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Factors Associated With Referring Close Contacts to an App With Individually-Tailored Vaccine Information

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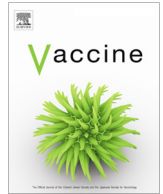
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Factors associated with referring close contacts to an app with individually-tailored vaccine information



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ABSTRACT

Background: Infants too young to be fully vaccinated are vulnerable to potentially deadly influenza and pertussis infections. The cocooning strategy limits this risk by vaccinating those likely to interact with the infant and mother during this vulnerable time, such as close friends and family members. Distribution of accurate and accessible vaccine information through existing social networks could be an important tool in increasing vaccine confidence and coverage.

Methods: We surveyed 1095 pregnant women from diverse prenatal care practices in Georgia and Colorado. These women were surveyed through a mobile app to assess vaccine intentions, attitudes, beliefs, norms, and levels of trust, and then presented brief individually-tailored educational videos about maternal and infant vaccines and the cocooning strategy. They were then given the opportunity to refer up to six contacts to enroll in the app and receive similar vaccine education.

Results: Twenty-eight percent of these women referred at least one contact, with an average of 2.67 contacts per referring woman. Most referrals (93%) were partners, parents, siblings, relatives, or close friends. Attitudinal constructs significantly associated with increased likelihood of referring contacts included: intention to receive maternal influenza vaccine, perceived safety of maternal Tdap vaccine, perceived efficacy of maternal influenza vaccine, perceived susceptibility to and severity of influenza during pregnancy, and trust in vaccine information from the Centers for Disease Control and Prevention (CDC) and academic institutions. Uncertainty about infant vaccine intentions was associated with decreased likelihood of referring contacts.

Conclusions: Pregnant women who valued vaccination and trusted vaccine information from academic institutions were more likely to refer an educational app about vaccines than those who did not. Further research is needed to determine the potential impact of this strategy on vaccine coverage when implemented on a large scale.

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1. Introduction

Children too young to be vaccinated against pertussis are at high risk for contracting pertussis disease (commonly known as whooping cough); they also have the highest complication rates [1–4]. Almost all pertussis deaths in the United States (US) occur in children less than 6 months of age [1,2]. For influenza, there is no licensed vaccine for infants less than 6 months of age, and this is the group at highest risk for influenza-associated hospitalization and death [5]. Influenza and tetanus, diphtheria and acellular pertussis (Tdap) vaccines are recommended during pregnancy to protect both the pregnant woman and her unborn infant against these diseases [2,6–8]. Only about half of pregnant women receiving either recommended vaccine in 2018 [9]. This leaves many infants vulnerable to potentially deadly influenza and pertussis infections in their early life [4,5,8,10].

Cocooning, the vaccination of close contacts of a newborn, is a strategy to further limit the risk of influenza and pertussis infection among vulnerable infants [11–13]. Factors such as high perceived benefits of vaccine, high perceived susceptibility to disease, and low perceived barriers to vaccination have been associated with higher rates of cocooning vaccination [14], illustrating the potential for educational intervention on this topic.

Vaccine decisions, like many other types of decisions, have been shown to be influenced by one's peers within their social network [15–19], especially among those with vaccine concerns [20]. Thus, by changing the vaccine attitudes and beliefs of a pregnant woman's social network, one may also change the vaccine attitudes and beliefs of that pregnant woman, and vice versa. Only one study so far has analyzed social networks to determine their impact on vaccine decision making in the US [18].

We designed an educational app about vaccines that pregnant women could experience and refer to their close friends and family, with the goal of increasing vaccine coverage among both pregnant women and their close contacts. The main objective of this analysis was to determine which factors were associated with an increased likelihood of pregnant women referring their close contacts to this educational app. A secondary objective was to determine the types of contacts (e.g., partner, parent, sibling, other relative, close friend, casual friend, caregiver, other) most commonly referred and enrolled in the app.

2. Methods

2.1. Study design

This study was possible due to the existing infrastructure of the P3+ study, a large randomized controlled trial of a three-level prenatal intervention to increase uptake of maternal and infant vaccines [clinicaltrials.gov registration number NCT02898688]. In P3+, pregnant women entering a geographically and socio-demographically diverse set of prenatal care settings in Georgia (GA) and Colorado (CO) for regularly scheduled appointments between June 2017 and July 2018 were recruited to participate by study staff. Eligibility criteria mandated that participating women must have been between 18 and 50 years old, between 8 and 26 weeks pregnant, and had not yet received Tdap vaccine during their current pregnancy.

As part of the P3+ study, we developed an application (“app”) for pregnant women entitled “MomsTalkShots” that can be used on smartphones, tablets and computers [21]. The app was designed to collect survey data on vaccine knowledge, attitudes and beliefs and to deliver educational videos about maternal and infant vaccines and the cocooning strategy, tailored to the individual's specific vaccine concerns as elicited by their survey responses. The baseline survey was administered to all P3+ participants via tablets in the waiting rooms, and a \$20 incentive was provided for survey completion [21]. Videos were only given to half of the participants, chosen at random. Videos were designed to present information in a scientifically accurate yet engaging manner with easily understandable language and representations of racially and ethnically diverse populations. This was done so that the app would have broad appeal to a variety of audiences with varying audiences.

All participating women randomized to receive videos were given the opportunity to refer up to 6 of their close friends and family to the app upon conclusion of the videos. Those who referred at least one contact received a \$10 gift card. Two-thirds of the referred contacts selected at random were then sent up to 10 emails, each spaced out by at least a week, with a link to the app inviting them to enroll. As in P3+, referred contacts who chose to enroll in the app were incentivized (\$20 gift card) to complete a survey and randomized (1:1) to receive individually-tailored educational videos. Enrolled contacts also were offered a small financial incentive (\$10 worth of Walgreens Balance Rewards points per vaccine) for receiving influenza and/or Tdap vaccinations at Walgreens.

2.2. Data collection

The baseline P3+ survey included multiple choice questions assessing intention to receive recommended maternal and infant vaccines and number of prior children. In addition, the survey included 58 Likert scale statements assessing latent attitudinal constructs such as: confidence in vaccine safety and efficacy, perceived risk of (susceptibility to and severity of) vaccine-preventable diseases (VPDs), self-efficacy (an individual's belief in their capacity to execute behaviors necessary to produce specific performance attainments) [22], descriptive (what people typically do) and injunctive (what people typically approve or disapprove) social norms [23], perception of knowledge, and trust in information sources. These were chosen after reviewing other relevant behavioral models, theories and scales [15,24], and each construct was assessed using several survey items. Likert scale response options were strongly agree, agree, disagree, and strongly disagree; trust and knowledge statements included a “don't know” option; and trust statements regarding pediatricians and naturopathic/chiropractic doctors included options for “I don't have a pediatrician yet” and “I don't see this type of doctor”, respectively. Sociodemographic information including ethnicity and education was collected.

2.3. Data analysis

Responses to questions assessing maternal and infant vaccine intention were dichotomized to represent those who intended to receive maternal influenza vaccine, those who intended to receive maternal Tdap vaccine, and those who intended to receive all

infant vaccines on time as recommended (versus those who did not). Likert scale responses were dichotomized to represent those who strongly agreed or agreed versus those who did not.

Likert scale responses were encoded (1 - strongly disagree, 2 - disagree, 3 - don't know, 4 - agree, 5 - strongly agree) and survey questions assessing each of the following attitudinal constructs were combined to create summary scores: confidence in vaccine safety (for the mother), confidence in vaccine safety (for the infant), confidence in vaccine efficacy (influenza), confidence in vaccine efficacy (whooping cough), risk perception (maternal influenza), risk perception (maternal whooping cough), risk perception (infant whooping cough), self-efficacy, social norms, perception of vaccine knowledge, trust in vaccine information (from pediatricians, obstetricians and midwives), trust in vaccine information (from naturopaths and chiropractors), and trust in vaccine information (from federal agencies and academic institutions).

Sociodemographic characteristics, individual survey responses, and construct summary scores were each analyzed as independent variables in simple logistic regressions with a dichotomous variable for having referred contacts versus not having referred contacts as the dependent variable, and odds ratios (ORs) and 95% confidence intervals (95% CIs) were calculated.

Percentages of contacts referred and enrolled in the app by type of relationship to the referrer were calculated. Pearson's chi-squared test for independence was used to assess differences in enrollment rates by relationship type. All p-values were two-sided, and $p < 0.05$ was considered statistically significant. Analysis was performed using Stata/IC 12.1 (STATA Corp., College Station, TX, USA).

3. Results

Among pregnant women participating in P3+, 1095 (542 from Colorado and 553 from Georgia) were randomized to receive videos and thus were given the opportunity to refer contacts to the app (Table 1). Forty-eight percent of these women were pregnant for the first time. Of those who provided education information ($n = 894$, 82% of total sample), 227 (25%) had an advanced degree and 389 (44%) had an associate's or bachelor's degree. Of those who provided their ethnicity ($n = 926$, 85% of total sample), 569 (61%) identified as white; 158 (17%) identified as black and 115 (12%) as Hispanic or Latino.

Three hundred and six women (28%) referred at least one contact to the app, with an average of 2.67 contacts per referring woman. Of these women, 39% referred one contact, 22% referred two contacts, 11% referred three contacts, 6% referred four contacts, 3% referred five contacts, and 18% referred the maximum of six contacts (Table 2).

A total of 819 contacts were referred (Table 3). Twenty-four percent of referred contacts were listed as parents, 20% as close friends, 19% as partners, 16% as siblings, 14% as other relatives, 2% as casual friends, 2% as caregivers to the infant, and 2% as other.

Several statistically significant associations were found between pregnant women who referred contacts and survey items assessing their vaccine intentions, knowledge, attitudes, beliefs and trust (Table 4). Women who intended to receive maternal influenza vaccine were more likely to refer contacts to the app (odds ratio: 1.37; 95% confidence interval: 1.04–1.81), and women who were unsure about their infant vaccine intentions were less likely to refer contacts to the app (OR: 0.47; 95%CI: 0.27–0.83). Women were more likely to refer contacts to the app if they were confident in the safety of maternal Tdap vaccine (OR: 1.64; 95%CI: 1.13–2.38) and the efficacy of maternal influenza vaccine (OR: 1.90; 95%CI: 1.21–2.98), had high perceived susceptibility to (OR: 1.62; 95%CI: 1.10–2.40) and severity of (OR: 2.19; 95%CI: 1.28–

Table 1

Percentage of pregnant women who referred contacts to educational App about vaccines, stratified by state, education, ethnicity and first child.

Selected characteristics	Total, N (%)	Referred contacts, N (%) [*]	P ^{**}
All	1095	306 (28)	
<i>State</i>			
Colorado	542 (50)	157 (29)	0.46
Georgia	553 (51)	149 (27)	
total	1,095	306 (28)	
<i>Education</i>			
Graduate degree ^{***}	227 (25)	82 (36)	0.03
Undergraduate degree ^{***}	389 (44)	107 (28)	
No college degree	278 (31)	72 (26)	
total	894	261 (29)	
<i>Ethnicity</i>			
Black or African American	158 (17)	39 (25)	0.15
Hispanic or Latino	115 (12)	35 (30)	
White	569 (61)	158 (28)	
Other	84 (9)	32 (38)	
total	926	264 (29)	
<i>First Child</i>			
Yes	523 (48)	150 (29)	0.60
No	572 (52)	156 (27)	
total	1,095	306 (28)	

^{*} Number and percentage in each sociodemographic group who referred contacts to app.

^{**} P-value for the Pearson chi-squared proportion test at significance level of (α) 5%; bolded if significant.

^{***} Graduate degree includes Master's, Doctoral, and Professional degrees; Undergraduate degree includes Bachelor's and Associate's degrees.

Table 2

Number of contacts referred to educational app about vaccines per pregnant woman.

Number of Contacts Referred	N (%)
0	789 (72)
1+	306 (28)
1	120 (11)
2	67 (6)
3	34 (3)
4	19 (2)
5	10 (1)
6 (maximum allowed)	56 (5)
total	1,095 (100)

Table 3

Contacts referred to educational app about vaccines by relationship to pregnant women who referred them.

Relationship	Referred, N (%)
Partner	154 (19)
Parent	200 (24)
Sibling	131 (16)
Other Relative	118 (14)
Close Friend	162 (20)
Casual Friend	19 (2)
Caregiver	14 (2)
Other	15 (2)
Unknown	6 (1)
total	819 (100)

3.73) influenza during pregnancy, and reported trust in maternal vaccine information from academic institutions (OR: 1.56; 95%CI: 1.09–2.25) as well as infant vaccine information from the CDC (OR: 1.44; 95%CI: 1.02–2.05) and academic institutions (OR: 1.85; 95%CI: 1.27–2.71). Attitudinal constructs found to be signifi-

Table 4

Odds ratios for survey items and attitudinal constructs associated with pregnant women referring contacts to educational app about vaccines.

Survey Items	Contacts Referred, OR (95%CI)*
<i>Vaccine Intentions**</i>	
Intention to Receive Maternal Influenza Vaccine	1.37 (1.04, 1.81)
Uncertain Infant Vaccine Intentions	0.47 (0.27, 0.83)
<i>Individual Survey Statements - Agreed or Strongly Agreed**</i>	
Confidence in Vaccine Safety	
I am confident that getting the whooping cough vaccine during my pregnancy is safe for me.	1.64 (1.13, 2.38)
Other Vaccine Knowledge, Attitudes and Beliefs	
I worry that I could get the flu while I am pregnant.	1.62 (1.10, 2.40)
The flu is more dangerous for pregnant women than for women who are not pregnant.	2.19 (1.28, 3.73)
Getting the flu vaccine will reduce my risk of getting the flu during my pregnancy.	1.90 (1.21, 2.98)
I trust the information provided by federal agencies such as the Centers for Disease Control and Prevention (CDC) about vaccines for babies after birth.	1.44 (1.02, 2.05)
I trust the information provided by scientists and doctors at universities and academic institutions about vaccines during pregnancy.	1.56 (1.09, 2.25)
I trust the information provided by scientists and doctors at universities and academic institutions about vaccines for babies after birth.	1.85 (1.27, 2.71)
<i>Attitudinal Constructs - Summary Scores***</i>	
Confidence in vaccine safety (for the mother)	1.10 (1.03–1.17)
Confidence in vaccine safety (for the infant)	1.03 (0.98–1.09)
Confidence in vaccine efficacy (influenza)	1.14 (1.03–1.26)
Confidence in vaccine efficacy (whooping cough)	1.08 (1.01–1.15)
Perceived risk (maternal influenza)	1.15 (1.06–1.26)
Perceived risk (maternal whooping cough)	0.96 (0.85–1.08)
Perceived risk (infant whooping cough)	1.02 (0.96–1.08)
Self-efficacy	1.03 (0.87–1.22)
Pro-vaccine social norms	1.04 (1.00–1.09)
Perception of vaccine knowledge	1.06 (0.99–1.14)
Trust in vaccine information (from obstetricians and pediatricians****)	1.02 (0.98–1.05)
Trust in vaccine information (from naturopaths and chiropractors****)	0.93 (0.87–1.00)
Trust in vaccine information (from federal agencies and academic institutions)	1.07 (1.03–1.12)

* Odds Ratio (95% Confidence Interval) for referring contacts to app.

** Survey items only listed if statistically significantly associated with referring contacts to app.

*** Construct summary scores all listed, bolded if significant.

**** Removed those who stated they hadn't yet seen this type of provider from this analysis.

cantly associated with referral of contacts were: confidence in vaccine safety for the mother (OR: 1.10; 95%CI: 1.03–1.17), perceived risk of maternal influenza (OR: 1.15; 95%CI: 1.06–1.26), confidence in efficacy of influenza (OR: 1.14; 95%CI: 1.03–1.26) and whooping cough (OR: 1.08; 95%CI: 1.01–1.15) vaccines, and trust in vaccine information from federal agencies and academic institutions (OR: 1.07; 95%CI: 1.03–1.12). There were no statistically significant associations between likelihood of referring contacts to the app and ethnicity, education, state, or having prior children.

Four hundred eighty-five (59%) of the contacts referred were randomly selected to be invited by email to join the study and enroll in the app (Table 5). Of these, 158 enrolled in the app (33% response rate). No statistically significant difference in enrollment rates by type of relationship to the referring pregnant woman was found ($p = 0.56$).

4. Discussion

Pregnant women were more likely to refer their friends and family to an educational app about vaccines if they were confident in the safety and efficacy of maternal vaccines, perceived risk of

Table 5

Contacts who chose to enroll in educational app about vaccines by relationship to pregnant women who referred them.**

Relationship	Enrolled, N (%)	Not Enrolled, N (%)	Total*
Partner	34 (39)	54 (61)	88
Parent	31 (29)	77 (71)	108
Sibling	19 (25)	57 (75)	76
Other Relative	25 (33)	50 (67)	75
Close Friend	39 (38)	64 (62)	103
Casual Friend	4 (33)	8 (67)	12
Caregiver	3 (38)	5 (63)	8
Other	2 (18)	9 (82)	11
Unknown	1 (25)	3 (75)	4
total*	158 (33)	327 (67)	485

* Only 485 of 819 referred contacts (59%) invited to enrol.

** Pearson chi-squared (8) = 6.76 ; p -value = 0.56.

influenza during pregnancy, and trusted vaccine information from federal agencies and academic institutions.

The vast majority of contacts referred to an educational app about vaccines by pregnant women were their partners, parents, siblings, relatives, or close friends. Very few users referred their casual friends or other caregivers for the infant. This is not surprising; women may be more comfortable referring close friends and family than caregivers with whom they do not have the same personal relationship. However, from a public health perspective, caregivers would be an ideal target for cocooning vaccinations, and ways to increase their inclusion in referral strategies such as this should be explored. No difference was seen in the likelihood of the referred contact enrolling in the app based on the type of relationship with the referring pregnant woman.

The positive association found between referring contacts to the app and trust in vaccine information from academic institutions is logical, as the app was clearly labeled as a product of the three universities collaborating on this study (Emory University, University of Colorado Anschutz Medical Campus, and Johns Hopkins Bloomberg School of Public Health). Previous vaccine-related studies have similarly identified institutional trust is strongly correlated with immunization intent, vaccine trial participation, and reported vaccine receipt [19,25,26].

The significant association of confidence in vaccine safety and efficacy and perceived risk of VPDs with contact referral suggests that a perceived lack of benefit of vaccination may decrease desire to share an educational app about vaccines with friends and family, which is consistent with a previous study [14]. Perceived pro-vaccine attitudes of women's friends and family was positively yet non-significantly ($P = 0.06$) associated with referring them to an educational app about vaccines. Social norms and the influences of others have been previously linked to maternal influenza vaccine receipt in similar clinical studies involving message framing [27–29]. Women may be more comfortable sharing information with their family and friends that they knew would resonate with their pre-existing beliefs; or perhaps that some were hesitant to share information they thought would be contradictory to their family and friends' pre-existing beliefs. This would align with existing research on the "echo chamber" effect on online spread of vaccine information [30], and may limit the ability of this referral strategy to decrease vaccine hesitancy if most referred contacts are already confident in vaccines. Even if true, the current strategy could still have an impact on vaccine coverage through the reinforcement of the importance of vaccination to an audience predisposed to agree with this message. However, to make the largest possible impact on vaccine confidence and uptake, effective methods for bypassing the echo chamber effect would need to be developed and confirmed through future research.

Women with uncertain infant vaccine intentions were less likely to refer contacts to the app than those who had already made

up their mind, perhaps implying limited utility of this strategy in helping uncertain women formulate positive infant vaccine intentions by educating their social network. However, no statistically significant effect was seen for women with uncertain maternal vaccine intentions, for which much greater frequency of uncertainty existed.

The ethnicity, education and state of residence (CO vs GA) of the pregnant women using the MomsTalkShots app did not appear to impact their likelihood of referring contacts, nor did having prior children. These data may indicate the broad appeal of this app and referral strategy to the general population regardless of ethnicity or education level.

This study has several limitations. First, these data are not nationally generalizable. This study was embedded into an existing study analyzing a comprehensive intervention to increase vaccination among pregnant women; the pregnant women who chose to enroll in the preexisting trial and were available to participate in this study may be different than those who did not participate in the study and therefore pregnant women in general. In addition, the income level of pregnant women participating in this study was not collected, so we are unable to properly control for this in our analysis. Because pregnant women were offered a \$10 gift card as an incentive for referring contacts to the app, their primary motivation may have been to do so to receive financial incentive, instead of the factors we measured and analyzed. However, somewhat reassuring is that having at least a college degree was not statistically significantly associated with referring contacts to the app, as education is generally associated with income status [31]. Since vaccine intentions were assessed before the videos but referral was available after the videos, any short-term effect of the videos on the decision to refer contacts was not captured by this analysis. Whether a referred contact enrolled in the app or not may have been impacted by email habits and spam filters, which may explain why no statistically significant difference was seen in likelihood of enrolling in the app by type of relationship with the referring pregnant woman.

As providing financial incentives for referring contacts would likely be impractical on a large scale, further research into the impact and sustainability of this type of app referral strategy without incentives is needed. Qualitative research on the specific reasons for referring and not referring such apps would complement quantitative research such as this. Further research is also needed to assess whether vaccination attitudes, intentions and uptake are impacted among referred contacts, and whether this in turn has any effect on the referring pregnant woman. If successful, such a strategy could increase vaccine confidence and coverage for very little cost, by spreading accurate, individually tailored vaccine information through existing social networks of pregnant women. This app referral strategy could also be refined for populations other than pregnant women, to widen its potential impact on vaccine coverage and disease prevention.

5. Conclusion

Pregnant women who valued vaccination and trusted vaccine information from academic institutions were more likely to refer an educational app about vaccines to their close friends and family than those who did not. Further research is needed to determine the potential impact of this app referral strategy on vaccine coverage when implemented on a large scale.

CRedit authorship contribution statement

Matthew Z. Dudley: Writing - original draft, Formal analysis, Data curation, Investigation, Writing - review & editing, Software.

Rupali J. Limaye: Investigation, Writing - review & editing, Software, Conceptualization, Methodology. **Saad B. Omer:** Investigation, Writing - review & editing, Conceptualization, Methodology, Funding acquisition. **Sean T. O'Leary:** Investigation, Writing - review & editing, Conceptualization, Methodology, Funding acquisition. **Mallory K. Ellingson:** Investigation, Writing - review & editing. **Christine I. Spina:** Investigation, Writing - review & editing. **Sarah E. Brewer:** Investigation, Writing - review & editing. **Allison T. Chamberlain:** Investigation, Writing - review & editing. **Robert A. Bednarczyk:** Investigation, Writing - review & editing. **Fauzia Malik:** Investigation, Writing - review & editing. **Paula M. Frew:** Investigation, Writing - review & editing. **Daniel A. Salmon:** Investigation, Writing - review & editing, Conceptualization, Methodology, Funding acquisition, Software.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: R Limaye, S Omer, S O'Leary, M Ellingson, C Spina, S Brewer, R Bednarczyk, F Malik, P Frew have no conflicts and report no financial disclosures. M Dudley received some support from Walgreens. A Chamberlain received paid consultancy with the American College of Obstetricians and Gynecologists regarding provider-to-patient communications. D Salmon received consulting and/or research support from Merck, Walgreens and Pfizer.

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