



Short communication

Covid-19 vaccine acceptance and associated factors among pregnant women in Pennsylvania 2020

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ARTICLE INFO

Keywords:

COVID-19
SARS-CoV-2
Immunization during pregnancy
Vaccine-preventable diseases
Pennsylvania
Pregnant Women
Vaccination

ABSTRACT

Data on factors associated with vaccine acceptance among pregnant women are critical to the rapid scale up of interventions to improve vaccine uptake. When COVID-19 vaccines were still in the testing phases of research, we surveyed pregnant women accessing prenatal care at an academic medical institution in Central Pennsylvania, United States to examine factors associated with vaccine acceptance. Willingness to receive a COVID-19 vaccine once a vaccine became available was asked as part of an ongoing study on the COVID-19 pandemic and pregnancy (n = 196). Overall, 65% of women reported they would be willing or somewhat willing to receive the COVID-19 vaccine. Women who had received an influenza vaccine within the past year were more likely to be willing to receive the COVID-19 vaccine than women who had never received an influenza vaccine or those who received it over one year ago (aOR 4.82; 95% CI 2.17, 10.72). Similarly, women who were employed full-time were more willing to receive the COVID-19 vaccine than women who were not employed full time (aOR 2.22; 95% CI 1.02, 4.81), and women who reported feeling overloaded were more willing to receive the COVID-19 vaccine than women who did not feel overloaded (aOR 2.18; 95% CI 1.02, 4.68). Our findings support the need to increase vaccination education among pregnant women before vaccines are rolled out, especially those who have not received an influenza vaccine within the past year. Improved understanding of willingness to vaccinate among pregnant women will improve future pandemic responses and current vaccination efforts.

1. Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has infected over 232 million people and led to more than four million deaths worldwide as of September 30, 2021. (Kaiser Family Foundation, 2021) In the United States (US), vaccines were first available in December 2020 and as of September 30, 2021, over 184 million people have been fully vaccinated. (Centers for Disease Control and Prevention, 2021) There are three approved COVID-19 vaccines in the US; the Pfizer-BioNTech and Moderna COVID-19 vaccines were approved for use under the emergency use authorization (EUA) in December 2020 and followed soon after by an EUA for the Janssen COVID-19 vaccine in February 2021. (Oliver et al., 2020; Oliver et al., 2020; MacNeil et al., 2021) Globally; other vaccines are available and approved by the World Health Organization including Sinopharm, Sinovac-CoronaVac, and Oxford/AstraZeneca vaccines. The efficacy for all approved vaccines

ranges from 66.9% to 96.3% in preventing moderate to severe COVID-19. (Pilishvili et al., 2021; Sadoff et al., 2021; Ghiasi et al., 2021; Doroftei et al., 2021; Organization, 2021) Although the approved and available vaccines are effective in preventing serious illness; vaccine acceptance varies across the globe from 56.9% in the US to 97.0% in Ecuador to 23.6% in Kuwait. (Sallam et al., 2021) Studies have shown vaccination greatly decreases COVID-19 cases; morbidity, and mortality and most scientists agree vaccination is a public health priority and is critical to curb the pandemic. (Calina et al., 2020; Christie et al., 2021)

The US Centers for Disease Control and Prevention (CDC) reported that pregnant women with SARS-CoV-2 have an increased rate of hospitalization, admission to the intensive care unit, and need for artificial ventilation compared with non-pregnant women with SARS-CoV-2. (Ellington et al., 2020) Pregnant women with COVID-19 have been found to have worse pregnancy outcomes including an increased risk for preeclampsia/eclampsia, severe infections, intensive care unit

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<https://doi.org/10.1016/j.pmedr.2022.101713>

Received 15 July 2021; Received in revised form 6 January 2022; Accepted 23 January 2022

Available online 29 January 2022

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admission, mortality, preterm birth, and neonatal morbidity and mortality compared with pregnant women without COVID-19. (Villar et al., 2021) The mortality rate for pregnant women with COVID-19 has been shown to be 1.6%. (Villar et al., 2021).

At the time this study was conducted COVID-19 vaccines were in development and little information on their safety and efficacy were available, especially among pregnant women. Since that time, more information on vaccine safety has been made available and vaccination among pregnant women is recommended in order to prevent severe COVID-19 and to provide immunity to the neonate by transferring active IgG to the fetus during pregnancy. (Albrecht and Arck, 2020) Although adverse events after vaccination among pregnant women are very rare, there have been reported cases of gestational hypertension, threatened labor, miscarriage, and premature delivery after receipt of the Pfizer-BioNTech vaccine (Kadali et al., 2021). Other common side effects of the Pfizer-BioNTech vaccination including sore arm, fatigue, headache, chills, myalgia, nausea, fever, and sweating were reported by both pregnant and non-pregnant women at the same rates (Kadali et al., 2021). Additionally, fever in early pregnancy, a possible side effect of vaccination has been found to have adverse pregnancy and child outcomes and may be a concern related to the COVID-19 vaccine. (Gustavson et al., 2019; Waller et al., 2018; Kerr et al., 2017). Although pregnant women experience a high COVID-19 burden and serious health outcomes associated with COVID-19 during pregnancy and vaccination protects against severe COVID-19 and transfers immunity to the neonate, pregnant women are considered a priority group for COVID-19 immunization only in the US and the United Kingdom and pregnant women are offered vaccination in just 11 of the top 20 countries affected by COVID-19. (Ellington et al., 2020; Albrecht and Arck, 2020; Centers for Disease Control and Prevention, 2021; Centers for Disease Control and Prevention, 2021; Sarwal et al., 2021)

In addition to concerns regarding vaccine availability and prioritization, positive vaccination attitudes and trust in the vaccine, health system, and provider are important predictors of vaccination uptake. (Jean-Jacques and Bauchner, 2021) In December 2020; 27% of the general public said they probably or definitely would not get a COVID-19 vaccine according to the Kaiser Family Foundation COVID-19 Vaccine Monitor. (Hamel et al., 2020) The main reasons cited in this study for not planning to get vaccinated were concerns about side effects (59%), safety and efficacy (55%), the vaccine being too new (53%), and the role of politics in the development process (51%). (Hamel et al., 2020) Evidence on COVID-19 vaccine acceptance among pregnant women is beginning to emerge. Between 48 and 61% of pregnant women were willing to receive the COVID-19 vaccine before vaccinations became available; with refusal reasons being concern for side effects, lack of safety data among pregnant women, and concern for their fetus. (Ahlers-Schmidt et al., 2020; Khubchandani et al., 2021; Ceulemans et al., 2021) Another study found pregnant women in the United Kingdom were 2.4 times more likely to be vaccine resistant than non-pregnant individuals. (Murphy, 2021) Recently, the CDC reported pregnant women were less likely to complete the COVID-19 vaccine series than non-pregnant women and vaccination rates among pregnant women remain low at under 40%. (Razzaghi et al., 2021; Centers for Disease Control and Prevention, 2021).

Although vaccine hesitancy remains higher among pregnant women even for other recommended vaccines (e.g., influenza and Tdap) (Bödeker et al., 2014), little is known about COVID-19 vaccine hesitancy in this group. The aim of this study is to explore factors associated with willingness to receive the COVID-19 vaccine among pregnant women.

2. Methods

This secondary analysis was part of a larger study conducted to study the effects COVID-19 on pregnant women. The study is ongoing, but the analysis conducted includes data collected between May 15, 2020 and December 1, 2020. Pregnant women receiving prenatal care at a mid-

size academic medical center in Central Pennsylvania who were over 18 years of age, had internet access for online surveys, and were able to read in English, were eligible to participate in this study. The medical center is the hub of a larger health system that includes four medical centers, three additional hospitals, 126 outpatient practices in 94 locations across 29 counties in central Pennsylvania. The medical center serves a population of predominantly white, middle class, suburban and rural pregnant women. Study participants were recruited through direct email, mail, and phone calls, as well as through social media and fliers. Direct recruitment was conducted by merging the list of pregnant women from the Department of Obstetrics and Gynecology with patient electronic health record contact data. The study aimed to assess multiple factors associated with the COVID-19 pandemic and pregnancy. One aspect of the survey assessed vaccine willingness.

Willingness to be vaccinated was measured by the following survey question: "While there is no COVID-19 vaccine available right now, how willing would you be to accept the vaccine once developed?" with responses as "Willing"; "Somewhat willing"; "Somewhat unwilling"; "Unwilling"; and "Don't know". We dichotomized their responses into Yes (willing and somewhat willing) and No (somewhat unwilling, unwilling, and don't know). (Laurence et al., 2012) We excluded women from the study who did not answer this question.

We collected the following information about enrolled participants using the REDCap secure online survey tool: race (white/ not white), ethnicity (Hispanic/ not Hispanic), age (35 or older/ <35) (Lean et al., 2017), gravida status (first pregnancy/ not first pregnancy), pregnancy trimester (first or second trimester/ third trimester), highest education level (college degree or higher/ less than college degree), employment status (employed full time/ not employed full time), whether the participant or their partner was an essential worker (e.g., healthcare, delivery worker, store worker, security, building maintenance, first responder, warehouse, meatpacking, factory, prison worker, etc.) (yes/ no), annual income level (\$100,000 USD or above/ less than \$100,000 USD per year), possible to isolate in their home (yes/ no), having more than two adults in the household (yes/ no), having children in the household (yes/ no), exposure to household smoking (yes/ no), time frame of survey completion as denoted by date of survey completion (May-July/ August-December), whether the participant was ever tested and/or diagnosed with COVID-19 (yes/ no), and whether the participant had family members and/or close friends diagnosed with COVID-19 (yes/ no). Further, women were asked about pertinent medical history of obesity, a previous miscarriage, diabetes, and lung disease with all responses being ever or never having a history of the conditions. Additionally, four measurements of stress were included: work related stress, stress about their baby's health, stress about their family's health, and feeling overloaded. Each stressor was classified into no stress or any stress (i.e., some stress, moderate stress, or severe stress). Questions from our survey were adopted and adapted from the First Baby Study Prenatal Questionnaire, the Psychosocial Hassles Scale, the Coronavirus Perinatal Experiences Impact Survey, and the COVID-19 Impact Scale. (Stoddard et al., 2021; Kjerulff et al., 2013; Da Costa et al., 1999; Thomsen et al., 2020)

3. Ethical approval

The study was approved by the Pennsylvania State University College of Medicine Institutional Review Board.

3.1. Statistical analysis

Bivariate analyses were completed to assess the association between factors hypothesized to be associated with willingness to vaccinate including sociodemographic variables, comorbidities, serving as an essential worker, vulnerable living conditions, stressors, and cohort effects (time when survey was completed, whether it was their first pregnancy and what time point in pregnancy the survey was completed)

with willingness to vaccinate using univariate logistic regression models. Next, variables that were significant ($p < 0.05$) in the unadjusted analyses were included in a full multivariable regression and backwards elimination multivariable regression. Multicollinearity was not found to exist among the independent variables included in the multivariable regression models. For further evaluation and verification, the importance of all variables was assessed based on random forests that quantified how a variable contributes to the homogeneity of the nodes and leaves in the resulting random forest. The forest plot shows each variable on the y-axis and the Gini index on the x-axis. A larger Gini index indicates greater inequality, and thus higher variable importance. All statistical analyses were completed using SAS 9.4.

4. Results

Of the 208 enrolled women, 196 answered their willingness to receive a COVID-19 vaccine. Between May and December 2020, 65% (95% CI 58%, 71%) of study participants reported a willingness to receive the COVID-19 vaccine (willing 36%, somewhat willing 29%, somewhat unwilling 5%, unwilling 14%, and don't know 17%). The characteristics of the study population (Table 1) show that 20% of women were 35 years or older, 90% were white, and 3% were Hispanic. The majority of women in this study had more than a college degree (70%) and reported having children at home (61%). Nearly 60% of partners had a college degree or higher. Among the study population, 63% were employed full-time and of those employed (full or part-time) 63% were essential workers, and 47% of study participants reported to live with essential workers. Among women in the study, 46% reported a household income of US \$100,000 per year or more. The majority of women (78%) reported their ability to isolate in their homes if necessary and 14% reported exposure to indoor smoking. Most women were multigravida (64%), in their first or second trimester of pregnancy (58%), completed the survey between May and July of 2020 (79%) and reported having received a flu vaccine within the last year (77%). Few women in this study had firsthand experience with COVID-19, 11% were ever tested for COVID-19, 4% had a COVID-19 diagnosis, and 13% had a family member or close friend diagnosed with COVID-19. Among study subjects, 25% were obese before pregnancy, 28% had a previous miscarriage, 15% had a history of lung diseases, and 6% reported a history of diabetes. Finally, women reported high levels of stress with 62% reporting stress at work, 80% reported stress about their baby's health, 65% reported stress about the health of their family and friends, and 68% reported feeling overloaded.

The bivariate analysis (Table 2) showed having a college degree or higher, being employed full time, having had an influenza vaccine in the last year, reporting work related stress, and reporting feeling overloaded as statistically significant factors associated with willingness to be vaccinated. The multivariable logistic models (Table 2) found that having had an influenza vaccination in the last year (full model: aOR 4.82; 95% CI 2.17, 10.72; backwards elimination model: aOR 4.78; 95% CI 2.25, 10.15), being employed full time (full model: aOR 2.22; 95% CI 1.02, 4.81; backwards elimination model: aOR 2.17; 95% CI 1.10, 4.28), and feeling overloaded (full model: aOR 2.18; 95% CI 1.02, 4.68) were independently associated with a willingness to receive the COVID-19 vaccine. Note the variable of feeling overloaded is detected to be significant in the full model, but not selected in the backwards elimination model. After ranking variables of importance, having had an influenza vaccination in the past year was the most important factor followed by education, being employed full time, feeling overloaded, and reporting work stress (Fig. 1).

5. Discussion

Our study assessed COVID-19 vaccine acceptance among pregnant women before vaccines were rolled out in the US. Factors associated with a willingness to receive a COVID-19 vaccine included having had

Table 1
Characteristics of study population n = 196.

Demographic Variable	N(%)
Willing to receive the COVID-19 vaccine	127 (65%)
Not willing to receive the COVID-19 vaccine	69 (35%)
Age \geq 35 years	39 (20%)
Age <35 years	157 (80%)
White race	173 (90%)
Not white race	19 (9.9)
Hispanic ethnicity	6 (3%)
Not Hispanic ethnicity	188 (97%)
Mother college degree+	137 (70%)
Mother < college degree	58 (30%)
Father college degree +	109 (57%)
Father < than college degree	84 (43%)
Employed full time	121 (63%)
Not employed full time	71 (37%)
Essential worker	95 (63%)
Not essential worker	56 (37%)
Adults in household essential worker	92 (47%)
No adults in household essential worker	103 (53%)
Possible to isolate in home	141 (78%)
Not possible to isolate at home	41 (23%)
Household \geq \$100,000/yr	85 (46%)
Household <\$100,000/yr	101 (54%)
2+ adults living in household	25 (13%)
\leq 2 adults living in household	171 (87%)
Someone smokes in home	27 (14%)
No one smokes in home	167 (86%)
Has children living in home	120 (61%)
No children living in home	76 (39%)
May-July survey completion	154 (79%)
August-December survey completion	42 (22%)
First or second trimester	111 (58%)
Third trimester	83 (44%)
First pregnancy	71 (36%)
Not first pregnancy	125 (64%)
Had a flu shot <1 year ago	144 (77%)
Had a flu shot 1 year ago or more or never	44 (23%)
Wears a mask every time within 6 feet of someone else	96 (46%)
Does not wear a mask every time within 6 feet of someone else	112 (54%)
Ever been tested for SARS-CoV-2	22 (11%)
Never tested for SARS-CoV-2	174 (89%)
Family or friend with COVID-19	25 (13%)
No family or friend with COVID-19	165 (87%)
Had a COVID-19 diagnosis	8 (4%)
No COVID-19 diagnosis	188 (96%)
Obese	47 (25%)
Not obese	140 (75%)
Previous miscarriage	54 (28%)
No previous miscarriage	141 (72%)
History of diabetes	12 (6%)
No history of diabetes	181 (94%)
History of lung disease	28 (15%)
No history of lung disease	164 (85%)
Work related stress	122 (62%)
No work related stress	74 (38%)
Stress about baby's health	155 (80%)
No stress about baby's health	40 (20%)
Stress about family's health	127 (65%)
No stress about family's health	68 (35%)
Stress about own health	119 (61%)
No stress about own health	76 (39%)
Feeling overloaded	133 (68%)
Not feeling overloaded	62 (32%)

an influenza vaccine within the previous year, being employed full time, and a general feeling of being overloaded. Since 2007 there have been six events that were declared as public health emergencies of international concern, including the H1N1 influenza pandemic, Ebola, and Zika. However, these events had a smaller direct impact on most Americans compared with the COVID-19 pandemic. (Wilder-Smith and Osman, 2020) Studies during the H1N1 pandemic on vaccination during pregnancy found many women were concerned with the safety of the vaccine; efficacy of the vaccine, and were not concerned regarding the severity of illness due to H1N1. (Fridman et al., 2011)

Table 2
Association between willingness to receive the COVID-19 vaccine and socio-demographic and health factors.

Demographic Variable	No n=69 (35%)	Yes n=127 (65%)	Univariate Models cOR (95% CI)	Full Model aOR (95% CI)	Backwards elimination aOR (95% CI)
Age ≥35 years	13 (33%)	26 (67%)	1.11 (0.53, 2.33)		
Age <35 years	56 (36%)	101 (64%)			
White race	62 (36%)	111 (64%)	1.05 (0.39, 2.79)		
Not white race	7 (37%)	12 (63%)			
Hispanic ethnicity	1 (17%)	5 (83%)	2.77 (0.32, 24.19)		
Not Hispanic ethnicity	67 (36%)	121 (64%)			
Mother college degree+	38 (28%)	99 (73%)	2.79 (1.48, 5.28)	1.69 (0.78, 3.64)	
Mother < college degree	30 (52%)	28 (48%)			
Father college degree +	32 (29%)	77 (71%)	1.72 (0.95, 3.13)		
Father < college degree	35 (42%)	49 (58%)			
Employed full time	33 (27%)	88 (73%)	2.59 (1.41, 4.79)	2.22 (1.02, 4.81)	2.17 (1.10, 4.28)
Not employed full time	35 (49%)	36 (51%)			
Essential worker	29 (31%)	66 (69%)	1.08 (0.53, 2.19)		
Not essential worker	18 (32%)	38 (68%)			
Adults in household essential worker	35 (38%)	57 (62%)	0.80 (0.45, 1.44)		
No adults in household essential worker	34 (33%)	69 (67%)			
Possible to isolate in home	49 (35%)	92 (65%)	1.20 (0.59, 2.46)		
Not possible	16 (39%)	25 (61%)			
Household ≥ \$100,000/yr	26 (31%)	59 (69%)	1.26 (0.68, 2.33)		
Household < \$100,000/yr	36 (36%)	65 (64%)			
2+ adults living in household	11 (44%)	14 (56%)	0.65 (0.28, 1.53)		
≤2 adults living in household	58 (34%)	113 (66%)			
Someone smokes in home	14 (52%)	13 (48%)	0.44 (0.19, 1.01)		
No one smokes in home	54 (32%)	113 (68%)			
Has children living in home	47 (39%)	73 (61%)	0.63 (0.34, 1.17)		
No children living in home	22 (29%)	54 (71%)			
May-July survey completion	54 (35%)	100 (65%)	1.03 (0.50, 2.09)		
August-December survey completion	15 (36%)	27 (64%)			

Table 2 (continued)

Demographic Variable	No n=69 (35%)	Yes n=127 (65%)	Univariate Models cOR (95% CI)	Full Model aOR (95% CI)	Backwards elimination aOR (95% CI)
First or second trimester	42 (38%)	69 (62%)	0.75 (0.41, 1.37)		
Third trimester	26 (31%)	57 (69%)			
First pregnancy	24 (34%)	47 (66%)	1.10 (0.59, 2.03)		
Not first pregnancy	45 (36%)	80 (64%)			
Had a flu shot <1 year ago	36 (25%)	108 (75%)	5.25 (2.55, 10.79)	4.82 (2.17, 10.72)	4.78 (2.25, 10.15)
Had a flu shot 1 year ago or more or never	28 (64%)	16 (36%)			
Wears a mask every time within 6 feet of someone else	34 (35%)	62 (65%)	0.98 (0.55, 1.77)		
Does not wear a mask every time within 6 feet of someone else	35 (35%)	65 (65%)			
Ever been tested for SARS-CoV-2	10 (45%)	12 (55%)	0.62 (0.25, 1.51)		
Never tested for SARS-CoV-2	59 (34%)	115 (66%)			
Family or friend with COVID-19	9 (36%)	16 (64%)	0.94 (0.39, 2.26)		
No family or friend with COVID-19	57 (35%)	108 (65%)			
Had a COVID-19 Diagnosis	3 (38%)	5 (64%)	0.90 (0.21, 3.89)		
No COVID-19 Diagnosis	66 (35%)	122 (65%)			
Obese	19 (40%)	28 (60%)	0.75 (0.38, 1.47)		
Not obese	47 (34%)	93 (66%)			
Previous miscarriage	20 (37%)	34 (63%)	0.88 (0.46, 1.69)		
No previous miscarriage	48 (34%)	93 (66%)			
History of diabetes	6 (50%)	6 (50%)	0.52 (0.16, 1.68)		
No history of diabetes	62 (34%)	119 (66%)			
History of lung disease	11 (39%)	17 (61%)	0.80 (0.35, 1.83)		
No history of lung disease	56 (34%)	108 (66%)			
Work related stress	36 (30%)	86 (70%)	1.92 (1.05, 3.51)	0.71 (0.31, 1.63)	
No work related stress	33 (45%)	41 (55%)			
Stress about baby's health	51 (33%)	104 (67%)	1.67 (0.82, 3.39)		
No stress about baby's health	18 (45%)	22 (55%)			
Stress about family's health	39 (31%)	88 (69%)	1.78 (0.97, 3.28)		
No stress about family's health	30 (44%)	38 (56%)			
Stress about own health	36 (30%)	83 (70%)	1.77 (0.97, 3.22)		

(continued on next page)

Table 2 (continued)

Demographic Variable	No n=69 (35%)	Yes n=127 (65%)	Univariate Models cOR (95% CI)	Full Model aOR (95% CI)	Backwards elimination aOR (95% CI)
No stress about own health	33 (43%)	43 (57%)			
Feeling overloaded	40 (30%)	93 (70%)	2.04 (1.09, 3.80)	2.18 (1.02, 4.68)	
Not feeling overloaded	29 (47%)	33 (53%)			

The results from this study, which found a 65% COVID-19 vaccine acceptance rate between May-December 2020, are in line with than previous prevalence estimates of COVID-19 vaccine willingness among pregnant women early in the pandemic ranging from to 48%-61%. (Ahlers-Schmidt et al., 2020; Ceulemans et al., 2021; Skjefte et al., 2021) The rates of vaccine acceptance among pregnant women have generally been lower than the rates found in the general population which have been estimated to be 65%-78% during the same time period; which are also similar to the rate found in this study.(Khubchandani et al., 2021; Murphy et al., 2021) Furthermore, research has shown higher income and higher education are associated with increased willingness to receive the COVID-19 vaccine.(Khubchandani et al., 2021) The rate of vaccine acceptance among pregnant women found in this study may be due to this study population having a higher education or higher income than women in other studies.(Ahlers-Schmidt et al., 2020; Ceulemans et al., 2021)

The strongest association with vaccine willingness in our study population was receiving an influenza vaccine within the last year. In our study population, 77% of women reported receiving an influenza vaccine during the previous year and of those, 75% were willing to receive the COVID-19 vaccine. This is in comparison to the 33% of women who did not report receiving an influenza vaccine in the previous year and of those just 35% were willing to receive the COVID-19 vaccine. Previous and recent influenza vaccination could serve as a

proxy for vaccine hesitancy more generally. In our study population, being employed full time was a stronger factor associated with vaccine willingness compared with education and income. Full time employment is likely indicative of higher education and income, but may also point to increased autonomy among women which has also been associated with increased childhood vaccination.(Jung et al., 2018) In our study, 63% of women reported being employed full time and among those women, 73% were willing to receive the COVID-19 vaccine compared to 51% of the 27% of women who reported not being employed full time. Additionally, our study found a significant association between willingness to be vaccinated and generally feeling overloaded. Sixty-eight percent of women in our study reported feeling overloaded and of those women, 70% reported a willingness to receive the COVID-19 vaccination. This is compared with 32% of women who did not report feeling overloaded and of those women only 53% reported being willing to receive the COVID-19 vaccine. The COVID-19 pandemic has altered the pregnancy and birth experience and dramatically impacted daily life, which has led to an increase in psychological distress among pregnant women.(Preis et al., 2020) A recent study showed an increased burden of household responsibilities for women compared to men during the COVID-19 pandemic.(Power et al., 2020) These family dynamics may have played a role in vaccine willingness, as women may be eager to receive the vaccine to increase family support. This finding is underlined by a previous study which found higher levels of stress increased pertussis immunization among pregnant women. (Mohammed et al., 2020)

In this study, factors not associated with willingness to receive the COVID-19 vaccination were notable. First, being employed as an essential worker or living with an essential worker did not impact willingness to receive the COVID-19 vaccine. This was unexpected as being an essential worker could carry higher risks for SARS-CoV-2 infection compared with those who were non-essential and therefore more likely to have a lower level of exposure to SARS-COV-2.(The, 2020) Additionally; having comorbidities that would increase one's risk for COVID-19 did not impact women's willingness to receive a vaccine. It was expected that women who were at a higher risk for severe COVID-

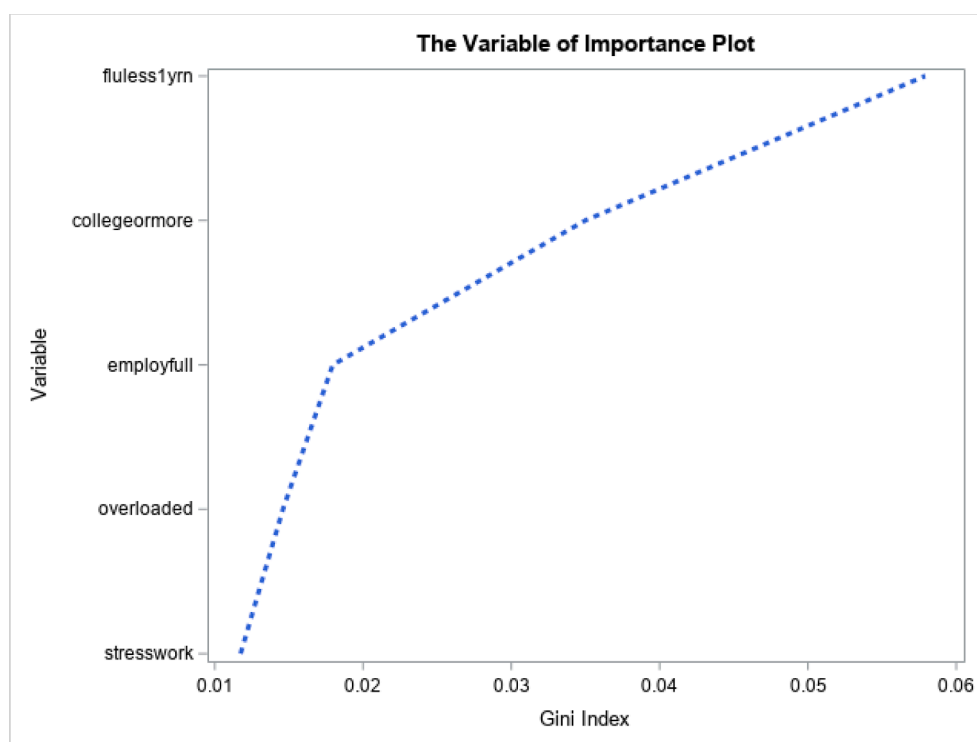


Fig. 1. The Variable of Importance Plot.

19 may have a higher level of vaccine acceptance.(Do et al., 2021) Furthermore; neither having had a personal diagnosis, having been tested for COVID-19, nor having a family member or close friend diagnosed with COVID-19 were associated with vaccine willingness. Having a personal connection to COVID-19 may increase one's willingness to be vaccinated, as personal stories are often reasons people choose to be vaccinated.(Xu et al., 2019; Gandhi et al., 2020) Moreover, feeling stress related to their own health, the health of their baby, or the health of their family or friends did not impact their willingness to be vaccinated, which was in contrast to previous research showing increased influenza vaccine uptake with a desire to protect family members.(Corace et al., 2013) Finally, although more information became available regarding the COVID-19 vaccine from May 2020 to December 2020, we did not observe any change in women's willingness to be vaccinated during the study period. This was striking, because we expected an increase in COVID-19 acceptability as vaccine information became clearer. This finding could be due to limited data on the safety and efficacy of the COVID-19 vaccine in pregnant women, because this population was excluded from the clinical trials.(Rasmussen et al., 2021) However, it could also be due to the politics surrounding the COVID-19 vaccine as one study assessing vaccine acceptability between March 2020 and August 2020 found that people who identified with the Democratic party did not change their attitudes towards vaccination and those who identified as Republican had decreasing levels of vaccine acceptability during the study time.(Fridman et al., 2021) We did not ask about political affiliation; and therefore cannot examine this variable in our data.

Factors associated with vaccine acceptance may differ across cultures, contexts, and settings. In more collective cultures, concern for others and the perception of increased social acceptance may be an important variable in the willingness to accept COVID-19 vaccination as was shown in China and Japan.(Machida et al., 2021; Fu et al., 2020) Trust and confidence in the healthcare system and vaccine are important factors that could differ across settings and contexts, and have been shown to play a role in vaccine acceptance in studies from the US and other regions of the world.(Al-Mohaithef and Padhi, 2020; Halpin and Reid, 2019; Jamison et al., 2019; Tran et al., 2021; Karafillakis et al., 2021) Since we did not observe any association between comorbidities and willingness to be vaccinated, it may point to a lack of trust in the healthcare system or little information or understanding of the patient's level of risk for severe COVID-19. Conversely, the finding that influenza vaccination was strongly associated with a willingness to receive the COVID-19 vaccine likely indicates a general trust in the healthcare system and vaccines.

Some limitations are noted for the current study. This study enrolled a population of mostly highly educated non-Hispanic white women with a high household income living in Pennsylvania and had a small sample size of 196 women. Compared with the demographics of Pennsylvania, women in this study more frequently identified as white (90% white in our study; 69% white in Pennsylvania) and less frequently identified as Hispanic (6% Hispanic in our study; 12% Hispanic in Pennsylvania).(Pennsylvania Department of Health, 2019) Minority populations have been found to have higher vaccine hesitancy compared with white populations.(Razai, et al., 2021; Webb Hooper et al., 2021) This reduces our ability to assess COVID-19 vaccine willingness across racial and ethnic groups as well as our ability to generalize our findings to broader populations. Additionally, although factors such as employment and previous vaccination could carry over to other contexts, the cultural meaning may differ. These factors could be explored further in larger samples in the US and in international contexts. Due to the small sample size of our study, we may not have sufficient power to assess associations in the data. Finally, our study did not include direct and precise questions on measures such as vaccine knowledge, perceptions, and practices that may have evolved over the course of the pandemic. Notwithstanding these limitations, our study provides important information on vaccine willingness before vaccine rollout among pregnant women and

can be useful in COVID-19 vaccine intervention development.

Our findings reveal vaccine willingness is not due to a single factor; instead, a complex intersection of many factors likely stemming from a long and complex history of vaccine hesitancy. Findings from this analysis suggest clinicians could offer the COVID-19 vaccine along with the influenza vaccine and remind women who are feeling overloaded that a COVID-19 vaccination could reduce their risk for severe COVID-19. This type of conversation between providers and patients may be an important building block to increase trust in the healthcare system which will be critical when countering wide-spread misinformation and disinformation about the COVID-19 vaccine when caring for pregnant women.(Karafillakis et al., 2021; Verger and Dubé, 2020) The study results may also help public health officials to address COVID-19 vaccine hesitancy in pregnant women and may help in designing interventions to improve vaccine uptake. Although COVID-19 vaccines are considered safe during pregnancy (Shimabukuro et al., 2021), providers should be cognizant about the conflicting messages pregnant women may receive and their persistent hesitancy, and engage in meaningful discussions with their patients regarding COVID-19 vaccination decision making.

CRediT authorship contribution statement

Kristin K. Sznajder: Conceptualization, Methodology, Visualization, Investigation, Resources, Writing – review & editing. **Kristen H. Kjerulf:** Software, Software, Formal analysis, Data curation, Writing – original draft, Investigation, Resources, Writing – review & editing. **Ming Wang:** Investigation, Resources, Writing – review & editing. **Wenke Hwang:** Investigation, Resources, Writing – review & editing. **Sarah I. Ramirez:** Investigation, Resources, Writing – review & editing. **Chintan K. Gandhi:** Investigation, Resources, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Our study was funded by the Pennsylvania State University Huck Institute of Life Sciences #7754. We thank the study participants for their time.

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