Association Between Food Insecurity and Anemia During Pregnancy

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Abstract

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Background: There is a high prevalence of maternal anemia in the United States, despite continued efforts to promote intake of iron supplements during pregnancy. Public health researchers are recognizing that there may be broader socio-economic mechanisms behind maternal anemia. One of the potential factors researchers are beginning to explore is food insecurity. The current study aimed to test the association between food insecurity and maternal anemia. A secondary aim of this study was to explore the potential association between maternal anemia and other food insecurity related socio-economic factors – housing, transportation, and financial coverage of basic expenses.

Methods: This study was conducted using a cross-sectional design and data collected from prenatal clinics within a Portland, Oregon healthcare system. Information from a total of 1,209 participants identified from among women attendants of prenatal clinics was obtained using patient intake forms and medical records. Associations between food insecurity and maternal anemia were evaluated using odds ratios (OR) and related 95% confidence intervals (CIs) from unadjusted and two adjusted logistic regression models. The first adjusted model included the following variables: race and ethnicity, parity, and age. The second adjusted model included all variables included in the first adjusted model as well as educational attainment, Medicaid/Medicare status, relationship status, planned pregnancy, and tobacco use. Similar

models were used to examine associations of housing, transportation, and financial coverage of basic expenses with maternal anemia.

Findings: Among study participants, 14.4% (n=165) of women were considered to be food insecure and 85.6% (n=981) were considered to be food secure. Overall, 35.6% (n=431) of women were considered anemic and 64.4% (n=778) were considered non-anemic. In the fully adjusted model, the odds of having maternal anemia were 1.56-fold higher (95% CI: 10.8-2.26) for women with food insecurity compared odds of having maternal anemia among food secure women.

Conclusion: We found independent associations of food insecurity and food insecurity related socio-economic factors with maternal anemia. This study supports previous research that has demonstrated an association between food insecurity and maternal anemia. This study also expands on the literature by exploring the relationship between maternal anemia and additional socio-economic variables. The findings from this study can be used to inform future intervention strategies within Providence Health and Services prenatal clinics in Oregon.

Background and Significance

The Centers for Disease Control and Prevention (CDC) recognizes iron deficiency as the most common known form of nutritional deficiency in the United States.[1] Iron deficiency is considered to be the most common cause of anemia.[2] Pregnant women are at a greater risk for iron-deficient anemia due to the transfer of iron to the developing fetus and metabolic needs of the mother.[3] A Hemoglobin concentration below 11 g/dL is considered anemic by many public health researchers and practitioners.[3-8]

Maternal anemia has been associated with adverse perinatal outcomes, including an increased risk of low birth weight, preterm delivery, and perinatal mortality.[4,7.8.9] Iron deficiency can also lead to decreased fetal oxygenation which can permanently alter the development of the brain and nervous system and may place the infant at risk for neurodevelopmental delay, long-term neurological dysfunction, and impaired intellectual abilities.[6,8] Additional evidence suggests that maternal anemia may also be associated with a higher risk of postpartum depression.[6,8] The impact of these adverse health outcomes is significant considering the prevalence of maternal anemia in the US. According to the World Health Organization (WHO), in 2016, the prevalence of anemia among the US pregnant population was 14.3% compared to 8.2% prevalence in the US among the non-pregnant female population.[10]

To address this public health issue, CDC and other US public health and medical associations have issued clinical recommendations for the screening and treatment of anemia during pregnancy.[11] The primary intervention approach, both in the US and globally, has been the use of iron supplements.[12] Due to the continued prevalence of anemia during pregnancy, however, researchers and public health advocates have begun investigating the barriers to adherence to the use of iron supplementation for pregnant women. A qualitative study by Tessema and colleagues found that, for a diverse population of women in the US, some barriers to prenatal vitamin uptake included lack of adequate supply, differing levels of support of supplement use by social networks, poor communication with healthcare providers,

forgetfulness, losing pills, palatability, and the size of pills.[3,13] There is also a growing body of evidence that suggests varying impact of socio-economic factors on prevalence of anemia among different US populations.[11] This research suggests that iron supplementation alone may not fully address maternal anemia due to social determinants and other socio-economic factors involved.

For this reason, one avenue that public health researchers are beginning to explore is the relationship between food insecurity and maternal anemia. The United States Department of Agriculture (USDA) defines food insecure households as having uncertainty or difficulty acquiring enough food to meet the needs of all their family members because of insufficient money or other resources for food at some point throughout the year.[14] Households with very low food security have disrupted food intake at times throughout the year, with self-reported food intake below levels that are considered adequate.[14] In 2017, 11.8% of US households were food insecure at some point during the year, with 4.5% of those households having very low food security.[14,15] Food insecurity is a variable of interest to researchers in the reproductive health field because the relative ability or inability to meet food needs may directly result in iron-poor diets, anemia, and other nutritional deficiencies.[16] Assessing food insecurity may also better capture the socio-economic disparities that impact maternal anemia, in that, rates of food insecurity in 2017 were substantially higher than the national average for single-parent households, households below the federal poverty line, non-suburban areas, and for Black and Hispanic households.[11,15]

Several recent studies have examined the complex issue of food insecurity and negative health outcomes within a larger socio-ecological model. For issues of healthcare utilization and poor health outcomes, including anemia, some variables and potential mediators that researchers have begun investigating include issues related to housing stability,[17] access to transportation,[18] family structure or relationship status,[19] antenatal tobacco use,[20] and basic financial security and income.[21,22] Because food insecurity is a complex social issue, we drew

from a socio-ecological model to explore a number of interrelated variables that may be a marker for food insecurity and/or a related risk factor for maternal anemia.[26-30] **Figure 1** depicts an adapted conceptual model from Balarajan et al[22] that demonstrates the ways in which these broader socio-economic factors may impact the relationship between food security and maternal anemia.

Very few studies have examined the association between food insecurity and maternal anemia and the results from those studies have been inconclusive.[12,16,23-25] For this reason, the current study aimed to explore this pressing public health issue within a local context, to better and more immediately serve at-risk patients receiving prenatal care at Providence Health and Services in Portland, Oregon. The objectives were to determine cross-sectional association between food insecurity and iron-deficiency anemia status for pregnant women at their prenatal intake appointment, and, determine whether this association differs by parity, race/ethnicity, and/or maternal Adverse Childhood Events (ACEs). In addition, we examined cross-sectional associations of housing insecurity, transportation insecurity or financial coverage of basic expenses with iron-deficiency anemia status for pregnant women at their prenatal intake appointment.

Finding an association between food insecurity and maternal anemia, or associations between food insecurity related socio-economic factors and maternal anemia could increase Providence Health and Service administrators' and clinicians' knowledge on the social factors that impact maternal anemia and could provide evidence to motivate appropriate clinical or non-clinical interventions.

Methods

Study Setting, Study Design, and Study Population

The current study was conducted using data from four of the five Providence Health and Services Prenatal Clinic sites in Portland, Oregon. See **Appendix A** for a map of the prenatal clinic sites.[31] We utilized a cross-sectional design to address the research questions.

The overall dataset included 1,209 women who completed patient intake forms between 2016 and 2018. We extracted data from patient medical charts as well as from patient intake forms. All women who did not have missing response for the food insecurity questions and/or anemia status were included in the analyses. The total number of women missing data on the exposure and/or outcome was 63. A total of 1,146 women were included in the analyses. All data were de-identified prior to data access and analysis. This study was deemed exempt from full review by both the University of Washington and Providence Health and Services in Oregon Institutional Review Boards.

Exposure Variable

The exposure variable for this study was food insecurity. Food insecurity was measured using the Family Well-Being Assessment (FWBA) intake form as well as the 2017 New OB Patient Intake Questionnaire Form. The FWBA is a standardized risk assessment tool developed by the Oregon Perinatal Collaborative in order to better coordinate prenatal care across Oregon and to be able to aggregate data by county, region, and state.[32] This assessment tool includes questions relating to a wide range of social determinants of health, including food insecurity.[32] The New OB Patient Intake Form, which is currently being used in Providence prenatal clinics, has an additional food insecurity related question. Measures of food insecurity were assessed from all of the following intake questions, drawn from both the FWBA and New OB Patient Intake Form:

1. In the past three months, how often have you worried about having enough food? Answer options included every day, most days, some days, and never, coded as 3, 2, 1, and 0, respectively.
2. Within the past 12 months we worried whether our food would run out before we got money to buy more? Answer options included: never true, sometimes true, often true and always true, coded as 0, 1, 2, and 3, respectively.
3. Within the past 12 months the food we bought just didn't last and we didn't have money to buy more. Answer options included: never true, sometimes true, often true and always true, coded as 0, 1, 2, and 3, respectively.

Responses to these questions were combined into a composite food insecurity binary variable. Study participants who reported 0 in all of these questions were considered food secure and those who reported a 1 or higher in any of these questions, whether from the FWBA or New OB Intake Form, were considered food insecure.

Outcome Variable

The outcome variable for this study was maternal anemia status. According to the American College of Obstetricians and Gynecologists (ACOG) guidelines,[8] anemia was operationally defined in this study as Hemoglobin (Hgb) concentration below 11 g/dL (Hematocrit (Hct) percentage below 33%). Data on Hgb/Hct were extracted from patient medical records.

Food Insecurity Related Variables: Housing, Transportation, and Financial Insecurity

Measures of housing, transportation, and financial insecurity were assessed using the following three questions on the New OB patient intake form:

1. In the past three months, how often have you worried about having a safe and stable place to live?
2. In the past three months, how often has transportation limited you in doing what you need to do?

3. In the past three months, how often have you have trouble paying for basic living expenses like housing, food, or clothes?

Response to each of these questions was coded as 0, 1, 2 and 3, for never, some days, most days, and every day, respectively. Similar to food insecurity, we created a binary variable for each of these responses with participants scoring a 1 or higher in any of these variables considered housing, transportation, or financially insecure, and participants scoring 0 as housing, transportation, or financially secure, respectively.

Potential Effect Modifiers and Confounders

We considered ACEs, parity and race as potential effect modifiers. Each of these variables were selected as potential effect modifiers due to the increased baseline risk for participants to be either food insecure or anemic during pregnancy. Participants with a history of ACEs may have a differential risk of being food insecure than their counterparts without a history of ACEs. Similarly, according to USDA data, racial minority groups may be differentially at risk for food insecurity than white participants.[11,15] Parity was selected as a potential effect modifier because participants who have had multiple deliveries may have a higher baseline biological risk for becoming anemic during pregnancy.[21,22]

History of ACEs was captured using the New OB patient intake form. ACEs listed on the patient intake form included: physical abuse or neglect, emotional abuse or neglect, sexual abuse, loss of a parent through death, separation, divorce, prison or abandonment, witnessing violence in the household, having a parent or caregiver addicted to alcohol or drugs, having a parent or caregiver with severe mental illness, and/or experiencing community violence or discrimination. The ACEs variable was then dichotomized into yes or no categories. Participants who experienced four or more of the listed events were considered to have had a history of ACEs and those who experienced less than four of the listed events was defined as not having had a history of ACEs.

Race and ethnicity was captured using patient medical records. This variable was defined categorically and included: White/Caucasian, Black/African American, Asian, Alaska Native/American Indian, Native Hawaiian/Pacific Islander, Other, Unknown, and Refused.

Parity was captured using the New OB Patient Intake Form. Parity was defined as a binary categorical variable. Participants who had previous deliveries were considered parous and those without previous deliveries were considered nulliparous.

The following key covariates were considered for inclusion in the partially and fully adjusted models: Medicaid/Medicare insurance status (yes/no), age (defined categorically within five year age ranges), relationship status (married, partner, single), planned pregnancy (yes/no), tobacco use status (Yes currently, Yes but I cut down with pregnancy, Yes but I stopped a while ago, Yes but I stopped with pregnancy, No) and highest level of education attainment (College, Graduate School, Some classes after high school, High school graduation or GED, Less than High school). See **Table 2** for a full list of covariate definitions. All covariate data were collected either from discrete fields on the patient intake forms or from patient medical records.

Statistical Analyses

Statistical analyses methods used for this study are as follows. We first used descriptive analyses to list the count/percentages for each of the categorical variables. For the first research question, we used unadjusted, partially adjusted, and fully adjusted logistic regression models to determine odds ratios (ORs) and corresponding 95% confidence intervals (CIs) and examine the independent cross-sectional association between food insecurity and maternal anemia at the time of intake. The partially adjusted models adjusted for age, race, and parity. The fully adjusted models adjusted for variables included in the partially adjusted models as well as educational attainment, Medicaid/Medicare status, relationship status, planned pregnancy, and tobacco use. Effect modification by ACEs, race, and parity was assessed using a model that included variables for the exposure, the potential effect modifier, as well as an interaction term of the exposure and the effect modifier, along with the other adjustment variables. The p-

value (p-value < 0.05 cut off) of the interaction term was used to determine statistical significance of the interaction at the multiplicative scale.[23]

Similarly, we used unadjusted, partially adjusted, and fully adjusted logistic regression models, described above, to examine independent cross-sectional associations of (1) housing insecurity, (2) transportation, and (3) financial coverage of basic expenses with maternal anemia at the time of intake. Findings were considered significant if the confidence intervals did not cross one or p-values were <0.05.[23] Data analyses were completed using R version 3.4.1.

Results

Among study participants, 14.4% (n=165) of women were considered to be food insecure and 85.6% (n=981) were considered to be food secure. Women who reported having worried about stable housing, transportation, and basic expenses were more likely to be food insecure than women who were food secure (**Table 1**). Overall, 35.6% (n=431) of women were considered anemic and 64.4% (n=778) were considered non-anemic.

In the unadjusted model, the odds of having maternal anemia was 1.92-fold higher (95% CI: 1.37-2.68) for women with food insecurity compared to odds of having maternal anemia among food secure women (**Table 3**). In the partially adjusted model, the odds of having maternal anemia was 1.75-fold higher (95% CI: 1.24-2.45) for women with food insecurity compared to odds of maternal anemia among food secure women. In the fully adjusted model, the odds of having maternal anemia was 1.56-fold higher (95% CI: 1.08-2.26) for women with food insecurity compared to the odds of maternal anemia among food secure women.

The interaction terms for food insecurity and potential effect modifiers (race parity, and ACEs) were not significant (P-values < 0.05) (**Table 4**). However, in the fully adjusted model, the estimates for association of food insecurity with maternal anemia among women who had experienced four or more ACEs (OR 2.70, 95% CI 1.29-5.83) were different to the estimates of similar association among women who had not experienced four or more events (OR 1.20, 95% CI 0.74-1.91) (P-value for interaction = 0.12).

In the unadjusted model, the odds of having maternal anemia was 1.77-fold higher (95% CI: 1.37-2.29) among women with housing insecurity compared to the odds of having maternal anemia among house secure women (**Table 5**). In the partially adjusted model, the odds of having maternal anemia was 1.70-fold higher (95% CI: 1.32-2.22) among women with housing insecurity compared to the odds of having maternal anemia among women with house security. In the fully adjusted model the odds of having maternal anemia was 1.65-fold higher (95% CI:

1.25-2.21) among women with housing insecurity compared with the odds of maternal anemia among women with house security

In the unadjusted model, the odds of having maternal anemia was 1.44-fold higher (95% CI: 1.15-1.80) among women with transportation insecurity compared to the odds of maternal anemia among transportation secure women. In the partially adjusted model, the odds of having maternal anemia was 1.38-fold higher (95% CI: 1.11-1.73) among women with transportation insecurity compared to the odds of maternal anemia among transportation secure women. In the adjusted model, the association between transportation insecurity and maternal anemia remained statistically significant (OR=1.28, 95% CI: 1.01-1.63).

In the unadjusted model, the odds of having maternal anemia was 1.44-fold higher (95% CI: 1.17-1.79) among women unable to financially cover basic expenses compared to the odds of maternal anemia among women able to do so. In the partially adjusted model, the odds of having maternal anemia was 1.38-fold higher (95% CI: 1.12-1.71) among women unable to financially cover basic expenses compared to the odds of maternal anemia among women able to do so. However, in the fully adjusted model, the association between coverage of basic expenses and maternal anemia was attenuated and became statistically insignificant (OR=1.27, 95% CI: 0.99-1.61).

Discussion

Findings from the current study indicate that food insecurity has a significant and independent association with maternal anemia, after controlling for important socio-ecological and behavioral confounders. In the fully adjusted model, the odds of having maternal anemia was 1.56-fold higher (95% CI: 1.08-2.26) for women with food insecurity. Findings also suggest that housing insecurity, access to reliable transportation, and possibly financial ability to cover expenses are independently and significantly associated with maternal anemia in this population. While we did not find statistically significant interactions between food insecurity and the three variables we considered (parity, race, and ACEs), in stratified analyses, we found that the association between food insecurity and maternal anemia was stronger among women who had history of ACEs.

One potential interpretation of our findings of similar associations of food insecurity and related socio-economic variables with maternal anemia is the idea of competing demands.[17] Families who experience food, housing, or transportation insecurity may prioritize one unmet need above another. For example, a family experiencing homelessness may prioritize the need to secure stable housing rather than food security and thereby jeopardize their ability to meet their nutrient and food intake requirements. Due to financial strain and competing demands, patients with a number of disparate needs and priorities may therefore be at a higher risk for maternal anemia.

Another possible explanation is that these factors contribute to each other and that maternal anemia may be the result of a series of interdependent events. For example, a family experiencing housing insecurity may lack the necessary food preparation supplies to ensure the consumption of iron-rich and nutrient dense foods.[28] In another situation, a family may be unable to secure reliable transportation needed to access affordable grocery stores or utilize healthcare services.[18] There may be a number of ways in which these variables interact and

reinforce each other that may place patients who experience one or more of these factors at a higher risk of anemia during pregnancy.

In this study, we also examined whether the relationship between food insecurity and maternal anemia differed according to parity, race and ethnicity, and the history of ACEs. There was a notable difference in associations between food insecurity and maternal anemia among participants who had a history of ACEs when compared to participants who did not have a history of ACEs. Previous studies have identified ACEs as a strong risk factor for a number of negative health and social outcomes for adults, including food and housing insecurity.[33,34] Participants with a history of ACEs may then have a higher baseline risk for food or housing insecurity and may therefore be more disproportionately at risk for maternal anemia.

Each of these findings contribute to the literature in several ways. First, this study supports previous research that has demonstrated an association between food insecurity and maternal anemia. As previous studies within this field have been limited and largely inconclusive, this study helps fortify the evidence of an association between food insecurity and anemia during pregnancy (see **Appendix B** for a chart documenting detailed characteristics of the previous studies and their findings).[12,16,23-25] Secondly, this study also draws on a larger socio-ecological framework and examined the impact of a number of different social determinants of health on maternal anemia. The inclusion of the secondary exploratory aim helps to expand our current understanding of potentially interrelated risk factors for maternal anemia. Lastly, this study is the first to formally assess ACEs as a potential effect modifier for the association between food insecurity and maternal anemia and provides important evidence to examine this relationship in future studies.

Despite the significance of these findings, there are several limitations to note. First, all information on the patient intake forms is self-reported and is likely subject to social-desirability bias and reporter bias. Additionally, the patient intake forms are sent and completed electronically by the patients prior to the first appointment. This may impact self-reporting bias

bi-directionally for certain questions, in that, patients may be more or less comfortable answering some questions privately whereas patients may be more or less comfortable answering some questions after having established a relationship with their provider. Secondly, this study utilized a composite binary variable for food insecurity captured by two different patient intake forms. This may have impacted the number of women included in the exposure group. Third, this is a secondary analysis and is limited by the types of data available. Although we included a large number of different covariates in the analyses, there are some important factors, such as birth intervals and supplement use, which we were unable to control for and there may be uncontrolled confounding as a result. Fourth, although a relatively small concern due to the overall patient response rate, findings from this study may have been impacted by missing data. Lastly, there is a limitation to generalizability of this study in terms of the location, service provider, sample population and food insecurity assessment tool and measurement. However, findings from this study may be applicable to other hospital and clinic providers in the Portland-Metro area who also use the FWBA assessment questions to measure food insecurity and other social determinants of health variables.

The findings from this study provide critical evidence for Providence Health and Services prenatal clinicians and administrators to integrate intervention strategies that target food insecurity as a way to mitigate the risk of maternal anemia. Another strength of the current study is broader exploration of socio-ecological factors to better understand the ways in which variables of insecurity may be separately or interrelatedly affecting maternal anemia within this population.

Future studies should continue investigating the relationship between food insecurity and maternal anemia to better address the complexity of this public health issue. Future studies should also aim to better understand the potential role of ACEs as an effect modifier within food insecurity and maternal anemia and explore intervention strategies that may have an upstream, life-course approach to reduce adverse childhood events. Finally, future studies should explore

short- and long-term impacts of intervention strategies that are most effective in ameliorating food insecurity and monitor the relative impact on maternal anemia.

Figure 1. Conceptual Model for Determinants of Maternal Anemia

Adapted from the conceptual model from Balarajan et al on the determinants of anemia[22]

Table 1. Selected Characteristics of Participants by Food Security Status

Characteristics	Food Secure (N=981)	Food Insecure (N=165)	Overall (N=1,146)
Age (N, %)			
10-15	2 (0.2%)	0 (0.0%)	2 (0.2%
16-20	43 (4.4%)	24 (14.5%)	71 (5.9%)
21-25	144 (14.7%)	38 (23.0%)	195 (16.1%)
26-30	310 (31.6%)	51 (30.9%)	382 (31.6%)
31-35	315 (32.1%)	36 (21.8%)	369 (30.5%)
36-40	145 (14.8%)	15 (9.1%)	165 (13.6%)
41-45	20 (2.0%)	0 (0.0%)	22 (1.8%)
46-50	2 (0.2%)	1 (0.6%)	3 (0.2%)
Parity (N, %)			
Parous	285 (29.1%)	56 (33.9%)	355 (29.4%)
Nulliparous	514 (52.4%)	70 (42.4%)	609 (50.4%)
Race/Ethnicity (N, %)			
Asian	146 (14.9%)	12 (7.3%)	161 (13.3%)
Black or African American	34 (3.5%)	7 (44.2%)	45 (3.7%)
White or Caucasian	591 (60.2%)	68 (41.2%)	685 (56.7%)
Other	184 (18.8%)	69 (41.8%)	282 (23.3%)
Medicaid or Medicare Coverage (N, %)			
Yes	291 (29.7%)	124 (75.2%)	453 (37.5%)
Relationship Status (N, %)			
I have a partner	252 (25.7%)	67 (40.6%)	337 (27.9%)
Married	651 (66.4%)	60 (36.4%)	744 (61.5%)
Partnered	4 (0.4%)	3 (1.8%)	7 (0.6%)
Single	72 (7.3%)	34 (20.6%)	115 (9.5%)
Planned Pregnancy (N, %)			
Yes	637 (64.9%)	70 (42.4%)	725 (60.0%)
Tobacco Use (N, %)			
Yes	0 (0.0%)	1 (0.6%)	1 (0.1%)
Yes, currently	7 (0.7%)	2 (1.2%)	10 (0.8%)
Yes, but I cut down with pregnancy	23 (2.3%)	18 (10.9%)	44 (3.6%)
Yes, but I stopped a while ago	50 (5.1%)	11 (6.7%)	62 (5.1%)
Yes, but I stopped with pregnancy	50 (5.1%)	19 (11.5%)	71 (5.9%)
No	836 (86.2%)	112 (67.9%)	992 (82.1%)
Education Level (N, %)			
College	414 (42.2%)	37 (22.4%)	461 (38.1%)
Graduate School	195 (19.9%)	9 (5.5%)	206 (17.0%)
Some classes after high school	137 (14.0%)	23 (13.9%)	164 (13.6%)
High school graduation/GED	171 (17.4%)	56 (33.9%)	236 (19.5%)

Less than high school	53 (5.4%)	38 (23.0%)	164 (13.6%)
ACEs (N, %)			
Yes	108 (11.0%)	52 (31.5%)	161 (13.3%)
Housing Insecurity (N, %)			
Every day	4 (0.4%)	12 (7.3%)	18 (1.5%)
Most days	6 (0.6%)	8 (4.8%)	14 (1.2%)
Some days	29 (3.0%)	44 (26.7%)	74 (6.1%)
Never	925 (94.3%)	88 (53.3%)	1017 (84.1%)
Transportation Insecurity (N, %)			
Every day	4 (0.4%)	9 (5.5%)	13 (1.1%)
Most days	19 (1.9%)	19 (11.5%)	38 (3.1%)
Some days	58 (5.9%)	38 (23.0%)	99 (8.2%)
Never	896 (91.3%)	98 (59.4%)	997 (82.5%)
Basic Expenses Coverage Insecurity (N, %)			
Every day	5 (0.5%)	8 (4.8%)	13 (1.1%)
Most days	5 (0.5%)	28 (17.0%)	35 (2.9%)
Some days	67 (6.8%)	87 (52.7%)	156 (12.9%)
Never	903 (92.0%)	40 (24.2%)	946 (78.2%)
Anemia (N, %)			
Yes	323 (32.9%)	80 (48.5%)	431 (35.6%)
No	658 (67.1%)	85 (51.5%)	778 (64.4%)

Table 2. Covariate Definitions and Measurements

Covariate	Measurement Tool	Variable Type	Definition	Response Options
Age	Intake Form	Categorical	Maternal Age	• 10-15 • 16-20 • 21-25 • 26-30 • 31-35 • 36-40 • 41-45 • 46-50
Race and Ethnicity	Intake Form	Categorical	Self-identified maternal race and ethnicity	• White/Caucasian • Black/African American • Asian • Alaska Native/ American Indian • Native Hawaiian/Pacific Islander • Other • Unknown • Refused
Medicaid or Medicare Insurance Status	Intake Form	Categorical	Enrollment in Medicaid or Medicare insurance	• Yes • No
Educational Attainment	Intake Form	Categorical	Assessment question: "What is the highest level of school you completed?"	• College • Graduate School • Some classes after high school • High school graduation or GED • Less than High school
Parity	Intake Form	Categorical	One or more deliveries or No previous deliveries	• Parous • Nulliparous
Relationship Status	Intake Form	Categorical	Marital status at time of intake	• I have a partner • Married • Partnered • Single
Planned Pregnancy	Intake Form	Categorical	Assessment question: "When you got pregnant with this current pregnancy, were you trying to get pregnant?"	• Yes • No
Tobacco Use	Intake Form	Categorical	Assessment question: "Have you used tobacco or nicotine in any form (cigarettes, vaping, chewing, etc.)?"	• Yes • Yes, currently • Yes, but I cut down with pregnancy • Yes, but I stopped a while ago • Yes, but I stopped with pregnancy • No

Table 3. Association between Food Insecurity and Maternal Anemia

Food Security Status	Anemia (Y)[a]	Model 1[b]	Model 2[c]	Model 3[d]
Food Secure (Reference)	323	1	1	1
Food Insecure	80	**1.92 (1.37-2.68)**	**1.75 (1.24-2.45)**	**1.56 (1.08-2.26)**

a. Number of participants that are anemic stratified by the exposure variable
b. Model 1: unadjusted model
c. Model 2: partially adjusted for parity, race/ethnicity, and age
d. Model 3: fully adjusted for age, educational attainment, Medicaid/Medicare status, relationship status, planned pregnancy, tobacco use, parity, and race/ethnicity

Table 4. Associations of food insecurity with maternal anemia among groups stratified by History of ACEs

	History of Adverse Childhood Events		
	Yes	No	P-value[c]
Model 2[a] OR	2.48 (1.26-4.98)	1.47 (0.94-2.27)	0.25
Model 3[b] OR	2.70 (1.29-5.83)	1.20 (0.74-1.91)	0.12

a. Model 2: partially adjusted for parity, race/ethnicity, and age
b. Model 3: fully adjusted for age, educational attainment, Medicaid/Medicare status, relationship status, planned pregnancy, tobacco use, parity, and race/ethnicity
c. P-value for the interaction between ACEs and food insecurity in each of the adjusted models

Table 5. Odds Ratios and 95% Confidence Intervals for Exploratory Aim Variables

		Maternal Anemia		
Housing Security Status	Anemia (Y)[a]	Model 1[b]	Model 2[c]	Model 3[d]
House Secure (Reference)	337	1	1	1
Housing Insecure	58	**1.77 (1.37-2.29)**	**1.70 (1.32-2.22)**	**1.65 (1.25-2.21)**
Transportation Security Status				
Transportation Secure (Reference)	333	1	1	1
Transportation Insecure	71	**1.44 (1.15-1.80)**	**1.38 (1.11-1.73)**	**1.28 (1.11-1.63)**
Basic Expenses Status				
Able to Cover Basic Expenses (Reference)	314	1	1	1
Unable to Cover Basic Expenses	90	**1.44 (1.17-1.79)**	**1.38 (1.12-1.71)**	1.27 (0.99-1.61)

a. Number of participants that are anemic stratified by the exposure variable
b. Model 1: unadjusted model
c. Model 2: partially adjusted for parity, race/ethnicity, and age
d. Model 3: fully adjusted for age, educational attainment, Medicaid/Medicare status, relationship status, planned pregnancy, tobacco use, parity, and race/ethnicity

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Appendix A: Map of Providence Health and Services Prenatal Sites for this study[31]

Appendix B: Literature Review, Study Characteristics and Findings

Study	Design	Population	Exposure	Outcome	Findings
Demetrio et al 2017[12]	Cross-sectional, nested cohort	Brazil, n=245	Food insecurity using North American short-scale food insecurity assessment categorized as either secure or insecure	Anemia, Hb < 11 g/dL Without Anemia, Hb > 11 g/dL	OR= 3.63, 95% CI= 1.77-7.45
Park et al 2014[16]	Cross-sectional	United States, n=1,045	Food insecurity, using NHANES questionnaire responses categorized as secure or insecure	Total Body Iron (TBI) <0 mg/kg, Soluble Transferrin Receptor (sTfR) >4.4 mg/L, or Ferritin <12 mg/L	OR TBI: 1.86, 95%CI (0.75-4.59) OR sTfR: 1.14, 95% CI (0.42-3.10), OR ferritin: 2.90, 95% CI (1.29-6.51)
Ghose et al 2016[24]	Cross-sectional	Bangladesh n=5,666	Food insecurity, using Household Food Insecurity Access Scale, categorized as secure or insecure	Anemic: Hb <11 g/dL or non-anemic: Hb >11 g/dL	OR= 1.571 95% CI: 1.348-1.830
Fischer et al 2014[23]	Cross-sectional	Mexico, n= 725	Household Food Insecurity (HFI), measured by Latin American and Caribbean Food Security Scale, categorized as secure, mild, moderate, severe	Anemic: <11 g/dL, Non-Anemic: > 11 g/dL Stratified by age: 12-20, 21-49	Mild: OR 1.16, 95% CI (0.95-1.41), Moderate: OR 1.33, 95% CI (1.05-1.68), Severe: OR 1.36, 95% CI (1.04-1.77) ORs 30-43% higher for 21-49 adults with moderate/ severe HFI

Laraia et al 2010[25]	Retrospective cohort	North Carolina, US n= 810	Food Insecurity measured by USDA 18-Item Core Food Security Model, categorized as secure, marginally secure, insecure	Multiple outcomes: Gestational weight gain, Hypertension, gestational diabetes, 2nd trimester anemia Anemic: Hb < 10.5 g/dL Non-Anemic: Hb > 10.5 g/dL	Anemia findings: Marginally: OR 1.75, 95% CI (0.85-3.59); Insecure: OR 0.94, 95% CI (0.35-2.50)