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Association between social vulnerability and COVID-19 vaccination hesitancy and vaccination in pregnant and postpartum individuals



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ARTICLE INFO

Article history:

Received 28 March 2022

Received in revised form 12 September 2022

Accepted 13 September 2022

Available online 21 September 2022

Keywords:

COVID-19
Maternal immunization
Pregnancy
Vaccine uptake
Vaccine hesitancy
Social vulnerability

ABSTRACT

Objective: To evaluate the association of community-level social vulnerability with COVID-19 vaccine hesitancy and vaccination among pregnant and postpartum individuals.

Methods: Prospective cohort study assessing COVID-19 vaccine hesitancy among pregnant and postpartum individuals. We performed a baseline survey on COVID-19 vaccine hesitancy from 03/22/21 to 04/02/21, and a follow-up survey on COVID-19 vaccination status 3- to 6-months later. The primary exposure was the Centers for Disease Control and Prevention SVI (Social Vulnerability Index), measured in quartiles. Higher SVI quartiles indicated greater community-level social vulnerability with the lowest quartile (quartile 1) as the referent group. The primary outcome was COVID-19 vaccine hesitancy on the baseline survey (uncertainty or refusal of the vaccine), and the secondary outcome was self-report of not being vaccinated (unvaccinated) for COVID-19 on the follow-up survey.

Results: Of 456 assessed individuals, 46% reported COVID-19 vaccine hesitancy on the baseline survey; and of 290 individuals (290/456, 64%) who completed the follow-up survey, 48% (140/290) were unvaccinated. The frequency of baseline vaccine hesitancy ranged from 25% in quartile 1 (low SVI) to 68% in quartile 4 (high SVI), and being unvaccinated at follow-up ranged from 29% in quartile 1 to 77% in quartile 4. As social vulnerability increased, the risk of COVID-19 vaccine hesitancy at baseline increased (quartile 2 aRR (adjusted relative risk): 1.46; 95% CI:0.98 to 2.19; quartile 3 aRR: 1.86; 95% CI:1.28 to 2.71; and quartile 4 aRR: 2.24; 95% CI:1.56 to 3.21), as did the risk of being unvaccinated at follow-up (quartile 2 aRR: 1.00; 95% CI:0.66 to 1.51; quartile 3 aRR: 1.68; 95% CI:1.17 to 2.41; and quartile 4 aRR: 1.82; 95% CI:1.30 to 2.56).

Conclusions: Pregnant and postpartum individuals living in an area with higher community-level social vulnerability were more likely to report COVID-19 vaccine hesitancy and subsequently to be unvaccinated at follow-up.

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1. Introduction

Vaccination in pregnancy is a public health priority, as it is an evidence-based strategy to prevent maternal and neonatal morbidity and mortality [1–5]. Over the past decade, vaccination rates among pregnant and postpartum individuals have remained inadequate with only half of all pregnant individuals being vaccinated for pertussis and influenza annually [6–8]. During the current COVID-19 pandemic, >50% of pregnant and postpartum individuals

have reported vaccine hesitancy [9–11]. Reasons for vaccine hesitancy in pregnancy are multifactorial and include inconsistent and infrequent provider recommendations, patient perceptions of lack of safety and efficacy data, and barriers to being able to access vaccines [8–9,11–14]. Current guidelines recommend COVID-19 vaccination in pregnancy [15–17]. COVID-19 infection in pregnancy increases the risk of preeclampsia, fetal growth restriction, and severe maternal morbidity and mortality [18–22]. While pregnant individuals were initially excluded from COVID-19 vaccine trials, data have since demonstrated the safety and efficacy of COVID-19 vaccines in pregnancy for the mother and fetus [23–25].

Pregnant individuals who experience a higher burden of adverse social determinants of health are less likely to be vacci-

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nated against influenza and tetanus-diphtheria-acellular pertussis [26–29], and whether this holds for COVID-19 remains to be studied. Social determinants of health include multiple aspects of the built environment and social setting that impact access and uptake of healthcare services, including access to safe housing, transportation, and neighborhoods; experiences of racism, discrimination, and violence; availability of education, job opportunities, and income; access to nutritious foods and physical activity opportunities; and living in a space with clean air and water [30]. The Social Vulnerability Index (SVI) is a standardized, publicly available, and online index available from the U.S. Centers for Disease Control and Prevention (CDC). It can be used to evaluate community-level social determinants of health based on an individual’s residential location. The SVI provides an overall score as well as four domain scores: socioeconomic status, household composition and disability, minority status and language, and housing type and transportation [31–33].

The current study evaluated the association between community-level social vulnerability and COVID-19 vaccine hesitancy at baseline and *not* being vaccinated (unvaccinated) at follow-up among pregnant and postpartum individuals.

2. Methods

2.1. Study setting and patients

We conducted a prospective study of COVID-19 vaccine hesitancy at baseline and subsequent COVID-19 vaccination at follow-up among pregnant and postpartum individuals receiving prenatal and postpartum care at a Midwestern tertiary care academic medical center. Inclusion criteria at enrollment were pregnancy with a confirmed intrauterine gestation or postpartum status < 10 weeks from delivery, English speaking, and receiving prenatal or postpartum care at our center. This study was approved by The Ohio State University Institutional Review Board (ID#: 2021H0023; date: 02/23/21). As the follow-up survey was not planned at the time of the initial assessment, informed consent was obtained at both the baseline and follow-up surveys. We followed Equator (Enhancing the QUALity and Transparency Of health Research) Network [34] and STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) reporting guidelines [35] for the baseline and follow-up surveys, respectively.

As previously described [11], the baseline survey of COVID-19 vaccine hesitancy occurred from March 22, 2021 to April 2, 2021. This was conducted concurrent with state-level guidance making COVID-19 vaccination available for pregnant and postpartum individuals [36], data describing the increased risk of severe COVID-19 infection in pregnancy [18–22], as well as initial professional guidelines endorsing COVID-19 vaccination in the peripartum period through shared decision making [15–16]. At the time of the baseline survey, participants may have been recently vaccinated, but this was not assessed. The written baseline survey was completed in person during a scheduled prenatal or postpartum visit. Participants received compensation of five dollars for completing the baseline survey.

The follow-up survey of self-reported COVID-19 vaccination occurred from June 29, 2021 to November 20, 2021, at which time COVID-19 vaccines were widely available and before the Omicron variant was reported [23–25]. The follow-up survey was conducted following professional guidelines recommending vaccination for pregnant and postpartum individuals, and growing data about the safety and efficacy of COVID-19 vaccination in pregnancy [23]. All previously enrolled participants were contacted three to six months after the baseline survey by either phone or email. If participants did not respond after two phone calls, they were sent

an email message. Those who did not respond to the email then received a final phone call. An identical survey by email or telephone was administered in English and was designed to be completed in five minutes.

2.2. Data collection

The baseline survey assessed socio-demographic characteristics and perceptions about vaccination for COVID-19, including willingness, barriers, and facilitators. At follow-up, self-reported COVID-19 vaccination was ascertained (yes/no) since baseline. Participant addresses as well as clinical data were manually abstracted from the electronic health record (EHR). Survey questions were adapted from the CDC adult internet panel survey to assess vaccination in pregnancy [37], the World Health Organization Vaccine Hesitancy Determinants Matrix [38], and the “3 Cs” model (complacency, convenience, and confidence) as outlined by the World Health Organization Vaccine Communications Working Group [39–40].

The primary exposure was community-level social vulnerability as measured by the CDC 2018 SVI. Participant addresses at baseline were geocoded using ArcGIS and then linked at the census tract level to the SVI [41]. The SVI, which ranged from 0 to 1, was assessed as quartiles. Higher quartile values indicated that the individual resided in an area with greater community-level social vulnerability, compared to the reference quartile 1. We then secondarily assessed each of the four SVI domains (socioeconomic status, household composition and disability, minority status and language, and housing type and transportation) (Table 1) [31–33].

The outcome at baseline was COVID-19 vaccine hesitancy as defined per the World Health Organization Strategic Advisory Group of Experts (SAGE) on Vaccine Hesitancy (i.e. uncertainty or refusal of vaccination despite availability of vaccination services) [40]. The outcome at follow-up was self-report of *not* being vaccinated for COVID-19 (i.e., unvaccinated). The primary outcome for the follow-up survey was self-report of being unvaccinated because by this time the standard of care was recommended vaccination for pregnant and postpartum individuals, compared to the baseline survey when vaccination had first become available and guidelines were evolving for this population. Vaccination was defined as self-reported receipt of at least one dose of any available COVID-19 vaccine.

Covariates included age, self-reported race and ethnicity, education, current employment status, health insurance, and substance use in pregnancy. These factors were assessed because they have been found to be associated with vaccine hesitancy [38]. Race and ethnicity were self-reported by participants, and was categorized using criteria as outlined by U.S. Vital Statistics [42]. In addition, the survey assessed participant perceptions that

Table 1
Social vulnerability Index (SVI) domains.

SVI Domain	Components of SVI domain
Overall	
Social Vulnerability Index (SVI)	Composite of Domains 1–4
Domains (1–4)	
1: Socioeconomic status	Includes unemployment, education (<high school), and income (poverty) status
2: Household composition and disability	Includes households with single parent, <17 or > 65 years of age, or > 5 years of age with a disability
3: Minority status and language	Includes minority status, and English fluency
4: Housing type and transportation	Includes assessment of multi-unit structures, mobile homes, crowding, no vehicle, and group quarters

were associated with vaccine hesitancy, including: counseling about risks and benefits of vaccination by the obstetrical health-care provider and the potential benefits of vaccination to the mother and infant [39]. Clinical characteristics inclusive of chronic comorbid conditions that have been associated with increased risk of COVID-19 complications and body mass index (BMI) were manually abstracted from the EHR.

2.3. Statistical analysis

We compared participant characteristics and vaccine perceptions by SVI quartile in the study sample at baseline. We compared categorical variables with a chi-square test and continuous variables with one-way analysis of variance (ANOVA). Modified Poisson regression with robust error variance were used to estimate the associations between SVI quartile score overall and by domain, with baseline COVID-19 vaccine hesitancy and follow-up COVID-19 vaccination. To do so we calculated unadjusted and adjusted risk ratios (RR, aRRs) and 95% confidence intervals (CI). Confounding variables were selected based on prior studies of vaccination in pregnancy and a directed acyclic graph (DAG). The final model for baseline vaccine hesitancy was adjusted for age (<25, 25–30, >30–35, >35 years), race/ethnicity, parity (0, 1, 2 or more), trimester of pregnancy at time of enrollment (1st, 2nd, 3rd, postpartum) and chronic comorbid conditions (0, 1 or more). In addition, the model for vaccination status at follow-up also adjusted for pregnancy status at follow-up (yes/no) and time from baseline to follow-up survey in weeks (continuous). Missing data imputation was not performed as > 99% of participants had complete data at both time points. Because not all participants who completed the baseline survey completed the follow-up survey, we repeated the analysis between SVI and vaccination status at follow-up under a best and worst case scenario, in which all individuals who were lost-to-follow-up were categorized as either vaccinated or unvaccinated, respectively. All statistical analyses were performed using Stata (StataCorp, version 16.1, College Station, TX).

3. Results

Four-hundred and eighty-one individuals were approached for participation in the baseline survey, of whom 456 individuals (95% pregnant, 5% postpartum) enrolled. Those who declined to enroll ($n = 25$) had a higher SVI score compared to those who did (mean: 0.63 vs. 0.44; $p < 0.01$). Of the 456 individuals enrolled, 335 (73%) were able to be contacted for the follow-up survey, of whom 290 (64%) consented to participate (24% pregnant; 76% postpartum) (Appendix Fig. A1.). Those who did not follow-up ($n = 165$) had a higher SVI score compared to those who did (mean: 0.51 vs. 0.40; $p < 0.001$). The median time from enrollment to follow-up was 18 weeks (interquartile range, IQR: 17, 31). The mean age was 29.3 ± 5.4 years, 47% Medicaid beneficiaries, 27% self-identified as non-Hispanic Black, and 52% had a bachelor's degree or greater (Table 2).

When the SVI was stratified by quartile, mean SVI score increased from quartile 1 (low SVI) to quartile 4 (high SVI) (quartile 1: 0.12; quartile 2: 0.43; quartile 3: 0.71; and quartile 4: 0.88). And for those with follow-up, mean SVI score at baseline increased from quartile 1 to quartile 4 (1: 0.07; 2: 0.27; 3: 0.57; and 4: 0.83). Individuals in the highest SVI quartile were more likely to identify as non-Hispanic Black, have lower educational attainment, be unemployed, have public insurance, use tobacco, be living with obesity, and have medical comorbidities compared to those in the lowest SVI quartile (overall $p < 0.01$) (Table 2). Individuals in the highest SVI quartile were less likely to have received the influenza vaccine during the current influenza season, to have discussed any

vaccination in pregnancy with their obstetric provider, and to be concerned about contracting COVID-19 in pregnancy (overall $p < 0.01$).

On the baseline survey, 46% (95% CI: 42% to 51%) reported COVID-19 vaccine hesitancy. The frequency of vaccine hesitancy increased as the SVI increased. In quartile 1 (low SVI), 25% of individuals reported vaccine hesitancy, 38% in quartile 2, 55% in quartile 3, and 68% in quartile 4 (high SVI) (Table 3). Similarly, by each SVI domain, the frequency of vaccine hesitancy increased from 24% to 73% from quartile 1 to 4 for socioeconomic status, 28% to 70% for household composition and disability, 33% to 61% for housing type and transportation, but not for minority status and language.

At follow-up, 48% (95% CI: 42% to 53%) reported that they were not vaccinated for COVID-19. The frequency of being unvaccinated for COVID-19 increased as the SVI increased. In quartile 1, 29% of individuals reported being unvaccinated, 32% in quartile 2, 64% in quartile 3, and 77% in quartile 4 (Table 4). Similarly, by each SVI domain, the frequency of being unvaccinated increased from 28% to 82% from quartile 1 to 4 for socioeconomic status, 27% to 73% for household composition and disability, 39% to 69% for minority status and language, and 37% to 65% for housing type and transportation.

In adjusted analyses, progressing from quartile 2 to quartile 4 (higher SVI) in comparison to quartile 1 (low SVI, reference), the risk of COVID-19 vaccine hesitancy increased (quartile 2 aRR: 1.46; 95% CI: 0.98 to 2.19; quartile 3 aRR: 1.86; 95% CI: 1.28 to 2.71; and quartile 4 aRR: 2.24; 95% CI: 1.56 to 3.21) (Table 3). Similarly, progressing from quartile 2 to quartile 4 in comparison to quartile 1, the risk of being unvaccinated for COVID-19 at follow-up increased (quartile 2 aRR: 1.00; 95% CI 0.66 to 1.51; quartile 3 aRR: 1.68; 95% CI: 1.17 to 2.41; and quartile 4 aRR: 1.82; 95% CI: 1.30 to 2.56) (Table 4).

These results generally held for 3 of 4 SVI domains for vaccine hesitancy at baseline. For the socioeconomic status domain, progressing from quartile 2 to quartile 4, the risk of COVID-19 vaccine hesitancy increased (quartile 2 aRR: 1.43; 95% CI: 0.95 to 2.14; quartile 3 aRR: 1.80; 95% CI: 1.23 to 2.63; and quartile 4 aRR: 2.39; 95% CI: 1.66 to 3.43), as it did for the household composition and disability domain (quartile 2 aRR: 1.22; 95% CI: 0.83 to 1.79; quartile 3 aRR: 1.76; 95% CI: 1.26 to 2.47; and quartile 4 aRR: 2.05; 95% CI: 1.48 to 2.85) and the housing type and transportation domain (quartile 2 aRR: 1.30; 95% CI: 0.94 to 1.80; quartile 3 aRR: 1.37; 95% CI: 1.00 to 1.89; and quartile 4 aRR: 1.65; 95% CI: 1.22 to 2.23), but not the minority status and language domain (Table 3).

Similarly, at follow-up, the risk of being unvaccinated for COVID-19 increased from quartile 2 to quartile 4 for the socioeconomic status domain (quartile 2 aRR: 1.09; 95% CI: 0.71 to 1.68; quartile 3 aRR: 1.73; 95% CI: 1.19 to 2.52; and quartile 4 aRR: 2.16; 95% CI: 1.53 to 3.04), and the household composition and disability domain (quartile 2 aRR: 1.35; 95% CI: 0.92 to 1.99; quartile 3 aRR: 1.93; 95% CI: 1.37 to 2.72; and quartile 4 aRR: 1.83; 95% CI: 1.28 to 2.62) (Table 4). For the domain of housing type and transportation, the risk of being unvaccinated increased from quartile 3 to quartile 4 (quartile 3 aRR: 1.09; 95% CI: 0.77 to 1.55; and quartile 4 aRR: 1.42; 95% CI: 1.05 to 1.93). There was no association between unvaccinated status and the minority status and language domain.

In sensitivity analysis, when the above analyses were repeated under a best and worst case scenario to account for loss-to-follow-up, the association between increasing SVI and the risk of being unvaccinated for COVID-19 held when all participants who did not follow-up were classified as unvaccinated (worst case scenario), as well as when they were classified as vaccinated (best case scenario) (Appendix Table A1).

Table 2
Patient demographic and clinical characteristics by quartile of overall community-level social vulnerability.

At baseline (n = 456)	Social Vulnerability Index (SVI), by quartile					p-value ¹
	Overall N = 456	1st quartile (<25%) n = 114	2nd quartile (≥25-49%) n = 111	3rd quartile (≥50-74%) n = 116	4th quartile (≥75-100%) n = 115	
Social Vulnerability Index (SVI)	0.44 ± 0.30	0.07 ± 0.05	0.27 ± 0.08	0.57 ± 0.08	0.83 ± 0.08	<0.01
Age, years	29.3 ± 5.4	31.2 ± 4.9	30.4 ± 5.2	20.1 ± 4.9	29.5 ± 5.5	<0.01
Race and ethnicity						
Non-Hispanic White	271 (59.4)	80 (70.2)	78 (70.3)	75 (64.7)	38 (33.0)	<0.01
Non-Hispanic Black	122 (26.8)	14 (12.3)	18 (7.2)	33 (28.5)	57 (49.6)	
Hispanic	33 (7.2)	6 (5.3)	8 (7.2)	4 (3.5)	15 (13.0)	
None of the above	30 (6.6)	14 (12.3)	7 (6.3)	4 (3.5)	5 (4.4)	
Education (n = 452)						
High school or less	130 (28.8)	10 (8.8)	17 (15.6)	47 (40.5)	56 (49.6)	<0.01
Some college	89 (19.7)	13 (11.4)	22 (20.2)	21 (18.1)	33 (29.2)	
Bachelors degree	145 (32.1)	48 (42.1)	44 (40.4)	34 (29.3)	19 (16.8)	
Advanced degree	88 (19.5)	43 (37.7)	26 (23.9)	14 (12.1)	5 (4.4)	
Parity						
0	167 (36.6)	49 (43.0)	41 (36.9)	34 (29.3)	43 (37.4)	0.08
1	142 (31.1)	41 (36.0)	33 (29.7)	38 (32.8)	30 (26.1)	
2 or more	147 (32.2)	24 (21.1)	37 (33.3)	44 (37.9)	42 (36.5)	
Employed	315 (69.1)	96 (84.2)	78 (70.3)	74 (63.8)	67 (58.3)	<0.01
Health insurance, Medicaid	215 (47.2)	28 (24.6)	39 (35.1)	68 (58.6)	80 (69.6)	<0.01
Substance use, current						
Tobacco	42 (9.2)	3 (2.7)	6 (5.4)	18 (15.5)	15 (13.0)	<0.01
Drug use ²	48 (10.5)	7 (6.1)	9 (8.1)	17 (14.7)	15 (13.0)	0.11
Gestational age, weeks						
First trimester	157 (34.4)	40 (35.1)	45 (40.5)	36 (31.0)	36 (31.3)	0.76
Second trimester	231 (50.7)	58 (50.9)	53 (47.8)	57 (49.1)	63 (54.8)	
Third trimester	47 (10.3)	12 (10.5)	9 (8.1)	15 (12.9)	11 (9.6)	
Fourth trimester (postpartum)	21 (4.6)	4 (3.5)	4 (3.6)	8 (6.9)	5 (4.4)	
Body mass index, kg/m ²	31.6 ± 8.17	28.1 ± 6.41	31.7 ± 7.97	32.7 ± 8.50	33.9 ± 8.56	<0.01
Chronic comorbid conditions						
None	136 (29.8)	50 (43.9)	34 (30.6)	26 (22.4)	26 (22.6)	<0.01
1 or more	320 (70.2)	64 (56.1)	77 (69.4)	90 (77.6)	89 (77.4)	
Influenza vaccination in the current season	263 (57.7)	94 (82.5)	89 (80.2)	82 (71.3)	73 (63.5)	<0.01
Vaccination discussion with provider about COVID-19 (n = 450)	227 (50.4)	79 (69.9)	74 (67.3)	42 (36.5)	32 (28.6)	<0.01
Concerned about contracting COVID-19 and impact to self and pregnancy, 1 to 10	5.7 ± 3.0	6.3 ± 2.9	5.8 ± 2.8	5.2 ± 3.0	5.3 ± 3.1	0.01
Benefit of COVID-19 vaccination (n = 415) ³						
Mother	93 (22.4)	23 (21.3)	25 (23.8)	24 (23.3)	21 (21.2)	0.66
Baby	7 (1.7)	3 (2.8)	0 (-)	3 (2.9)	1 (1.0)	
Both	315 (75.9)	82 (75.9)	80 (76.2)	76 (73.8)	77 (77.8)	

Abbreviations: SD: standard deviation; SVI: social vulnerability index.

Data presented as mean ± SD or n (%).

¹ Categorical variables compared using an overall chi square test and continuous variables compared using one-way analysis of variance (ANOVA).

² Reported drug use inclusive of illicit drugs and prescribed opioids.

³ When asked if the COVID-19 vaccination was for the benefit of the mother, baby, or both.

Table 3
Association between community-level social vulnerability and COVID-19 vaccine hesitancy at baseline SVI Domain.

	Frequency n (%)	Unadjusted risk ratio, RR (95% CI)	Adjusted risk ratio, aRR (95% CI) ^{1,2,3,4}
Overall	212/456 (46.5)		
Social Vulnerability Index (SVI)			
Quartile 1 ⁵	28/114 (24.6)	1.00	1.00
Quartile 2	42/111 (37.8)	1.56 (1.03 to 2.34)	1.46 (0.98 to 2.19)
Quartile 3	64/116 (55.2)	2.29 (1.58 to 3.31)	1.86 (1.28 to 2.71)
Quartile 4	78/115 (67.8)	2.83 (1.99 to 4.04)	2.24 (1.56 to 3.21)
Domains (1–4)			
1: Socioeconomic status			
Quartile 1	28/115 (24.4)	1.00	1.00
Quartile 2	41/113 (36.3)	1.53 (1.01 to 2.30)	1.43 (0.95 to 2.14)
Quartile 3	61/115 (53.0)	2.22 (1.53 to 3.22)	1.80 (1.23 to 2.63)
Quartile 4	82/113 (72.6)	3.05 (2.15 to 4.32)	2.39 (1.66 to 3.43)
2: Household composition and disability			
Quartile 1	33/118 (28.0)	1.00	1.00
Quartile 2	39/114 (34.2)	1.25 (0.84 to 1.84)	1.22 (0.83 to 1.79)
Quartile 3	62/113 (54.9)	1.99 (1.4 to 2.79)	1.76 (1.26 to 2.47)
Quartile 4	78/111 (70.3)	2.56 (1.85 to 3.52)	2.05 (1.48 to 2.85)
3: Minority status and language			
Quartile 1	59/114 (51.8)	1.00	1.00
Quartile 2	41 (36.0)	0.67 (0.49 to 0.91)	0.63 (0.48 to 0.85)
Quartile 3	45 (39.5)	0.76 (0.57 to 1.01)	0.73 (0.54 to 0.97)
Quartile 4	67 (58.8)	1.12 (0.89 to 1.42)	1.00 (0.79 to 1.27)
4: Housing type and transportation			
Quartile 1	38/115 (33.0)	1.00	1.00
Quartile 2	51/113 (45.1)	1.44 (1.02 to 2.03)	1.30 (0.94 to 1.80)
Quartile 3	54/114 (47.4)	1.51 (1.08 to 2.12)	1.37 (1.00 to 1.89)
Quartile 4	69/114 (60.5)	1.93 (1.41 to 2.64)	1.65 (1.22 to 2.23)

Abbreviations: SVI: social vulnerability index, RR: risk ratio, aRR: adjusted risk ratio, CI: confidence interval.

¹ Model adjusted for: age, race and ethnicity, parity, trimester of pregnancy at baseline, and chronic comorbidities.

² Unadjusted and adjusted risk ratios calculated using modified Poisson regression with robust error variance.

³ N = 456 in the unadjusted model and 453 in the adjusted model.

⁴ aRR per every one unit increase in SVI quartile.

⁵ Mean SVI value (0 to 1) by quartile among individuals with baseline data: <25%, 0.12; ≥25–49%, 0.43; ≥50–74%, 0.71; and ≥ 75–100%, 0.88.

4. Discussion

Pregnant and postpartum individuals living in areas with higher community-level social vulnerability were more likely to report baseline COVID-19 vaccine hesitancy and to be unvaccinated for COVID-19 at follow-up. These findings suggest that experiencing a higher burden of adverse community-level social determinants of health may be associated with persistent COVID-19 vaccine hesitancy in the peripartum period.

In the current study, vaccine hesitancy and follow-up vaccination were assessed at two critical time points: when vaccines first became available for pregnant individuals statewide and then, when vaccines were widely available. Follow-up was at a time when professional guidelines recommended vaccination for all pregnant and postpartum individuals [15–17], and after publication of population-level data demonstrating the safety of vaccination in pregnancy for both the mother and infant [23–25]. The findings of the current study are consistent with prior studies that found patient socio-demographic characteristics, such as receipt of public health insurance, lower education attainment, and non-Hispanic Black race, were associated with higher COVID-19 vaccine hesitancy in pregnant [9,11] and non-pregnant populations [43–45]. These associations between individual socio-demographic risk factors and vaccine hesitancy have also been previously identified for influenza vaccination in pregnancy [12,26,29,46]. However, the current study focused on a community-level and standardized metric of social determinants of health as opposed to individual socio-demographic risk factors. Outside of pregnancy, higher SVI scores have been associated with an increased risk of being unvaccinated for influenza [47–48] and COVID-19 [48–50].

The SVI is an online tool available from the CDC and is readily accessible to healthcare providers across the U.S. Further studies

are needed to understand how knowledge of the SVI during the peripartum period could be used to improve vaccine delivery and outcomes in this population. More broadly, whether the SVI could be used as a tool to identify communities in which pregnant and postpartum individuals are at the greatest risk of not receiving recommended vaccinations remains to be studied. Current public health efforts for identifying prevention strategies for COVID-19 are increasingly being implemented based on location and local disease burden. It is possible that interventions to increase vaccination and decrease vaccine hesitancy could be targeted to those pregnant individuals at the greatest risk of not being vaccinated using the SVI as a measure of community-level social determinants of health. However, the efficacy of interventions that address community-level social determinants of health utilizing the SVI to decrease vaccine hesitancy in the peripartum period needs to be studied further. Such programs may include targeting community-based programs to increase vaccination uptake (i.e., mobile clinics, awareness campaigns) to individuals who live in communities with high SVI, and identifying individuals with a high SVI in the EHR for further provider vaccination counseling as part of prenatal care.

There are several limitations to note. Selection bias is possible. Although we had high enrollment (95%) for the initial survey, the follow-up rate was 64%. We performed a sensitivity analysis to examine the robustness of study findings with regards to potential selection bias. While we assessed for prior COVID-19 infection in the household, we did not assess whether the individuals had prior COVID-19 infection. Furthermore, baseline factors associated with vaccine hesitancy, including prior personal exposure to COVID-19 and provider recommendations, were assessed only at enrollment in the current study. These factors may evolve over time given the changing epidemiology of COVID-19 as well as clinical guidelines.

Table 4
Association between community-level social vulnerability and being unvaccinated for COVID-19 at follow-up.

SVI Domain	Frequency N (%)	Unadjusted risk ratio, RR (95% CI)	Adjusted risk ratio, aRR (95% CI) ^{1,2,3,4}
Overall	139/290 (47.9)		
Social Vulnerability Index (SVI)			
Quartile 1 ⁵	26/89 (29.2)	1.00	1.00
Quartile 2	23/73 (31.5)	1.32 (0.92 to 1.89)	1.00 (0.66 to 1.51)
Quartile 3	43/67 (64.2)	1.16 (0.78 to 1.71)	1.68 (1.17 to 2.41)
Quartile 4	47/61 (77.1)	1.73 (1.23 to 2.43)	1.82 (1.30 to 2.56)
Domains (1–4)			
1: Socioeconomic status			
Quartile 1	24/87 (27.6)	1.00	1.00
Quartile 2	23/75 (30.7)	1.11 (0.68 to 1.80)	1.09 (0.71 to 1.68)
Quartile 3	39/63 (61.9)	2.19 (1.47 to 3.26)	1.73 (1.19 to 2.52)
Quartile 4	53/65 (81.5)	2.95 (2.06 to 4.23)	2.16 (1.53 to 3.04)
2: Household composition and disability			
Quartile 1	24/88 (27.3)	1.00	1.00
Quartile 2	30/78 (38.5)	1.41 (0.90 to 2.19)	1.35 (0.92 to 1.99)
Quartile 3	41/64 (64.1)	2.30 (1.55 to 3.41)	1.93 (1.37 to 2.72)
Quartile 4	44/60 (73.3)	2.68 (1.84 to 3.90)	1.83 (1.28 to 2.62)
3: Minority status and language			
Quartile 1	27/69 (39.1)	1.00	1.00
Quartile 2	34/77 (44.2)	1.13 (0.76 to 1.68)	0.90 (0.63 to 1.27)
Quartile 3	31/76 (40.8)	1.06 (0.71 to 1.60)	0.93 (0.65 to 1.33)
Quartile 4	47/68 (69.1)	1.80 (1.28 to 2.54)	1.25 (0.92 to 1.69)
4: Housing type and transportation			
Quartile 1	31/83 (37.4)	1.00	1.00
Quartile 2	40/80 (50.0)	1.32 (0.92 to 1.89)	1.30 (0.96 to 1.78)
Quartile 3	31/70 (44.3)	1.16 (0.78 to 1.71)	1.09 (0.77 to 1.55)
Quartile 4	37/57 (64.9)	1.73 (1.23 to 2.43)	1.42 (1.05 to 1.93)

Abbreviations: SVI: social vulnerability index, RR: risk ratio, aRR: adjusted risk ratio, CI: confidence interval.

¹ Model adjusted for: age, race and ethnicity, parity, trimester of pregnancy at baseline, chronic comorbidities, time from baseline to follow-up assessment, and pregnant at follow-up.

² Unadjusted and adjusted risk ratios calculated using modified Poisson regression with robust error variance.

³ N = 290 in the unadjusted model and 288 in the adjusted model.

⁴ aRR per every one unit increase in SVI quartile.

⁵ Mean SVI (0 to 1) by quartile among individuals with follow-up data: <25%, 0.07; ≥25–49%, 0.27; ≥50–74%, 0.57; and ≥ 75–100%, 0.83.

Social desirability bias is also possible at follow-up because those who were vaccinated may have been more likely to enroll and or those who did enroll may have been more likely to say they were vaccinated even if they were not. However, self-report of vaccination status has been shown to be accurate outside of pregnancy [44]. Differential follow-up by vaccination status is possible, as those who reported not being vaccinated at 3 months were not reassessed again at 6 months (i.e., at the end of the study period). We did not assess whether documented provider counseling in the EHR varied with patient report of counseling. Furthermore, we were unable to assess whether those in higher SVI categories received differential prenatal care, including inferior provider vaccination counseling. This analysis included individuals from the first through fourth trimesters, and COVID-19 vaccine hesitancy may vary by trimester. However, we adjusted for trimester and pregnancy status in our analysis. Given the relatively small proportion of postpartum participants at baseline and pregnant participants at follow-up, assessing differences in the association between SVI and vaccine hesitancy and vaccination status between pregnant versus postpartum individuals was not possible. We did not assess whether vaccine hesitancy differed by pregnancy status wherein participants would be more or less willing to get vaccinated following the peripartum period in this analysis. Because vaccine hesitancy is likely dynamic, further prospective follow-up of individuals over time is needed. Finally, the current study was a convenience sample at a tertiary care center of only individuals who spoke English. We did not assess participant health literacy which may also impact vaccine hesitancy. These factors may limit the generalizability of our study to other healthcare settings or populations. However, the SVI is a nationally generalizable measure of community level social vulnerability.

In summary, pregnant and postpartum individuals living in an area with higher community-level social vulnerability were more likely to report COVID-19 vaccine hesitancy and to be unvaccinated at follow-up. These results raise the possibility that the SVI could be used as a tool to identify individuals experiencing a higher burden of adverse social determinants of health to decrease vaccine hesitancy and increase vaccination in the peripartum period.

5. Details of ethics approval

This study was approved by The Ohio State University Institutional Review Board (ID#: 2021H0023; date: 02/23/21).

Funding

Dr. Venkatesh was supported by the Care Innovation and Community Improvement Program and the Division of Maternal Fetal Medicine at The Ohio State University Wexner Medical Center.

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.

Acknowledgement

None

Appendix A

See Fig. A1 and Table A1.

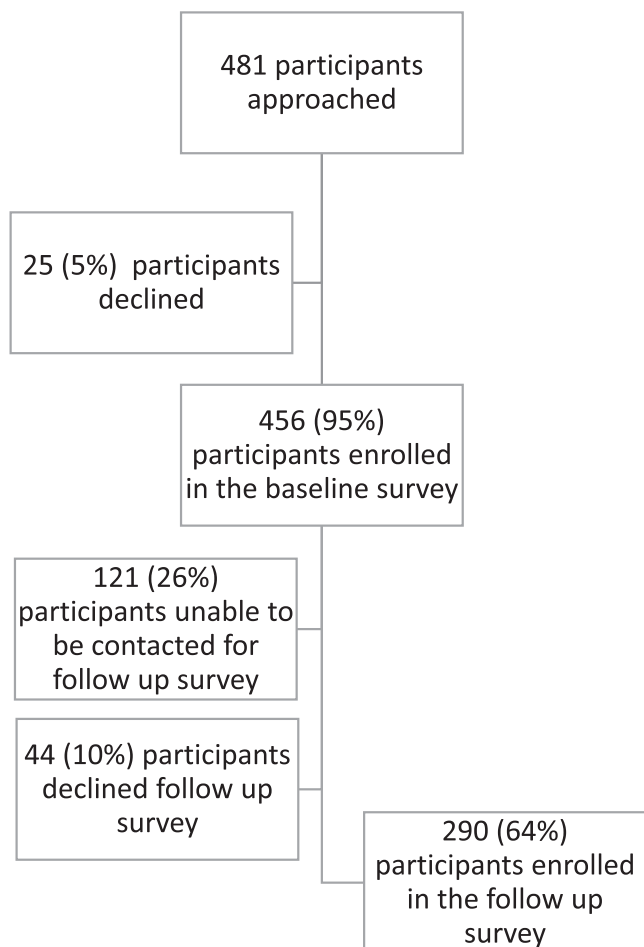


Fig. A1. Flow diagram of participant enrollment in baseline and follow-up survey.

Table A1 Association between community-level social vulnerability and being unvaccinated for COVID-19 at follow-up.

	Best case ¹ at follow-up aRR (95% CI) ^{3,4,5,6}	Worst case ² at follow-up aRR (95% CI) ^{3,4,5,6}
Overall		
Social Vulnerability Index (SVI)		
Quartile 1	1.00	1.00
Quartile 2	1.00 (0.66 to 1.51)	1.00 (0.66 to 1.51)
Quartile 3	1.68 (1.17 to 2.41)	1.68 (1.17 to 2.41)
Quartile 4	1.82 (1.30 to 2.56)	1.82 (1.30 to 2.56)

Abbreviations: SVI: social vulnerability index, aRR: adjusted risk ratio, CI: confidence interval.

¹ Best case scenario: individuals who did not follow-up were categorized as vaccinated.

² Worst case scenario: individuals who did not follow-up were categorized as unvaccinated.

³ Model adjusted for: age, parity, race and ethnicity, trimester of pregnancy at baseline, chronic comorbidities; however not adjusted for follow-up covariates, which were not available for those without follow-up (pregnancy status at follow-up, and time to follow-up).

⁴ Adjusted risk ratios calculated using modified Poisson regression with robust error variance.

⁵ N = 288 in the adjusted model.

⁶ aRR per every one unit increase in SVI quartile.

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