



REVIEW



## Interventions to increase pediatric vaccine uptake: An overview of recent findings

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### ABSTRACT

Although much is known about factors contributing to variation in pediatric immunization uptake, there is a need for synthesis of effective vaccine promotion strategies. With growing public health concern on how to best sustain high pediatric immunization rates, and improve where the rates are suboptimal, this review offers evidence gathered from several studies on the achievement of these goals. We identified and analyzed reported findings on childhood (primarily  $\leq 7$  years) immunization outcomes from tested intervention strategies that focused on parents, guardians, and caregivers, as well as providers, clinics/practices, and communities. The findings suggest that targeted and tailored interventions offer substantial possibilities, especially in a combined manner. We describe promising intervention models that have been operationalized with success and provide evidence for scalability across contexts. Moreover, they are sensitive to parents' and providers' needs, are feasibly integrated in daily clinical practice, and account for broader community concerns and issues.

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### Introduction

Immunization rates among children in the United States have steadily increased over recent decades, now exceeding  $\geq 90\%$  for most recommended vaccines among children entering kindergarten.<sup>1</sup> Despite these high levels, however, immunization coverage rates fall short of Healthy People 2020 initiation and completion rate goals for many vaccines recommended for children.<sup>2</sup> For example, the series completion rate among children 19–35 months for  $\geq 4$  doses of diphtheria and tetanus toxoids and acellular pertussis vaccine (DTaP) (84.6%), *Haemophilus influenzae* type b (Hib) (82.7%) vaccine and  $\geq 4$  doses of pneumococcal conjugate (PCV) vaccine (84.1%) remain below 90%.<sup>3</sup> Additionally, although target uptake rates for  $\geq 2$  doses of hepatitis A (HepA) vaccine and hepatitis B (HepB) birth doses are set at 85%, actual coverage rates are lower (59.6% and 72.4%, respectively). Rotavirus vaccination (73.2%) and the combined 7-vaccine series (which includes  $\geq 4$  doses of DTaP;  $\geq 3$  doses of poliovirus vaccine;  $\geq 1$  dose of measles-containing vaccine;  $\geq 3$  or  $\geq 4$  doses of Hib (depending upon product type of vaccine);  $\geq 3$  doses of HepB;  $\geq 1$  dose of varicella vaccine; and  $\geq 4$  doses of PCV) (72.2%) remain below the target of 80% for children 19–35 months.<sup>3</sup> Additionally, there is a growing public health concern over persistent vaccine hesitancy in light of recent, high-profile outbreaks of vaccine-preventable diseases.<sup>3–11</sup>

Regional, state, and local variation in uptake and coverage has consistently been documented.<sup>3–5,12</sup> Although national rates of vaccine refusal according to the National Immunization Survey (NIS) are estimated at  $<1\%$ , recent CDC survey evidence also reflects regional disparities in coverage and hesitancy.<sup>3</sup>

One study describing reported parental refusal and delay of one or more childhood immunizations in the United States during 2012–2014 identified a decrease in intentional vaccine refusal in the Southern region (from 5% to 2.1%) of the US during this time, but also identified higher rates ( $> 6\%$ ) of vaccine refusal in the Midwest during these years (2012–2014).<sup>8</sup> An increase in vaccine delay in the Northeast (from 3.2% to 8.8%) was also observed during this same timeframe.<sup>8</sup>

There is also considerable variation in vaccination coverage among states. In 2015, the lowest and highest rates for the birth-dose of hepatitis B differed by 36.1% (49.4% in Vermont, 87.5% in North Dakota).<sup>3,5</sup> Coverage for completion of the combined 7-vaccine series among children 19–35 months old ranged from 64.4% (Virginia) to 80.6% (Connecticut).<sup>3</sup> In Arkansas, philosophical or personal belief exemptions have been accepted since 2002; exemptions among kindergarteners increased more than 15-fold from when the legislation changed before the 2002–2003 school year (.5/1000) to the 2009–2010 (8.21/1000) school year.<sup>13</sup> A recent report showed that states permitting personal belief/philosophical exemptions, such as Arkansas, have adjusted exemption rates 2.8 times higher than states that only allow religious and medical exemptions, such as Connecticut, Florida, or Montana.<sup>14</sup> On January 1, 2016, California joined Mississippi and West Virginia as the only 3 states that only permit medical exemptions.<sup>15,16</sup> The latter 2 states had some of the highest immunization rates in the country among kindergarteners for the 2015–2016 school year, with Mississippi reporting  $\geq 99\%$  coverage for 2 doses of MMR, 2 doses of varicella, and 5 doses of DTaP.<sup>1</sup>

Gaps in reported immunization coverage are even greater at the local level, as hesitance, refusal, and exemptions tend to cluster in smaller geographic pockets.<sup>17-19</sup> In spring 2017, for example, the state of Minnesota experienced a measles outbreak across 4 counties: Hennepin, Ramsey, Crow Wing, and Le Sueur.<sup>20</sup> Of the 76 confirmed cases by mid-June, 70 were identified as unvaccinated and 64 were Somali Minnesotan.<sup>20</sup> Inter-county personal belief exemptions rates differ by as much as 24.3 percentage points in Arizona, California, North Dakota, and Washington.<sup>19</sup> Finally, although the Vaccines for Children program has narrowed racial/ethnic and socioeconomic disparities considerably, lower immunization coverage levels still occur among impoverished and non-white populations,<sup>3,12,21-25</sup> as well as among urban and inner-city populations compared with other suburban and rural areas.<sup>12,21,26</sup>

To maintain and improve rates, it is critical to identify, understand, and promote strategies and interventions proven to increase vaccination coverage among children. This is especially important in an era of increasing complexity of immunization schedules and the advent of new vaccines, rising expectations for performance in primary care, and exhaustive demands on primary care physicians. This review identifies strategies aimed at parents (the primary decision-makers), providers, clinics/offices, and communities that have proven to be effective in increasing childhood immunization coverage.

## Methods

We conducted keyword searches that identified pediatric immunization studies focused on improving immunization rates and uptake among young children that were published from 1990 to 2017. Our search was conducted using the PubMed database and the following keywords in titles or abstracts: *childhood* or *pediatric*; *vaccine*, *vaccination*, or *immunization*; and *intervention*. We subsequently reviewed the references of retrieved articles. Inclusion criteria included the following: (1) intervention studies that focused on pre-adolescent young children and/or infants, (2) reported any outcome of pediatric immunization rates, and (3) included a comparison group. We excluded studies that focused on adolescents, were published >30 y ago, and/or did not test an intervention. We reviewed 66 studies: 39 randomized controlled trials (RCTs), and 27 quasi-experimental studies (before-and-after trial, non-randomized controlled trial, time-series, etc.).

## Evidence to improve pediatric immunization uptake

### Interventions for parents

Multiple studies have documented successful strategies for improving childhood immunization rates via changes geared toward parents of pediatric patients. As one of the simpler strategies to implement, reminder/recall systems have been endorsed by the American Academy of Pediatrics<sup>27</sup> and the Task Force on Community Preventive Services.<sup>28</sup> This approach has been tested extensively using randomized controlled trial (RCT) and quasi-experimental designs. We reviewed 34 studies testing a recall/reminder system and found that the majority (n = 27, 79%) reported odds ratios (ORs)

between 1.09–1.55 – meaning an increase in the likelihood of immunization uptake of 9–55% – and increases in immunization rates of +1 to +44 percentage points from study baseline.<sup>26,29-54</sup> The other 7 studies reported either non-statistically significant effects,<sup>55-59</sup> limited effects (e.g. changes among only one antigen or group),<sup>60</sup> or no effect at all.<sup>61</sup> Challenges in obtaining accurate immunization history and/or inability to reach a high proportion of study participants were major impediments to the success of reminder/recall efforts in several studies reviewed.<sup>55,57,59,61</sup> In addition, high baseline immunization rates among study participants and a ceiling effect also help explain differences in reported recall/reminder effectiveness. Trying to improve immunization rates among populations with already high rates is much more challenging than targeting populations with moderate or low rates, as those most amenable to interventions have likely already been reached.<sup>56,60</sup>

The existing evidence suggests that the majority of reminder/recall approaches (postcard, letter, telephone, or combination) offer promise as strategies to improve pediatric vaccination uptake. The concept of reminder/recall is also easily modifiable. One study examined the effects of a tailored calendar on immunization rates of children from birth or one year up to 24 months of age. Parents of children randomized to the intervention group were given a personalized calendar for the months leading up to their baby's next scheduled immunization and received subsequent months of the calendar only by returning to the health center when the scheduled vaccination was due. Calendars were personalized with the baby's picture, monthly birthday greetings, messages tailored to the unique characteristics of the baby and family (based on information obtained from a pre-intervention interview), and a reminder of the baby's next immunization appointment. Through this intervention, although parents were not contacted regarding reminders for immunizations, a visual reminder was available on a daily basis and recall was achieved by making subsequent calendar months only available after completing the infant's next immunization. Up-to-date immunization rates were 66% among children whose parents were given a calendar versus 47% among controls (p-value < .001).<sup>62</sup>

In addition to reminder/recall systems, the evidence suggests that patient outreach and home visits are effective strategies to improving childhood immunizations. A review of 12 studies indicated that the majority (n = 11, 92%) of RCTs and quasi-experimental studies have demonstrated that outreach facilitates parent interaction with trusted healthcare personnel (e.g., nurses or community outreach volunteers) and leads to increases in immunization uptake. As a stand-alone intervention or in addition to reminder/recall programs, outreach may be a useful, albeit expensive, interventional strategy, especially for marginalized or hard to reach populations. In fact, outreach has been used as an intense, last resort effort when reminder/recall systems fail to prompt caregivers to bring children in for immunizations.<sup>26,41,48,51,56</sup> Studies involving outreach, case management, home visits, and in-home vaccinations have reported ORs of 1.03–3.43, suggesting 3–243% greater odds of receiving immunizations among children who receive this type of intervention; increases in immunization rates of +3 to +44 percentage points have been reported over time periods of 10 months to 10 y (median = 16.5 months, mean = 27.9 months,

among 10 studies that reported a defined study period).<sup>26,35,37,38,41,46,48,51,59,60,63,64</sup> Most studies testing outreach interventions ( $n = 8$  of 12 studies) reported percentage point changes, and among those reporting ORs ( $n = 4$  of 12 studies), half reported comparable findings ( $OR = 1.53, 1.55$ ). Differences in study design and outcome measures may explain the wide disparity reflected in the 2 studies reporting the least and greatest effect of outreach interventions. The study reporting the smallest OR (1.03) had a study population made up of predominantly white mothers with at least some college education,<sup>63</sup> whereas the study reporting the largest OR (3.43) had a population made up of entirely African American mothers with a mean education level of some or completion of high school.<sup>64</sup> In addition, the former study included 2 intervention levels: Healthy Steps, an integrated child health delivery system, and Healthy Steps plus home visits. The reported OR (1.03) reflects the effectiveness of the home visits combined with Healthy Steps vs. Healthy Steps only. The latter study tested intense case management, including in-depth assessments before children were 6 weeks old, home visits 2 weeks before scheduled immunization appointments, and follow-up visits as needed. Finally, the study reporting an OR of 1.03 measured 14 child health and development indicators (including appropriate immunization by 24 months), as well as parenting practices and parental well-being, whereas the study reporting an OR of 3.43 measured appropriate immunization as the primary outcome of interest.<sup>64</sup> Furthermore, during statistical analysis, the study reporting a 3.43 OR included the number of well-child visits children in the intervention group were taken to in the logistic regression model (fewer visits were associated with statistically significant increased odds of the intervention's effectiveness); when this variable was excluded from the model, the OR was 1.90 ( $p$ -value = .008), which is more consistent with ORs from other studies we reviewed.<sup>64</sup> While this partially accounts for the wide range of reported effectiveness of outreach in increasing childhood immunization rates, it also supports the conclusion that this type of intervention may be especially useful in vulnerable, underserved populations. When combined with provider prompts, one RCT found that outreach resulted in 95% of preschool-aged children being up-to-date for immunizations within 18 months (compared with 74% of control children,  $p$ -value < .001).<sup>48</sup> However, it is also noted that this type of approach introduces considerable expense beyond that observed with reminder/recall systems.<sup>41,60</sup>

Finally, educating parents regarding vaccines and the immunization schedule empowers them to make informed decisions for their child and are therefore valuable strategies. Parent education may be in the form of conversations with a healthcare provider,<sup>35,38,51,58</sup> posters and other informational "advertisements" in waiting or exam rooms,<sup>43,52,53,65</sup> or more traditional educational materials such as Vaccine Information Sheets, brochures, or webpages.<sup>31-33,51,58,65-67</sup> An RCT testing the combination of an educational video and information handout resulted in a statistically significant score reduction of 5.2 points on PACV (Parent Attitudes about Childhood Vaccines)<sup>68</sup> survey scores, indicating a reduction in parental vaccine hesitancy.<sup>69</sup> PACV is scored on a scale of 0 to 100, with 100 indicating high vaccine hesitance and lower scores representing less vaccine hesitance.<sup>68</sup> Additional strategies have

included the development of targeted and tailored information delivered through electronic applications (apps).<sup>70,71</sup> Results from several studies reflect that educating parents can increase baseline immunization rates by +4.7 to +16 percentage points (mean = +10 percentage points), but there appears to be limited advantages to implementing more involved education vs. providing routine information. One study reported statistically significant higher vaccination rates among children whose parents received an educational plus interactive text message reminder (38.5%) vs. children whose parents received an education-only text reminder (35.3%) or those who received usual care only (34.8%).<sup>54</sup> However, another study reported no difference ( $p$ -value = 0.93) in rates of receipt of age-appropriate vaccines by 7 months between infants whose parents received routine information only (57.9%) and those who received routine information and an educational intervention graphic card (58.3%); although missed opportunities did decrease by 50% in the group that received the education card.<sup>72</sup> An additional study demonstrated statistically significant increases in parents who intended to vaccinate their children among both intervention (tailored messages) and control (non-tailored messages) groups, although the effect was more pronounced among those exposed to the tailored message.<sup>66</sup>

Another important parental education strategy is to target expectant mothers during prenatal healthcare visits. One RCT found that a stepwise education intervention that delivered interactive education at different time points (prenatal, postnatal, and one month after birth) significantly improved immunization schedule adherence.<sup>73</sup> The mean time elapsed until completion of the third dose for 3 vaccine series was shorter among the intervention group than for the control group: Hib (129.3 vs. 133 days,  $p$ -value = 0.003), PCV13 (129.5 vs. 133.5 days,  $p$ -value = 0.006), and DTaP-IPV (160.1 vs. 164.9 days,  $p$ -value = 0.03).<sup>73</sup> Additionally, another RCT found that 90.0% of children whose mothers had received prenatal vaccination education were fully immunized by 12 months of age, compared with 82.9% of children whose mothers had not received the intervention.<sup>74</sup> Children in the intervention group were 3.4 times more likely to complete the full vaccination series and 2.3 times more likely to complete the series on time than children whose mothers did not receive the intervention.<sup>75</sup>

Despite the value in educating parents, however, making vaccines more readily available may be more effective in improving coverage. In one study, offering the influenza vaccine to pediatric patients at an emergency department was significantly more effective than educating parents (57% vs. 36%, relative risk = 1.59).<sup>75</sup> This suggests the importance of seizing upon immediate opportunities to immunize, as parents have to return with their children for multiple appointments and educational messages may become lost or forgotten in the interim.

### Interventions for providers

Interventions targeting providers include provider education, prompts/reminders, feedback, nurse assessment, and tools such as flow sheets and tracking systems. Flow sheets are placed in a child's medical chart and include tables or diagrams that list age-specific preventive services indicated. Tracking systems are computer mechanisms to identify children who have not been

seen at a practice recently and/or are not up-to-date on preventive care.<sup>31</sup> As tested via RCT and other rigorous designs (e.g., before-after trials), provider education and feedback have shown inconsistent effects on immunization rates,<sup>56,76-80</sup> however, when implemented in concert with other strategies as part of a multicomponent intervention, provider education and feedback have been shown to be very effective, improving rates by up to 47 percentage points over 6-month to 2-year periods.<sup>32,34,35,52,53,81-83</sup> Additionally, the “AFIX” (Assessment, Feedback, Incentives, and eXchange of information) framework is an example of a multicomponent provider-based intervention modeled after a program in the state of Georgia that improved pediatric immunization coverage in public clinics from 40% to 91% from 1986 to 2001.<sup>84,85</sup> AFIX is widely recognized as an effective strategy for improving childhood immunization rates and is strongly recommended by the Task Force on Community Preventive Services.<sup>80,85,86</sup>

Provider education combined with prompting has also been shown to reduce missed opportunities by 36 percentage points in a before-after trial conducted over 2 y.<sup>87</sup> Prompts, or physician reminders, usually consist of electronic prompts in the Electronic Health Record (EHR) or notes/flags in paper charts. One study reported statistically significant improved rates over a one year period for DTP4 (+15%), OPV3 (+14%), and MMR1 (+16%), but not for overall up-to-date rates.<sup>88</sup> Another showed that prompts decreased missed opportunities by 10.2%.<sup>89</sup> Similar to provider education, however, provider prompts are most effective when part of a larger strategy and have shown to increase immunization rates by 12.1 to 46 percentage points<sup>31,34,48,52,53,82,90</sup> when implemented with other interventions in 6–12 months study periods. The combination of EHRs with alerts delivered to providers at the point of care represents a promising approach to improve routine vaccination rates in pediatric care.

Finally, in previous studies focused on adult immunization rates, physicians have reported that having nurses or other staff members take a more active role in the immunization process, such as patient assessment, is helpful and improves practice workflow.<sup>91-93</sup> We found 4 out of 5 identified studies that reported including a heightened level of nurse involvement component in interventions supported and improved immunization rates among children as well,<sup>34,48,82,88,94</sup> contributing to increasing coverage up to 95% over 18 months in one instance.<sup>48</sup> Offering providers incentives such as bonuses and enhanced fee for service have also resulted in modest improvements in up-to-date rates.<sup>95,96</sup> For example, one RCT resulted in increases of up-to-date children from 49.7% to 59.6% for physicians offered bonuses, and from 50.8% to 58.2% for physicians offered enhanced fee-for-service.<sup>96</sup> Although these increases were largely due to improvements in documentation rather than actual immunization practices, maintaining an accurate vaccination history is a critical component of the immunization process.

### **Interventions for clinics and communities**

Due to their wider scope, clinic- and community-based interventions have the potential to impact the greatest number of children. Changes made at the clinic-level are endorsed by AAP as effective means to improving childhood immunization rates.<sup>97</sup> Standing order protocols (SOPs), electronic health

record (EHR) templates and interfaces, computerized interface registries (between clinical practices and the state), and standardized documentation and tracking streamline clinic workflow and minimize clinician burden. SOPs negate the need to acquire a written physician order before immunization and reflect improvements of +8 to +47 percentage points during single influenza seasons.<sup>32,52,53,65</sup> Computerized immunization registries are also highly sustainable interventions; one study reported sustained increases in immunization rates of 26% and 47% for one and 2 y olds respectively, over a 10 y period.<sup>98</sup> Registries are powerful vehicles for identifying children in need of vaccination and generating reminders for both parents and providers. EHR templates and interfaces, computerized registries, and standardized documentation are often components of quality improvement projects and demonstrate similar rates of improvement<sup>31,53,81,82,90,98</sup> (+12.1% to +47%) as SOPs. One multisite study reported the use of a “multicomponent change package,” consisting of 9 strategies (including SOPs and a web-based patient registry) intervention sites were encouraged to choose from and tailor to their individual practice needs. During the 2004–5 influenza season, one site reported 82.1% of at-risk children were immunized against influenza.<sup>32</sup>

Though more labor- and resource-intensive, walk-in and after-hours vaccination clinics, providing vaccinations free of charge, and implementing quality indicators are also effective strategies for improving childhood immunization rates.<sup>32,52,53,81,98,99</sup> After identifying and implementing key quality measures, one study reported an increase in the percentage of children up-to-date for age-appropriate immunizations of 31.6% to 62% and 29.2% to 63.8% for those aged 7–11 and 24 months, respectively.<sup>81</sup>

Community-level approaches are the most challenging to implement, as they require the greatest amount of time, human labor, and financial resources.<sup>100</sup> However, efforts that encourage community buy-in and involvement are often high-impact (i.e. reach a large number of participants).<sup>37,38</sup> In a study aimed at reducing recognized childhood immunization disparities between inner-city, urban, and suburban children, immunization coverage among inner-city children 24 months old increased by 29 percentage points from 1993 to 1996 as a result of the combined reminder, recall, and outreach (RRO) intervention. More impressively, however, this community-based strategy to improve immunization uptake decreased immunization disparities between suburban and inner-city children from 18% to 4% within 6 y.<sup>26</sup> Collaborations between healthcare organizations and other stakeholders such as pharmacies and daycares also improve rates;<sup>32,52</sup> a county-wide, school-based vaccination campaign resulted in 26–75% of elementary school children receiving the influenza vaccine.<sup>101</sup> Offering vaccines to eligible children in 2 emergency departments resulted in increases of 8–11%.<sup>102</sup> Finally, one community-based study reported an increase in coverage from 40.6% to 80.5% over 2 y through incorporating immunization promotion activities into pre-established community programs.<sup>103</sup>

### **Discussion**

Findings from this review are consistent with previous reviews, such as those detailed in the Centers for Disease Control and



Prevention's Community Guide.<sup>104</sup> The interventions reviewed here have demonstrated success in improving childhood immunizations. As such, they should be considered in planning efforts to maintain current immunization coverage among children and address existing gaps. However, even among those that are most effective, there are still challenges to overcome if they are to be universally beneficial. Several studies testing recall/reminder effectiveness reported a large percentage of patients that were not able to be reached due to incorrect addresses or telephone numbers.<sup>49,50</sup> Verification of contact information with parents at every visit will therefore minimize missed opportunities and wasted resources. In addition, although offering immunizations to children in the emergency department resulted in modest gains, the substantial personnel time required may nullify the sustainability of these approaches. Furthermore, those children treated in emergency or urgent care centers represent a small subset of those who can be reached through broader immunization approaches.

This review suggests that developing multicomponent interventions may be the most impactful as far as maintaining and improving pediatric immunization rates. Interventions done in combination with one or more other interventions were found to be consistently more successful than those implemented in isolation. Future efforts should focus on solutions that are easily adopted and customized within practice contextual factors, able to be scaled to individual practice needs with minimal burden, and are evidence-based. Barriers to childhood immunizations manifest largely as environmental or parental psychological factors.<sup>105-107</sup> Tailored multicomponent interventions should be able to combat both practical barriers – such as parental forgetfulness or problems accessing healthcare – as well as address vaccine hesitancy across the spectrum.<sup>11</sup>

Additionally, although we did not review any studies that tested communication strategies for providers during delivery of vaccine information to parents and patients, one observational study demonstrates the impact of different message frameworks.<sup>108</sup> The proportion of parents who accepted the influenza vaccine for their child was significantly higher when clinicians initiated a vaccine recommendation using a presumptive approach vs. a participatory approach (94% vs. 28%,  $p$ -value =  $<0.001$ ). Parental acceptance was also higher when clinicians pursued original recommendations despite initial refusal.<sup>108</sup> These results reflect the importance of presenting vaccination as the norm to parents and providing a strong recommendation for vaccine uptake. Future studies should address these considerations to facilitate the development of better communication strategies for providers.

Maternal immunization interventions also represent a promising strategy to increase uptake of childhood immunizations. Although interventions to increase maternal immunization are beyond the scope of the current review, intent to immunize oneself against influenza during pregnancy has been shown to have a strong effect on the intent to have the child immunized.<sup>109</sup> Pregnancy represents an optimal point in time to build trust with healthcare providers, reshape preexisting negative attitudes, and foster intent and positive immunization behaviors that form the foundation for future decisions made regarding the health of her child. Several studies have demonstrated that previous receipt of the influenza vaccine is highly

predictive of a woman choosing to receive vaccines (influenza or Tdap) during pregnancy.<sup>110,111</sup> Barriers to immunization during pregnancy are often related to concerns regarding safety for both mother and baby, perceived low risk of disease or seriousness of infection if ill, and a history of nonreceipt.<sup>111-115</sup> Communicating the safety of vaccines and the danger of infection during pregnancy to correct these misconceptions is therefore vital to the immunization process. Studies have been conducted with pregnant women to evaluate which messaging frameworks are most effective.<sup>110,116,117</sup> Continued work with this population is needed, however, as results reflect the limitations associated with a single exposure to varying maternal influenza immunization message approaches on vaccine behavior. For pregnant women, repeated immunization message exposures may be warranted with alterations in message format, content, and relevance for coverage improvement.<sup>116</sup>

Fostering a foundation of positive immunization habits and beliefs is especially important in light of the recent prediction that immunization coverage will decrease in the next 10 y.<sup>118</sup> Parental attitudes toward childhood immunizations are highly predictive of a child's immunization status,<sup>119,120</sup> and several recent studies have demonstrated a growing trend in parental hesitation and refusal of childhood immunizations.<sup>14,17,121</sup> Increased efforts to understand and successfully implement evidence-based strategies are warranted to counter persistent hesitance. It is incumbent upon healthcare providers, healthcare organizations, and public health departments to learn to use the tools reviewed here in concert with one another and to collaborate with each other to form effective partnerships and maintain the strength of the pediatric immunization infrastructure.

This review is subject to limitations. We report findings from RCTs and quasi-experimental studies primarily aimed at recommended early pediatric immunization (i.e.,  $\leq 7$  years) to focus on improving vaccine uptake for this younger age group. Based on guidelines from the US Preventive Task Force for assessing interventions in the clinical setting, we focused our exploration of recent RCTs and quasi-experimental studies to identify the most promising pediatric immunization interventions. Therefore, there may be additional studies that offer evidence for intervention success that were excluded for review based on non-experimental study design; this review may not be definitive of all potential successful interventions. Varied study populations and wide differences in measurement of outcomes limited our ability to conduct a comprehensive meta-analysis at this time. Finally, although we did not intentionally exclude international studies, this review focused on interventions reporting greatest outcome effects and differences. As a result, we reviewed a predominance of literature originating from the United States.

## Conclusions

This review presented a comprehensive examination of the literature regarding successful pediatric immunization interventions, making information easily accessible to healthcare providers and public health officials. Overall, the literature indicates a multitude of promising strategies. Future research should focus on best practices for translating the reviewed

evidence into comprehensive strategies that can be implemented in a variety of clinical settings and patient populations.

## Disclosure of potential conflicts of interest

The authors report no conflict of interest.

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