Vaccine 37 (2019) 235–247

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Review

Interventions to help people understand community immunity: A systematic review

Hina Hakim [a], Thierry Provencher [b], Christine T. Chambers [c], S. Michelle Driedger [d], Eve Dube [e], Teresa Gavaruzzi [f], Anik M.C. Giguere [a], Noah M. Ivers [g], Shannon MacDonald [h], Jean-Sebastien Paquette [a], Kumanan Wilson [i], Daniel Reinharz [j], Holly O. Witteman [a,*]

[a] Department of Family and Emergency Medicine, Laval University, 1050 avenue de la Médecine, Pavillon Ferdinand-Vandry, Quebec City, QC G1V 0A6, Canada
[b] School of Psychology, Laval University, Quebec City, QC, Canada
[c] Department of Pediatrics and Psychology and Neuroscience, Dalhousie University, Halifax, NS, Canada
[d] Department of Community Health Sciences, University of Manitoba, Winnipeg, MB, Canada
[e] Institut national de santé publique du Québec, Quebec City, QC, Canada
[f] Department of Developmental Psychology and Socialization, University of Padova, Italy
[g] Department of Family and Community Medicine, Women's College Hospital – University of Toronto, Toronto, ON, Canada
[h] Faculty of Nursing, University of Alberta, Edmonton, AB, Canada
[i] Department of Medicine, University of Ottawa, Ottawa Hospital Research Institute, Ottawa, ON, Canada
[j] Department of Social and Preventive Medicine, Laval University, Quebec City, QC, Canada

ARTICLE INFO

Article history:
Received 13 June 2018
Received in revised form 5 October 2018
Accepted 1 November 2018
Available online 6 December 2018

Keywords:
Community immunity
Herd immunity
Vaccination
Vaccine hesitancy

ABSTRACT

Background: Herd immunity, or community immunity, occurs when susceptible people in a population are indirectly protected from infection thanks to the pervasiveness of immunity within the population. In this study, we aimed to systematically review interventions designed to communicate what community immunity is and how community immunity works to members of the general public.
Methods: We searched PubMed, EMBASE, CINAHL, the Cochrane Central Register of Controlled Trials and Web of Science for peer-reviewed articles describing interventions with or without evaluations. We then conducted web searches with Google to identify interventions lacking associated publications. We extracted data about the target population of the interventions, the interventions themselves (e.g., did they describe what community immunity is, and how it works), any effects of evaluated interventions, and synthesized data narratively.
Results: We identified 32 interventions: 11 interventions described in peer-reviewed articles and 21 interventions without associated articles. Of the 32 interventions, 5 described what community immunity is, 6 described the mechanisms of how community immunity occurs and 21 described both. Fourteen of the 32 addressed infectious diseases in general while the other 13 addressed one or more specific diseases. Twelve of the 32 interventions used videos, 7 used interactive simulations and 6 used questionnaires. Ten of the 11 peer-reviewed articles described studies evaluating at least one effect of the interventions. Within these 10, 4/4 reported increased knowledge, 3/5 reported shifts of attitudes in favour of vaccination, 2/5 reported increased intentions to vaccinate. Of 3 studies evaluating interventions specifically about community immunity, 2 reported increased intentions to vaccinate.
Conclusions: A compelling benefit of vaccination exists at the population level in the form of community immunity. Identifying ways to optimally communicate about this benefit may be important, because some evidence suggests that effective communication about community immunity can increase vaccination intentions.

Abbreviations: MMAT, Mixed method assessment tool; SD, Sample standard deviation; MMR, Measles Mumps and Rubella; IB, Individual Benefits; SB, Social Benefits; Ctl, Control.

* Corresponding author.
E-mail addresses: hina.hakim.1@ulaval.ca (H. Hakim), thierry.provencher@fmed.ulaval.ca (T. Provencher), christine.chambers@dal.ca (C.T. Chambers), Michelle.Driedger@umanitoba.ca (S.M. Driedger), eve.dube@inspq.qc.ca (E. Dube), teresa.gavaruzzi@unipd.it (T. Gavaruzzi), anik.giguere@fmed.ulaval.ca (A.M.C. Giguere), noah.ivers@utoronto.ca (N.M. Ivers), smacdon@ualberta.ca (S. MacDonald), jean-sebastien.Paquette@fmed.ulaval.ca (J.-S. Paquette), kwilson@ohri.ca (K. Wilson), daniel.reinharz@fmed.ulaval.ca (D. Reinharz), holly.witteman@fmed.ulaval.ca (H.O. Witteman).

https://doi.org/10.1016/j.vaccine.2018.11.016
0264-410X/

Contents

1. Introduction

Many vaccines protect against disease not only by preventing infection in those receiving the vaccine, but also by preventing the infection from being transmitted from one person to another [1,2]. The terms herd immunity and community immunity refer to the indirect protection of unvaccinated people obtained by elevating the pervasiveness of immunity within a population. Such an elevation breaks the chain of transmission and decreases one's probability of contact with an infectious agent [2]. In this paper we use the term *community immunity*.

Previous research has suggested that potential benefits and harms at the individual level are more influential than those at the community level on people's decisions to immunize or not [3]. However, it is not clear whether community-level benefits are well-understood but simply not important to people, or whether community-level benefits lack influence in individual decisions because such benefits are poorly communicated. That is, are the relationships between individual-level vaccination behaviour and individual- and community-level benefits and harms communicated well to people? If they are communicated well, are people more favourable towards vaccination? Communicating well about community immunity is a complex task, because whether or not a given population achieves community immunity depends on many variables, including vaccine effectiveness, vaccine coverage, distribution patterns of infection among populations, timing of vaccine administration and serotype replacement [4]. Given the underlying complexity of community immunity as a concept, it is plausible that its lack of observed influence on vaccination decisions [5,6] may stem at least partly from a lack of clarity about the concept among members of the public.

In this systematic review, we aimed to synthesize evidence about interventions intended to help members of the general public better understand the concept of community immunity. By interventions, we mean any method, strategy, or tool developed to help people understand the concept of community immunity. Because visualization is a powerful way to convey complex topics [7,8] and because visualizations have proved effective at helping members of the public understand other related mathematical concepts such as how population-based statistics apply to an individual [7,9], we were particularly interested in web-based visualizations as interventions. By visualization, we mean visual presentations of data or information. These presentations may be static or dynamic, and interactive or not. The objective of this systematic review was therefore to describe interventions, including web-based interventions, aimed at conveying the concept of community immunity and to describe any reported effects of such interventions.

2. Methods

2.1. Search strategy

To identify peer-reviewed literature describing interventions designed to communicate the concept of community immunity, we searched PubMed, EMBASE, CINAHL, the Cochrane Central Register of Controlled Trials and Web of Science on April 19, 2016, updated on January 25, 2018 to identify any newer articles. The full search strategy is available in Supplemental file 1. We did not apply any language or publication date restrictions. In addition, we retrieved further studies by searching the references of relevant review articles [10–19], by a hand search of articles cited by or cited in the included articles, and by consulting with 33 experts through professional networks of co-authors for suggestions of relevant published or unpublished literature or web-based interventions missed during our search.

To identify interventions that may not have associated publications, we conducted an online Google search in two stages. We sought any web-based representations conveying the concept of herd immunity or community immunity. First, on April 24th 2017, we conducted a standard search using Google to find web-based representations which had herd immunity components or

were about explaining community immunity. We used six search terms "Herd immunity", "Herd protection", "Herd effect", "Community protection", "Indirect protection", "Community immunity" combining each with, "AND (simulation OR animation OR visualization)". We reviewed the first 30 results for each search, as it is rare for users to click past the third page of ten search results per page, and therefore, researchers analyzing medical content available on the web often use 30 as a threshold [20–22]. On June 9, 2017, we conducted the same searches in private browsing mode to ascertain whether our results had been affected by a "filter bubble" [23]; that is, the way Google search results are adapted to one's previous browsing activity.

2.2. Study selection and screening process

Two reviewers (HH, TP) independently identified and screened all studies and web-based interventions for their eligibility. Conflicts were resolved by a third reviewer (HW). We used PICO (Population, Intervention, Comparison, and Outcome) to structure study inclusion and exclusion criteria. Our population of interest was the general public or any subgroup thereof. We sought studies describing any strategies, tools or methods (including campaigns and educational tools) designed to help people understand more about the concept of community immunity. Our comparator was any control, including offering no education about community immunity or comparing participants before and after an intervention. Our outcomes of interest included common outcomes in vaccination acceptance studies: knowledge (comprehension, understanding), attitudes (attitudes toward or against vaccination), beliefs (risk perceptions, perceived benefits), and behavioural intentions (intentions to be vaccinated or not). We also sought to extract any data about emotions (e.g., fear, anxiety), as emotions are key drivers of decisions [24].

We excluded studies that did not have a component specifically about community immunity; for example, studies about policies, policy decision-making, vaccine provision programs, vaccine hesitancy, or anti-vaccine movements. For web-based tools, our inclusion and exclusion criteria used the same specifications regarding population and intervention. We did not apply comparison and outcome criteria to web-based tools because we did not expect these to report evaluation studies. We report this review according to PRISMA guidelines (see PRISMA checklist in Supplemental file 2). This systematic review was registered in PROSPERO (CRD42017069206).

2.3. Data extraction

Two people (HH, TP) independently extracted data from included articles and web-based interventions. Conflicts were resolved by a third reviewer (HW). From included articles and web-based interventions, we extracted information about: (1) the type of intervention (educational material for home use, live education session, etc.) (2) the medium of the intervention (paper, web, etc.), (3) the objective of the study or intervention, (4) whether the intervention was solely about community immunity or whether it was a broader intervention, (5) whether the intervention aimed to convey the importance or existence of community immunity (the "what" of community immunity; i.e., the existence of community-level protection to safeguard those who are not immune), how it works (the "how" of community immunity; i.e., community immunity is achieved by preventing the spread of infection from one person to another within the community), or both. For evaluated interventions, we extracted (6) the characteristics of study participants and (7) outcomes observed. We extracted data about interventions' effects on knowledge, attitudes, beliefs (perceived benefits, perceived risks), and behaviours. We preselected these outcomes based on the Health Belief Model [25,26], a model widely used to predict health related-behaviours and to assess outcomes in studies of interventions about vaccination and immunization [10–13]. People may also rely on emotional, cultural, and social factors before making a decision about vaccination [27,28]. Cultural and social factors are unlikely to be changed by interventions, but emotions may be affected. Therefore, we also extracted data about emotions elicited by interventions based on the Affect Heuristic theoretical framework, which describes the role and importance of emotions in judgment and decisions [24]. Because we sought to understand all possible effects, we did not prespecify any of these as a primary outcome.

2.4. Data validation

When we were missing details or were uncertain about data, we contacted authors to review the data we had extracted about their studies. We contacted four authors via email. We received responses from three of these four, who reviewed the draft extractions we had sent as well as provided us with additional data not reported in their publication. After a reminder email with no response, we also followed up with the nonresponding author and their co-authors by email and phone, but were not able to reach any member of the authorship team.

2.5. Quality assessment

We used the Mixed Methods Appraisal Tool (MMAT) by Pluye and colleagues [29] to assess the quality of all studies. Quality assessment was conducted independently by two reviewers (HH, TP) and disagreements were settled through discussion until consensus was reached. Remaining conflicts among them was resolved by a third reviewer (HW).

2.6. Data synthesis

We organized data in tables and synthesized it descriptively. We also calculated observed heterogeneity (Higgins I^2) to determine whether it would be possible to conduct meta-analyses of available randomized controlled trials [30,31] on common outcomes, namely, behavioural intentions, perceived risk of disease, and perceived risks of vaccination. We used package meta version 4.4.0 [32] within R version 3.3.0 [33] for these calculations.

3. Results

3.1. Articles identified, scope of literature

We identified a total of 16,012 records through database searches and 529 interventions through Google searches. After removing duplicates, we screened 9,380 database records and 285 Web-based representations. After our private browsing mode search, no change was detected that was different from our previous search. Through these methods, we identified 8 articles and 19 web-based representations. Hand-searching yielded three other articles and two additional web-based representations. Thus, our final data set included 11 peer-reviewed articles and 21 web-based representations, for a total of 32 interventions. Fig. 1 shows our PRISMA diagram.

Out of 11 interventions described in peer-reviewed articles, 3 were solely about community immunity while the other 8 had a component about community immunity within a larger intervention (Table 1). Out of 21 web-based representations, 18 were solely about community immunity while the other 3 had a component about community immunity within a larger intervention (Table 2).

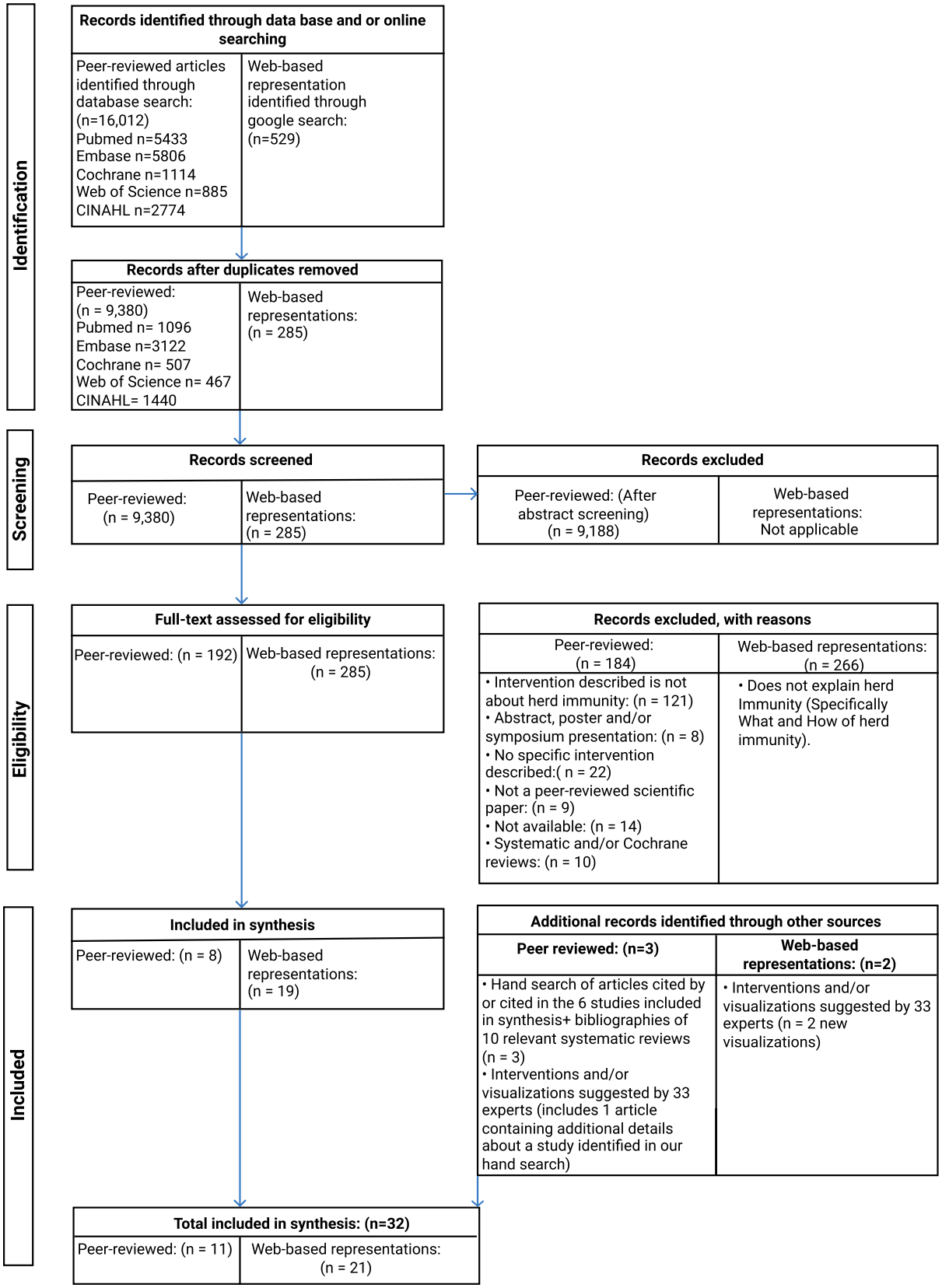

Fig. 1. PRISMA diagram.

Thus, out of 32 interventions in total (peer-reviewed and web-based representations together), 21 were solely about community immunity, and 11 had included community immunity as a component of a larger intervention. Five interventions aimed to convey the "what" of community immunity, meaning what it is, six addressed the "how" of community immunity, meaning how it

Table 1
Peer-reviewed literature regarding interventions about community immunity.

Reference	Type of intervention	Medium of intervention	Objective of study/paper	Is intervention solely about community immunity?	Was the intervention evaluated?	Disease(s) used to explain community immunity
Anderson [45]	Questionnaire	Online	To increase the knowledge, skills, and attitudes of nurse practitioners and assist them in their understanding of immunizations and its impact on humans.	No	No	Not reported
Awadh et al. [34]	Educational animated 10-min video + Didactic 50-min PowerPoint lecture	Online + Verbal	To assess short educational intervention for improving parents' knowledge about childhood vaccination.	No	Yes	Not reported
Betsch et al. [30]	Questionnaire	Online	To assess the consequences of communicating the social and/or individual benefits of herd immunity on vaccination intentions.	Yes	Yes	Fictitious disease
Betsch et al.; Brockmann; Dirk Brockmann [31,46,47]	Interactive simulation + Text-based	Online	To assess the influence of communicating the mechanism of herd immunity on vaccination intentions.	Yes	Yes	Not Reported
Carolan et al. [38]	PowerPoint presentation + Interactive simulation	Online	To assess the effects of an interactive simulation and traditional educational interventions on young adults' attitudes towards vaccination and level of confidence in knowledge of vaccination.	No	Yes	Measles, Mumps, Smallpox or Influenza
Gargano et al. [35]	Brochure (for parents)/ PowerPoint presentation + Videos (for adolescents)	Paper + Online + Verbal	To describe the development, theoretical framework and evaluation of an intervention designed to enhance adolescent vaccination rates and to promote adolescent vaccine acceptance among parents and adolescents attending middle and high schools.	No	Yes	Influenza, Diphtheria, Tetanus, Pertussis, Meningococcal disease and Human papillomavirus
Glik et al. [36]	10- to 15-min motivational video and 5-module curriculum (1 describing herd immunity).	Online + Paper	To increase awareness, improve attitudes, and facilitate proactive behaviour about immunization by implementing an immunization promotion curriculum (Immunization Plus) for young adolescents, their parents, and teachers.	No	Yes	Not Reported
Hendrix et al. [48]	Questionnaire	Online	To determine whether emphasizing the benefits of measles-mumps-rubella (MMR) vaccination directly to the vaccine recipient or to society differentially impacts parents' vaccine intentions for their infants.	No	Yes	Measles, Mumps and Rubella
Kennedy et al. [39]	Questionnaire	Paper	To obtain suggestions for the optimal presentation of vaccine-related information and to determine if an educational intervention influences mothers' vaccine safety attitudes.	No	Yes	Measles, Mumps and Rubella
Melton et al.; Schoeppe et al. [37,49]	Training and materials (physical materials, website) for parent advocates to share with others in their networks	Verbal + Paper + Online	To address parental vaccine hesitancy by empowering parents to be immunization advocates, improving awareness of immunization as a social norm among parents at participating sites, and changing those parents' attitudes and behaviours.	No	Yes	Not Reported
Vietri et al. [40]	Questionnaire (in which scenarios were embedded)	Online	To evaluate the circumstances under which vaccination decisions are influenced by a potential benefit for others (altruism) and examine the conditions under which potential benefit for others operates.	Yes	Yes	Human Papillomavirus and Influenza

works, and 21 interventions addressed both (Table 3). As shown in Table 3, web-based representations generally included elements of the "how" of community immunity whereas this was not necessarily the case for interventions presented in the peer-reviewed literature. For example, 4 out of 11 (36%) interventions described in the peer-reviewed literature conveyed that community immunity works by preventing the spread of infection, whereas 17 out of 21 (81%) web-based representations did the same. Ten out of 11 peer-reviewed articles reported evaluating the intervention according to at least one of our outcomes of interest and described the demographic characteristics of participants (Table 4; Table 5).

3.2. Quality assessment

Table 4 provides Mixed Methods Assessment Tool scores of all evaluated peer-reviewed articles included in our review. Of the ten studies, four had high quality scores (75% or above), two were of medium quality (50%) and four were of low quality (25%) on this measure. Supplemental files 3 and 4 provides full details.

3.3. Effects of evaluated interventions

Ten studies evaluated at least one of our outcomes of interest. Summarized outcomes are shown in Tables 5 and 6.

Table 2
Web-based visualizations regarding interventions about community immunity.

Reference	URL	Country	Type of intervention	Medium of intervention	Is intervention solely about community immunity?	Disease(s) used to explain community immunity
Amanda Martyn, 2016 (North Carolina School of Science and Mathematics)	https://www.ncssm.edu/learning-innovations/2016/10/27/ncssm-instructor-s-animation-stresses-the-importance-of-vaccination-and-herd-immunity	United States	Video	Online	Yes	No specific disease
Carolyn Kylstra, 2015 (Buzzfeed News)	https://www.buzzfeed.com/carolynkylstra/vaccines-and-herd-immunity?utm_term=.drmPwQzxo0#.pl8e0YMaKx	United States	GIF	Online	Yes	Measles and Ebola.
College of Physicians of Philadelphia	https://www.historyofvaccines.org/content/herd-immunity-0	United States	Video	Online	Yes	No specific disease
Emily Willingham and Laura Helft, 2014	http://www.pbs.org/wgbh/nova/body/herd-immunity.html	United States	Static Image	Online	Yes	Measles, Chicken pox and Polio
ExSciEd, 2013	https://www.youtube.com/watch?v=CPcC4oGB_o8	Unknown	Video	Online	Yes	Diphtheria, Tetanus, Mumps, Polio, Measles and Smallpox
Guardian US interactive team, 2015	http://www.theguardian.com/society/ng-interactive/2015/feb/05/-sp-watch-how-measles-outbreak-spreads-when-kids-get-vaccinated	United Kingdom (US branch)	Simulation	Online	No	Measles
Harvard Health Publication	http://www.health.harvard.edu/herd-immunity-animation	United States	Video	Online	Yes	No specific disease
Liz Ruttenbur, 2014	http://www.wsusignpost.com/2014/11/13/herd-immunity/	United States	Static Image	Online	Yes	No specific disease
[Name not given]	http://op12no2.me/toys/herd/	Unknown	Interactive simulation	Online	Yes	No specific disease
Never Stop Dreaming, 2016	https://www.youtube.com/watch?v=6waMp4GgvcA	Unknown	Video	Online	Yes	No specific disease
NHS Public Health England, 2015	http://www.nhs.uk/Video/Pages/Vaccinationanimation2.aspx	England	Video	Online	Yes	No specific disease
NRVS, 2016	http://nrvs.info/faqs/herd-immunity-or-community-immunity/	Australia	Graphics	Online	Yes	No specific disease
Romina Libster, 2015 (Ted Talk)	https://www.ted.com/speakers/romina_libster	Argentina	Talk	Online	Yes	Measles
Salathé Group 2014	http://vax.herokuapp.com/herdImmunity	Switzerland	Interactive game	Online	Yes	Measles
Sarah Stapleton, 2015	https://www.vinceandassociates.com/blog/herd-immunity-explained-by-gif/	United States	Blog (with GIFs)	Online	Yes	Measles
Shane Killian, 2010	http://www.software3d.com/Home/Vax/Immunity.php	Unknown	Interactive simulation	Online	Yes	No specific disease
Techydad, 2010	http://www.techydad.com/Vaccinate/	Unknown	Interactive simulation	Online	No	No specific disease
Theotheredmund, 2016	https://www.reddit.com/r/dataisbeautiful/comments/5v72fw/how_herd_immunity_works_oc/	Unknown	Simulation	Online	Yes	No specific disease
Thomas Lumley, 2014	(https://www.youtube.com/watch?v=KkMD6KGgltU; https://www.youtube.com/watch?v=uw93SdC-ouo; https://www.youtube.com/watch?v=ivRBM03gPwM; https://www.youtube.com/watch?v=xTmHUegqcrA)	Unknown	Video	Online	Yes	No specific disease
University of Pittsburgh, 2015	http://fred.publichealth.pitt.edu/measles/	United States	Interactive simulation	Online	No	Measles
Vaccines Today, 2015	https://www.vaccinestoday.eu/stories/what-is-herd-immunity/	Europe	Video	Online	Yes	No specific disease

3.3.1. Effects on knowledge

Four studies that assessed knowledge (2 high quality, 1 medium quality, 1 low quality) showed an increase in knowledge about immunization in general [34–37]. These studies were larger interventions that included information about community immunity as a component of the intervention. The community immunity component was not evaluated independently.

3.3.2. Effects on attitudes

Three studies out of five that assessed attitudes (1 high quality, 1 medium quality, 3 low quality) showed the intervention may have shifted attitudes more in favour of vaccination [35–39]. These studies were also larger interventions that included information about community immunity as a component of the intervention.

3.3.3. Effects on intentions to vaccinate

Two of the five studies that assessed intentions to vaccinate (3 high quality, 1 medium quality, 1 low quality) showed increased intentions to vaccinate. One of these two studies (high-quality) was of an intervention specifically about community immunity showed an increase in intentions to vaccinate when the intervention was interactive and the concept of community immunity was explained [31]. The other of the two studies (low quality) showed that the intervention may increase interest in vaccination if the concept of community immunity was explained as one's vaccination protecting others in society [40].

3.3.4. Effects on emotions

No studies evaluated the effects of interventions on emotions.

Table 3
The importance and mechanisms of community immunity in the interventions.

References	"What?" Were they seeking to convey the importance/existence of community immunity (e.g., community immunity protects those who aren't or can't be vaccinated)? If yes, what was the message?		"How?" Were they seeking to convey how community immunity works; i.e., the mechanism of community immunity (e.g., community immunity works by preventing the spread of infection such that those who aren't or can't be vaccinated are less likely to encounter the infection)? If yes, what was the message?		
	Community immunity protects others who are not immune	Community immunity protects people who are vulnerable (old, young, sick, immunocompromised)	Community immunity provides protection by reducing/stopping the spread of infection	Community immunity provides protection when enough people are immune/ get vaccinated	"Enough" people being immune/ getting vaccinated varies by disease
Peer-reviewed literature					
Anderson [45]	Conveyed	Not conveyed	Conveyed	Conveyed	Not conveyed
Awadh et al. [34]	Conveyed	Not conveyed	Not conveyed	Not conveyed	Not conveyed
Betsch et al. [30]	Conveyed	Conveyed	Conveyed	Conveyed	Not conveyed
Betsch et al.; Brockmann; Dirk Brockmann [31,46,47]	Conveyed	Conveyed	Conveyed	Conveyed	Conveyed
Carolan et al. [38]	Conveyed	Conveyed	Not conveyed	Conveyed	Conveyed
Gargano et al. [35]	Conveyed	Conveyed	Conveyed	Conveyed	Not conveyed
Glik et al. [36]	Conveyed	Not conveyed	Not conveyed	Not conveyed	Not conveyed
Hendrix et al. [48]	Conveyed	Conveyed	Not conveyed	Not conveyed	Not conveyed
Kennedy et al. [39]	Not conveyed	Not conveyed	Not conveyed	Conveyed	Conveyed
Melton et al.; Schoeppe et al. [37,49]	Conveyed	Not conveyed	Not conveyed	Not conveyed	Not conveyed
Vietri et al. [40]	Not conveyed	Not conveyed	Not conveyed	Conveyed	Conveyed
Web-based representations					
Amanda Martyn, 2016 (North Carolina School of Science and Mathematics) [50]	Conveyed	Conveyed	Not conveyed	Not conveyed	Not conveyed
Carolyn Kylstra, 2015 (Buzzfeed News) [51]	Conveyed	Conveyed	Conveyed	Conveyed	Conveyed
College of Physicians of Philadelphia [52]	Conveyed	Conveyed	Conveyed	Conveyed	Not conveyed
Emily Willingham and Laura Helft, 2014 [53]	Conveyed	Conveyed	Conveyed	Conveyed	Not conveyed
ExSciEd, 2013 [54]	Conveyed	Not conveyed	Conveyed	Conveyed	Not conveyed
Guardian US interactive team [55]	Conveyed	Not conveyed	Not conveyed	Conveyed	Conveyed
Harvard Health Publication [56]	Conveyed	Not conveyed	Not conveyed	Conveyed	Not conveyed
Liz Ruttenbur [57]	Conveyed	Not conveyed	Conveyed	Conveyed	Not conveyed
Never Stop Dreaming [58]	Conveyed	Not conveyed	Conveyed	Conveyed	Conveyed
NHS Public Health England [59]	Conveyed	Not conveyed	Conveyed	Conveyed	Not conveyed
[Name not given] [60]	Conveyed	Conveyed	Conveyed	Conveyed	Not conveyed
NRVS [61]	Conveyed	Conveyed	Conveyed	Conveyed	Not conveyed
Romina Libster Ted Talk [62]	Conveyed	Not conveyed	Conveyed	Conveyed	Conveyed
Salathé Group [63]	Conveyed	Conveyed	Conveyed	Conveyed	Conveyed
Sarah Stapleton [64]	Conveyed	Conveyed	Conveyed	Conveyed	Conveyed
Shane Killian [65]	Not conveyed	Not conveyed	Conveyed	Conveyed	Not conveyed
Techydad [66]	Not conveyed	Not conveyed	Conveyed	Conveyed	Not conveyed
Theotheredmund [67]	Conveyed	Conveyed	Conveyed	Conveyed	Not conveyed
Thomas Lumley [68]	Not conveyed	Not conveyed	Conveyed	Conveyed	Not conveyed
University of Pittsburgh [69]	Not conveyed	Not conveyed	Not conveyed	Conveyed	Conveyed
VaccinesToday [70]	Conveyed	Conveyed	Conveyed	Conveyed	Conveyed

3.3.5. Effects of interventions solely about community immunity

Out of the three studies that evaluated the effects of an intervention solely about community immunity, all three assessed intentions to vaccinate as their sole outcome. Two of the three resulted in an increase in intentions to vaccinate [31,40] while the other demonstrated no change [30].

3.4. Meta-analysis

Two randomized controlled trials [30,31] tested outcomes in common, specifically, the effects of communicating information about community immunity on behavioural intentions, perceived risk of disease, and perceived risk of vaccination. Mean I^2 estimates were 63% (see Supplemental file 5). This high heterogeneity between the two studies meant that reliable meta-analytic results were not possible.

4. Discussion

In this study, we aimed to describe interventions aimed at conveying the concept of community immunity and to describe any

Table 4
Characteristics of participants and quality score of peer-reviewed literature describing the interventions.

Reference	Country	Sample size (n)	Study population/ intended audience	Age	Sex/gender (n, percentage)	Ethnicity (n, percentage)	Socioeconomic variables	*MMAT Quality score (percentage)
Anderson [45]	United States	Not applicable (intervention not evaluated)	Nurse practitioners	Not applicable (intervention not evaluated)	Not applicable (intervention not evaluated)	Not applicable (intervention not evaluated)	Not applicable (intervention not evaluated)	Not applicable (intervention not evaluated)
Awadh et al. [34]	Malaysia (Kuantan)	n = 73	Parents	20 to 30 years (n = 30, 41%); 30 to 40 years (n = 35, 48%); >40 years (n = 8, 11%)	Women (n = 64, 88%); Men (n = 9, 12%)	Malay (n = 66, 90%); Chinese (n = 7, 10%)	Employed (n = 59/73); Unemployed (n = 14/73)	75%
Betsch et al. [30]	Germany	n = 342	Students and non-students	Mean age 30 years (*SD 13)	Female (n = 221, 64%)	Not reported	Abitur (German University entrance diploma) or higher level of education (n = 301, 88%)	50%
Betsch et al.; Brockmann; Dirk Brockmann [31,46,47]	South Korea, Vietnam, Hong Kong, United States, Germany and the Netherlands	n = 2107 participants	General population	Mean age 29 years (SD 10)	1217 respondents were women (58%). 890 respondents were male (42%).	Not reported	85% of the sample had a high school diploma or a higher level of education.	100%
Carolan et al. [38]	England	n = 63	Students	Age ranging from 14 to 18 years	Male (n = 34, 54%); Female (n = 29, 46%)	Asian/Asian British (n = 3, 5%); Mixed Ethnic Background (n = 1, 2%); White British (n = 94%)	Not Reported	25%
Gargano et al. [35]	United States (Georgia)	n = 184 (parents); n = 667 (middle-school students); n = 401 (high-school students)	Parents/ Adolescents	Not Reported	Not Reported	Not Reported	Not Reported	25%
Glik et al. [36]	United States (California counties)	n = 929	Students (6th to 8th grade)	Age ranging from 10 to 12 years	Equal numbers of boys and girls	Hispanic (n = 460, 50%); Mixed Hispanic and another Race (n = 16, 2%); White (n = 185, 20%); White and other (n = 20, 2%); Black (n = 131, 14%); Asian Americans (n = 94, 10%); Native Americans (n = 20, 2%)	Not Reported	75%
Hendrix et al. [48]	United States (Indiana)	n = 802	Parents	Mean age 29 years (SD 7)	Male (n = 172, 21.6%); Female (n = 626, 78.5%)	Hispanic/ Latino (n = 125, 16%; Not Hispanic/Latino (n = 673, 84%)	Household income (<10 000: n = 90, 11%; $10,000-$24,999: n = 135, 17%; $25,000-$49,999: n = 248, 31%; $50,000-$75,000: n = 181, 23%; >$75,000: n = 136, 17%)	75%

Table 4 (*continued*)

Reference	Country	Sample size (n)	Study population/ intended audience	Age	Sex/gender (n, percentage)	Ethnicity (n, percentage)	Socioeconomic variables	*MMAT Quality score (percentage)
Kennedy et al. [39]	United States cities	n = 927	Mothers; Scientists; Women with no children	25 to 34 years (n = 496, 54%); 35 to 45 years (n = 431, 47%)	Female	Non-Hispanic white mothers (n = 927, 100%)	Employment status: Employed (n = 873, 94%); Not employed (n = 54, 6%); Education: Less than a high school graduate (n = 27, 3%); High school graduate (n = 160, 17%); Some college (n = 373, 40%); College graduate (n = 266, 29%); Post graduate degree (n = 98, 11%)	25%
Melton et al.; Schoeppe et al. [37,49]	United States (Washington State)	Pre-test n = 460; Post-test n = 238	Parents	Not Reported	Not Reported	Not Reported	Not Reported	50%
Vietri et al. [40]	Not reported	n = 292 (1st study); n = 291 (2nd study); n = 299 (3rd study)	College students	Not Reported	Study 1: Female (n = 124, 43%); Male (n = 168, 58%) Study 2 and Study 3: Not Reported	Not Reported	Not Reported	25%

*MMAT = Mixed method assessment tool; *SD = Sample standard deviation; Inter rater reliability = 83%.

reported effects of such interventions. Our results lead us to four principal findings.

First, there is relatively little evidence about the effects of communicating about community immunity. Although a number of interventions described in the literature included a component about community immunity, few studies isolated the effects of such a component. This makes it difficult to interpret and report the effectiveness of interventions about community immunity, as any effects of these larger interventions may be due to their other components. However, within the limited sample of interventions specifically about community immunity, we observed that two out of three such interventions resulted in increases in intentions to vaccinate [31,40]. This suggests that communicating population-level benefits of vaccination may encourage vaccine uptake.

Second, we identified a number of interventions available online for which we were unable to find associated evaluation studies. These web-based representations often showed people not only what community immunity is, but also how it is achieved. This may be easier to do using dynamic methods such as visualization. It is unknown, however, whether such demonstrations make a difference, meaning that although communicating about community immunity may encourage vaccination, there remains little evidence about how to do this most effectively. Future research could compare different ways of communicating about community immunity to assess their influence on people's views about their role in protecting their community from infectious disease.

Third, studies in this review offered few results regarding variables that shape vaccination intentions, such as knowledge or emotion. Although several studies reported effects on knowledge about immunization, few reported knowledge specifically about community immunity and none assessed emotions as outcomes. Emotions are critical to human decision-making [41] and influence decisions through their effects on risk perception [47], attitudes, and behavioural intentions [42–44]. Future research about the effects of communication interventions might therefore be improved by evaluating interventions' effects on emotions in addition to knowledge, attitudes, beliefs, and behavioural intentions.

Fourth and finally, our review documented that most included interventions were designed for high-income, Western countries. Moreover, evaluation studies measured the effects of their intervention mostly on sub-populations of school, college or university students. These population selection factors raise questions about the potential differential effects of interventions among members of the general population with varied age groups or education levels. One intervention that was designed to be used across cultures was more effective in encouraging vaccination intentions in Western countries than it was in Eastern countries. The authors noted that this was possibly because baseline vaccine uptake was already high in Eastern countries and there was therefore less room for change [31]. Cultural differences and differences between countries in terms of vaccination programs may be important to consider when analyzing public responses to interventions.

To the best of our knowledge, there are no previous systematic reviews synthesizing interventions to convey the concept of community immunity. Previous work has been mostly focused on improving knowledge, attitudes, beliefs, and behavioural intentions in order to improve immunization or vaccination coverage, with limited research on how and whether the concept of community immunity might be conveyed.

Our systematic review had two main limitations. First, we may be missing relevant data. Although we aimed to be meticulous in our search strategy, it is possible that we missed some relevant studies or interventions. Even among included studies, when publications lacked details, some authors responded to our queries while others were not reachable. In addition, although we did not apply any language restriction when searching databases, our

Table 5
Summaries of evaluation studies.

Article(s)	Study design and comparison type(s)	Comparison and sample size (n)	Summary of findings relevant to cognition (includes knowledge, comprehension, understanding, etc.), attitudes (includes attitudes toward or against vaccination, etc.), behavioural intentions (includes getting vaccinated or not, etc.) and emotions (fear, anxiety, etc.).
Awadh et al. [34]	Cross-sectional study using pre- and post-test intervention survey of a single group.	Compared difference in knowledge before and after intervention. (n = 73)	Parents' knowledge improved by 2.31 points on 10-point scale ($p < 0.001$). Pre-intervention mean knowledge score was 6.84 (˚SD 1.52); post-intervention mean knowledge score was 9.15 (SD 0.79).
Betsch et al. [30] *(community immunity component evaluated independently)*	Online randomized controlled trial using a factorial 2 × 2 × 2 between-subjects experimental design with individual benefit of herd immunity (communicated versus. not communicated), social benefit of herd immunity (communicated versus. not communicated), and costs of vaccination (low versus. high) as factors. A control group received no information about herd immunity.	Vaccination intentions were assessed when communicating or not communicating the social benefits of herd immunity. (n = 342)	Communicating the social benefits of vaccination did not influence vaccination intentions. Mean intentions to vaccinate on a scale from 1 = 'definitely not vaccinate' to 7 = 'definitely vaccinate' were 3.89 in the control group (SD 1.78) and 4.01 in the group receiving information about social benefits of vaccination (SD 1.86).
Betsch et al.; Brockmann; Dirk Brockmann [31,46,47] *(community immunity component evaluated i ndependently)*	Online randomized controlled trial using a factorial experimental design with both within- and between-subject factors. Specifically, the experiment used a 2 (cultural background: collectivistic Eastern countries versus individualistic Western countries; quasi-experimental between subjects) × 3 (communication format: interactive simulation versus text-based explanation versus no explanation of herd immunity; between subjects) × 2 (individual versus social benefit of herd immunity; between subjects) × 2 (basic reproduction number of the disease determining the contagiousness, R0: 3 versus 15; within subjects with counterbalanced order of appearance) × 2 (vaccination uptake: 42% versus 62%; randomly selected for each scenario) mixed design. The control group received no information.	Vaccination intentions were assessed when information was communicated through interactive simulation versus text-based explanation. Vaccination intentions were assessed when the mechanism of herd immunity was explained versus when no information about herd immunity was provided. Vaccination intentions were assessed among Eastern and Western countries when herd immunity mechanism was explained versus no information. (n = 2,107)	Mean increases in intentions to vaccinate on a 101-point scale were 8.71 (SD 28.91) in the group receiving an interactive simulation to explain herd immunity and 4.05 (SD 29.55) in the group receiving text to explain herd immunity. Mean increases in intentions to vaccinate on a 101-point scale were 58.64 (SD 29.37) in conditions when herd immunity was explained and 52.95 (SD 29.16) receiving no information. Mean increases in intentions to vaccinate on a 101-point scale were 11.27 (SD 31.45) in Western countries when herd immunity was explained relative to no information and 1.18 (SD 26.03) in Eastern countries.
Carolan et al. [38]	Randomized controlled trial (three parallel arms): (a) presentation-based intervention, (b) interactive simulation-based intervention; and (c) control arm (no intervention)	Attitudes towards vaccination were assessed among students. (n = 63)	No statistically significant differences were found between the three groups immediately after the intervention, nor after six months.
Gargano et al. [35]	Randomized controlled trial (three parallel arms): (a) an educational brochure targeted to parents, (b) the parent brochure and a science teacher–delivered intervention targeted to students; and (c) a control arm (no intervention).	Vaccine related knowledge was assessed among students. Attitudes towards vaccines and vaccination were assessed (influenza vaccines) among students. (n = 667 middle-school students; n = 401 high-school students)	There was an increase in knowledge about vaccines and how they work: a statistically significant increase in knowledge among students of middle and high school for the item about herd immunity, "By getting a vaccination, you protect others as well as yourself." The intervention may have shifted attitudes towards seeing flu as serious disease and vaccines providing protection; however, there was no adjustment for multiple hypothesis tests.
Glik et al. [36]	Quasi-experimental non-equivalent comparison-groups waiting list design (4 parallel arms): (a) training of teachers in the curriculum followed by curriculum implementation; (b) curriculum implementation, without teacher training; (c) screening of the *Immunization Day* video as the only intervention; and (d) no intervention.	Knowledge, attitudes towards immunization and health related behaviours were assessed. (n = 929)	The intervention (curriculum) increased knowledge about immunization and health related behaviours and shifted attitudes more in favor of vaccination. It did not improve vaccination intention nor vaccination status.
Hendrix et al. [48]	Randomized controlled trial (4 parallel arms) of vaccine messages (a) the MMR (Measles Mumps and Rubella) Vaccine Information Statement (VIS), which is standard information from the CDC describing MMR and the MMR vaccine; (b) VIS plus additional information highlighting the MMR vaccine's benefits directly to the child receiving the vaccine; (c) VIS plus additional information highlighting the MMR vaccine's benefits to society at large; and (d) VIS plus additional information highlighting the MMR vaccine's benefits directly to the child receiving the vaccine and to society at large.	Vaccine-related intentions were assessed by questionnaire among parents (1-item questionnaire: "On the scale below, please indicate how likely you are to have your baby receive the MMR vaccine." 11-point response scale ranged from 0 not at all likely, to 100 extremely likely, in increments of 10) (n = 802)	Information emphasizing the MMR vaccine's benefits to society did not significantly change intentions to vaccinate one's child.

Table 5 (*continued*)

Article(s)	Study design and comparison type(s)	Comparison and sample size (n)	Summary of findings relevant to cognition (includes knowledge, comprehension, understanding, etc.), attitudes (includes attitudes toward or against vaccination, etc.), behavioural intentions (includes getting vaccinated or not, etc.) and emotions (fear, anxiety, etc.).
Kennedy et al. [39]	Randomized controlled trial (5 parallel arms): (a) "risk comparison" message, vaccination information statement (VIS), (b) "reduced coverage" message VIS, (c) "both messages" VIS, (d) standard VIS ("control group"), or (e) no test materials ("surveys only" group).	Vaccine-related attitudes were assessed pre- and post-intervention by a questionnaire (one item, 5-point Likert scale) related to herd immunity: "It is important to vaccinate my child in order to prevent the spread of disease in my community." (n = 927)	No significant changes in vaccine-related attitudes.
Melton et al.; Schoeppe et al. [37,49]	Unmatched cross-sectional web-based surveys before and after implementation of intervention.	Parents' vaccine knowledge, attitudes and beliefs were assessed. Knowledge was defined as selecting the correct multiple choice answer to the question, "What percentage of people in your community need to be vaccinated for everyone to be protected from disease?" with the correct answer, "almost all (95% to 100%)". Attitudes and beliefs were measured using responses on a Likert scale to 13 statements. (Pre-test n = 460; Post-test n = 238)	75.9% of parents selected the correct response pre-intervention and 78.4% of parents selected the correct response post-intervention (non-significant). Four out of 13 items describing statements of attitudes and beliefs showed statistically significant differences; however, no adjustments were made to account for multiple hypothesis testing.
Vietri et al. [40] *(community immunity component evaluated independently)*	Three cross-sectional studies	Likelihood to get vaccinated was assessed for different vaccines under different conditions (e.g., percentage of others immune, percentage of others vulnerable) using an 11-point scale of intervals of 10% ranging from 0% to 100%. (Study 1: n = 292; Study 2: n = 291; Study 3: n = 299)	In two of the three studies, likelihood of being vaccinated was sensitive to how many others could potentially be helped by one's own vaccination. In Study 2, mean likelihood of getting vaccinated when there would be no benefit to oneself was 81% (SD 30%) when 95% of the population would benefit compared to 74% (SD 27%) when 10% of the population would benefit ($p < 0.001$, eta-squared = 0.10). Study 3 replicated the finding that people indicate willingness to be vaccinated purely to help others (means not reported).

*SD = Sample standard deviation.

Table 6
Summary of effects in evaluation studies.

Article(s)	Knowledge	Attitudes	Intentions	Emotions
Awadh et al. [34]	**Measured: increased**	Not measured	Not measured	Not measured
Betsch et al. [30] *(community immunity component evaluated independently)*	Not measured	Not measured	**Measured: no change**	Not measured
Betsch et al.; Brockmann; Dirk Brockmann; [31,46,47] *(community immunity component evaluated independently)*	Not measured	Not measured	**Measured: increased**	Not measured
Carolan et al. [38]	Not measured	**Measured: no change**	Not measured	Not measured
Gargano et al. [35]	**Measured: increased**	**Measured: may have shifted towards seeing flu as a serious disease and vaccines providing protection, but no adjustments for multiple hypothesis testing**	Not measured	Not measured
Glik et al. [36]	**Measured: increased**	**Measured: shifted more in favour of vaccination**	**Measured: no change**	Not measured
Hendrix et al. [48]	Not measured	Not measured	**Measured: no change**	Not measured
Kennedy et al. [39]	Not measured	**Measured: no change**	Not measured	Not measured
Melton et al.; Schoeppe et al. [37,49]	**Measured: small increase (2.5 percentage points) in people selecting correct answer but no statistical test of significance**	**Measured: some items changed but no adjustments for multiple hypothesis testing**	Not measured	Not measured
Vietri et al. [40] *(community immunity component evaluated independently)*	Not measured	Not measured	**Measured: sensitive to how many people would be helped**	Not measured

web searches used English keywords, and therefore, we may have missed interventions in other languages. Second, most of our evaluation data came from studies of interventions that included information about community immunity as a component of an overall intervention. This means that, in most cases, we were unable to isolate the effects of community immunity components.

5. Conclusions

This systematic review demonstrates that despite the existence of a number of interventions available for conveying the concept of community immunity, little is known about how to make this concept comprehensible to members of the general population. Identifying ways to do this may be important, because some evidence suggests that effective communication about community immunity can increase vaccine intentions. Future research should focus on how to communicate this concept effectively and should evaluate interventions' effects on vaccine intentions and uptake as well as their precursors, such as knowledge, attitudes, beliefs and emotions.

Authors' contributions

HH, HW contributed to the design of the study. HH, TP and HW contributed to data collection. HH and HW conducted data analysis and interpretation. HH and HW drafted the first version of the article with early revision by HH, TP and HW. HH, TP, CTC, ED, TG, AMCG, NMI, SMD, JSP, KW, DR, HW critically revised the article and approved the final version for submission for publication. HH, TP and HW had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Conflict of interest

None.

Funding

This study was funded by the Canadian Institutes of Health Research (grant number FDN-148426, 2016–2021, PI: Witteman). The CIHR had no role in determining the study design, the plans for data collection or analysis, the decision to publish, nor the preparation of this manuscript. HW receives salary support from a Research Scholar Junior 2 Career Development Award by the Fonds de Recherche du Québec—Santé.

Acknowledgements

The authors gratefully acknowledge the contributions of Virginie Sirois to this project as a research assistant, Jordie Croteau (statistician) and Hervé Zomahoun for assistance with statistical analyses, Frédéric Bergeron (librarian) for assistance with search strategy, and Selma Chipenda Dansokho, Ruth Ndjaboue, Gratianne Vaisson, Olivia Drescher, Elizabeth Parent, and other colleagues for their constructive comments on earlier versions of this paper. We thank all authors of the original articles who helped validate the data we had extracted from their papers.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2018.11.016.

References

[1] Metcalf CJE, Ferrari M, Graham AL, Grenfell BT. Understanding Herd Immunity. Trends Immunol 2015;36:753–5.
[2] Rashid H, Khandaker G, Booy R. Vaccination and herd immunity: what more do we know? Curr Opin Infect Dis 2012;25:243–9.
[3] Quadri-Sheriff M, Hendrix KS, Downs SM, Sturm LA, Zimet GD, Finnell SME. The role of herd immunity in parents' decision to vaccinate children: a systematic review. Pediatrics 2012;130:522–30.

[4] Scarbrough Lefebvre CD, Terlinden A, Standaert B. Dissecting the indirect effects caused by vaccines into the basic elements. Hum Vaccin Immunother 2015;11:2142–57.
[5] Fefferman NH, Naumova EN. Dangers of vaccine refusal near the herd immunity threshold: a modelling study. Lancet Infect Dis 2015;15:922–6.
[6] Betsch C. Innovations in communication: the Internet and the psychology of vaccination decisions. Euro Surveill 2011;16.
[7] Hawley ST, Zikmund-Fisher B, Ubel P, Jancovic A, Lucas T, Fagerlin A. The impact of the format of graphical presentation on health-related knowledge and treatment choices. Patient Educ Couns 2008;73:448–55.
[8] Okan Y, Garcia-Retamero R, Cokely ET, Maldonado A. Improving risk understanding across ability levels: Encouraging active processing with dynamic icon arrays. J Exp Psychol Appl 2015;21:178–94.
[9] Garcia-Retamero R, Cokely ET. Effective communication of risks to young adults: using message framing and visual aids to increase condom use and STD screening. J Exp Psychol Appl 2011;17:270.
[10] Dubé E, Gagnon D, MacDonald NE. Strategies intended to address vaccine hesitancy: Review of published reviews. Vaccine 2015;33:4191–203.
[11] Kaufman J, Synnot A, Ryan R, Hill S, Horey D, Willis N, et al. Face to face interventions for informing or educating parents about early childhood vaccination. The Cochrane Library 2013.
[12] Cairns G, MacDonald L, Angus K, Walker L, Cairns-Haylor T, Bowdler T. Systematic literature review of the evidence for effective national immunisation schedule promotional communications. European Centre for Disease Prevention and Control (ECDC) 2012.
[13] Saeterdal I, Lewin S, Austvoll-Dahlgren A, Glenton C, Munabi-Babigumira S. Interventions aimed at communities to inform and/or educate about early childhood vaccination. The Cochrane Library 2014.
[14] Odone A, Ferrari A, Spagnoli F, Visciarelli S, Shefer A, Pasquarella C, et al. Effectiveness of interventions that apply new media to improve vaccine uptake and vaccine coverage: A systematic review. Hum Vaccin Immunother 2015;11:72–82.
[15] Jarrett C, Wilson R, O'Leary M, Eckersberger E, Larson HJ. Strategies for addressing vaccine hesitancy–a systematic review. Vaccine 2015;33:4180–90.
[16] Sadaf A, Richards JL, Glanz J, Salmon DA, Omer SB. A systematic review of interventions for reducing parental vaccine refusal and vaccine hesitancy. Vaccine 2013;31:4293–304.
[17] Lorini C, Santomauro F, Donzellini M, Capecchi L, Bechini A, Boccalini S, et al. Health literacy and vaccination: A systematic review. Hum Vaccin Immunother 2018;14:478–88.
[18] Crocker-Buque T, Mindra G, Duncan R, Mounier-Jack S. Immunization, urbanization and slums - a systematic review of factors and interventions. BMC Public Health 2017;17:556.
[19] Jordan R, Connock M, Albon E, Fry-Smith A, Olowokure B, Hawker J, et al. Universal vaccination of children against influenza: are there indirect benefits to the community? A systematic review of the evidence. Vaccine 2006;24:1047–62.
[20] Hargrave DR, Hargrave UA, Bouffet E. Quality of health information on the Internet in pediatric neuro-oncology. Neuro Oncol 2006;8:175–82.
[21] Petrescu P. Google organic click-through rates in 2014. MOZ Blog (October 1st)-http://moz Com/blog/google-Organic-Click-through-Rates-in-2014 [2016 05 30] 2014.
[22] van der Marel S, Duijvestein M, Hardwick JC, van den Brink GR, Veenendaal R, Hommes DW, et al. Quality of web-based information on inflammatory bowel diseases. Inflamm Bowel Dis 2009;15:1891–6.
[23] Resnick P, Garrett RK, Kriplean T, Munson SA, Stroud NJ. Bursting your (filter) bubble: strategies for promoting diverse exposure. In: Proceedings of the 2013 conference on computer supported cooperative work companion, New York, NY, USA: ACM; 2013. p. 95–100.
[24] Slovic P, Finucane ML, Peters E, MacGregor DG. The affect heuristic. Eur J Oper Res 2007;177:1333–52.
[25] Janz NK, Becker MH. The health belief model: a decade later. Health Educ Q 1984;11:1–47.
[26] Rosenstock IM. Historical origins of the health belief model. Health Educ Monogr 1974;2:328–35.
[27] Dubé E, Laberge C, Guay M, Bramadat P, Roy R, Bettinger J. Vaccine hesitancy: an overview. Hum Vaccin Immunother 2013;9:1763–73.
[28] Hobson-West P. Understanding vaccination resistance: moving beyond risk. Health Risk Soc 2003;5:273–83.
[29] Pluye P, Gagnon M-P, Griffiths F, Johnson-Lafleur J. A scoring system for appraising mixed methods research, and concomitantly appraising qualitative, quantitative and mixed methods primary studies in mixed studies reviews. Int J Nurs Stud 2009;46:529–46.
[30] Betsch C, Böhm R, Korn L. Inviting free-riders or appealing to prosocial behavior? game-theoretical reflections on communicating herd immunity in vaccine advocacy. Health Psychol 2013;32:978.
[31] Betsch C, Böhm R, Korn L, Holtmann C. On the benefits of explaining herd immunity in vaccine advocacy. Nat Hum Behav 2017. 1:s41562–017 – 0056.
[32] Tran A. Meta Box 4.4.0 Released - Meta Box. Meta Box 2014. https://metabox.io/version-4-4-0/ [accessed November 15, 2017].
[33] Development Core R, Team R. A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2017.
[34] Awadh AI, Hassali MA, Al-Lela OQ, Bux SH, Elkalmi RM, Hadi H. Does an educational intervention improve parents' knowledge about immunization? Experience from Malaysia. BMC Pediatr 2014;14:254.
[35] Gargano LM, Herbert NL, Painter JE, Sales JM, Vogt TM, Morfaw C, et al. Development, theoretical framework, and evaluation of a parent and teacher-delivered intervention on adolescent vaccination. Health Promot Pract 2014;1524839913518222.
[36] Glik D, Macpherson F, Todd W, Stone K, Ang A, Connell Jones M. Impact of an immunization education program on middle school adolescents. Am J Health Behav 2004;28:487–97.
[37] Schoeppe J, Cheadle A, Melton M, Faubion T, Miller C, Matthys J, et al. The immunity community: a community engagement strategy for reducing vaccine hesitancy. Health Promot Pract 2017;18:654–61.
[38] Carolan K, Verran J, Crossley M, Redfern J, Whitton N, Amos M. Impact of educational interventions on adolescent attitudes and knowledge regarding vaccination: A pilot study. PLoS One 2018;13. e0190984.
[39] Kennedy A, Glasser J, Covello V, Gust D. Development of vaccine risk communication messages using risk comparisons and mathematical modeling. J Health Commun 2008;13:793–807.
[40] Vietri JT, Li M, Galvani AP, Chapman GB. Vaccinating to help ourselves and others. Med Decis Making 2012;32:447–58.
[41] Lerner JS, Li Y, Valdesolo P, Kassam KS. Emotion and Decision Making 2015. https://doi.org/10.1146/annurev-psych-010213-115043.
[42] Kahneman D, Ritov I. Determinants of stated willingness to pay for public goods: A study in the headline method. J Risk Uncertain 1994;9:5–37.
[43] Kahneman D, Schkade D, Sunstein C. Shared outrage and erratic awards: the psychology of punitive damages. J Risk Uncertain 1998;16:49–86.
[44] Fazio - Attitude strength: Antecedents and consequences RH, 1995. Attitudes as object-evaluation associations: Determinants, consequences, and correlates of attitude accessibility. Books.google.com 1995.
[45] Anderson VL. Promoting childhood immunizations. J Nurse Pract 2015;11:1–10.
[46] Brockmann D. Public health: This message must be herd. Nat Hum Behav 2017;1:0065.
[47] How Herd Immunity Works n.d. http://rocs.hu-berlin.de/D3/herd/ [accessed August 27, 2018].
[48] Hendrix KS, Finnell SME, Zimet GD, Sturm LA, Lane KA, Downs SM. Vaccine message framing and parents' intent to immunize their infants for MMR. Pediatrics 2014;134:e675–83.
[49] Melton M. Does your community have immunity? mobilizing parents who immunize to influence their vaccine-hesitant peers through community engagement approaches. 141st APHA Annual Meeting (November 2-November 6, 2013), APHA; 2013.
[50] NCSSM instructor's animation stresses the importance of vaccination and herd immunity n.d. https://www.ncssm.edu/learning-innovations/2016/10/27/ncssm-instructor-s-animation-stresses-the-importance-of-vaccination-and-herd-immunity [accessed August 27, 2018].
[51] Kylstra C. 5 GIFs that show why herd immunity is so important. BuzzFeed 2015. https://www.buzzfeed.com/carolynkylstra/vaccines-and-herd-immunity [accessed August 27, 2018].
[52] Herd immunity | history of vaccines n.d. https://www.historyofvaccines.org/content/herd-immunity-0 [accessed August 27, 2018].
[53] What is herd immunity? — NOVA | PBS n.d. http://www.pbs.org/wgbh/nova/body/herd-immunity.html [accessed August 27, 2018].
[54] ExSciEd. Vaccines, herd immunity, and gummi bears - Oh My! Youtube; 2013.
[55] Harris R, Popovich N, Powell K. Watch how the measles outbreak spreads when kids get vaccinated–and when they don't. Guardian 2015.
[56] Harvard health publishing. Herd immunity animation - harvard health. Harvard health n.d. https://www.health.harvard.edu/staying-healthy/herd-immunity-animation [accessed August 27, 2018].
[57] wsusignpost. Herd immunity: Fact or fiction? Signpost 2014. http://signpost.mywebermedia.com/2014/11/13/herd-immunity/ [accessed August 27, 2018].
[58] Never stop dreaming. Herd immunity animation. Youtube; 2016.
[59] Choices N. NHS VIDEOS | Vaccinations: part 2 - Health videos - NHS choices; 2018.
[60] Epidemic sir model to reveal herd immunity n.d. http://op12no2.me/toys/herd/ [accessed August 27, 2018].
[61] Herd immunity (or community immunity) | northern rivers vaccination supporters n.d. https://nrvs.info/faqs/herd-immunity-or-community-immunity/ [accessed August 27, 2018].
[62] Libster R. Romina Libster | Speaker | TED 2015. https://www.ted.com/speakers/romina_libster [accessed August 27, 2018].
[63] Vax | Gamifying epidemic prevention n.d. http://vax.herokuapp.com/herdImmunity [accessed August 27, 2018].
[64] Herd immunity explained by GIF | Vince & Associates Clinical Research n.d. https://www.vinceandassociates.com/blog/herd-immunity-explained-by-gif/ [accessed August 27, 2018].
[65] Herd immunity simulator n.d. https://www.software3d.com/Home/Vax/Immunity.php [accessed August 27, 2018].
[66] Vaccinate! n.d. http://www.techydad.com/Vaccinate/ [accessed August 27, 2018].
[67] r/dataisbeautiful - How herd immunity works [OC]. n.d.
[68] Thomas Lumley. Herd immunity simulation: 10% vaccinated. Youtube; 2014.
[69] FRED Web n.d. https://fred.publichealth.pitt.edu/measles [accessed August 27, 2018].
[70] Editorial team. What is herd immunity? - VaccinesToday. VaccinesToday 2015. https://www.vaccinestoday.eu/stories/what-is-herd-immunity/ [accessed August 27, 2018].