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Racial disparities in U.S. maternal influenza vaccine uptake: Results from analysis of Pregnancy Risk Assessment Monitoring System (PRAMS) data, 2012–2015

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ABSTRACT

Background: Pregnant women are at increased risk of hospitalization, serious complications, poor pregnancy outcomes, and mortality from influenza. Prior research suggests that there are racial/ethnic disparities in vaccination coverage and that a healthcare provider vaccination recommendation is associated with significantly higher vaccine uptake than without such a recommendation. The purpose of this study is to examine racial/ethnic disparities in healthcare providers' recommendations for pregnant women to receive the influenza vaccine and in vaccine uptake.

Methods: This cross-sectional population-based study analyzed data from the Centers for Disease Control and Prevention's Pregnancy Risk Assessment Monitoring System (PRAMS) during 2012–2015 (n = 130161). Both healthcare provider recommendation and vaccine uptake were assessed dichotomously. Logistic regression was conducted to ascertain adjusted odds ratios and 95% confidence intervals, controlling for maternal age, marital status, education, prenatal care utilization, and smoking status.

Results: Influenza vaccine uptake during pregnancy ranged from 39.1% among non-Hispanic (NH) Black women to 55.4% among NH Asian women. In the adjusted analysis, NH Black and NH Asian women had 19% (95% CI 0.75–0.86) and 34% (95% CI 0.61–0.72) decreased odds of receiving a provider recommendation for influenza vaccine during pregnancy, respectively, compared to NH White women. For influenza vaccine uptake, NH Black women were 30% less likely (95% CI 0.65–0.74) to receive influenza vaccine during pregnancy compared to NH White women.

Conclusions: Our findings indicate that there are racial/ethnic disparities in healthcare provider recommendation and influenza vaccine uptake among pregnant women in the United States. Targeted efforts toward providers and interventions focusing on pregnant women may be warranted to reduce the disparity.

1. Introduction

As the eighth leading cause of death in the United States [1], influenza (flu) is an important public health concern. Each year, an estimated 12000–56000 influenza-related deaths occur [2]; mortality is difficult to quantify, as not all states require reporting of adult influenza deaths and because many influenza-related deaths occur from complications that present weeks after initial infection [3]. During the 2016–2017 influenza season, approximately 31 million Americans had the flu [4], nearly half of which saw a healthcare provider. Approximately 600000 were hospitalized due to influenza complications [4]. The economic impact is estimated at $11 billion, accounting for both direct medical costs and indirect costs (e.g. lost work days) [5].

Pregnant woman and infants are at elevated risk for complications of influenza [6,7]. Pregnant women are more likely than non-pregnant women to be hospitalized for influenza-related reasons [8]. There is also evidence for increased risk of fetal death [9], preterm birth [9,10], and perinatal mortality [10] among pregnant women who contract influenza. During the first trimester of pregnancy, maternal influenza exposure may increase risk for congenital anomalies [11]. These complications underscore the severity of morbidity and mortality due to influenza in the pregnant population.

Maternal influenza vaccination has benefits not only for pregnant women but also for their unborn children and infants

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[12,13]. For example, evidence indicates that vaccination reduces influenza-related morbidity and hospitalizations among pregnant women [14,15]. Maternal vaccination also has been shown to reduce infant influenza infection [16–19] and is associated with lowered risk of influenza-related morbidity and influenza-related hospitalization among newborns up to six months of age [20,21]. Lastly, a recent RCT provided evidence for a reduction in low birthweight babies born to mothers vaccinated for influenza [17]. The influenza vaccine can be administered throughout pregnancy [22]; if given during the last trimester, it has the potential to confer passive immunity to the newborn [23]. Overall, influenza vaccination is a safe option for pregnant women and does not increase risk for fetal complications [24].

Even though influenza vaccination is recommended for all pregnant women and women who may become pregnant during flu season [22], uptake is suboptimal and below the Healthy People 2020 goal [25]. Just over 33% of pregnant women in the U.S. received an influenza vaccine during the 2016–2017 flu season, with another 16% receiving the vaccine prior to pregnancy [26]. The proportion of pregnant women vaccinated in 2016–2017 was greater in those ≥25 years, with private or military health insurance, at or above the poverty level, or with higher educational attainment. Uptake was lower among Black women, despite similar proportions of women reporting receipt of provider recommendation for vaccination as White women. Unlike previous years, a higher proportion of Hispanic women reported influenza vaccination than non-Hispanic White and Black women [26].

There are a number of facilitators of maternal influenza vaccination uptake, with healthcare provider recommendation as one of the strongest predictors [27–29]. However, in 2016–2017, 20% of women who were pregnant or who could become pregnant during flu season reported that the vaccine was never recommended by their healthcare provider [26]. Other facilitators to vaccination include perceived susceptibility to influenza [27,30], perceived severity of influenza [30], and a desire to protect their unborn child [27].

Despite the racial/ethnic differences in vaccine uptake in recent flu seasons [26], several recent studies found that race/ethnicity was not associated with maternal willingness to get an influenza vaccine [27–29]. Thus, there is a need to better understand racial/ethnic differences in U.S. maternal influenza vaccine uptake and factors contributing to these disparities. To address this gap, a secondary analysis of Pregnancy Risk Assessment Monitoring System (PRAMS) data from 2012 to 2015 was conducted to evaluate the prevalence of maternal influenza vaccination by race and the potential role of provider recommendation.

2. Materials and methods

This cross-sectional study utilized publicly available data from the Pregnancy Risk Assessment Monitoring System (PRAMS), 2012–2015; the dataset was downloaded from the Internet with no additional permissions needed. PRAMS is an ongoing, population-based surveillance survey conducted by the Centers for Disease Control and Prevention (CDC) and state/city/regional health departments. Standardized mail and telephone survey methodology are used to collect information about maternal behaviors and health conditions before, during, and after pregnancy [31]. The survey is conducted in 47 states (all but California, Idaho, and Ohio), Puerto Rico, New York City, the District of Columbia, and Great Plains Tribal Chairmen's Health Board [32] representing 83% of U.S. births [31,32].

PRAMS consists of a core questionnaire administered by all participating states/regions and a second questionnaire that is unique to each participating state/region; the latter can include questions developed and pretested by the CDC or state-specific questions. The core questionnaire addresses major issues related to pregnancy, such as content and source of prenatal care, pregnancy-related morbidity, contraceptive use, and mother's health complications [33]. Each month, participating states use birth certificates to select a stratified random sample of 100–250 women with recent live births. Annual sample size varies by state, ranging from 1000 to more than 3400 women. The first study invitation and survey are mailed 2–4 months after delivery; nonrespondents are followed up first with additional mailings and then by telephone. Completed survey responses are linked to data extracted from the corresponding birth certificate and state vital statistics records. Data are weighted to account for the stratified sampling design and the nonresponse rate [34]. The current analysis used self-reported data from the core questionnaire administered from 2012 to 2015 (n = 137,625).

2.1. Measures

The exposure of interest was maternal race/ethnicity, defined as non-Hispanic (NH) White, NH Black, NH Asian (Chinese, Japanese, Filipino, and other Asian), Hispanic and NH Other (American Indian, Hawaiian, and Other). Outcomes include healthcare provider recommendation for influenza vaccine among pregnant women and influenza vaccine uptake among pregnant women. These were assessed using two questions from the PRMAS core questionnaire*: (Q21) During the 12 months before the delivery of your new baby, did a doctor, nurse, or other health care worker offer you a flu shot or tell you to get one? (Q22) During the 12 months before the delivery of your new baby, did you get a flu shot?* Healthcare provider recommendation and influenza vaccine uptake were measured dichotomously (yes/no).

Covariates of interest were identified based on those demonstrated in past studies to be associated with influenza vaccine uptake or receiving recommendations for vaccination [6–8,12–19]. These covariates included maternal age, marital status, education level, prenatal care utilization, and cigarette use during pregnancy. Maternal age was categorized as ≤17 years, 18–34 years, and ≥35 years. Maternal marital status was dichotomized into married and not married. Maternal education level was categorized into less than high school, high school graduate, some college, and college graduate/above. Prenatal care utilization was based on the Kotelchuck Index, categorized as inadequate, intermediate, adequate, and intensive prenatal care [35]. Cigarette use during pregnancy was dichotomized into mothers who smoked during pregnancy and those who did not.

2.2. Statistical analysis

Differences in sample characteristics by maternal race/ethnicity were assessed by using the Pearson Chi-square test (χ^2) for categorical variables and *t*-test for continuous variables. Multivariable binary logistic regression was performed to estimate the crude and adjusted odds ratios (OR) and associated 95% confidence intervals (CI). To reduce the bias in the parameter estimation, potential confounders were evaluated using the 10% change-in-point-estimate rule [36]. Variables were entered in a backward stepwise manner with the most relevant potential confounders entering the model first following less relevant potential confounders. Relevancy of potential confounders were based on past literature on influenza vaccination. If removing a variable from the model resulted in more than 10% change in the effect of maternal race/ethnicity on the outcomes, then that variable was retained in the final model. To evaluate if maternal age is an effect modifier, the Wald test was used to test if the regression coefficient of the product term of maternal race/ethnicity and maternal age was statistically dif-

ferent from zero. Because a significant interaction effect was detected for both outcomes, provider recommendation for influenza vaccine and influenza vaccine uptake, (interaction term $p < 0.01$) for the product term of maternal race/ethnicity and maternal age, the multivariable models were stratified by age. To generate nationally representative estimates, analyses were weighted and adjusted for clustering data structure using the weighting variables provided in the PRAMS dataset. All tests were two-tailed, and a p–value less than 0.05 was considered significant. All statistical analyses were performed using SAS statistical software v. 9.4.

3. Results

There were a total of 131743 women included in the study; 130161 women for the relationship between race and influenza shot recommendation, and 115775 women for the relationship between race and influenza vaccine uptake during pregnancy. Among the 131743 women included in the study, 51% were NH White, 17% were NH Black, 8% were NH-Asian, 17% were Hispanic, and 8% were NH-other. There were significant differences in distribution of demographics and health behaviors across racial/ethnic groups. Weighted sample characteristics are shown in Table 1. Relative to other racial/ethnic groups, a greater proportion of NH Black women reported their highest level of education as a high school degree. More than half of Asian women reported earning a college degree, the highest proportion of all racial/ethnic groups. While the majority of NH White and Asian women were married (71.5%, 84.2% respectively), the majority of NH Black women were unmarried (70.9%). Less than half of women surveyed received adequate prenatal care (43.5% NH White, 39.2% NH Black, 44.9% Asian), with nearly one in five NH Black women receiving inadequate care (17.7%).

The majority of women surveyed (>75%) received a recommendation for maternal influenza vaccination, regardless of race/ethnicity, but far fewer actually got vaccinated. About half of all NH White, Hispanic, and Asian women (49.8%, 51.5%, and 55.4%, respectively) got vaccinated; less than half of the Black women (39.1%) reported receiving the vaccine. I

After adjustment for mother's age, marital status, education level, prenatal care utilization, and smoking status during pregnancy (Table 2), NH Asian women had a 34% lower odds of having an influenza vaccine recommendation by their healthcare providers compared to NH White women (aOR = 0.66, 95% CI 0.61–0.72), but there were no significant differences in vaccine uptake between these groups. NH Black women had 19% lower odds of having an influenza vaccine recommendation (aOR = 0.81, 95% CI 0.75–0.86) and 30% lower odds of receiving an influenza vaccine during pregnancy (aOR = 0.7, 95% CI 0.65–0.74) relative to NH White women. Though Hispanic ethnicity was not significantly associated with vaccine recommendation, Hispanic women had a 21% higher odds of getting vaccinated (aOR = 1.21, 95% CI 1.13–1.29) relative to their NH White counterparts.

In the adjusted analysis stratified by maternal age (Table 3), race/ethnicity was significantly associated with health care provider recommendation for influenza vaccine for several racial/ethnic groups, with evidence for effect modification by maternal age. Compared to NH White mothers, the odds of provider recommendation for influenza vaccination was increased for mothers in the youngest age category (≤17 years) among all racial/ethnic groups, with findings statistically significant for Hispanic mothers (aOR = 1.61, 95% CI 1.04–2.49). However, among the two older groups of mothers (18–34 years, ≥35 years), there was a significantly decreased odds of influenza vaccine recommendation for Asian and HN Black mothers. Specifically, among mothers aged 18–34 years, Asian and NH Black women had a 35% (aOR = 0.65,

Table 1
Weighted Sample Characteristics by Race/Ethnicity, CDC PRAMS Data 2012–2015 (N = 131,743).

Covariates	Ethnic/Racial Groups					
	NH[a] White N = 66546 (51%)	NH Black N = 22107 (17%)	NH Asian N = 10278 (8%)	Hispanic N = 22638 (17%)	NH Others N = 10174 (8%)	p value[b]
Influenza Vaccine Recommendation						<0.0001
Yes	52975 (80.5)	16526 (76.8)	7805 (77.4)	17278 (78.1)	8112 (81.3)	
Influenza vaccination						<0.0001
Yes	28478 (49.8)	7250 (39.1)	4667 (55.4)	9468 (51.5)	4329 (51.7)	
Maternal smoking Status during pregnancy						<0.0001
Yes	9170 (14.0)	2284 (10.5)	149 (1.5)	899 (4.0)	1635 (17.1)	
Maternal Age						<0.0001
≤17 years	785 (1.2)	780 (3.5)	56 (0.5)	751 (3.3)	343 (3.4)	
18–34 years	55320 (83.1)	18304 (82.8)	7772 (75.6)	18392 (81.2)	8612 (84.6)	
≥35 years	10440 (15.7)	3022 (13.7)	2450 (23.8)	3495 (15.5)	1218 (12.0	
Marital Status						<0.0001
Married	47510 (71.5)	6432 (29.1)	8548 (84.2)	10923 (48.5)	4464 (44.8)	
Not married	18957 (28.5)	15660 (70.9)	1609 (15.8)	11607 (51.5)	5500 (55.2)	
Maternal Education						<0.0001
Less than high school	5333 (8.1)	1646 (16.6)	897 (8.8)	7884 (33.4)	1804 (17.9)	
High school graduate	14313 (21.7)	7232 (33.0)	1508 (14.8)	6305 (28.3)	3057 (30.3)	
Some college	19437 (29.4)	7733 (35.3)	1918 (18.8)	5296 (23.8)	3403 (33.7)	
College graduate	26972 (40.8)	3320 (15.1)	5870 (57.6)	2804 (12.6)	1830 (18.1)	
Prenatal care[c]						<0.0001
Inadequate	5915 (9.2)	3713 (17.7)	1109 (11.2)	3319 (15.2)	1668 (17.0)	
Intermediate	6866 (10.7)	2602 (12.4)	1321 (13.3)	2580 (11.8)	1404 (14.3)	
Adequate	27979 (43.5)	7603 (39.2)	4463 (44.9)	9031 (41.4)	3823 (38.9)	
Intensive	23591 (36.7)	7092 (33.8)	3044 (30.6)	6912 (31.6)	2932 (29.8)	

[a] NH = Non-Hispanic.
[b] p-value was acquired from Chi-square test.
[c] Per the Kotelechuck Index, the levels of prenatal care are based on the ratio of observed to expected prenatal care visits, with inadequate as >50%; intermediate as 50–79%; adequate as 80–109%; and intensive as ≥110%. http://health.utah.gov/opha/IBIShelp/kotelchuck.html.

Table 2
Adjusted odd ratios for the relationship between race/ethnicity and influenza vaccine recommendation by providers and race/ethnicity and influenza vaccine uptake.

Variables	Outcomes	
	Influenza Vaccine Recommendation aOR (95% CI)[a] (p-value)[d]	Influenza Vaccine Uptake aOR (95% CI)[a] (p-value)[d]
Race/Ethnicity[b]		
NH White	Reference	Reference
NH Asian	**0.66 (0.61-0.72) (<0.001)**	0.96 (0.88-1.03)
NH Black	**0.81 (0.75-0.86) (<0.001)**	**0.7 (0.65-0.74) (<0.001)**
Hispanic	1 (0.92-1.08)	**1.21 (1.13-1.29) (<0.001)**
NH Other	1.06 (0.95-1.19)	1.13 (1.03-1.25)
Maternal Age		
18-34 years	Reference	Reference
≤17 years	0.89 (0.75-1.05)	1.05 (0.88-1.26)
≥ 35 years	1.02 (0.96-1.09)	1.06 (1-1.12)
Marital status		
Married	Reference	Reference
Not married	**0.91 (0.86-0.96) (0.001)**	**0.91 (0.87-0.96) (<0.001)**
Maternal smoking status		
Non-Smoker	Reference	Reference
Smoker	0.95 (0.88-1.03)	**0.83 (0.78-0.9) (<0.001)**
Maternal education		
College graduate	Reference	Reference
Less than high school	**0.45 (0.41-0.49) (<0.001)**	**0.51 (0.47-0.55) (<0.001)**
High school graduate	**0.51 (0.48-0.55) (<0.001)**	**0.49 (0.46-0.52) (<0.001)**
Some college	**0.66 (0.62-0.7) (<0.001)**	**0.56 (0.53-0.59) (<0.001)**
Prenatal care[c]		
Adequate	Reference	Reference
Inadequate	**0.75 (0.69-0.8) (<0.001)**	**0.73 (0.68-0.78) (<0.001)**
Intermediate	**0.91 (0.85-0.98) (0.016)**	**0.88 (0.83-0.94) (<0.001)**
Intensive	1.03 (0.98-1.09)	1.04 (1-1.09)

[a] Adjusted for maternal age, marital status, and education; prenatal care utilization; and maternal smoking status during pregnancy; aOR = Adjusted odds ratio; CI = Confidence Interval; Bold results are statistically significant.
[b] NH = Non-Hispanic.
[c] Per the Kotelchuck Index, the levels of prenatal care are based on the ratio of observed to expected prenatal care visits, with inadequate as >50%; intermediate as 50–79%; adequate as 80–109%; and intensive as ≥110%. http://health.utah.gov/opha/IBIShelp/kotelchuck.html.
[d] p-values were provided for all significant ORs.

95% CI 0.59–0.72) and 19% (aOR = 0.81, 95% CI 0.75–0.88) decreased odds of getting an influenza vaccine recommendation, respectively, compared to NH White women. Similarly, among mothers aged ≥ 35 years, Asian and NH Black women had 34% (aOR = 0.66, 95% CI 0.55–0.80) and 29% (aOR = 0.71, 95% CI 0.59–0.84) decreased odds of receiving a recommendation for influenza vaccination by a health care provider compared to NH White women.

After stratifying by age, adjusted odds ratios indicated that with the exception of Asian women, race/ethnicity is significantly associated with influenza vaccine uptake in mothers of all ages (Table 4), with evidence again for age as an effect modifier. With the exception of NH Black women, all racial/ethnic groups had an increased odds of influenza vaccine uptake among the youngest group of mothers (≤17 years), with statistically significant findings for Hispanic and NH Other mothers (aOR = 2.07, 95% CI 1.31–3.27 and aOR = 2.06, 95% CI 1.11–3.80 respectively). Similarly, Hispanic and NH other mothers aged 18 to 34 years also had a significantly higher odds of being vaccinated for influenza during pregnancy than NH White women, although the effect was not as strong as in the youngest group of mothers. Among women 18 years or older, NH Black women were the least likely to get an influenza vaccine during pregnancy. This association was greatest in NH Black mothers aged 35 years and older; these women had a 39% lesser odds of getting the influenza vaccine relative to their NH White counterparts. Among women aged 18 to 34 years, NH Black women were 29% less likely than NH White women to be vaccinated (aOR 0.71, CI 0.66–0.76) while Hispanic and NH Other women were more likely to be vaccinated (22% and 16% increased odds, respectively). In the oldest age group of mothers (those ≥ 35 years), vaccine uptake was equal across all racial/ethnic groups, except that NH Black women had a 39% decreased odds (aOR 0.61, CI 0.52–0.71) of getting vaccinated for influenza during pregnancy compared to NH White women.

4. Discussion

This secondary analysis of PRAMS data found that race/ethnicity were significantly associated with both healthcare provider recommendation for influenza vaccine and receipt of influenza vaccine during pregnancy and that maternal age was an effect modifier of this association. These findings provide additional insight to recent national influenza vaccine surveillance data. Whereas surveillance data indicate that there were no significant differences in influenza vaccine uptake before or during pregnancy by race/ethnicity in 2015–2016 [26], data from past flu seasons found racial disparities in maternal influenza vaccine update [37–39]. These disparities were again seen in the 2016–2017 flu season, where a higher proportion of Hispanic women and a lower proportion of NH Black women reported maternal influenza vaccination relative to their NH White counterparts in 2016–2017; Asian

Table 3
Adjusted odd ratios for the relationship between race/ethnicity and health care provider recommendation for influenza vaccination, stratified by maternal age.

Variables	Influenza Vaccine Recommendation aOR (95% CI)[a] (p-value)[d]					
	≤17 years		18-34 years		≥35 years	
	N (%)[b]	OR (95%CI)	N (%)[b]	OR (95%CI)	N (%)[b]	OR (95%CI)
Race/Ethnicity[c]						
NH White	499 (65.4)	Reference	43822 (80.2)	Reference	8653 (83.7)	Reference
NH Asian	34 (61.8)	1.63 (0.4-6.65)	5862 (76.9)	**0.65 (0.59-0.72) (<0.001)**	1909 (79.0)	**0.66 (0.55-0.8) (<0.001)**
NH Black	513 (68.1)	1.22 (0.82-1.8)	13679 (77)	**0.81 (0.75-0.88) (<0.001)**	2334 (79.0)	**0.71 (0.59-0.84) (<0.001)**
Hispanic	539 (73.7)	**1.61 (1.04-2.49) (0.034)**	14093 (78.3)	1.01 (0.93-1.1)	2646 (77.6)	0.85 (0.7-1.05)
NH Other	237 (70.7)	1.05 (0.59-1.86)	6888 (81.5)	1.12 (0.99-1.26)	987 (82.6)	0.8 (0.58-1.09)

[a] Adjusted for marital status, education, prenatal care utilization, and maternal smoking status during pregnancy; aOR = Adjusted odds ratio; CI = Confidence Interval; Bold results are statistically significant.
[b] N is the number of individuals with vaccine recommendation and % is the percentage of individual with vaccine uptake for the specific race.
[c] NH = Non-Hispanic.
[d] p-values were provided for all significant ORs.

Table 4
Adjusted odd ratios for the relationship between race/ethnicity and influenza vaccine uptake stratified by maternal age.

Variables	Influenza Vaccine Uptake aOR (95% CI)[a] (p-value)[d]					
	≤ 17 years		18–34 years		≥ 35 years	
	N (%)[c]	OR (95%CI)	N (%)[c]	OR (95%CI)	N (%)[c]	OR (95%CI)
Race/Ethnicity[b]						
NH White	231 (34.5)	Reference	23345 (48.8)	Reference	4901 (56.2)	Reference
NH Asian	205 (33.3)	4.21 (0.92-19.33)	3534 (55.1)	0.94 (0.86-1.03)	1117 (57.0)	0.96 (0.81-1.13)
NH Black	16 (34.0)	0.86 (0.56-1.32)	6017 (38.9)	**0.71 (0.66-0.76) (<0.001)**	1028 (42.1)	**0.61 (0.52-0.71) (<0.001)**
Hispanic	300 (52.9)	**2.07 (1.31-3.27) (0.002)**	7743 (51.4)	**1.22 (1.14-1.32) (<0.001)**	1425 (51.4)	1.04 (0.87-1.25)
NH Other	124 (46.1)	**2.06 (1.11-3.8) (0.021)**	3690 (51.7)	**1.16 (1.05-1.28) (0.005**	514 (52.5)	0.87 (0.67-1.13)

[a] Adjusted for marital status, education, prenatal care utilization, and maternal smoking status during pregnancy; aOR = Adjusted odds ratio; CI = Confidence Interval; Bold results are statistically significant.
[b] NH = Non-Hispanic.
[c] N = Number of individuals with vaccine uptake; % = Percentage of individuals with vaccine uptake for the specific race.
[d] p-values were provided for all significant ORs.

women were not examined as a distinct group in these surveillance data [26]. Additionally, for the past few influenza seasons, vaccine uptake has been greater in U.S. mothers aged 35 years and older relative to their younger counterparts, although this trend has not always been statistically significant [26]. To our knowledge, the interaction of age with race/ethnicity as related to maternal influenza vaccine recommendation and uptake has yet to be explored. This analysis of PRAMS data demonstrated that Hispanic women <35 years were significantly more likely than their White counterparts to receive influenza vaccine during pregnancy. This finding was strongest in the youngest stratum of pregnant Hispanic women (those ≤17 years), a finding paralleled in NH Other women. It is acknowledged that stratification by age may have reduced power in this youngest age group due to a smaller sample size. Yet, had the data not be stratified by age, the increased odds of vaccination in these youngest age groups would have been obscured. This finding deserves further investigation; something must be causing these youngest mothers to get the influenza vaccine at a higher rate than other age groups, and understanding what differentiates them from even the older Hispanic and NH Other mothers could help inform interventions that could be used to increase influenza vaccine uptake in the other age groups of pregnant women.

Historically, Blacks are less likely than Whites to get the influenza vaccine [40]. As such, many efforts to understand racial/ethnic disparities in influenza vaccination have focused on facilitators for vaccine uptake among Blacks. Factors associated with increased influenza vaccination in Blacks include greater knowledge about and trust in the vaccine, positive attitudes, and perceived risk for influenza [41]. Access to (or lack thereof) influenza vaccine can contribute to these racial disparities among older adults [42]. However, even after controlling for typical access barriers (e.g. insurance, lack of regular medical care, and not receiving an annual check-up in the past 12 months) in a high-risk group of cancer survivors, Black-White influenza vaccination disparities persisted [43]. Perhaps most important from these findings is that much diversity has emerged in reasons for and against influenza vaccine uptake among Blacks in the U.S., adding to the challenge of developing interventions to address the Black-White disparity [41]. This heterogeneity must be considered when addressing racial disparities in influenza vaccination in the pregnant population as well.

While the aforementioned factors could not be examined in the current analysis due to the fact that they were not assessed in the PRAMS survey or because of missing data (e.g. 19% and 31% of insurance data were missing for influenza vaccine recommendation and uptake, respectively), it is noted that a Black-White disparity in influenza vaccination existed in all age groups except for women 17 years and younger. This may point to different concerns about – or barriers to – influenza vaccine among NH Black mothers based on age, underscoring the heterogeneity of attitudes and barriers seen in the literature. In other words, one intervention to increase influenza vaccine rates may not be equally effective across pregnant Black women of all ages. Thus, additional research is needed to further understand the unique needs of each age group of Black mothers in an effort to develop interventions that can close the gap in influenza vaccine uptake.

Consistent with national data for the 2016–2017 influenza season [26] and with the recent literature [44], this analysis found that influenza vaccine uptake was greater in Hispanic women than NH White women. Although this finding was most pronounced in mothers 17 years and younger, the wide 95% CI for this youngest group suggests imprecision in the estimate, and thus the finding should be interpreted with caution. As noted earlier, though, provider recommendation is one of the strongest predictors of influenza vaccination [27,28,30]. However, national data indicate that younger women are the least likely to have adequate prenatal care in the United States [45]. suggesting that these younger mothers-to-be may have less opportunities for a healthcare provider to recommend the influenza vaccine. Based on this prior research, and as noted earlier, the current finding that the youngest-aged Hispanic mothers in this study had such high rates of vaccine uptake is unexpected. Future studies should examine what is happening within this specific sub-group of women to determine the factors influencing their vaccination decision. This could lead to identification of interventions to help further increase the rate of vaccine uptake in their older counterparts.

Interestingly, although Asian women aged 18 and older had a decreased odds of receiving a recommendation for the influenza vaccine, there were no significant differences in vaccine uptake among Asian women compared to NH White women. This indicates that while Asian women may not be getting a recommendation for the influenza vaccine during pregnancy, they still get the vaccine at a rate comparable to NH White women after accounting for marital status, education, prenatal care, and smoking status during pregnancy. The lack of differences by race/ethnicity in vaccine uptake is consistent with a prior study that examined influenza vaccination in Asian Americans [46]. However, this earlier study did find within-group differences between Asian Indians, Filipino Americans, and Chinese Americans in relation to Whites [46], something that was not possible in this study due to limitations within the PRAMS dataset. Keeping in mind the importance of considering heterogeneity of groups, the current analysis took the prior study one step further in that it considered the role of

maternal age. Yet, even when stratifying by age, there were no differences in vaccine uptake among Asians versus NH Whites in any age group. The current study's findings cannot be compared to national surveillance data, as the national data do not provide subsets of the pregnant Asian population [26], likely due to a small sample size.

Among the strengths of this PRAMS analysis is the population-based nature of the dataset. National influenza surveillance data are drawn from a non-probability sample of women who respond to an Internet survey [26], which may lead to selection bias in the sample. However, PRAMS randomly samples from population-based birth data across the United States and links survey responses to birth certificate and vital statistics data [34]. In this way, PRAMS methodology strengthens generalizability of findings and minimizes recall bias for certain variables (e.g. prenatal care, poor birth outcomes). Any residual measurement error due to self-reported data is likely non-differential, which would bias the effect estimate toward the null value. Our estimated effects of provider recommendation and vaccine uptake in this study may be overestimated; when the outcome is common, the odds ratio may overestimate the relative risk [47]. However, modeling based on Survey command cannot accommodate a modified Poisson regression [48] to avoid the pitfall of using the odds ratio to estimate the risk ratio when the outcome is common. As with all secondary analyses, findings are limited in that the data were originally collected for a purpose other than the primary research question. Specifically, PRAMS focuses on a number of prenatal behaviors and experiences, not just influenza vaccination during pregnancy. Thus the survey did not include specific questions on attitudes towards influenza vaccination, reasons for or against the decision to be vaccinated, and ability to access the vaccine. Thus, it was not possible to explore in depth factors that might affect provider recommendation and vaccine uptake within the age-stratified racial/ethnic groups of pregnant women. However, the findings presented here provide a rationale for pursuing exploration of these avenues in future studies, potentially through mixed-method approaches which would allow for a more in-depth examination of experiences and behaviors than possible through a survey alone.

5. Conclusion

Influenza is a serious public health issue whose impact on the health of pregnant women, their unborn children, and their newborns can be tempered by vaccination. Even though influenza vaccination is safe and recommended for pregnant women, uptake remains low at less than 50% in the United States. Racial/ethnic disparities persist in maternal influenza vaccination, and age is an effect modifier for this association. For those over the age of 18 years and relative to NH White women, NH Black women have the lowest odds for receiving the influenza vaccine prior to or during pregnancy. Conversely, Hispanic women aged 34 years or younger had a significantly higher odds of receiving the influenza vaccine during pregnancy. Interesting, although provider recommendation is often the strongest predictor of maternal influenza vaccination, there were no differences in vaccine uptake among Asian women compared to NH Whites, despite the fact that Asian women 18 years or older had a lower odds of receiving a healthcare provider recommendation for the vaccine. As some age subgroups may be at higher risk for non-vaccination or for non-recommendation than others, maternal age should be considered when providers discuss influenza vaccination with their pregnant patients. Targeting these higher risk subgroups and understanding their reasons for non-vaccination may help to inform interventions that close racial/ethnic gaps in maternal influenza vaccine coverage.

Declarations of interest

LDA owns <$10000 of Merck stock. TR, LL, and JJC have no declarations of interest.

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