


Using Gaming to Promote Vaccination Among Youth: A Systematic Review

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Lihong Ou, PhD, RN¹ ,
Elizabeth Reifsnider, PhD, RN, WHNP-BC, PHCNS-BC, FAANP, FAAN¹,
Angela Chia-Chen Chen, PhD, MS, RN, PMHNP-BC, FAANP²,
Michael Todd, PhD¹, Ashish Amresh, PhD^{3,4}, and Chung Jung Mun, PhD^{1,5}

Abstract

Introduction: While vaccines are crucial for disease prevention, disparities in vaccination coverage persist among youths aged 10 to 29 years, including within the United States. Serious games are emerging as a new strategy to address vaccine hesitancy. This systematic review aimed to aggregate and assess the current evidence on game-based interventions to improve youth vaccination rates, evaluating their impact and identifying factors influencing their effectiveness.

Methods: This systematic review was conducted through a meticulous search and evaluation of literature from databases including PubMed, Cumulative Index to Nursing and Allied Health Literature database, ProQuest platform, Cochrane Library, and Google Scholar. Studies were included if they (a) were designed with the purpose of improving youth vaccination rates; (b) were published in English; (c) were published between January 2011 and June 2023; and (d) evaluated the effect of game-based interventions. Search terms included Medical Subject Headings terms and keywords of the eligible articles.

Results: Out of 269 studies, 11 were included in the final analysis of this review. The earliest study dated back to 2013, with 5 being randomized controlled trial and 6 studies incorporating theoretical models in their design or outcome measures. The findings indicated a generally positive effect of game-based interventions on vaccine-related knowledge. However, the impact on actual vaccine uptake was limited. In-game avatar customization and collaboration games were found as effective tools for player engagement.

Conclusion: The review findings indicated that serious games boost vaccine knowledge but lack strong evidence for influencing youth vaccine uptake. More rigorous research and tailored game designs are needed to determine the effectiveness of game-based interventions and effectively address the diverse needs of youth in vaccine decision-making.

Keywords

gaming, vaccination, vaccination promotion, youth, systematic review

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Introduction

Vaccines are critical for disease prevention and the control of infectious disease outbreaks. They offer a safe and effective approach to establishing protection against a variety of severe diseases, helping to reduce morbidity and mortality (World Health Organization [WHO], 2021). This is particularly relevant for youth, as defined by the U.S. Agency for International Development (USAID) in its Youth in Development Policy, which includes individuals aged 10 to 29 years (U.S. Agency for International Development [USAID], 2021). Within this age group, it is imperative to obtain complete vaccination coverage due to increased risk of infections linked to more frequent social encounters and the biological changes occurring at this life stage, potentially intensifying susceptibility to diseases and the likelihood of their spread.

As per the Centers for Disease Control and Prevention (CDC) guidelines, for ages 10 to 18, recommended vaccinations include Coronavirus Disease 2019 (COVID-19)

¹Edson College of Nursing and Healthcare Innovation, Arizona State University, Phoenix, AZ, USA

²College of Nursing, Michigan State University, East Lansing, MI, USA

³College of Engineering, Informatics, and Applied Sciences, Northern Arizona University, Flagstaff, AZ, USA

⁴School of Informatics, Computing, and Cyber Systems, Northern Arizona University, Flagstaff, AZ, USA

⁵Department of Psychiatry and Behavioral Sciences, Johns Hopkins School of Medicine, Baltimore, MD, USA

Corresponding Author:

Lihong Ou, Edson College of Nursing and Healthcare Innovation, Arizona State University, 550 N 3rd St, Phoenix, AZ, USA.
Email: lihongou@asu.edu



vaccines, Influenza (flu), Tetanus, Diphtheria, Pertussis (Tdap), Human Papillomavirus (HPV), Meningococcal Vaccines (Centers for Disease Control and Prevention [CDC], 2023a). For those aged 19 to 29, the focus is on completing the routine series of flu and Tdap vaccines. Additionally, the HPV vaccine is recommended for those up to 26 years old who have not been fully vaccinated previously (CDC, 2023a).

However, despite the recognized importance of vaccines, the coverage rates for those recommended during adolescence and young adulthood often lag behind the levels achieved for vaccines given in infancy and early childhood. This gap was evident in the CDC's TeenVaxView and SchoolVaxView, which delineated discrepancies in vaccine uptake among various age groups (CDC, 2022a; 2022b). Specifically, TeenVaxView illustrated that coverage for vaccines such as HPV (with up-to-date HPV vaccination coverage for both females and males aged 13–17 less than 60% as of 2022) and meningococcal disease (at 88.6% for adolescents at the same age) was lower compared to the coverage for childhood vaccinations against diseases like measles, mumps, and rubella reported by SchoolVaxView (at 93.1%).

Data from COVIDVaxView and FluVaxView indicated that vaccine coverage among youth also lagged behind coverage among older adults. As of January 2024, only 20.6% of individuals over 18 had received their COVID-19 vaccinations, while the rate for children aged 6 months to 17 years was even lower at 12.2%. In contrast, the vaccination rate for seniors aged 65 and over was higher, at 28.1% (CDC, 2024a). Regarding the flu vaccine, 46.2% of young adults aged 18 and over were vaccinated in the 2022 and 2023 season, which was less than the 54.5% vaccination rate seen in those aged 65 and older during the same period (CDC, 2024b). Moreover, these vaccination rates did not meet the objectives set by Healthy People 2030, which aims for at least a 70% immunization rate for flu among everyone older than 6 months, and an 80% vaccination rate for HPV in adolescents (U.S. Department of Health and Human Services [HHS], n.d.). The comparative lag in uptake for these vaccines highlights a critical area for public health intervention to meet immunization goals for U.S. youth.

The challenges in vaccinating youth were complex, further exacerbated by the COVID-19 pandemic, which posed additional hurdles for vaccination efforts and resulted in setbacks in coverage. Vaccination rates for vaccines such as Tdap, HPV, and MenACWY had seen decreases during the pandemic period. Specifically, there was an average drop of 36% in tetanus-containing vaccines for US adolescents from January 2020 to July 2021, compared to the same months in 2019. Such declines in vaccination coverage rates raised concerns about the potential resurgence of vaccine-preventable diseases and the risk of HPV-associated cancers (Cunniff et al., 2023).

The 2022 report by the World Health Organization (WHO) and the United Nations International Children's

Emergency Fund (UNICEF) also draws attention to vaccine equity issues, especially in low- and lower-middle-income countries. Although global coverage for the diphtheria-tetanus-pertussis-containing vaccine (DTPcv1) increased from 86% to 89% from 2021 to 2022, regions like the African Region have stagnated at 80% and 72% for the vaccine, respectively. Such enduring disparities in vaccine coverage among different economic groups call for dedicated efforts to rectify these inequities and improve health outcomes in line with the objectives of the Immunization Agenda 2030 (IA2030). This initiative aims to reduce the count of zero-dose children (those missing all routine immunizations) and the under-vaccinated. Achieving these targets requires ongoing commitment and precise initiatives that enhance education, raise awareness, and provide equitable vaccine access (CDC, 2023b).

Besides, addressing vaccine hesitancy is also crucial in overcoming barriers to vaccination acceptance and achieving optimal immunization coverage. Vaccine hesitancy, characterized by delay or refusal of vaccination despite the availability of vaccination services, was also one of the leading health threats (WHO, 2014, 2022). Factors contributing to vaccine hesitancy among US parents centered on the benefits of the vaccination, vaccine effectiveness, side effects, and the novelty of the vaccine (Kempe et al., 2020; Szilagyi et al., 2020). On the other hand, healthcare professionals were acknowledged as trusted authorities on COVID-19 vaccine information and had a pivotal role in addressing vaccine hesitancy. Their guidance could be a cornerstone of family vaccination decisions, offering reassurance and fostering vaccine confidence. By effectively communicating the safety and benefits of vaccines, healthcare providers could influence vaccination intentions and acceptance among both parents and adolescents (Scherer et al., 2021).

The emergence of the serious game dated back to 1970s and its use of it was primarily focused on education as opposed to just entertainment (Wilkinson, 2016). The level to which a game accomplishes its intended objectives could serve as a criterion for determining its seriousness (Abt, 1987). With its potential to influence learning, the application of serious games has expanded to different platforms beyond personal computers and had served a diverse audience from children to adults (Breuer & Bente, 2010; Wouters et al., 2013). Serious games had been found to be particularly effective for young learners in improving participation in learning activities and academic achievements (Nazry & Romano, 2017; Yu, 2019). In recent decades, there has been an increasing use of serious games in other fields of study, including healthcare. Interventions with gaming features had been adopted as innovative and promising tools in disease prevention and health promotion, such as addressing the vaccination gap in the general public (de Souza Gaspar et al., 2020; Peng & Bai, 2021).

Nevertheless, to our knowledge, there is a paucity of research up to date to examine the impact of serious games on vaccination among the young population, particularly in US children and adolescents. There is a need to understand the determinants of successful serious-gamed-based vaccination interventions in youth as the findings could be important for increasing vaccine uptake and coverage in the youth population. Hence, this review aimed to critically appraise and synthesize the existing evidence on how game-based interventions were implemented to improve youth’s vaccine knowledge and behaviors, and what factors contributed to the effectiveness of the intervention.

Methods

The conduct of this systematic review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The search strategy and flow chart of included and excluded studies were presented in Figure 1.

Data Sources and Search Strategy

Two authors worked independently to identify and appraise empirical studies describing the outcomes of game-based intervention on youth’s vaccine knowledge and behaviors. The PubMed, Cumulative Index to Nursing and Allied Health Literature database (CINAHL), ProQuest platform, Cochrane Library, and Google Scholar were searched. A broad search targeting the young population was used to compensate for the limited number of studies on the application of game-based intervention for increasing vaccine knowledge and behaviors among children and adolescents. Additional studies were also determined by hand searches of reference citations in the studies identified.

In the search strategy, a combination of Medical Subject Headings (MeSH) terms and keywords from eligible articles was used to identify relevant literature. The search terms were organized around several main concepts: games, interventions, youth, and vaccines. In exploring the various concepts, terms such as “games,” “gamification,” “serious

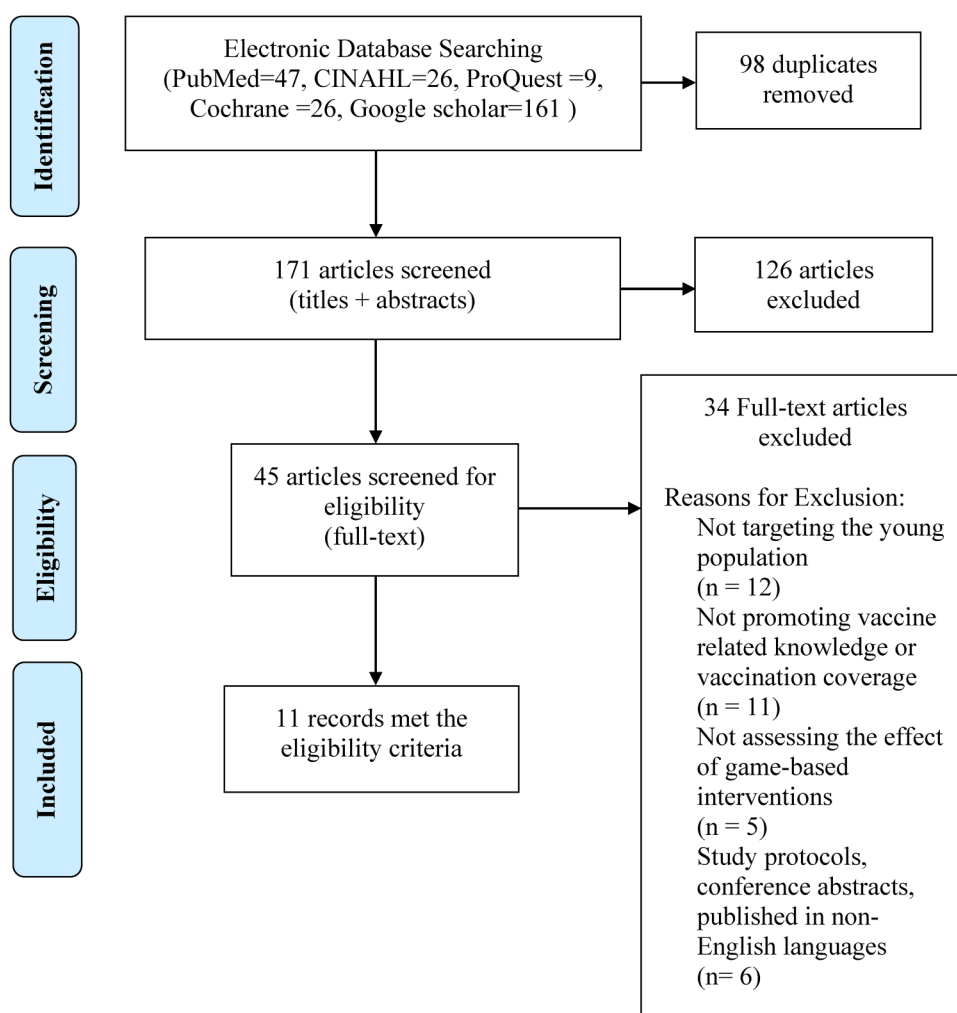


Figure 1. PRISMA Flow Diagram of Literature Search.

games,” and others related to digital gaming were used. For interventions, inclusion encompassed terms “intervention,” “programs,” and “strategies,” alongside variations related to computerized and technology-based interventions. The vaccines concept entailed terms such as “vaccines,” “vaccinations,” “immunizations,” and others associated with vaccine uptake and acceptance. Finally, for youth, employed terms “youth,” “adolescent,” and “young adult” were used to capture literature relevant to this demographic group (see Appendix 1).

Eligibility Criteria

The criteria (a) were to improve vaccination rates, (b) were published in English, (c) were published between January 2011 and June 2023, and (d) evaluated the effect of game-based interventions. Study protocols, conference abstracts, studies published in non-English languages, and studies that did not target the young population or evaluate the effectiveness of the intervention will be excluded.

The review period was selected to highlight significant advancements in digital health interventions, especially technology-based strategies for increasing vaccination coverage. These advancements were largely driven by the widespread adoption of smartphones (Pew Research Center, 2012) and continuous technological progress. The timeframe, concluding in June 2023, also ensured the inclusion of recent studies to assess interventions and their adaptation to the vaccination challenges posed by the COVID-19 pandemic.

Data Extraction, Analysis, and Synthesis

Two authors independently conducted the search and review, scanned all the titles, and abstracts, and identified potential studies that met the eligibility criteria for inclusion. Disagreements over the search and interpretation results were further discussed between the reviewers until the conflicts were solved.

The studies included were assessed for information on participant characteristics, study location, study design, the theory used for guiding the study, the game length, content, game features or elements, game platforms, and the effect of game-based interventions on vaccine knowledge and behaviors. Each study was subjected to critical appraisal based on the modified Melnyk Levels of Evidence. The Melnyk model was used to evaluate and rank the quality of the study design, resulting in seven levels of evidence, with a lower number indicating a higher level of evidence (Melnik & Fineout-Overholt, 2015).

Additionally, the quality of evidence of studies with randomized controlled trial (RCT) designs was assessed using the Cochrane Collaboration’s risk of bias tool, a summary rating of “high,” “low” risk of bias, or “some concerns” was assigned to each study based on criteria related to bias in the domain of randomization process, deviations from

intended interventions, missing outcome data, measurement of outcomes, and selection of reported results (Cochrane, 2019). Extracted information was summarized in the literature review table (see Appendix 2). The table included the purpose of the study, the purpose of the game-based interventions, study design, theories incorporated in the research, study samples, procedures, outcome measures, results, and assessment findings of study quality to describe the characteristics of the included studies. Meta-analysis on the impact of the game-based interventions on young participants’ vaccine knowledge and behaviors was not performed due to the sparse and heterogeneous data. Therefore, the findings summarized and appraised in this review focused on the use of game-based interventions and their effectiveness in enhancing vaccine knowledge and behaviors among young people.

Results

A total of 269 records were identified through the search. After removing the duplicates, the remaining 171 articles were assessed by the titles and abstracts, and 126 articles were excluded based on the described selection criteria. As a result, the full text of 45 articles was assessed for eligibility, and 11 studies were included in the final review.

General Description of Included Studies

The reviewed studies, spanning from 2013 to 2023, investigated game-based interventions across various demographics and international locales, revealing a concentration of research in recent years, particularly from 2019 to 2023. Four studies used RCTs, which were rated as Level II evidence by the Melnyk model (Cates et al., 2020; Darville et al., 2018; Epstein et al., 2021; Fadda et al., 2017; Melnyk & Fineout-Overholt, 2015). Concerns about bias arose from the incomplete reporting of the randomization process, particularly the details of generating the allocation sequence and applying blinding techniques. Notably, only one study described difference in baseline participants’ characteristics across study groups for the randomization check (Fadda et al., 2017), and another provided detailed information on the blinding methods used during the study (Epstein et al., 2021). Moreover, there was insufficient information on the validity and reliability of the instruments used for outcome assessment (Cates et al., 2020; Darville et al., 2018; Epstein et al., 2021; Fadda et al., 2017). These were complemented by three quasi-experimental studies, providing Level III evidence (Bertozzi et al., 2013; Mitchell et al., 2021; Venigalla et al., 2021), and four mixed-methods approaches, which were assigned Level II or III evidence based on whether randomization was included (Eley et al., 2019; Frick et al., 2023; Occa et al., 2022; Ruiz-López et al., 2019).

Geographically diverse, the studies were conducted across seven countries, with sample sizes ranging from 12 to 3,087 participants, including specific demographics such as parent-teen dyads (Cates et al., 2020), parents of young children (Fadda et al., 2017), school-aged children (Bertoizzi et al., 2013; Eley et al., 2019; Epstein et al., 2021; Occa et al., 2022), high school (Ruiz-López et al., 2019), and university students (Darville et al., 2018; Mitchell et al., 2021; Venigalla et al., 2021), as well as young adults (Frick et al., 2023). One study only included male participants (Darville et al., 2018); no other studies reported limiting participation by gender. Most studies did not report the racial or ethnic composition of their participants, with two exceptions (Cates et al., 2020; Darville et al., 2018), highlighting a significant gap in demographic transparency.

Game-Based Interventions Characteristics

Type of Game Platforms. Most of the games were digital-based games, such as having the game installed on mobile devices and using desktop, smartphone, or tablet-based applications or accessing through web applications for playing (Bertoizzi et al., 2013; Cates et al., 2020; Darville et al., 2018; Eley et al., 2019; Fadda et al., 2017; Frick et al., 2023; Mitchell et al., 2021; Occa et al., 2022; Ruiz-López et al., 2019; Venigalla et al., 2021). Instead, Epstein et al. (2021) used collectible vaccine card packs as the gamification intervention in the study.

Total Game Duration. Six studies did not report the length of the game (Bertoizzi et al., 2013; Darville et al., 2018; Epstein et al., 2021; Frick et al., 2023; Occa et al., 2022; Ruiz-López et al., 2019). Those who reported the duration of the game playing described the time varied from a span of two minutes to fifteen minutes (Cates et al., 2020; Eley et al., 2019; Fadda et al., 2017; Mitchell et al., 2021; Venigalla et al., 2021).

Game Content and Goals. The game's content presented in the studies was all related to vaccine-preventable diseases, vaccines, and vaccination. They often provided an interactive scenario, assigned players specific roles, and made them navigate through a specific path towards protecting from the virus, fighting against the virus, solving puzzles, or achieving particular status which was considered a success (Bertoizzi et al., 2013; Cates et al., 2018, 2020; Darville et al., 2018; Eley et al., 2019; Frick et al., 2023; Mitchell et al., 2021; Ruiz-López et al., 2019; Venigalla et al., 2021). Players were also exposed to messages about the diseases and their vaccinations in the games, how the game proceeded could rely on players' responses to the messages. Fadda et al. (2017), Occa et al. (2022), and Frick et al. (2023) specifically provided quiz in combination with videos associated with vaccination knowledge and uptake.

Epstein et al. (2021), on the other hand, used card games as an incentive to encourage children's return of vaccination consent forms. The card set comprised 13 disease character cards with each of them representing the vaccine-preventable diseases covered by the recommended childhood immunization schedule, it showed terminology and symptomatology of the disease and reinforced knowledge related to global incidence and mortality, symptoms, and modes of transmission of the disease.

Despite the primary goals of the game-based vaccine interventions in the studies being to promote the knowledge of vaccine-preventable diseases, the preventive vaccination against them, and vaccination initiation or completion, the studies addressed different types of vaccines. Specifically, two studies targeted the flu vaccine (Bertoizzi et al., 2013; Mitchell et al., 2021), one for the MMR vaccine (Fadda et al., 2017), two for the COVID-19 vaccine (Frick et al., 2023; Venigalla et al., 2021), four for the HPV vaccine (Cates et al., 2020; Darville et al., 2018; Occa et al., 2022; Ruiz-López et al., 2019), one for general vaccinations (Eley et al., 2019), and one for HPV and other vaccine-preventable diseases, including diphtheria, tetanus, and pertussis (DTaP), MMR, Hemophilus B, rotavirus, pneumococcal, meningococcal, hepatitis B, varicella vaccine (Epstein et al., 2021).

Game Features or Elements. The studies highlighted several key game features or elements to improve players' motivation to play the game as well as engagement with the game, including customized game characters or in-game avatars, an immersive narrative-driven game context, various difficulty levels, game progress bar, simulated real-life situation, and scenarios (Bertoizzi et al., 2013; Cates et al., 2020; Darville et al., 2018; Occa et al., 2022; Ruiz-López et al., 2019; Venigalla et al., 2021); in-game help system and resource links, in-game feedback such as additional information regarding the questions the participants answered, digital rewards for correct answers, monetary voucher as real-world prizes, leaderboard to track players' ranking or sound effects and character animations in response to players' completion of different levels (Cates et al., 2020; Eley et al., 2019; Fadda et al., 2017; Frick et al., 2023; Mitchell et al., 2021; Occa et al., 2022; Ruiz-López et al., 2019; Venigalla et al., 2021).

Venigalla et al. (2021) described a multiplayer-based game. Four distinct roles were assigned in the game and players were encouraged to work together to complete specific tasks. Three games also contained complementary social features that direct links to social network platforms were embedded in the game and players were provided the option to share the game or invite others to play the game via social media (Fadda et al., 2017; Mitchell et al., 2021; Ruiz-López et al., 2019). Additionally, the vaccine card game served as a social tool in addition to its incentive and educational purpose since it could improve meaningful

interactions between children and their peers, parents, and teachers and possibly provoke dialogues around the vaccine and associated diseases (Epstein et al., 2021).

Theory Use in Study. In total, six studies incorporated theoretical models with five of them primarily aiming at health behavior change and one assessing players' gaming experience and usability. Among them, the health belief model (HBM) and the theory of planned behavior (TPB) were the most mentioned. The HBM used in one study was to inform the development of the game messages (Cates et al., 2018, 2020), and another study used the model to guide the measurement of the gaming practice outcomes (Darville et al., 2018). Similarly, Darville et al. (2018) adopted the TPB for assessing the behavioral intention to receive the vaccine while Occa et al. (2022) used key constructs of the TPB (i.e., attitudes toward the behavior, perceived social norms, behavioral control) to create an animated video and the game. The social cognitive theory (SCT) was also applied in the study when designing the scenes of the game and the animated video to increase engagement (Occa et al., 2022).

In addition, one study was grounded in the Health Empowerment Model, it targeted the constructs of knowledge and empowerment to improve the effects on vaccination attitude, behavior, and recommendation (Fadda et al., 2017). Another intervention addressed intrinsic motivation and incorporated the self-determination theory (SDT) into the game design to make it engaging and entertaining (Cates et al., 2018, 2020). Epstein et al. (2021) described a multifaceted vaccination intervention in which the logic model of the theory of change was presented to specify the key components of the card game project, including resources, constraints, activities, outputs, and effects. For a comprehensive assessment of the player experience, Venigalla et al. (2021) developed questionnaires based on the Model for the Evaluation of Educational Games which was adapted to fit the study context and provide detailed information regarding pedagogy-related factors, player experience, and usability.

Primary Findings on Intervention Effects

Change in Knowledge. Eight out of the eleven studies evaluated the knowledge related to the disease, disease prevention, and the associated vaccination. Except for the study by Frick et al. (2023), which found no change in participants' COVID-19 knowledge after the intervention, all other studies demonstrated statistically significant improvements in knowledge from playing the game, with p-values ranging from 0.03 to less than 0.001 (Bertozzi et al., 2013; Cates et al., 2020; Eley et al., 2019; Fadda et al., 2017; Mitchell et al., 2021; Occa et al., 2022; Ruiz-López et al., 2019). While senior school-aged pupils had greater pre-gaming knowledge than junior students, they also exhibited

greater post-gaming knowledge, despite having similar perspectives on the game functions (Eley et al., 2019). Additionally, Venigalla et al. (2021) found that the collaborative game helped players better understand different professions work together to control the spread of diseases in a community.

Behavioral Self-Efficacy. The effects of the game-based intervention on self-efficacy for vaccination differed between studies. Cates et al. (2020) discussed that the higher self-efficacy score in the preteens who did not play the game could be related to a lack of awareness of the vaccination barrier. Nevertheless, Darville et al. (2018) found a positive impact of customizable avatars resembling players' actual selves on their self-efficacy to receive the vaccine. Additionally, children's intentions and self-efficacy to discuss vaccines with healthcare professionals or parents significantly increased after exposure to the game-based intervention (Occa et al., 2022).

Vaccination Intention and Vaccine Uptake. Two studies reported significant increases in vaccination intention, with one specifically attributing this effect to customizing avatars to resemble the player's ideal self in the game (Darville et al., 2018; Fadda et al., 2017). Frick et al. (2023) also reported a 20% increase in the number of participants who indicated their willingness to receive vaccination during the 6-week follow-up period. Self-reported vaccination behavior was measured in three studies and one of them also evaluated the completion of the vaccine series of 3 doses. However, despite the increase in overall vaccine initiation and completion, no statistically significant differences were reported (Bertozzi et al., 2013; Cates et al., 2020; Mitchell et al., 2021). Epstein et al. (2021), on the other hand, assessed return consent forms acts of secondary school students but regardless of whether the consent was obtained to vaccinate, the findings also revealed an insignificant effect of the intervention efforts (Epstein et al., 2021).

Perceptions of Game-Based Intervention

Four studies in the review evaluated game functions and gaming experience primarily focused on elements influencing players' immersive experience in the game. The favorable gaming experience was found about the game interface, pace and ease of the game, enjoyment of gameplay, game esthetics, design of game characters, and clear, simple, or pictorial game instructions to facilitate comprehension of educational messages, incentives, and rewards in the game (Cates et al., 2020; Eley et al., 2019; Occa et al., 2022; Venigalla et al., 2021). Mitchell et al. (2021) also reported that undergraduate nursing student participants were more inclined to recommend flu vaccination to their patients after playing the game.

Discussion

This review is among the first to identify and evaluate the impact of game-based vaccine interventions and core game components contributing to effectively promoting vaccine-related knowledge and behaviors among a diverse population of children, adolescents, young adults, dyads of parents and children, and parents of young children across seven different countries. A final set of eleven studies meeting the eligibility criteria was included after an iterative process of literature search, review, and critical appraisal of the findings. Despite the diversity in game design, the difference in countries in the studies had been conducted and the types of vaccines the intervention focused on, collected evidence of the studies indicated a generally favorable effect of game-based interventions in promoting vaccine knowledge and vaccination behaviors.

A consistent improvement in vaccine knowledge across game-based interventions was found in the review, particularly in understanding disease transmission and benefits of prevention, with variable effects on knowledge among school-aged students possibly due to differences in baseline vaccination status and motivational factors. This aligns with the study by Frick et al. (2023), which suggested that prior health experiences could influence new learning. The absence of an increase in knowledge among young asylum seekers after the intervention could be attributed to their prior vaccination and reduced motivation to learn about disease preventive measures (Frick et al., 2023). Exploring motivational factors among diverse groups could enable the development of strategies to improve knowledge acquisition and promote the adoption of preventive behaviors.

The review also highlighted a nuanced picture of vaccination self-efficacy influenced by serious games, with evidence from two studies suggesting that games could positively affect participants' confidence in obtaining vaccinations and engaging in health-related discussions (Darville et al., 2018; Occa et al., 2022). However, findings such as those from Cates et al. (2020), which showed no improvement in self-efficacy outcomes for parents and preteens playing the game compared to non-players, illustrate the variability in research outcomes and the need for further investigation. The validity of these findings could be further complicated by disparities in psychometric reporting, which cast doubt on the reliability of the measures used in studies. Such inconsistency in results and reporting standards underscores the critical need for more rigorous research methodologies to ascertain the true impact of serious games on self-efficacy and subsequent health behaviors.

Moreover, while two studies reported increased vaccination intentions among college students and parents (Darville et al., 2018; Fadda et al., 2017), these studies did not extend to tracking actual vaccine uptake. Without direct measurement of vaccination behavior, the relationship between the intentions fostered by serious games and real-

world vaccine behavior remains to be fully understood. Only three out of eleven studies explored post-game vaccination behavior, revealing no significant changes (Bertozi et al., 2013; Cates et al., 2020; Mitchell et al., 2021). Prior studies also noted disparities between intention and uptake in adolescent girls (Wegwarth et al., 2014). This indicates a persistent gap between intentions and behaviors, suggesting that while game-based interventions have the potential to influence vaccination intentions, this does not consistently translate into higher vaccination rates. These findings underscore the urgent need for research that bridges the divide between vaccine knowledge and behavior, especially among groups that demonstrate high knowledge or awareness but low vaccine uptake.

In addition, the lack of impact on vaccine coverage observed in studies could be attributable to the gap between the knowledge, attitudes, and intentions of youth and their actual vaccination behavior, which is often influenced by parental control. This highlights the challenge of translating educational interventions into tangible health behaviors in real-world settings, especially when the young audience lacks the autonomy to act on their intentions. The reliance of young individuals on parental decision-making could create a disconnection between what youth learn and feel empowered by through game-based interventions and the actions taken regarding their health. To bridge this gap, future research could explore parental education and involvement in game-based interventions to align the intentions of youth with the health behaviors facilitated by their caregivers or guardians.

Regarding the game design, In-game avatar customization could be a key element of game design that significantly boosted engagement with serious games. This feature enabled personalization, fostering player identification, which could lead to improved learning outcomes for a variety of cognitive styles and gaming experiences (Birk et al., 2016; Chen et al., 2019). This personal connection not only promoted emotional engagement but also appeared to strengthen the intent to engage in health behaviors, such as vaccination, among children and young adults (Bertozi et al., 2013; Darville et al., 2018; Kim & Sundar, 2012).

Additionally, serious games were found effective in catalyzing discussions about health between children, their parents, and healthcare professionals, offering a platform to address topics that may otherwise be challenging to approach. The communicative power of these games not only extended to facilitating conversations on sensitive health topics such as sexual health, which were often met with reluctance (Cates et al., 2018, 2020; Occa et al., 2022) but could also be vital in empowering youth to engage in informed discussions with their parents, potentially influencing parental attitudes and decisions about vaccinations. Beyond communication, the social elements of gaming, including in-game networking features and multiplayer collaboration, have been acknowledged for their capacity to

nudge behavior and enhance team-based learning, resulting in favorable health outcomes (Pasupuleti et al., 2022; Ruiz-López et al., 2019; Venigalla et al., 2021). These findings collectively underline the multifaceted role of serious games in not just learning but also in influencing health behaviors and providing innovative avenues for health education and behavioral change among adolescents and young adults.

Serious games have also shown potential to impact health behaviors other than vaccination, serving as transformative tools that influenced a broad range of health behaviors, spanning from managing chronic diseases to improving mental health and encouraging physical activity, across various age groups (Bossen et al., 2020; Dewhurst et al., 2022; Holtz et al., 2018). The effectiveness of the intervention relied on aligning the game's objectives with the user's autonomy and their social environment. The youth's surrounding environment, including the involvement of key influencers such as parents and guardians, could be imperative to ensure that the intentions fostered by serious games translate into tangible health behaviors, thereby effectively bridging the gap between intention and action in health behaviors facilitated by serious games.

Implications for Practice

The review highlights the value of serious games in youth health education, especially for promoting vaccinations. This can guide efforts to boost youth vaccination rates. Healthcare providers and nurse educators can partner with game developers to craft engaging campaigns that educate youths about vaccines and address myths.

Conclusion

Overall, the review sheds light on the efficacy of serious games as a tool for improving vaccine knowledge among youths and parent-youth dyads. While the results indicated that such games could be effective in increasing knowledge about vaccinations, the evidence did not conclusively show that this translated into improved vaccine uptake and completion behaviors. This gap highlights the complex nature of converting educational engagement into actionable health behaviors, particularly in a population that does not typically have autonomous control over health decisions. Future research is imperative to substantiate the impact of serious gaming on actual vaccination behavior, with a focus on designing interventions that resonate with the varied decision-making dynamics of young individuals, considering age, gender, and the pivotal role of parental influence in the vaccination process.

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ORCID iD

Lihong Ou  <https://orcid.org/0000-0002-4104-7935>

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Appendix I. Search Terms for Searched Databases.

Databases	Searching Terms	Number of Studies	Searching Period
PubMed	("games" OR "gamification" OR "serious games" OR "digital games" OR "gaming" OR "digital gaming" [All Fields]) AND ("intervention" OR "programs" OR "strategies" OR "practices" OR "computerized intervention" OR "technology-based intervention" OR "tech-based intervention" [All Fields]) AND ("vaccines" [MeSH Terms] OR "vaccination" [MeSH Terms] OR "immunizations" [MeSH Terms] OR "vaccine uptake" OR "vaccine acceptance" OR "vaccine hesitancy" [MeSH Terms] OR "vaccine refusal" [All Fields]) AND ("adolescent"[MeSH Terms] OR "youth" OR "young people" OR "young adult" [MeSH Terms] OR "teenager" OR "teen" [All Fields])	47	From January 2011 to June 2023
CINAHL	"games" or "gaming" or "gamification" AND "interventions" or "strategies" or "best practices" or "program" AND "youth" or "adolescents" or "young people" or "teen" or "young adults" AND "vaccines" or "vaccinations" or "immunizations" or "vaccine hesitancy" or "vaccine refusal"	26	
ProQuest	"games" or "gaming" or "gamification" AND "youth" or "adolescents" or "young adults" or "young people" or "teenagers" or "teen" AND "vaccines" or "vaccinations" or "immunizations"	9	
Cochrane Library	"games" or "gaming" or "gamification" AND "youth" or "adolescents" or "teen" or "teenager" or "young adult" AND "vaccinate" or "vaccines" or "vaccination" or "immunization"	26	
Google Scholar	"games" and "gamification" and "serious games" and "serious gaming" and "digital game" and "intervention" and "programs" and "strategies" and "vaccine" and "vaccination" and "immunizations" and "youth" and "adolescent" and "young people" and "young adult" and "teenager"	161	
Total searched articles		269	
Total articles that fulfill the eligibility criteria for review		11	

Appendix 2. Literature Review Table.

Author & Study Purpose	Game Purpose	Design and Theory	Sample, Procedure and Measures	Results	Level of Evidence and Quality of RCT Study
Bertozzi et al. (2013) Purpose: Discusses the creation of two serious games (Flu Busters and Emergency Birth) developed by the Engender Games Group with the intention of meeting specific outcomes in the healthcare field	The Flu Busters! Purpose: Explain how the flu vaccine works and encourages children to get vaccinated	Quasi-experimental design Not mentioned theory	Sample 12 children in New York, USA Procedure The game was installed on several laptops at Winthrop-University Hospital and utilized for testing purposes among the children in the clinics. Measures Flu vaccination rates after playing the game	Knowledge related Understanding of germs invading the body and altering its cells was bad and that the vaccine could be helpful Communication The game very effectively communicates how prevalent the flu virus was in heavily populated environments Vaccination rate 10 of 12 children got flu shots after playing the game	III
Fadda et al. (2017) Purpose: Look into the effects of smartphone-based interventions targeting MMR vaccination knowledge and psychological empowerment	Smartphone App Morbiquiz Purpose: Increase parents' knowledge about the MMR vaccination and the other to augment empowerment in the MMR vaccination decision	Randomized controlled trial Health Empowerment Model	Sample 184 Italian parents of young children Procedure 3 experimental groups or the control group - 1st group: received the app containing only the intervention targeting the MMR literacy - 2nd group: received the app containing only the intervention targeting empowerment - 3rd group: received the app containing both the knowledge and empowerment interventions.	Primary outcomes Experimental groups - significantly increased post-experiment knowledge, compared with the control group - having the highest knowledge gain - increased post-experiment empowerment against the control group - searched information more often Secondary outcomes - stronger post-experiment intention to vaccinate in group receiving the intervention addressing vaccination knowledge - similar intention to vaccinate between the intervention addressing empowerment and the group receiving both interventions - intervention targeting	II Some concerns in randomization process and outcome measurements

(continued)

Appendix 2. Continued.

Author & Study Purpose	Game Purpose	Design and Theory	Sample, Procedure and Measures	Results	Level of Evidence and Quality of RCT Study
Darville et al. (2018) Purpose: Evaluate the effectiveness of a digital gaming intervention aimed at increasing HPV risk perceptions, self-efficacy and behavioral intention to receive the HPV vaccine among college age men	VAX game Purpose: Change HPV knowledge and impact HPV vaccine	Randomized controlled trial The Health Belief Model	MMR vaccination side effects and of measles - MMR vaccination attitude, intention to vaccinate, recommend, confidence in the decision (single item respectively) Sample 168 full-time US male students from a large research-intensive university in the southeastern	knowledge reported significantly higher intention to vaccinate and higher confidence in the decision Risk Perception for the HPV virus no main or interaction effect for risk perception Self-Efficacy having a customized avatar most representative of one's actual self being most indicative of an increased level of self-efficacy or confidence to receive the HPV vaccine Behavioral customizing an avatar to represent ideal self being the most indicative of an increased level of behavioral intention to receive the HPV vaccine	II Some concerns in randomization process and outcome measurements
Ruiz-López et al. (2019) Purpose: Describe the development of a mobile app called FightHPV, a game-based learning tool that educates mobile technology users about HPV, the disease risks associated with HPV infection, and existing preventive methods	FightHPV Purpose: Leverage the power of mobile communication and social nudging by allowing players to share information about HPV and cervical cancer with their social network	Mixed-methods study Social cognitive theories	Sample: 29 focus group participants Focus group 1: 6 women aged 40–60, members of the Norwegian Women's Public Health Association Focus group 2: 23 high school students (10 girls, aged 16–18 living in Oslo, Norway) Procedure Focus groups played the game before the focus group discussions, semi structured interviewed conducted to receive both general and specific feedback about game, items)	General Feedback on FightHPV the game as an appealing educational tool 69% reported that they liked the game, and 81% stated that the game was challenging also found the game to be thought provoking, requested more information on HPV Effect on Knowledge - significant improvement in knowledge about epithelial cells, HPV, and HPV transmission, concepts about HPV vaccination were best	III

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Appendix 2. Continued.

Author & Study Purpose	Game Purpose	Design and Theory	Sample, Procedure and Measures	Results	Level of Evidence and Quality of RCT Study
<p>Eley et al. (2019) Purpose: Determine students' baseline knowledge, views on 2 e-Bug games, and knowledge improvement</p>	<p>Body Busters and Stop the Spread Purpose: Teach children and young people about hygiene, the spread of infections, antibiotic use, resistance, and vaccinations</p>	<p>Mixed-methods study Not mentioned theory</p>	<p>experiences with the game, the usefulness of game to disseminate information about health and willingness to share -pre and post questionnaire about the game and a test of knowledge of HPV Measures Knowledge about different topics related to human papillomavirus (epithelial cells, HPV, HPV transmission, vaccine, and screening)</p>	<p>understood, with the highest IQR</p>	<p>III</p>
			<p>Sample 473 school-aged children (junior and senior students aged 7–16) from 5 educational providers across 3 local authorities in the United Kingdom Procedure: 473 pre- and post-game play questionnaire, and 26 conducted semi structured focus groups after playing the games Measures</p>	<p>Significant improvements in - knowledge about antibiotic use, appropriate sneezing behaviors, and vaccinations for both age groups - greatest improvement in knowledge seen in (By getting vaccinated, you can also protect others around you from infections) and (Antibiotics kill good and bad bacteria)</p>	
			<p>- Pre-game play questionnaire regarding knowledge about vaccinations, antibiotics</p> <p>- Post-game play questionnaire 2 included an additional 7 questions on game enjoyment, including 2 Likert scale questions and 5 open-ended questions</p>	<p>Body Busters Game both age groups reported positive perceptions of user experience, such as the microbe characters and the different levels of the game and the useful pictorial instructions Suggestions to modify: Pace of the game and keeping the pictorial instructions but adding written instructions for clarity Stop the Spread Game both age groups reported positive</p>	

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Appendix 2. Continued.

Author & Study Purpose	Game Purpose	Design and Theory	Sample, Procedure and Measures	Results	Level of Evidence and Quality of RCT Study
<p>Cates et al. (2020) Purpose: Evaluate preliminary data to determine whether children who received the game had better self-reported outcomes related to HPV knowledge or vaccination self-efficacy compared with those in a control group who did not receive the game. Evaluate outcomes related to the game play experience</p>	<p>Land of Secret Gardens Purpose: Foster HPV vaccination awareness, information seeking, and communication among preteens</p>	<p>Randomized controlled trial Self-determination theory</p>	<p>Sample: 55 dyads of parents and preteens from 18 primary practices in North Carolina who had not initiated HPV vaccination Procedure: - Intervention group: play the game and complete 3 tasks in the video game activities: (1) play a shield game with blue spikey virus balls, (2) find hidden objects in 4 different rooms, and (3) create a potion - Baseline and postintervention (4 months after completion of baseline surveys)</p>	<p>perceptions of user experience, including game esthetics, pace of the game, different levels of difficulty, and reporting an increase in knowledge about the spread of infection and the importance of vaccinations Knowledge: Higher knowledge in the intervention group Vaccine self-efficacy score higher self-efficacy in the comparison group (plausible explanation: less aware of barriers to HPV vaccination) PENS mixed reviews on the game - positive scores on game autonomy and competence, ease, and freedom of playing the game - not being impacted emotionally and not holding their attention</p>	<p>II Some concerns in randomization process and outcome measurements</p>
			<p>Measures - 5 item Knowledge scale: - 17 item Vaccination Self-efficacy and decisional balance scales - Physical/Emotional/Narrative Presence Scale (PENS) to gauge preteens' immersion in the game - Gaming experience - HPV immunization records</p>	<p>Vaccine initiation and completion rates - higher in the intervention group than in the comparison group while the difference not significant</p>	(continued)

Appendix 2. Continued.

Author & Study Purpose	Game Purpose	Design and Theory	Sample, Procedure and Measures	Results	Level of Evidence and Quality of RCT Study
Mitchell et al. (2021) Purpose: Examine nursing student perceptions about their attitudes and understanding of influenza before and after playing the game To learn if playing the “serious game” increased nursing student knowledge about influenza To establish if playing the “serious game” correlated with increases in flu vaccination uptake in nursing students	Flu Bee Game Purpose: Create awareness about influenza, dispel myths associated with the influenza vaccine and increase uptake the vaccination	Quasi-Experimental Design Not Mentioned Theory	Sample Northern Ireland university students taking BSc Honours Degree in Nursing (enrolled in one of the four programs); adult nursing, mental health nursing, children’s nursing or learning disability nursing) (n = 430 accessed the game, n = 356 completed vaccination uptake questionnaire) Procedure survey collected between 1st September 2018 and 31st March 2019; April 2019 collected vaccination questionnaire Measures - 8-Item questionnaire about attitudes and perception. - 2-Item questionnaire about influenza vaccine uptake; - 40-Item knowledge questionnaire about influenza and vaccination	After playing the game - increased good or very good knowledge about influenza and the vaccination - willingness to receive the vaccination doubled - increased perception about the importance of promoting the influenza vaccination Vaccine uptake 36.7% → 47.8% received an influenza vaccination Reported perceived improvements in knowledge, intention to get the vaccination and intention to recommend the vaccination to their patients after playing the game	III
Venigalla et al. (2021) Purpose: Perform a preliminary evaluation of a COVID-19 game	SurviveCovid-19++ Purpose: Facilitate better understanding about safety measures to be taken against COVID-19	Quasi-experimental design Evolution of the Model for the Evaluation of Educational Games (MEEGA + model); Technology Acceptance Model; Unified Theory of Acceptance and Use of Technology	Sample 28 volunteers (4 female college students in India) Procedure After answering the questionnaire, each team (4 players) played the game for 15 min Four roles supported in the game —doctor, sanitation worker; citizen, and law enforcer Measures Adapted MEEGA + questionnaire; pedagogical value (learning outcomes, attitudinal/behavioral change); evaluation of the game	Better understanding about safety measures, and recognize the need for the collaborative efforts and role of each profession in the context of COVID Positive experience with the game; high quality score of game	III

(continued)

Appendix 2. Continued.

Author & Study Purpose	Game Purpose	Design and Theory	Sample, Procedure and Measures	Results	Level of Evidence and Quality of RCT Study
Epstein et al. (2021) Purpose: Test the use of Vaxcards as an ethical, non-monetary incentive to support school vaccination programmers for secondary school students	Vaxcards Purpose: Help children to engage learning about the diseases vaccinated against during the routine childhood immunization schedule in Australia	Randomized controlled trial Theory of Change	Sample: 3087 secondary school students from 19 school clusters in Southeast Melbourne, Australia Procedure Block randomization to allocate participating schools to one of two groups (control and the experimental group in which parent/caregiver were advising a “basic pack” of the card game) Card pack given when returning the vaccine consent form Measures Primary outcome being consent to vaccination based on the returned council consent forms	No statistically significant difference between the change in the proportion of returned consent forms with a consent to vaccination between the experimental and control groups Subgroup analysis - significant improvement in consent to vaccination between 2018 and 2019 for students from small schools (<100 students in the year level)	II Some concerns in randomization process and outcome measurements
Occa et al. (2022) Purpose: Assess the feasibility of using an evidence-based animated video and a web-based game to help children (aged 11–12 years) participate in discussions about their health—in particular when such conversations center around the HPV vaccination—and improve HPV related outcomes	Salute e HPV (Health and HPV) Purpose: Improve attitudes, knowledge, subjective norms, self-efficacy, intentions, and emotions regarding the HPV vaccine	Mixed-methods study Theory of planned behavior	Sample 35 children aged 11–12 years, all enrolled in the second year of middle school in Italy Procedure: 9 focus groups participants randomly assigned to either the animated video or game conditions preintervention questionnaire followed by the animated video (20/35) or played the game (15/35) postintervention questionnaire (same as the preintervention questionnaire) Measures - 8-item vaccine knowledge scale - 5-point attitude scale vaccinating against HPV	The two educational materials well received - effective in improving children's knowledge about the HPV vaccination - effective in intentions to discuss the HPV vaccine with parents and health care professionals Appreciated features in both the animated video and the game included personality and caring attitude of the characters	II Some concerns in randomization process and outcome measurements

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Appendix 2. Continued.

Author & Study Purpose	Game Purpose	Design and Theory	Sample, Procedure and Measures	Results	Level of Evidence and Quality of RCT Study
<p>Frick et al. (2023) Purpose: Test feasibility and efficacy of a culture-sensitive approach combining app games and a face-to-face group intervention to improve knowledge about COVID-19 and promote vaccination readiness among collectively accommodated Arabic-speaking adolescents and young adults</p>	<p>CAYPVAR app Purpose: Provide information in a culture-sensitive and age-adapted mode of presentation, improve understanding of COVID-19 disease mechanisms and increase willingness to be vaccinated</p>	<p>Mixed-methods study Not mentioned theory</p>	<ul style="list-style-type: none"> - 1 item intention to participate in health conversations - 5-item Self-efficacy scale - 4-item subject norm scale - 6-item scale fear of vaccination - 2 items game enjoyment - 2 items message involvement <p>Sample 88 participants, aged 16 to 26 years, from 8 collective housing institutions (4 in Bavaria, 4 in Berlin) in Germany Procedure: Randomly assigned to either the Group A receiving the CAYPVAR app as a pretest-posttest comparison, or Group B having the app along with a face-to-face group intervention on behavior planning Measures</p> <ul style="list-style-type: none"> - 12-item knowledge test - Vaccination readiness on a 4-point scale - Patient Health Questionnaire-4 on a 4-point scale - 9-item questionnaire on attitude toward preventive behaviors 	<p>Knowledge Increase in knowledge observed at follow-up assessment, but not statistically significant Vaccination readiness</p> <ul style="list-style-type: none"> - additional 13 (20%) participants willing to get vaccinated - 3 (5%) participants reluctant to be vaccinated <p>Attitudes toward preventive measures descriptive values provided without pretest-posttest comparisons, relative low attitudes favoring the behaviors</p>	<p>II Some concerns in randomization process and outcome measurements</p>