies assessing barriers to vaccination for employees within the non-health critical infrastructure sectors is scanty. This knowledge gap is particularly time sensitive for COVID-19 as our review identified only one COVID-19 study that met the inclusion criteria.[50] Therefore, future research should focus on identifying COVID-19 barriers to vaccination, motivators, and vaccine uptake strategies for employees within these sectors.

Motivators for vaccination

In addition to understanding barriers to vaccination, understanding the factors that motivate people to get vaccinated is important to combating vaccine hesitancy and increasing vaccine uptake. We found that the most common motivator for vaccination was protecting oneself and family.[35,37,39,44,46,48,34] Our finding supports other studies that also found that protecting oneself and family is the most common motivator for vaccination.[16,59] Other motivators included recommendations made by physicians or public health professionals and vaccination ease and convenience, and vaccine mandates. To reduce vaccine hesitancy and increase uptake, public health messaging and education within the critical infrastructure sector could leverage identified motivators in addition to addressing identified barriers. For instance, one study from our review extended a workplace immunization program to also include employee family members and the result was not only an increase in employee vaccination rates but also an increase in community vaccination rates.[37] Therefore, events where vaccine uptake strategies are implemented should also be extended to employee families who can play a critical role in getting employees vaccinated.

Vaccine uptake strategies

There was consensus in the reviewed studies that the use of multicomponent interventions yields better results for increasing vaccine uptake within the critical infrastructure sectors. This result was expected because existing literature has shown that multicomponent interventions are more effective at increasing vaccination rates than single interventions.[22–24] For example, one study utilized four different interventions that addressed communication (tailored posters and flyers), education (health professional-led education), vaccine policy (incentives), and vaccine access (on-site vaccination clinic, no-cost immunizations) needs.[52] Vaccine uptake for this study increased from 35% (achieved during the previous year) to 37% (achieved during the intervention year).[51] Furthermore, the intervention site in the study (where n = 201) achieved a 45% vaccination rate, while the comparison site achieved a 32% vaccine rate.[51] However, a few studies found that even with the implementation of multicomponent interventions addressing

communication, vaccine access, education, and/or incentives, an increase in vaccine uptake was still suboptimal.[38,52] According to site audits, these suboptimal vaccine uptake increases could have been due to factors such as poor management as compared to sites with successful vaccination increases.[35,36] Even though these studies did not achieve the expected vaccination rate increase, there was a consensus that multicomponent intervention can increase vaccine uptake as compared to single interventions. Our review also found that single-component interventions such as community mobilization and pharmacist-led immunization checkups at employee health screening events increased vaccine uptake when implemented within the farming and retail industries, respectively.[52,38] Depending on resource availability, it is worth considering utilizing evidence-based single-component vaccine uptake strategies. We therefore recommend the utilization of either multicomponent or evidence-based single-component vaccine uptake strategies as needed by the critical infrastructure sectors. Furthermore, sectors should consider incorporating program planning (includes conducting employee needs assessments), implementation, monitoring, and evaluation plans that are vital to determining the impact and effectiveness of an implemented strategy.[60]

Influenza vaccine uptake strategies

Finally, the synthesis of vaccine uptake strategies by infectious diseases was possible only for influenza because all studies except one focused on increasing influenza vaccine uptake. As a result, the most common vaccine uptake strategies for influenza were those that addressed convenience and confidence barriers. These strategies included free worksite vaccination for employees and varying education programs that stressed the benefits of vaccination.[14,38,51–53] This finding is consistent with the finding mentioned earlier that common barriers to influenza vaccination among employees were confidence and convenience related. While utilizing these strategies to address the identified barriers is critical to increasing vaccine uptake, it is important to consider the concerns of already vaccinated employees during the planning of vaccination campaigns. One of the reviewed studies found that despite being vaccinated, employees still had concerns about vaccine side effects and vaccination cost.[39] Therefore, there is a need to not only focus on increasing vaccine uptake among unvaccinated employees but also a need to focus on reducing vaccine hesitancy among vaccinated employees by reinforcing their decision to be vaccinated and addressing concerns about vaccine safety.

Reasons for vaccine hesitancy by WHO 3C model

The identified barriers were matched with corresponding factors from the 3C model of vaccine hesitancy. We found that common barriers to employee vaccination were convenience related which supports our earlier statement that employees within our target population are likely to forego vaccination due to lack of time or cost of vaccination. Principally, employee reasons for vaccine hesitancy fit within the categories of the 3C model. However, our review exposed weaknesses of the model because reasons such as religion, no knowledge of specific vaccines, and known allergies to certain vaccines did not fit within any of the three categories. In this light, Betsch et al. expanded the 3C model to a 5C model. This model maintains the definition of confidence and complacency and expands constraints (formerly convenience) to include both structural and psychological barriers to vaccination, and adds two categories: calculation (engaging in extensive information searching) and collective responsibility (willingness to protect others).[61] As stated by Betsch, the 5C model takes on a more psychological approach to understanding the determinants of vaccination behaviors.[61] However, using the 5C model, we still could not the fit reasons for hesitancy such as religious beliefs and known vaccine allergies into any of the categories. Although an argument could be made to include both reasons within the "constraints" category, the author's definition does not allow for such. Therefore, we recommend the development of revised or additional models that can account for less common barriers to vaccination when applicable.

Limitations

Our rapid review is subject to language bias due to the exclusion of non-English studies, which increases the risk of omitting key non-English findings. The findings are not generalizable to critical infrastructure sectors not represented in the identified studies; this limitation applies also to the healthcare sector, which was excluded consistently with the study scope. In line with the rapid nature of the review approach, this review was conducted within a three-month timeframe making it less comprehensive than a systematic review. The likelihood of errors increases because only one person conducted the data extraction process. Our review also increases the potential for bias because we did not include gray literature that excludes unpublished data and negative results. Lastly, excluding studies published before 2012 may have increased the likelihood of not considering older significant results. Despite these limitations, our rapid review is the first to assess barriers to vaccination and effective vaccine uptake strategies across different infectious diseases among employees in the critical infrastructure sectors while utilizing the WHO's 3C model of vaccine hesitancy.

Recommendations

Based on our findings, we recommend the implementation of disease-specific vaccine uptake strategies because barriers to employee vaccination differ by infectious disease. For example, for boosters like for MMR, tetanus, and COVID-19, program planners should focus on communicating/reminding employees about boosting and the importance of receiving boosters. Further, where possible, employers should include employee families within workplace vaccination programs as this strategy has been effective at not only increasing workplace vaccination but also community vaccination. Additionally, depending on resource availability, critical infrastructure sectors can utilize the multicomponent strategy approach to determine which combination of strategies works best for their specific sector. To determine the most effective multicomponent strategy

combination, sectors are advised to document implemented strategies and develop a program monitoring and evaluation plan. We recommend the implementation of evidence-based single-component strategies that address the most common barrier to employee vaccination. To achieve this, sectors should consider conducting an employee needs assessment. We also recommend understanding the concerns that vaccinated employees have about vaccines. This can be achieved by utilizing health professionals or respected community leaders in vaccine campaign events or by creating forums where employees can talk about vaccine concerns.

This review identified critical knowledge gaps in the available literature regarding critical infrastructure-sector employee vaccination. For instance, the limited number of studies assessing barriers to employee vaccination and effective vaccine uptake strategies for non-healthcare related critical infrastructure sectors suggests an urgent need to study the key determinants of vaccination within these sectors. Additionally, the lack of studies representing other critical infrastructure sectors is unsettling and should be remedied by studies focused on determining factors that influence employee vaccination behaviors within these unrepresented sectors. Despite the effectiveness of the multicomponent strategies identified within this review, vaccine uptake cannot be attributed to any one strategy. Therefore, additional strategies should be evaluated for effectiveness at increasing vaccine uptake to ensure that resources are prioritized to strategies that yield higher vaccination rates in a particular critical infrastructure sector. In summary, our review provides new insight on the existence of differences to vaccination barriers for employees by sector and by infectious disease. Consequently, these findings will play a vital role in informing future research and policies aimed at addressing low vaccination and reducing vaccine hesitancy.

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