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Examining variation within Hispanic ethnicity: An intersectional multilevel analysis of individual heterogeneity and discriminatory accuracy (MAIHDA) of birthweight inequities in New York City, 2012–2019

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ABSTRACT

Birthweight inequities in the United States have been persistent with variations observed across maternal age, race/ethnicity, education, and nativity status. However, the Hispanic/Latino population is often treated as a monolithic category, ignoring within-group diversity and heterogeneity of health outcomes. This study employed an intersectional MAIHDA (multilevel analysis of individual heterogeneity and discriminatory accuracy) to examine birthweight inequities among singleton births in New York City from 2012 to 2019 (n = 819,920 records of singleton births) by maternal age, race/ethnicity, education, and nativity status, with particular attention to within-group heterogeneity among Hispanic/Latino mothers. Birthweight was measured in grams and was considered continuous for analytical purposes. The analysis was conducted using both the aggregate "Hispanic" category and disaggregated into Hispanic subgroups, based on the country/region of birth as part of the racial/ethnic categories. We found that 2.7%–3.2% of the variation in birthweight means among NYC women lies between intersectional strata, suggesting both meaningful between-stratum birthweight inequities and a high-degree of between-person birthweight variation. The finding of between-stratum inequities is consistent with a difference of 384.7g. between strata with the highest and lowest predicted birthweight means. We found consistent additive inequity patterns in birthweight by maternal age, race/ethnicity, educational attainment, and nativity status. The latter explained 81.2% of the variation in birthweight inequities. While attention to subgroup differences is often limited by sample size, intersectional MAIHDA allows for the identification of between- and within-strata variations regardless of whether Hispanic ethnicity was treated as an aggregate or subgroup based on country/region of origin.

1. Introduction

Birthweight is an important indicator of infant health and well-being ("The Global Health Observatory. Low birtweight number 2020. World Health Organization, Geneva," 2023). In the United States (U.S.), birthweight inequities are consistently patterned by maternal age, race/ethnicity, education, and nativity status. For example, there is a U-shaped relationship between maternal age and low birthweight, with younger (<19 years of age) and older (≥40 years) women being more likely to have low birthweight infants (<2500 g) than women aged 20–39 years (Osterman et al., 2024). Moreover, birthweight inequities by maternal race/ethnicity have been pervasive in the U.S. for years. Data from 2022 show that non-Hispanic Black or African American women are more likely to have low birthweight infants (14.7%) than non-Hispanic white women (7.1%), whereas Hispanic/Latino (7.9%) and Asian (9.4%) women have infants with birthweight closer to non-Hispanic white women (Osterman et al., 2024).

While data on birthweight by maternal education are not widely available in the U.S., infants of mothers with higher education (4.6%) are less likely to be of low birthweight than infants of mothers with less than a high school education (7.3%), regardless of maternal race/ethnicity (Pollock et al., 2021). However, this pattern was less notable

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among Hispanic mothers. Similarly, evidence suggests that foreign-born women are less likely to have infants with low birthweights than their U.S.-born counterparts, regardless of race/ethnicity (Acevedo-Garcia et al., 2005, 2007; Almeida et al., 2014; Andrasfay & Goldman, 2020; Driscoll, 2023; Singh & Yu, 1996). For instance, among Hispanics/Latinos, foreign-born women (7.4%) are less likely to have low birthweight babies than their U.S.-born counterparts (8.1%), regardless of country of origin (Driscoll, 2023). Notably, the effects of these maternal characteristics are often examined together or combined through interactions. For example, the joint effects of maternal nativity and educational attainment can differ by race/ethnicity, with Hispanic foreign-born women with less than a high school education having better birthweight outcomes than non-Hispanic Black and white women with similar or higher education, regardless of nativity status (Acevedo-Garcia et al., 2005). Thus, given that these characteristics capture the embodiment of social exposures (Krieger, 2024), patterned along a matrix of dominance represented by the intersecting effects of systems of marginalization, oppression, and socioeconomic inequality (Collins, 1999; Crenshaw, 1989, pp. 139–167), it is imperative to continue examining birthweight inequities using an intersectional approach (Evans et al., 2023; Nieves et al., 2023).

Despite growing interest in racial/ethnic health inequities, research tends to focus on the broad U.S. Census categories, ignoring within-category differences, and heterogeneity of health outcomes. For instance, a few studies have considered variations in the risk of low birthweight among subgroups of Hispanic/Latino women (Borrell et al., 2022; Montoya-Williams et al., 2021; Sanchez-Vaznaugh et al., 2016; Stein et al., 2009). Instead, the 'Hispanic/Latino' population is typically treated as an aggregate homogenous category, leading to the "Hispanic Paradox" findings (Borrell & Markides, 2024; Markides & Coreil, 1986), where birth outcomes are similar to or better than those observed among non-Hispanic white women, despite their low socioeconomic indicators and access to healthcare. This approach pays little attention to within-group heterogeneity in low birthweight, for which women from Central and South America (7.3%), Mexico (7.7%), and Cuba (7.5%) had better outcomes than those from the Dominican Republic (8.9%) and Puerto Rico (9.9%) in the U.S. (Osterman et al., 2024). Moreover, Borrell et al. showed similar patterns in New York City (NYC), with Hispanic women as an aggregate having the same risk of low birthweight as non-Hispanic women (6.2%) (Borrell et al., 2022). However, when disaggregating NYC Hispanic women by country/region of origin, the risk of low birthweight ranges from 4.6% in South American women to 8.1% in Puerto Rican women (Borrell et al., 2022). Thus, using aggregate data is problematic for understanding health inequities because it perpetuates the "Hispanic Paradox" and assumes that individuals self-identified with a broad racial/ethnic category have similar disease risks. Additionally, such aggregation ignores variations in important characteristics such as age, education, and nativity status, which may affect birthweight differently in subgroups and may be missed in the overall group. These variations and differences can be better captured with an intersectional approach capable of handling high-degree of interactions between several social identities that affect birthweight outcomes.

Using birth records for singleton infants born to women residing in NYC from 2012 to 2019, we examined the intersectional birthweight inequities by maternal age, race/ethnicity, education, and nativity status with particular attention to within-group diversity in Hispanic mothers. To capture the interactions across various intersecting maternal characteristics of interest while obtaining robust estimates, we used intersectional MAIHDA (multilevel analysis of individual heterogeneity and discriminatory accuracy), an approach that provides more robust estimates than conventional single-level models, even when sample sizes are smaller – allowing greater disaggregation of our sample (Evans et al., 2018, 2024b). To tease out inequities, we conducted our intersectional analysis in two ways: using Hispanic as a broad category and disaggregating it into subgroups. Specifically, we investigate: 1) How using the aggregate "Hispanic" category versus Hispanic subgroups (defined using country/region of birth) affects the observed racial/ethnic birthweight inequities and potentially hides subgroup inequities, and 2) How the inequities observe among Hispanics and Hispanic subgroups are patterned intersectionally by maternal age, education, and nativity status. Therefore, we used intersectional MAIHDA to identify racial/ethnic inequities that are not possible using conventional analytical approaches.

2. Methods

2.1. Data sources

We used the composite birth and infant death files for years 2012–2019 provided by the Bureau of Vital Statistics of the NYC Department of Health and Mental Hygiene (DOHMH). Birth data were collected following the U.S. Centers for Disease Control and Prevention guidelines and include maternal and infant information for 99% of all births registered in NYC for the years considered in the analyses (Li et al., 2021). The data yielded 832,349 records of singleton births from women residing in NYC between January 1, 2012, and December 31, 2019.

2.2. Outcome

Birthweight was measured in grams and was considered continuous for analytical purposes.

2.3. Exposure

We defined intersectional strata as a combination of four dimensions of maternal social identity and position: age group, race/ethnicity, educational attainment, and nativity status. Maternal age was collected in years. To capture biological differences and social experiences over the life course (Deal et al., 2014; Geronimus, 1992), age was categorized as follows: 1) 14–19, 2) 20–29, 3) 30–39, and 4) 40–55 years of age. According to the U.S. Census Office of Management and Budget categories (Humes et al., 2011), maternal race/ethnicity was recorded in the birth certificates using two self-reported questions, one for race and one for ethnicity. Using the responses to these questions, maternal race/ethnicity was specified as follows: 1) non-Hispanic white, 2) non-Hispanic Black, 3) Asian/Native Hawaiian and Pacific Islander, 4) Other non-Hispanic including American Indian and Alaska Native, some other race alone, and one or two more races, and 5) Hispanic or Latino (hereafter referred to as white, Black, Asian, other non-Hispanic, and Hispanic). When the Hispanic category was disaggregated into country/region of origin, the following categories were used: 1) Mexican American, 2) Puerto Rican, 3) Cuban, 4) Central American, 5) South American, 6) Dominican, 7) other Hispanic, 8) white, 9) Black, 10) Asian, and 11) other non-Hispanic, including women from Spain.

Maternal education was self-reported and collected using the following categories: 8th grade or less/None, 9th-12th grade/No diploma, high school (HS) graduate or GED, some college credit but no degree, associate's degree, bachelor's degree, master's degree, doctorate, or professional degree. Maternal education was categorized as follows: 1) less than HS diploma, 2) HS diploma/some college (but no degree), and 3) college degree or higher (including an associate's degree). Finally, maternal nativity status or country of birth was collected using the following categories: NYC, NY state outside of NYC, U.S. outside of NY state, or Other. Women were classified as 1) U.S.-born if they identified their birthplace as NYC, NY State outside NYC, or U.S. outside NYC (including Puerto Rico), and 0) foreign-born if they reported their place of birth as Other. However, while people from Puerto Rico are U.S. citizens, many tend to identify as foreign-born in the U.S. because of their distinct culture and immigration history (Rivera Pichardo et al., 2021; Thomas, 2015).

The combination of age group, race/ethnicity, education, and nativity status resulted in 120 strata when the Hispanic category was used as an aggregate category, and 264 strata when the Hispanic category was disaggregated into subgroups. However, because of missing values, we ended up with 118 and 257 strata, respectively. Each stratum was assigned a unique identifier (ID), including four digits when the Hispanic category was used and five digits when the Hispanic subgroups were considered in the analyses. Each digit of the strata ID represents one of the four axes considered for the social strata definition (first digit = age group; second digit = race/ethnicity; third digit = education; and fourth digit = nativity status), using the coding associated with each variable above. For example, ID 2311 corresponds to women aged 20–29 years (age group = 2), Asian (race/ethnicity = 3), with less than a high school diploma (education = 1), who were born in the U.S. (nativity status = 1).

Of the 832,349 records for singleton births from women aged 14–55 years residing in NYC between 2012 and 2019, we excluded records of births with congenital malformations (n = 8093); births with weight less than 250 g or greater than 6000 g, or a gestational age less than 22 and greater than 42 weeks (n = 470); infants born dead (n = 701); and missing information on race and ethnicity (n = 920), education (n = 2114), and nativity status (n = 131). These exclusions resulted in an analytical sample size of 819,920 records.

2.4. Statistical analysis

Descriptive statistics were presented for the maternal characteristics considered in the definitions of the social strata. Specifically, we calculated the means and standard deviations (SD) for continuous variables, and frequencies and percentages (%) for categorical variables. We also calculated the numbers and percentages of intersectional strata according to the study population distribution.

To address our aims, we used intersectional MAIHDA (Evans et al., 2018, 2024a) to evaluate inequities between strata in which Hispanic was treated as an aggregate category (Model 1s) and disaggregated into subgroups (Model 2s). Following the MAIHDA method (Evans et al., 2024a), we fitted two versions of each model: An empty or "null" random intercept model with individual observations at level 1 clustered within intersectional strata at level 2 (Model A), and a random intercept model with the additive fixed effects but no fixed interaction terms (the "main effects" (ME) model, or Model B).

The null model provides an estimate of the total between-stratum variance in birthweight σ_u^2 (and thus, a measure of between-stratum inequity). To standardize this value against the total variation in the sample (the sum of level 1 between-individual variance σ_e^2 and level 2 between-stratum variance σ_u^2), we calculated the Variance Partition Coefficient (VPC), defined as the proportion of the total variance corresponding to level 2, or the between-stratum variance out of the total variance. The VPC was calculated as follows: $VPC = \sigma_u^2 / (\sigma_u^2 + \sigma_e^2)$.

The ME model included the set of variables used to define intersectional strata (i.e., age group, race/ethnicity, educational attainment, and nativity status) as level 2 fixed effects. The ME model has two key uses (Evans et al., 2024a). First, to generate final predicted values for all strata, leveraging the advantages of multilevel models to produce more reliable and stable estimates for strata even when sample sizes are small within strata (Bell et al., 2019; Evans et al., 2018; Mahendran et al., 2022). With these predicted estimates, we examined racial/ethnic inequities in birthweight associated with maternal age, educational attainment, and nativity status. And second, to determine the degree to which between-stratum inequities are patterned additively (that is, following consistent patterns) or with interactions (therefore, requiring specificity when describing inequity patterns). We calculated the Proportional Change in Variance (PCV), which estimates the change in between-stratum variance (level 2) from model A to model B for the Hispanic and Hispanic subgroup categories, respectively, and thus, the extent to which between-stratum variance is accounted for by additive main effects. The PCV was calculated as follows: $PCV = \left(\sigma^2_{u,ModelA} - \sigma^2_{u,ModelB}\right) / \sigma^2_{u,ModelA.}$

Data management and statistical analyses were conducted using SAS

Table 1
Descriptive statistics for women who gave a singleton birth in New York City: 2012–2019

Characteristics	N (%)	Birthweight (g), Mean (SD)
Total Sample	819,920 (100)	3266.1 (534.4)
Strata Dimensions		
Age Group (years)		
14–19	29,526 (3.6)	3149.9 (521.8)
20–29	348,642 (42.5)	3249.3 (520.8)
30–39	397,467 (48.5)	3290.6 (539.7)
40–55	44,285 (5.4)	3255.2 (582.3)
Race/Ethnicity		
Non-Hispanic white	258,524 (31.5)	3355.1 (491.0)
Non-Hispanic Black	161,072 (19.6)	3169.2 (597.9)
Asian/Native Hawaiian & Other Pacific Islander	141,020 (17.2)	3196.4 (489.2)
Other non-Hispanic	10,912 (1.3)	3244.7 (554.0)
Hispanic/Latino (Aggregate)	248,392 (30.3)	3276.7 (542.7)
Subgroups[a]:		
Mexican American	44,685 (18.0)	3292.9 (511.2)
Puerto Rican	51,509 (20.7)	3223.6 (571.8)
Cuban	1942 (0.8)	3284.2 (542.5)
Dominican	79,633 (32.1)	3284.1 (548.3)
Central American	22,109 (8.9)	3263.0 (539.2)
South American	37,575 (15.1)	3332.8 (507.6)
Other Hispanic	10,939 (4.4)	3239.0 (561.8)
Education		
Less than high school (HS) diploma	158,530 (19.3)	3235.7 (542.8)
HS diploma/some college (no degree)	316,920 (38.7)	3254.2 (546.2)
College degree or higher	344,461 (42.0)	3290.9 (518.2)
Nativity Status		
Foreign-born	433,129 (52.8)	3267.5 (525.2)
U.S.-born	386,791 (47.2)	3264.4 (544.6)

[a] Subgroup percent refers to percent of the aggregate Hispanic/Latino group sample (n = 248,392).

Table 2
Sample size of social strata defined as a combination of maternal age group, race/ethnicity, education, and nativity status including Hispanic as aggregate (N = 118) and as subgroups as indicated by country/region of origin (n = 257).

	Hispanic/Latino as an aggregate category		Hispanic/Latino subgroups	
Sample size	Number of Strata (n = 118)	% of Strata	Number of Strata (n = 257)	% of Strata
1–50	13	11.0	51	19.8
51–100	4	3.4	12	4.7
101–500	18	15.2	58	22.6
501 - 1000	12	10.2	36	14.0
1001–5000	32	27.1	56	21.8
5001–10,000	10	8.5	21	8.2
10,001–78,165	29	24.6	23	8.9

9.4 for Windows.

3. Results

Table 1 presents the distribution of the characteristics of NYC women and their birthweight means. Among women who gave birth to singletons in NYC from 2012 to 2019, 91% were aged 20–39 years, 31.5% were white, 80.7% had at least a high school education, and 52.8% were foreign-born. Hispanic women accounted for 30.3% of the sample, with most identifying as Dominican (32.1%) or Puerto Rican (20.7%), and the least as Cuban (0.8%). Among NYC women, the birthweight mean was 3266.1 g (g, SD = 534.4), with lower means observed among teen mothers aged 14–19 years (3149.9g, SD = 521.8), Black women (3169.2g, SD = 597.9), those with less than a high school diploma (3235.7g, SD = 542.8), and U.S.-born women (3264.4g, SD = 544.6). In contrast, the higher birthweight means were observed for women aged 30–39 years (3290.6g, SD = 539.7), white women (3355.1g, SD = 491.0), and those with a college degree or higher (3290.9g, SD = 518.2). Among Hispanic women, Puerto Rican women had the lowest mean birthweight (3223.6g, SD = 571.8), while South American women had the highest (3332.8g, SD = 507.6).

Using the Hispanic aggregate category for the intersectional strata (n = 118 strata), the sample sizes ranged from 6 to 78,023, with 11% having fewer than 50 observations. When considering Hispanic subgroups, the sample sizes for the strata (n = 257) ranged from 1 to 78,023, with 19.8% having fewer than 50 observations (Table 2).

Table 3 displays the results of the MAIHDA models. The VPC in the null model with Hispanic as an aggregate category for race/ethnicity (Model 1A) indicated that 3.2% of the total variation in birthweight means among NYC women lies between the intersectional strata. The model including the additive main fixed effects explained 81.2% of the variance between strata, reducing the VPC to 0.6% (Model 1B). The remaining 19% of between-stratum variance suggests that interactions are necessary to fully characterize inequities and that some strata have predicted birthweight means that deviate meaningfully from the 'universal' or general inequity patterns predicted by the additive fixed effects. Model 1B or the ME model also shows that, on average, teen women aged 14–19 years had infants with birthweights 92.1g lower than those of women aged 20–29 years.

Compared with infants of white women, infants of Black women had the greatest decrease in birthweight (179.3g), while Hispanic women had the smallest decrease (71.7g). Infants of Asian (166.9g) and other non-Hispanic (131.3g) women also had lower birthweight means on average than white women. Higher education levels were associated with increased birthweight means, with a high school and college degree or higher being associated with increases of 26.9g and 44.6g, respectively, relative to having less than a high school education. Foreign-born women had infants with an average birthweight of 30.0g higher than that of U.S.-born women. Fig. 1a shows the predicted mean birthweights

Table 3
Estimates from multilevel models of infant birthweight among women who gave a singleton birth in NYC from 2012 to 2019.

	Hispanic/Latino Aggregate		Hispanic/Latino Subgroups	
	Model 1A	Model 1B	Model 2A	Model 2B
Intercept	3211.3 (3192.8, 3229.7)	3293.6 (3266.3, 3321.0)	3231.1 (3219.2, 3242.9)	3299.4 (3278.5, 3320.3)
Age Group (Ref: 20–29)				
14–19		−92.1 (−119.1, −65.2)		−81.4 (−99.2, −63.5)
30–39		37.8 (15.6, 60.1)		29.6 (15.4, 43.8)
40–55		−12.5 (−36.3, 11.3)		−16.9 (−33.5, −0.37)
Race/Ethnicity (Ref: Non-Hispanic white)				
Non-Hispanic Black		−179.3 (−204.9, −153.7)		−179.7 (−202.2, −157.1)
Asian/Native Hawaiian & Other Pacific Islander		−166.9 (−194.2, −139.5)		−166.2 (−190.4, −142.1)
Other non-Hispanic		−131.3 (−161.0, −102.7)		−128.8 (−155.4, −102.2)
Hispanic/Latino		−71.7 (−97.2, −46.3)		
Subgroups				
Mexican American				−45.9 (−70.2, −21.6)
Puerto Rican				−105.4 (−132.0, −78.8)
Cuban				−62.5 (−99.7, −25.2)
Dominican				−73.5 (−96.8, −50.2)
Central American				−92.3 (−117,5, −67.1)
South American				−20.1 (−44.2, 4.0)
Other Hispanic				−97.0 (−124.3, −69.7)
Education (Ref: Less than high school)				
High school diploma/some college (no degree)		26.9 (6.0, 47.7)		20.8 (7.0, 34.6)
College degree or higher		44.6 (22.4, 66.7)		41.9 (27.0, 56.8)
Nativity Status (Ref: U.S.-born)				
Foreign-born		30.0 (12.7, 47.3)		28.6 (16.7, 40.5)
Random Effects				
Strata-level Variance (σ_u^2)	9184.84	1729.02	7401.26	1326.02
Individual-level Variance (σ_e^2)	278802	278804	278621	278632
Summary Statistics				
Variance Partition Coefficient (%)	3.2	0.6	2.7	0.5
Proportional Change in Variance (%)		81.2		82.1

NOTE: Models 1A and 2A are the empty or null models whereas Models 1B and 2B include the main additive effects or the components of the intersectional social strata.

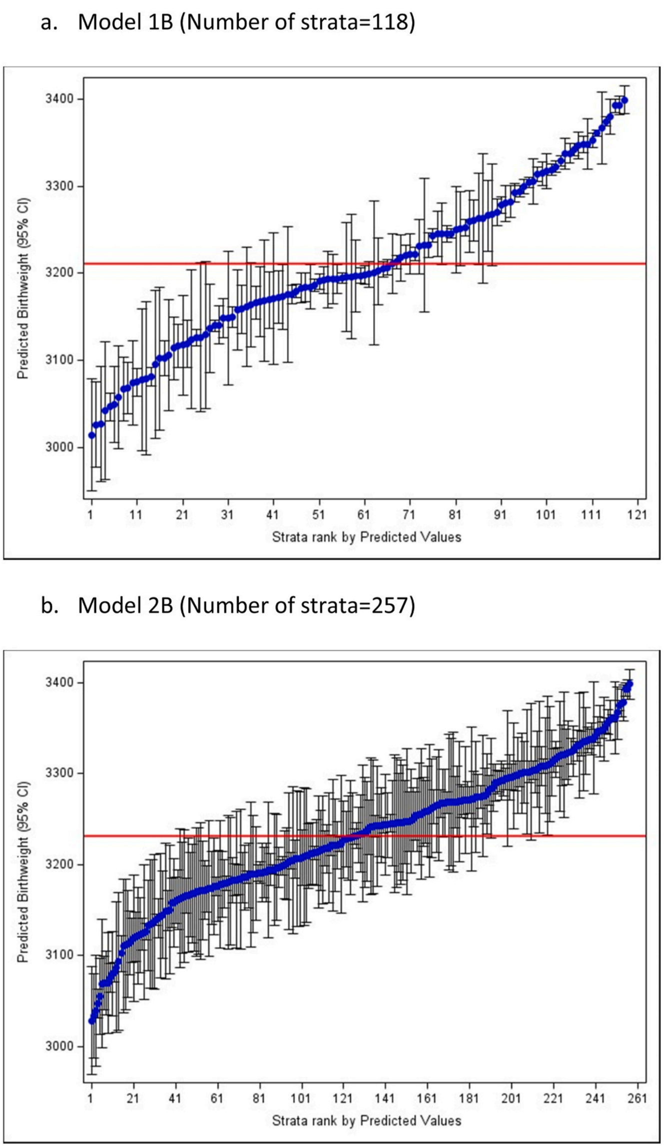

Fig. 1. Predicted values of birthweight rank by strata for women who gave a singleton birth in New York City: 2012-2019
NOTE: The horizontal red line is the intercepts from Model 1A (3211.3) and Model 2A (3231.1).

by strata, ranked from low to high. In 55.9% of the strata (66 out of 118), the mean infant birthweight falls below the overall predicted mean of 3211.3g from Model 1A. Table S1 highlights inequities across strata, showing the five lowest and five highest predicted birthweight means.

Models 2A and 2B include Hispanic subgroups instead of the aggregate Hispanic category as part of race/ethnicity. The VPC in Model 2A was slightly lower than that in Model 1A (2.7% vs. 3.2%), whereas the PCV was slightly higher (82.1% vs. 81.2%). As expected, the additive patterns of birthweight inequity by maternal age, education, and nativity status, as well as for infants of Black, Asian, and other non-Hispanic women, remain consistent with those for Model 1B, using the aggregate Hispanic category. However, examination of Hispanic subgroups revealed significant birthweight variations. For instance, in additive terms, infants of South American women had birthweight means similar to those of white infants, while Puerto Rican infants had the lowest mean birthweight (105.4g) and Mexican American infants had the closest mean birthweight (45.9g) to white infants. Fig. 1b shows the final birthweight predictions of all 257 strata, ranked low to high, inclusive of the interaction effects. Comparing Fig. 1a and b, we see that the range (min/max) of the predicted birthweight means are similar. However, when Hispanic subgroups were included, the ranked caterpillar plot shape changed to one with more pronounced tails, particularly with a significant drop in the predicted mean values at the low end of the distribution. For detailed stratum-specific results for the five lowest and five highest predicted birthweight means, see Table S2.

Fig. 2 presents the predicted birthweights for all strata, highlighting specific intersectional inequity patterns. Predicted values for non-Hispanic strata and the Hispanic aggregate category (Model 1B) are shown in Fig. 2a, while the Hispanic aggregate category and Hispanic subgroups (Model 2B) are shown in Fig. 2b. These predicted values are shown side-by-side to 1) visually compare predictions for the Hispanic aggregate with other racial/ethnic groups and 2) illustrate the distinct patterns among Hispanic subgroups relative to the Hispanic aggregate category. The predictions for all the strata combined are shown in Fig. S1.

Among U.S.-born women, infants of white women generally have the highest mean birthweight, although this mean is lower for those with a college degree or higher (Fig. 2a). Infants of teen women aged 14–19 years exhibited the lowest mean birthweight, whereas those of women aged 30–39 years showed the highest mean birthweight. Infants of Black women frequently had the lowest birthweight means, regardless of educational attainment, with the lowest observed in women aged 40–55 years with less than a high school education. Infants of Asian women also showed lower means than infants of white women, particularly among teen women aged 14–19 years, irrespective of education.

Relative to infants of Black and Asian mothers, infants of Hispanic women had birthweights closer to those of white women, though still 71.7g lighter on average, regardless of nativity status. However, the intersectional results disaggregated by Hispanic subgroups provide insights into Hispanic birthweight inequities. For instance, among the six Hispanic subgroups, infants of South American and Mexican American women had the highest mean birthweights, whereas infants from Central American and Puerto Rican women had the lowest means (Fig. 2b).

Overall, foreign-born women exhibited less pronounced racial/ethnic birthweight inequities than U.S.-born women (Fig. S1), although this may be driven by inequities among infants of white, Black, and Asian women. While Black women's infants had lower birthweight means than those of white women regardless of age, education, and nativity status, their infants' birthweight means were higher among foreign-born women than among U.S.-born women. Similarly, infants of Hispanic women had higher birthweight means than infants of their U.S.-born counterparts, regardless of age and education, although Puerto Rican women with less than a high school education had the lowest birthweight means among Hispanic women. Moreover, among U.S.-born mothers older than 20 years with less than a high school education, infants of white mothers had a substantially higher mean birthweight than those of South American mothers, whereas this was reversed among some other strata (i.e., foreign-born with less than high school education).

4. Discussion

Consistent with previous studies (Evans et al., 2023, 2024a; Nieves et al., 2023), we found that 2.7%–3.2% of the variation in birthweight means among NYC women lies between intersectional strata, and the difference between strata with the highest and lowest predicted birthweight means was 384.7g. While a VPC of ~3% appears modest, this is expected in models of outcomes with large between-person (level 1) variation, such as birthweight, even in the presence of significant between-stratum inequities. The observed between-stratum difference in predicted birthweight means supports this interpretation, as 384g. is not only clinically meaningful but also a significant inequity *average* difference. As a point of reference, this difference is consistent and larger than the average birthweight difference observed among women who smoked during pregnacy relative to those who never smoked (~160g.

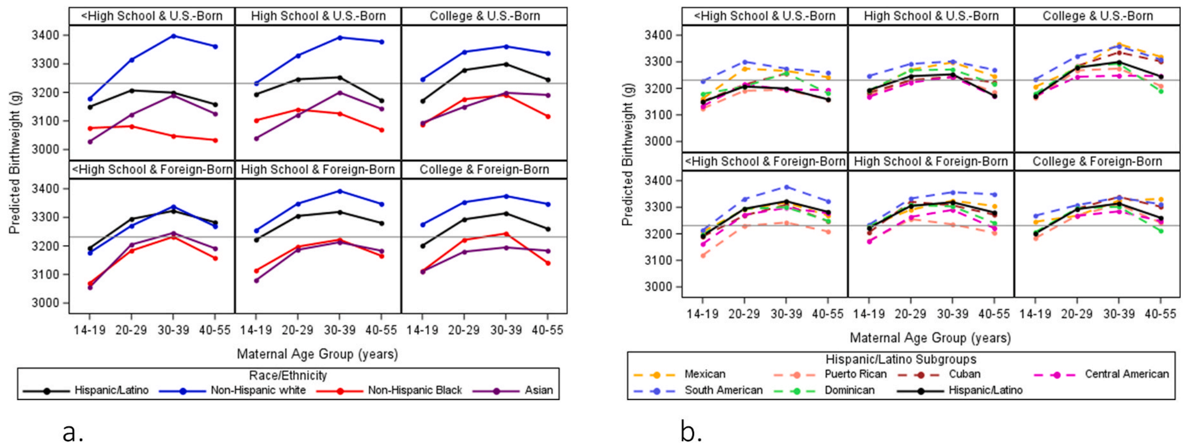

Fig. 2. Predicted birthweight means by maternal age, race/ethnicity, education, and nativity status, for women who gave a singleton birth in New York City: 2012-2019
NOTE: The horizontal gray line is the intercept from Model 2A (3231.1).

and 240g.) (Berlin et al., 2017; Gunther et al., 2021) Together, these findings suggest that there are meaningful between-stratum birthweight inequities and a high degree of between-person birthweight variation (level 1). Of the between-stratum inequities, most inequities were patterned in consistent additive ways by maternal age, race/ethnicity, educational attainment, and nativity status (PCV: 81.2%–82.1%). Therefore, approximately 18% of birthweight inequities remain unexplained by these factors, suggesting that interactions are necessary to fully characterize birthweight inequities. However, additive patterns emerged in our findings, showing that, on average, teen women aged 14–19 years had infants with lower birthweights than those aged 20–29 years. Compared with infants of white women, infants of Black women had the greatest decrease in birthweight, while infants of Hispanic women as a group had the smallest decrease. Higher education levels were associated with increased birthweights, while foreign-born women had infants with an average birthweight higher than that of U.S.-born women.

Notably, examination of Hispanic subgroups revealed significant birthweight variations by maternal country/region of origin, supporting the need for disaggregation of the Hispanic category in future studies. Specifically, infants of women from Puerto Rico had the lowest birthweight means whereas those from Mexican American women had similar birthweight means to infants of white women. Moreover, Cuban, Dominican, and other Hispanic women (i.e., women from Spain) had infants with lower birthweight means than white women. Finally, when holding age, education, and nativity status constant, there was great variation in birthweight means among women from Hispanic subgroups. For example, among foreign-born college graduate Hispanic women aged 30–39, the difference in birthweight means between an infant of Cuban women and an infant of Central American women was 54.4g. Among U.S.-born women of the same age and education level, the difference in birthweight means between infants of Mexican American and Central American women was 119.1g. This difference is lost if Hispanic women are compared by nativity status (3361g for U.S.-born vs. 3374.6g for foreign-born).

Our findings regarding the associations between the main additive effects (i.e., maternal age, race/ethnicity, education, and nativity status) and birthweight are consistent with those of previous studies that have focused on these characteristics independently or jointly (i.e., age, education, and nativity status with race/ethnicity). For instance, maternal age has been found to influence birthweight outcomes, with older maternal ages associated with higher probabilities of low birthweight regardless of race/ethnicity. However, these associations were stronger among U.S.-born women than among foreign-born women across various racial/ethnic-nativity status groups (Fishman, 2020). Race/ethnicity also plays a significant role, as infants of non-Hispanic Black women had lower mean birthweights than those of non-Hispanic white and Hispanic women (Swamy et al., 2012). However, non-Hispanic Black and white women aged 35 or older tend to have infants with lower mean birthweights than their younger counterparts (de Jongh et al., 2015; Swamy et al., 2012). This pattern was observed in Hispanic women aged 25 years (Swamy et al., 2012). Additionally, while foreign-born status seems to be associated with better birthweight means, this protective effect seems to be different across racial/ethnic groups: Infants from Black, Asian and Hispanic women are less likely to have low birthweight than those of their U. S.-born counterparts. However, when educational attainment was considered, the protective effect of being foreign-born was stronger among white, Black, and Hispanic women with less than a high school education than among those with a high school or higher education (Acevedo-Garcia et al., 2005). A similar pattern has been observed among Hispanic subgroups, where the protective effect of being a foreign-born woman was observed for Mexican Americans but not for Puerto Rican, Cuban, or Central/South American women. However, the protective effect of foreign-born status was stronger among Mexican and Central/South American women with low education (i.e., 0–11 and 12 years of education) than among women with higher education (i.e., 13–15 and 16+ years of education) (Acevedo-Garcia et al., 2007).

When we examined racial/ethnic birthweight inequities across maternal age, education, and nativity status, foreign-born women exhibited less pronounced birthweight inequities regardless of age and education. However, the greatest inequity in birthweight means was observed between foreign- and U.S.-born Black women. The findings for Black women are somewhat consistent with the "Weathering" hypothesis which posits that cumulative exposure to social, economic, and structural stressors such as racism and socioeconomic inequalities accelerates biological aging and deteriorates health (Geronimus, 1992). We found that Black women have infants with lower birthweight means than white women, regardless of age, education, and nativity status. However, a direct relationship between maternal age and birthweight means was observed only among Black women with less than high school education. Moreover, and related to structural racism and socioeconomic inequalities, our findings for Black women are consistent with the "Diminishing Returns" hypothesis, whereas Black people have progressively lower health benefits at each level of education than their white counterparts do (Farmer & Ferraro, 2005). We observed lower birthweight means in infants of Black women than in infants of white women at each level of education, regardless of age and nativity status. These findings highlight how the compounding effects of structural racism lead to poor birthweight outcomes among Black women, supporting the need for an intersectional approach such as MAIHDA to address birthweight inequities. To that end, our study makes two contributions: First, our findings underscore how systems of oppression/-privilege such as racism and xenophobia may act as a matrix of dominance (Collins, 1999) to create and perpetuate health inequities; and second, they call attention to the danger of assuming homogeneity when using the U.S. Census racial/ethnic categories to examine health inequities and, in the case of Hispanic women specifically, its implications for the "Hispanic Paradox."

Evidence consistently suggests that structural racism and xenophobia, as systems of oppression, contribute to health inequities, functioning as a matrix of dominance that shapes social determinants of health and disproportionately affects marginalized populations (Abubakar et al., 2022; Blankenship et al., 2023; Crear-Perry et al., 2021; Macias-Konstantopoulos et al., 2023; Samari et al., 2024; Selvarajah et al., 2022; Williams et al., 2019). These systems of oppression do not act independently but intersect with other forms of discrimination, such as sexism and classism, exacerbating inequities in birth outcomes (Crear-Perry et al., 2021; Samari et al., 2024). This 'matrix of dominance' explanation is consistent with our findings. For instance, the intersection of "U.S.-born" and "Black racialization" meant women had lower birthweight infants, regardless of their education (Farmer & Ferraro, 2005). Thus, lower birthweight may result from a biological embodiment of a life-long cumulative stress exposure due to structural racism as well as the lack of buffer and health benefits associated with education and related resources (Krieger, 1999). Although the impact of these systems of oppression is widely acknowledged, there is a lack of universal recognition of racism and xenophobia as health determinants (Selvarajah et al., 2022). The latter is despite the fact that the intersectionality of these oppressive systems is evident in the health outcomes of women exposed to sexism, racism, and xenophobia due to their sex/gender, race/ethnicity, and nativity status (Samari et al., 2024). Thus, it is imperative to use an intersectional multilevel approach to capture not only the variation explained by the combination of social identities and positions, but also the changes associated with the additive effect of each social identity and position on birthweight (Evans, 2024; Evans et al., 2024a, 2024b).

Assumptions of homogeneity within U.S. racial/ethnic census categories obscured significant health inequities within these broad groups. Wong et al. illustrated this by highlighting health inequities among Asian American subgroups, particularly middle-aged women, who experience distinct social stressors and variations in social support and self-rated health (Wong et al., 2023). Similarly, Borrell et al. found that heterogeneity across birth outcomes among New York Hispanic women was obscured when a broad Hispanic category was used. Specifically, they found that while Hispanic infants had better birthweight and small-for-gestational-age (SGA) outcomes but worse preterm birth and infant mortality outcomes than white women, these findings were not observed in all Hispanic subgroups. In fact, better birthweight and SGA were only observed in infants of Mexican, Central, and South American women, whereas worse preterm and infant mortality outcomes were observed in infants of Puerto Rican and Dominican women (Borrell et al., 2022). These findings underscore the danger of treating racial and ethnic groups as monolithic when examining health inequities. Kauh et al. emphasized the need to disaggregate racial/ethnic data to accurately target resources and address health inequities (Kauh et al., 2021). Such disaggregation is even more important for Hispanics, given the paradox that despite their low socioeconomic status and access to healthcare, they have better health outcomes, including birth outcomes, than whites (Markides & Rote, 2019). Thus, this evidence highlights the complexity of health inequities and the risks of assuming homogeneity within the broad U.S. Census racial/ethnic categories. The latter is even more important for groups such as Hispanics given their heterogeneity in country of origin, nativity status, immigration patterns, ancestry, and racial identity (Borrell & Viladrich, 2024). Thus, the homogeneity assumption can hinder efforts to address the unique needs of subgroups within the Hispanic population, and may perpetuate the misconception of the "Hispanic Paradox" as a one-size-fits-all (Borrell & Markides, 2024).

4.1. Limitations and strengths

Our study has several limitations. First, our definition of intersectional strata may have missed variables capturing social identities and positions in our society important to birthweight, such as disability status, and other socioeconomic indicators such as income, poverty, or wealth. For instance, we used education and acknowledged that its meaning may vary according to birth cohort and country of origin. However, education is not only highly correlated with the aforementioned socioeconomic indicators but is also considered relevant to health, regardless of age or working status (Galobardes et al., 2006). In addition, education is a stable socioeconomic indicator with direct and indirect effects on health: direct because it provides access to income and health insurance via employment, and indirect because it allows for informed health decisions for individuals and those around them. Moreover, we may have misspecified the categories of the social positions included in the study. However, this misspecification is not unique to MAIHDA but to all analytical approaches using categorical data. Second, we classified all birthing individuals as "women" to ensure consistency with the data source. However, it is possible that not all birthing individuals self-identify as women or mothers. Third, we aggregated American Indian and Alaska Native, some other race alone, and one or two more races into a category, Other non-Hispanic, which may have missed or masked inequities for these groups. The same applies to the aggregation by region of origin, such as Central and South America, and the other Hispanic category in the subgroup analyses. The Central American category aggregates women mostly from Guatemala, Honduras, and El Salvador; the South American category includes women from Colombia and Ecuador; and the other Hispanic category includes women from Spain. Fourth, we specified birthweight as continuous for our analysis because of its easy interpretation in multilevel analyses. However, increased birthweight may not always be associated with a positive birth outcome, such as in the case of fetal macrosomia or a birthweight >4000g (Ju et al., 2009). Therefore, we repeated the analyses using birthweight z-scores adjusted for gestational age and sex, and low birthweight using a cut-off point of <2500g, and the results were nearly identical to those presented in this study. Fifth, the use of a single locale may preclude the generalization of our findings. However, NYC has a heterogeneous population, allowing the examination of different dimensions of social identities and positions used in the intersectional strata and Hispanic subgroups. Furthermore, the use of these data enabled us to examine maternal variables (e.g., Hispanic subgroups) that are not available in other data sources.

Finally, a small number of strata in our analysis had very small sample sizes (the smallest had $n = 6$ in the Hispanic aggregate analyses and $n = 1$ in the Hispanic subgroup analyses). Although predictions from strata based on very small samples should always be treated with caution, simulation studies have shown that MAIHDA produces more reliable and robust estimates than conventional models, especially when samples are smaller than usually considered acceptable (e.g., $n < 20$). This is due to the shrinkage of the random effects in multilevel models (Bell et al., 2019; Evans et al., 2018, 2024b; Mahendran et al., 2022; Van Dusen et al., 2024), which effectively pool information across strata with shared/overlapping characteristics. Thus, our use of MAIHDA in this case is also a strength, as it enables us to disaggregate our data far more than would previously have been possible to consider experiences at more diverse and often invisible intersections.

Despite these limitations, our study included a large and heterogeneous sample size, including 99% of all births in NYC in each year of analysis. Moreover, NYC birth data were collected using an algorithm comparable to that used for national data collection, in terms of quality and completion. The large and diverse sample combined with the use of the MAIHDA analytic approach allowed us to examine intersectional birthweight inequities across numerous high-dimensional intersections (e.g., maternal age, race/ethnicity, education, and nativity status), and the disaggregation of the Hispanic population, which is often treated as monolithic in research despite recognized, meaningful within-group differences in social experiences, economic status, and other social determinants of health. This study, while substantive in orientation, is also a useful methodological example of how to leverage intersectional MAIHDA for more granular treatment of the Hispanic population, as well as other axes of identity and positionality that are often overlooked.

4.2. Conclusions

We found meaningful birthweight inequities by maternal age, race/ethnicity, educational attainment, and nativity status among singleton infants born to NYC women, and important subgroup differences within the Hispanic super-category. Intersectional strata with the lowest mean birthweights included teen women aged 14–19, Black women, women with less than a high school education, U.S.-born women, and among Hispanic women, Puerto Rican. These findings call attention to social identities and positions impacted by structural racism, such as age, race/ethnicity, education, and nativity status, and suggest that intersectional MAIHDA can identify birthweight inequities between- and within-strata, regardless of the level of disaggregation used for the Hispanic population, and could help identify inequities beyond the racial/ethnic categories used for population health studies. We encourage further examination of subgroup inequities in future studies and recommend that researchers avoid treating "Hispanic" and other racial/ethnic categories as monolith whenever is possible.

CRediT authorship contribution statement

Luisa N. Borrell: Writing – review & editing, Writing – original draft, Visualization, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Christina I. Nieves:** Writing – review & editing, Visualization. **Clare R. Evans:** Writing – review & editing, Methodology.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Luisa N. Borrell serves as a member of the Editorial Board for SSM and SSM-Population Health. Clare R. Evans serves as a member of the Editorial Board for SSM. Christina I. Nieves declares no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2025.101759.

Data availability

The authors do not have permission to share the data.

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