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Investigating the association of preterm birth and residential stability in Georgia

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Master of Science in Public Health

Epidemiology

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An abstract of

A thesis submitted to the Faculty of the
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Abstract

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Background: Due to the past 30-40 years improvements in prenatal care and medical technology, outcomes for infants born after short gestations have declined both in mortality and morbidity. However, preterm birth still causes considerable morbidity and mortality in the United States. The mechanism for the environmental risk factors association with preterm birth is not fully explained so far. There is evidence that environmental level socioeconomic status influences maternal related health such as preterm birth. We selected residential stability that living in a same household for more than 5 years as exposure, in order to test its association with outcome preterm birth.
Methods: Simple logistic regression and hierarchical multilevel logistic regression were performed to investigate the association between preterm birth and residential stability while controlling for potential infants, maternal related risk factors and environmental level confounders. Our study sample was limited to the singleton births within Georgia from 1998 to 2002.
Results: Among the 338,435 observations, the overall risk of preterm birth is 10.38%, and the risk of preterm birth is increasing from 1998 to 2002. Previous preterm birth history, maternal use of tobacco and alcohol during pregnancy and prenatal care are strongly associated with the preterm birth. Residential stability is strongly associated with the preterm birth even considering location as a random effect. The residential stability showed statistically significant interaction with household tenure in the final logistic model without random effect. After considering the random effect of location, house hold tenure is not significant associated with preterm birth in the model.
Discussion: The result showed that residential stability is statistically significant risk factor in this study, even including location as random effect. The potential model of the mechanism indicated that residential stability would contribute to an increased risk of preterm birth.

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Introduction:

The rate of preterm birth has increased predominantly because of increasing indicated preterm births and preterm delivery of artificially conceived multiple pregnancies(1). The frequency of preterm birth is high—11.72% in 2011 for the USA(2) and 5–9% in many other developed countries—and the incidence is increasing until 2010, then it plateaued (3). And preterm birth is the second leading cause of neonatal mortality in the United States, after birth defects (4). Due to the past 30-40 years improvement in perinatal care and medical technology, outcomes for infants born after short gestations have declined both in mortality and morbidity(5). In the United Kingdom the boundary of viability was lowered from 28 completed weeks' gestation to 24 weeks' gestation in 1992. Because the technology has allowed many very preterm infants to survive when they previously would not have, globally the number of weeks of completed gestation that defines whether a birth is preterm or not has become smaller(5). Although improvements in neonatal care have increased survival for preterm infants, prevention researchers have not succeeded in reducing the rate of preterm births. While among the potential risk factors of increasing preterm birth rate, whether exposure of different demographic, social, or economic risks, frequent absence of health insurance, and absence of a strong supportive economic and social safety have contribute to the increasing preterm birth rates is unknown(1, 6, 7).

Preterm birth was defined as birth at less than 37 completed weeks of gestation for much of the 20th century not only places a considerable emotional, psychological, and financial burden on parents and families but also disproportionately affects racial minorities, health care resources and society(8-10). Although medical efforts did improve neonatal outcomes(11), traditional medical efforts were focused on ameliorating the consequences of prematurity rather than preventing preterm birth occurrence. In addition, its costs associated with preterm birth typically contain the direct medical costs of the initial hospital and outpatient follow-up care, and non-financial costs such as adverse psychosocial and emotional effects, family disruption and deterioration in physical and mental health(8). Most recently studies focused on preterm birth prevention and people are realizing the importance of prevention(8).

Compared with other developed countries(6), USA had a higher preterm birth rate. Many researchers hold an opinion that the majority of the discrepancy in preterm birth rates between the USA and other countries might be due to the comparative higher preterm births rate among the black population of USA, although preterm birth rate among white women in the US is higher than the preterm birth rate in European countries (1). In addition, the higher preterm birth rates among black women have been consistent for decades, and many other maternal demographic characteristics such as low socioeconomic and educational status, low and high maternal ages, and single marital status are associated with preterm birth(6, 10, 12). However, the mechanisms discrepant preterm birth risk among different maternal demographic characteristics population are still unknown. In the USA, self-classified black or African-American, and Afro-Caribbean women are consistently reported to be at higher risk of preterm birth or low birth weight, and on average the black infants face twice the risk of death(13). Especially in the low-income population, black women had more preterm birth infants with growth restriction and with low birth weight than white women did (14). Data from the National Survey on Drug Use and Health (NSDUH) indicates among the pregnant woman percentage of white smoking women is 1.7 times the percentage of black women while the black pregnant women are more exposed to using illicit drugs including marijuana and cocaine(15). Even many of the risk factors for preterm birth were more common among white women than black women. For instance, from Goldenberg's study the white women smoked more cigarettes, moved more frequently, and had worse psychosocial scores, while the black women had lower incomes, were less likely to be married, and had more hypertension, anemia, and diabetes. Nevertheless, the 1980s' studies of various maternal characteristics did not explain these differences of birth outcome between races(14).

Interaction of the many factors that contribute to the association of preterm birth with socioeconomic status is complex. Consequently, our knowledge of the possible mechanisms for the association between socioeconomic risk factors and preterm delivery is limited. However, there have been great advances in our understanding of the molecular and cellular pathways operative in reproductive tissues in the maintenance of uterine quiescence during pregnancy, and in initiating term and preterm labour(16). This understanding has led to the development of new prevention strategies to reduce the preterm birth rate.

Outcome -- Preterm birth

Preterm birth is one of the most intractable cause of perinatal morbidity and mortality in developed countries(1) and contributes to neurological impairment and disability in obstetric practice (5). Common reasons of indicated preterm births are pre-eclampsia or eclampsia, and intrauterine growth restriction. And for spontaneous preterm births, infection or inflammation, vascular disease, and uterine over distension are regarded as causes. Also risk factors such as vulnerable population with preterm birth history, black race, periodontal disease, and low maternal body-mass index are considered contribution for spontaneous preterm births(1). And among these epidemiological risk factors, parental socioeconomic status is one of the most important factors and has a huge bearing on incidence and outcome of preterm birth, while controlled on unmarried status, smoking, low educational level, age over 34 years, unwantedness of the pregnancy, and poor earlier obstetric history(17). And black race, poor social environment, and work during pregnancy were associated with increased risk for nulliparous women. Also preterm birth history is another important risk factors as parental socioeconomic risk factors, it has a 2 fold increase in the odds of spontaneous preterm delivery for prior spontaneous preterm delivery among multiparous women (18).

Among the preterm births, very preterm infants (those born before 32 weeks' gestation) are most vulnerable proportion for mortality and morbidity, and especially “extremely preterm” infants (those born before 28 weeks of gestation)(5).(See Figure1)

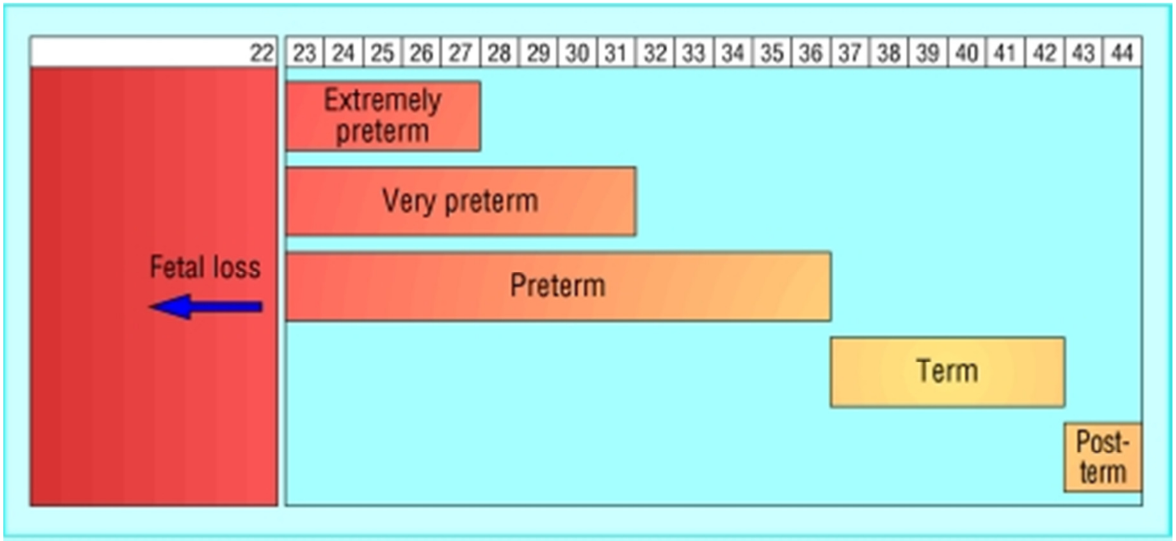

Figure1 Definitions of preterm live births by completed weeks of gestation(5)

Preterm birth rate has risen in the United States by more than one-third from the early 1980s through 2006(19). However, the preterm birth rate has fallen for 5 years after 2006, from the peak 12.80%(2006) to 11.72% (2011) (2). The reduction might be due to the recent efforts of prevention have paid off, although the lowest level(10.62% 1990 rate) has last more than a decade, the 2011 rate of preterm birth(11.72%) is still higher than rates reported during the 1980s and most of the 1990s(2) (See Figure2) . Research efforts to address this increasing rate have increased over the past 10 years, but have not resulted in improvements in prediction and prevention of preterm delivery(10).

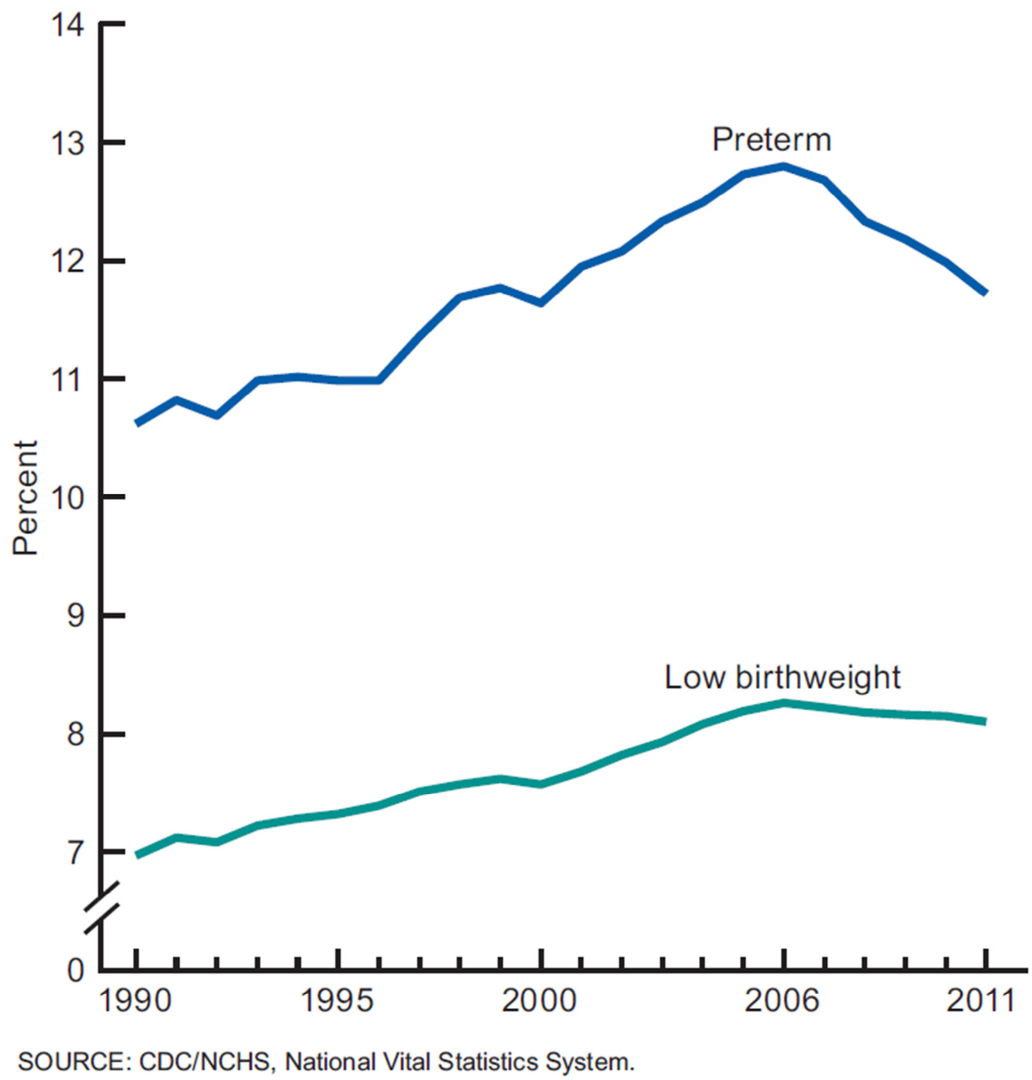

Figure2 Preterm l and low birth weight rates: United States, final 1990-2010 and preliminary 2011(2)

Exposure -- Residential stability

We defined residential stability as the proportion of families who lived in the same household for 5 years from 1995 to 2000. Research in Chicago suggests that community residential stability can influence personal support networks, and that norms of behavior within these networks can be significantly different between communities of different racial and ethnic compositions. In addition, the neighborhood variations in housing costs and crowding are among the clearest legacies of segregation within the city and are therefore also indicated as potential covariates with individual health status. In contrast, Lynne's study suggested that residential stability were not associated with preterm birth in their analyses when they combined the domain estimates across eight study sites to produce pooled effect estimates for the socioeconomic domains on preterm birth(20). Their research suggests that specific neighborhood-level socioeconomic features may be especially influential to health outcomes. We consider location may have effect in the causal path, so we include residential stability and other demographic risk factors in the model and treat location as random effect. And our study is to reveal whether the residential stability has an effect on increasing the risk of preterm birth after including location in the model with random effect. Our study question is to examine the association between the risk of preterm birth and the neighborhood residential stability in a population based cross sectional study in Georgia from 1998 to 2002 considering random effect of location.

Other risk factors

Pregnancy history

A major risk factor of current gestation outcome is the previous preterm birth history, the women with early preterm births history are far more likely to have subsequent preterm births, and women with indicated preterm births tend to repeat such births(21, 22). The recurrence risk of preterm birth among women with a previous preterm history ranges from 15% to more than 50%, which varies because of the number and gestational age of previous deliveries. And women with previous preterm history had a 2.5- fold increase in their risk of preterm birth during next pregnancy compared with those with no preterm birth history(22, 23).

From Mercer's research, preterm birth history was more closely associated with subsequent early preterm birth at <28 weeks' gestation than for preterm birth overall. And an early preterm birth history (23-27 weeks' gestation) was most highly associated with early preterm birth (<28 weeks' gestation) in the current gestation. The relationship between preterm birth history and current gestation outcome was not as strong for those with a very early spontaneous preterm delivery (13-22 weeks' gestation)(23). In addition, the risk of next preterm birth is inversely related to the gestational age of the previous preterm birth and the greatest risk of recurrence of preterm birth in the second pregnancy tended to occur around the same gestational age as preterm birth in the first pregnancy(22). The recurrence of preterm birth may be due to the persistent or recurrent intrauterine infections and underlying disorder including diabetes, hypertension, or obesity (1, 22).

Location

Research showed that different community neighborhood with different locations had different preterm birth risk. And the preterm birth proportion even varies within same neighborhood, which requires location specific analysis to develop targeted interventions(24). In addition, geographically separate areas also played a different role for preterm birth in different location despite similarities in demographics and physical location(24). The proportion of history of preterm birth also differed when comparing areas with different preterm birth proportions(24).

Race

The contribution of the causes of preterm births to all preterm births varies between ethnic groups(1). Temporal trends from 1989 to 2000 of preterm birth varied substantially based on underlying subtype and maternal race, the largest decline in perinatal mortality among whites was associated with increases in medically indicated preterm birth, whereas the largest decline in perinatal mortality among blacks was associated with declines in preterm birth following ruptured membranes and spontaneous preterm birth(25). In the United States, the incidence of preterm birth in black women is higher than that in white women of similar age. The reason for this variation is unclear because differences remain after taking into account socioeconomic risk factors(3). Black women had significantly higher rates of bacterial vaginosis (64%) compared with white women (35%), there is a significant proportion of the racial disparity in the rates of occurrence of bacterial vaginosis in pregnancy in a sample of women of low income in the inner city(26).

Since 2006, the preterm rate has declined between 8% and 9% for non-Hispanic white and non-Hispanic black infants, and 5% for Hispanic infants. Although still substantially higher than that of other groups, the 2010 and 2011 preterm rates for non-Hispanic black infants are the lowest reported in the three decades for which comparable data have been available(2). From 2010 to 2011, the preterm birth has declined in each of the largest race and Hispanic groups(2) and since 2006 preterm birth rate has declined between 8% and 9% for non-Hispanic white and non-Hispanic black infants, and 5% for Hispanic infants(19).

Smoking

Besides race and preterm birth history, smoking also had a consistent impact on preterm birth (14). The risk of preterm birth before 32 weeks of gestation for smoking mothers double that seen in non-smoking mothers to deliver (5). In addition, smoking is causally associated with fetal growth restriction, stillbirth, placental abruption, and possibly also sudden infant death syndrome(27). Evidence from a randomized controlled trials showed that prenatal smoking cessation programs can lower the incidence of preterm birth (25). In Goldenberg's research sample, the white women smoked cigarettes at twice the rate of black women and reported using more drugs(13).

Racial residential segregation

Racial residential segregation is a fundamental cause of racial disparities in health, the degree of residential segregation remains extremely high for most African Americans in the United States(28, 29). The relationship between ethnic density (the relative size of a given ethnic group in a multi-ethnic neighborhood) and health risk is that the smaller the ethnic group, the higher its health risk in comparison to both the risk of other residents in the same area and that of members of the same ethnic group living in areas where they constituted a numerical majority(30). Residential segregation is a common aspect of the urban experiences of African-Americans in the United States (US), while a few studies have considered how segregation might influence perinatal health(31).

Residential segregation studies suggest that the risk of low birth weight of blacks in the United States is greater in majority-black compared with mixed-race neighborhoods(32), however, in Mason's study ethnic density seems to be more strongly associated with preterm birth for US-born non-Hispanic blacks than for non-Hispanic black immigrants(33). Bell et. found higher isolation was associated with lower birth weight, higher rates of prematurity and higher rates of fetal growth restriction.

Also Sue C. Grady's study found that residential segregation and neighborhood poverty operate at different scales to increase the risk of low birth weight. Her multilevel analysis revealed that at the neighborhood scale residential segregation is positively and significantly associated with low birth weight, after controlling for individual-level risk factors and neighborhood poverty and at the individual scale-increasing levels of residential segregation does not significantly reduce or exacerbate individual-level risk factors for low birth weight; whereas increasing levels of neighborhood poverty significantly eliminates the race effect and reduces the protective effect of being foreign-born on low birth weight, after controlling for other individual-level risk factors and residential segregation(32).

Household size

Household size is defined as the number of residents in the same household regardless of the tenure of the house. Household size may indicate the family structure and economic status, it also may cause psychological stress in the preterm birth causal pathway. And it has special relevance to pregnancy outcomes as evidence accumulates regarding the importance of social and psychological factors to maternal and fetal health(34).

Group density

Associations between group density and pregnancy outcomes among White, Black, and Hispanic infants in an urban population have been found recently. The result of cross-sectional study among singleton live births in Chicago shows that besides violent crime rate, group density was also associated with birth weight and preterm birth. Furthermore, this association between preterm birth and group density was stronger among Whites and Hispanics than among Blacks (34). Further study revealed different mechanisms of group density and violent crime may impact birth weight. Group density was more strongly associated with preterm birth while violent crime rate was more strongly associated with small for gestational age (34).

Method:

Data

In this study, the birth data was extracted from Georgia birth certificates between the years 1998 and 2002.Our study was focused on live singleton births born with mothers residing within Georgia at the time of given birth, because multiple gestation is a risk factor for preterm birth. And the census data was collected from census tract website, Census 2000 Summary File 3 of Georgia for 5 years, which contains the household size, family living in same house for 5 years, household tenure and family status. Each census variable was calculated as the proportion of the total number of households. Furthermore, the analytic data was a combination of individual birth data and census tract data, which were merged using a de-identified geographic ID. The total data set included 338,435 births.

In our analysis, the included infants birth record are limited to infants no less than 20 weeks gestation and with a birth weight no less than 500g, and the birth data included variables such as gestation weeks, birth weight, mother education level, race, insurance status, mother tobacco status, mother alcohol status, previous preterm birth history, prenatal care status and mother marriage status.

Variables

In this analysis, gestational age was estimated from the mother's last menstrual period. Preterm birth definition followed the criteria mentioned in the introduction: preterm birth as outcome is the infants born before the 37th week of gestation. Also residential stability was defined as the exposure, which is proportion of families in a given census tract which had lived in the same household for 5 or more years. Individual level birth data was merged with census data using maternal residence census tract identifiers; this was done by Dr. Michael Kramer, and a geographically de-identified dataset was created as the analytic dataset for this thesis.

From literature review, potential individual-level confounders considered were parity (first birth or not), maternal race (Hispanic, non-Hispanic white, non-Hispanic black and other), payment for delivery hospitalization (Medicaid or other), mother education (less than high school education, high school graduate degree, and at least some college degree) and maternal marital status (married or unmarried). Also previous history of preterm birth (previous history of preterm birth or not), maternal alcohol consumption (drink alcohol during pregnancy or not), maternal smoking (tobacco use during pregnancy or not) and adequacy of prenatal care (none, inadequate, adequate, and adequate-plus) were considered as individual level covariates for the outcome. What's more, neighborhood household tenure (owned or rent) was considered as confounders for the outcome. In addition, maternal marital status and neighborhood household tenure were considered as potential modifiers of residential stability.

Statistics

All analyses were performed using SAS, version 9.3 (SAS Institute, Inc., Cary, NC). Alpha was 0.05 for all tests. For descriptive analysis, chi square test was performed to test for different risks of preterm births among individual level dichotomous variables. For the continuous environmental level variables, t-test was carried out to test the different association with preterm birth among each variable. Categorical variables were tested by ANOVA for association of multi-categorical variables and outcome. Also the same analysis strategy was performed to test the association between the potential risk variables and the exposure. All potential risk factors from the literature were assessed for association with the residential stability and preterm birth. The risk factors with a strongly significant association between both exposure and outcome were considered further in multivariable models.

Because of the dichotomous outcome, simple logistic regression was performed to evaluate the relationships between outcome and various risk factors. The full model contained significant potential covariate of individual and environmental risk factors and potential possible interaction terms of these potentially confounding covariates with the exposure. During the modeling analysis, we used Wald test to assess and interaction terms and used backward selection strategy and eliminate the non- significant potential confounders by 10% rule, non- significant confounder are also eliminated by testing its association with both residential stability and preterm birth. If one interaction term was deemed to be significant, not only the interaction term but also the constituent terms were retained in the model. In addition, the strongly associated risk factors from literature review and individual and neighborhood level covariates which were significantly associated with both preterm birth and with residential stability in descriptive analyses were included in the final models. Logistic regression models were conducted, in which continuous tract % residential stability as exposure. The reduced model was created by dropping the covariates that do not significantly affect the risk ratio. Residential stability was included as continuous variable in the logistic model and separately was divided into quartiles through the distribution of exposed mothers and included as categorical variables in logistic model.

Initial full model for logistic modeling before variable elimination:

$$\begin{aligned}
&logitP(Preterm\ birth) \\
&\quad = \beta_0 + \beta_1(Residentual\ stability) + \gamma_1(marital\ status) \\
&\quad + \gamma_2(maternal\ alcohol) + \gamma_3(maternal\ tobacco) + \gamma_4(prenatal\ care) \\
&\quad + \gamma_5(birth\ order\ ) + \gamma_6(maternal\ education) + \gamma_7(race) \\
&\quad + \gamma_8(houseowned) + \gamma_9(preterm\ birth\ history) + \gamma_7(pay) \\
&\quad + \delta_1(Residentual\ stability * houseown) \\
&\quad + \delta_2(Residentual\ stability * martial\ status) \\
&\quad + \delta_2(Residentual\ stability * martial\ tobacco) \\
&\quad + \delta_2(Residentual\ stability * martial\ alcohol) + b + \varepsilon
\end{aligned}$$

β_0 $is\ the\ intercept$

β_1 $is\ the\ slope$

γ_i $is\ the\ covariate\ estimates$

δ_i $is\ the\ interaction\ estimates$

$b\ is\ the\ random\ effect\ estimates$

$\varepsilon\ is\ the\ residual$

In addition, in order to for assessing the different effect of residential stability on preterm birth risk based on different census location area, hierarchical multilevel logistic regression was performed to estimate the association of individual level risk factors and preterm birth risk within different census tract area. Because the information of both individual level and environmental level were nested in the different census tract areas, we included a random intercept for each anonymized tract ID in the model to allow for consideration of otherwise unmeasured variation of the preterm birth. The multilevel random-intercept logistic regression was performed in SAS using PROC GLIMMIX. The full model of the hierarchical regression was from the final model of the sample logistic regression with additional random effect of location.

Result

Descriptive analysis

Before the exclusion of missing values, the whole data set has 338,435 observations, and all of them are limited to no less than 20 weeks gestation and with a birth weight no less than 500g singleton birth. Table 1 showed the risk of preterm birth based on the characteristics of Georgia mothers of live singleton birth and the infant demographic information between 1998 and 2002. Among the study sample, the risk of preterm birth increased from 1998 to 2002. The overall risk of the preterm birth for the five years is 10.4%. There is no significant difference of preterm birth risk between infants' gender. The peak of risk of preterm birth lies in maternal age under 20 (13.1%), and as the maternal age increases the risk decreases, till maternal age30-34(9%) then the risk of preterm birth began to increase again but maternal age 35+ (10.2%) is still less than the peak of maternal age under 20. The unmarried mothers (13.6%) were more likely to have preterm birth than married ones (8.5%). And the non-Hispanic black mothers (14.1%) have almost 2 times risk of preterm birth compared to all the other races (Hispanic 7.8%, other races 8.5%). The higher maternal education level the mother had, the less risk of preterm birth they would have. The difference of risk indicated that there is influence on preterm birth whether the mother had somewhat college level education (8.6%). The mother used Medicaid for birth delivery (12.2%) has a higher risk of preterm birth compared with other payment for the birth delivery (9%) and the risk ratio is 1.355(Table1).

Table 2 lists the maternal health related risk factors and its risk of preterm birth. Mothers with previous preterm history (19.1%) have a 2 times risk of preterm birth than the mothers without previous preterm birth history (9%). Mothers, who reported tobacco (13.8%) and alcohol (13.2%) use during pregnancy, are more likely to experience a preterm birth compared with those non-users (Non-smoking 10%, Non-alcohol 10.3%). The prenatal care information was categorized by the Kotelchuk index into four groups, mothers with "adequate plus" (20.7%) prenatal care during pregnancy had an almost 7 times preterm birth risk than the mothers with inadequate (3.9%) and adequate (3.1%) prenatal care. Also preterm birth risk of the mothers with no prenatal care (13.5%) is higher than the mothers with inadequate (3.9%) and adequate (3.1%) prenatal care. The order of birth is also associated with preterm birth, the fourth or greater birth (13.4%) has a higher risk of preterm birth than the first, second birth and third birth (10%).

Table 3 shows the t-test of environmental related risk factors among different preterm birth outcomes. The results indicated that the mothers with preterm birth or not had a significant different exposure of house tenure information (rent) and residential stability, household size (one person) and residential stability, the variable mean of residential stability and rent (preterm 0.36; Not preterm 0.33) varies about 10% in different preterm birth outcome group. Table 4 shows the ANOVA test for the association of residential stability and individual and environmental level risk factors. There is statistical significance that the year of birth, maternal age, marital status, maternal age, race, maternal education, delivery payment, preterm birth history, prenatal care, smoking and alcohol use and order of birth are associated with residential stability. However, infant's gender does not show any evidence of significant association with residential stability. Table 5 lists the association of the environmental risk factors and the residential stability, and there is no variable which shows a strong correlation with the residential stability.

Modeling

For further analysis, the observations with missing data of potential risk factors were eliminated for logistic modeling. After the exclusion of missing values, there were 308,086 observations included in the final modeling procession. The final model obtained by backward elimination, we dropped the interaction terms: Marital status*Residential stability, Marital tobacco*Residential stability, Marital alcohol*Residential stability and covariate: pay. The estimates of the simple logistic model are showed in the table 6. The residential stability, preterm birth history, maternal alcohol use, maternal tobacco use and lower education level has a significant effect on increasing the odds ratio of preterm birth. In contrast, college level education, early prenatal care and house tenure has a protective effect of preterm birth. In addition, prenatal care plus, third birth or more and black race had a significant risk of preterm birth. While the Hispanic race has a lower risk of preterm birth compared with black and white race people. And marriage is a protective covariate in the model. What's more, the fitness of this final model is not significant for predicting (table 7), however, that's the best model using the backward elimination for the study population. The effect modifier of household tenure and residential stability is show in the table 8, after stratified of household tenure, we can draw the conclusion that in the area of household tenure around 50% and 100% residential stability has a stronger risk effect of preterm birth. For the hierarchy model with random effect of location, residential stability become significant as fixed effect after backward elimination of the interaction term of residential stability and household tenure (table 9 and table 10). Then we eliminated the household tenure to get the final hierarchy model (table11).

Discussion

To answer our study question, the examination of the association between the risk of preterm birth and the neighborhood residential stability, which is a population based cross sectional study in Georgia from 1998 to 2002 considering random effect of location, was conducted. In the final model, residential stability has risk effect for preterm birth and it has an interaction with house tenure. In contrast, Lynne's study suggested that residential stability were not associated with preterm birth. In our study, preterm birth is associated with preterm birth in the interaction with household tenure, the residential stability alone does not show a significant association of increasing the preterm birth risk. In addition the preterm birth is associated with different marital status, race, maternal education and delivery payment and there are similar results of the risk differences from literature review (35). And in our study the house tenure itself does not has significant association with preterm birth, maternal tobacco use showed a stronger risk effect than the maternal alcohol use, and the non-Hispanic black group has a much higher risk than other ethnic groups compared with Copper's study(35). Also the college level education had the same portent protection effect in both our study and Copper's study.

For the modeling part, we dropped the interaction terms of residential stability with marital status. In addition, we keep the rest risk factors and the interaction term of household tenure and residential stability in the model, the preterm birth history has a significant association with preterm birth, and its risk of previous preterm birth varies a lot in different studies. Also the adequate-plus prenatal care is an index for pregnancy infections or complications, so the adequate prenatal care is a protective factor while the adequate-plus prenatal care is a risk factor. This variance illustrate that the appropriate prenatal care is protective for preterm birth, while excessive prenatal care (indicating infection and other complications) is a risk factor for increasing the preterm birth. However, the smoking and alcohol usage during pregnancy is a risk factor alone, but they don't have an interaction with the residential stability. There seems no interaction between these risk factors and association between the maternal health related information and the residential stability is not in their causal pathway, while house tenure has association with residential stability and itself did not increase the risk of preterm birth .so it may show protective effect of preterm birth due to an economic effect modifier rather than lifestyle effect modifier.

From table6 we can draw the conclusion that preterm birth history had a strong association with preterm birth. In addition, maternal alcohol and maternal tobacco has a little stronger effect on increasing the risk of preterm birth. While household tenure is protective for the risk of preterm birth, but it is not significant in the model.

By including these individual and maternal health related risk factors in hierarchical multilevel logistic regression model, we estimated the association between residential stability and preterm birth while including the location as a random effect. We find statistically significant evidence to support an association between residential stability and preterm birth. In simple logistic regression, when controlling for all individual and environmental level covariates, census data of living in the same household for more than 5years or not is a risk in the model as an exposure. Maternal health related information suggested that previous preterm birth history, maternal use of tobacco and alcohol during pregnancy were strongly associated with the preterm birth alone while their interaction with residential stability were not. For environmental level, all the variables are not strongly associated with both preterm birth and residential stability.

For public implications, the residential stability showed statistically significant interaction with household tenure in the final logistic model, so the household tenure should be examined when considering the residential stability as a risk factor for preterm birth. We need to focus on the life style or socio-economic status in the population with strong residential stability in the future study. The final model result showed that association of preterm birth and residential stability is statistically significant in this study, even including location as random effect. So the potential model of the mechanism indicated that residential stability would contribute to an increased risk of preterm birth.

In these analyses, we conducted GLIMMIX logistic regression that contained both random effect of location and fixed effect of individual level risk factors in the model. So after considering the location as random effect, the association between residential stability and preterm birth become insignificant. We conducted additional analyses that drop the interaction term and household tenure, which can allow for a random effect of location for residential stability within census tract area. Thus we tested for a different effect of residential stability on preterm birth within census tract area.

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Table 1 Risk of preterm birth based on the characteristics of Georgia mothers of live singleton birth and the infant demographic information between 1998 and 2002

Infant demographics	Preterm N	Total N	Risk	RD	95% CI		RR	95% CI	
Gender									
Male	18815	172507	0.1091	0.0000			1.0000		
Female	16314	165928	0.0983	-0.0107	-0.0128	-0.0087	0.9015	0.8837	0.9195
Year of birth									
1998	6008	60121	0.0999	0.0000			1.0000		
1999	6518	63544	0.1026	0.0026	-0.0007	0.0060	1.0264	0.9929	1.0611
2000	7248	71373	0.1016	0.0016	-0.0016	0.0049	1.0162	0.9838	1.0497
2001	7709	71970	0.1071	0.0072	0.0039	0.0105	1.0719	1.0382	1.1067
2002	7646	71427	0.1070	0.0071	0.0038	0.0104	1.0712	1.0375	1.1060
Maternal demographics									
Maternal age									
<20	6095	46401	0.1314	0.0000			1.0000		
20-24	10597	94237	0.1125	-0.0189	-0.0226	-0.0152	0.8561	0.8312	0.8817
25-29	8469	91100	0.0930	-0.0384	-0.0420	-0.0348	0.7077	0.6861	0.7300
30-34	6572	73279	0.0897	-0.0417	-0.0454	-0.0380	0.6828	0.6607	0.7056
35+	3396	33418	0.1016	-0.0297	-0.0342	-0.0253	0.7736	0.7436	0.8048
Marital status									
Unmarried	16702	122516	0.1363	0.0000			1.0000		
Married	18421	215882	0.0853	-0.0510	-0.0533	-0.0487	0.6259	0.6137	0.6384
Missing	6	37	0.1622	0.0258	-0.0929	0.1446	1.1895	0.5718	2.4746
Race/ethnicity									
Non-Hispanic white	15918	186849	0.0852	0.0000			1.0000		
Non-Hispanic black	16374	115872	0.1413	0.0561	0.0537	0.0585	1.6587	1.6250	1.6932
Hispanic	2064	26648	0.0775	-0.0077	-0.0112	-0.0043	0.9092	0.8700	0.9501
Other	773	9066	0.0853	0.0001	-0.0058	0.0060	1.0008	0.9341	1.0724
Maternal education									
No high school	9967	79442	0.1255	0.0000			1.0000		
High school degree	11297	100078	0.1129	-0.0126	-0.0156	-0.0096	0.8997	0.8773	0.9228
At least some college	13258	153569	0.0863	-0.0391	-0.0418	-0.0364	0.6881	0.6714	0.7052
Missing	607	5346	0.1135	-0.0119	-0.0207	-0.0031	0.9050	0.8378	0.9775
Delivery payment									
Medicaid	18036	148160	0.1217	0.0000			1.0000		
Other	17093	190275	0.0898	-0.0319	-0.0340	-0.0298	0.7380	0.7235	0.7527
Overall	35129	338435	0.1038						

Table 2 Risk of preterm birth based on the characteristics of Georgia mothers of live singleton birth and the maternal health related information between 1998 and 2002

Maternal health related	Preterm N	Total N	R	RD	95% CI		RR	95% CI	
Preterm birth history									
No previous preterm birth history	26430	292946	0.0902	0.0000			1.00		
Previous preterm birth history	8699	45489	0.1912	0.1010	0.0973	0.1048	2.12	2.07	2.17
Adequacy of prenatal care									
None	4137	30566	0.1353	0.0000			1.00		
Inadequate	1517	38711	0.0392	-0.0962	-0.1005	-0.0919	0.29	0.27	0.31
Adequate	4499	143708	0.0313	-0.1040	-0.1080	-0.1001	0.23	0.22	0.24
Adequate-Plus	22831	110508	0.2066	0.0713	0.0667	0.0758	1.53	1.48	1.57
Missing	2145	14942	0.1436	0.0082	0.0014	0.0150	1.06	1.01	1.11
Maternal smoking									
Nonsmoking during pregnancy	31003	308824	0.1004	0.0000			1.00		
Smoking during pregnancy	3641	26411	0.1379	0.0375	0.0332	0.0418	1.37	1.33	1.42
Missing	485	3200	0.1516	0.0512	0.0387	0.0636	1.51	1.39	1.64
Maternal alcohol consumption									
Don't drink alcohol during pregnancy	34308	332698	0.1031	0.0000			1.00		
Drink alcohol during pregnancy	330	2500	0.1320	0.0289	0.0156	0.0422	1.28	1.16	1.42
Missing	491	3237	0.1517	0.0486	0.0362	0.0610	1.47	1.36	1.60
Order of birth									
First birth	12252	122705	0.0998	0.0000			1.00		
Second and third birth	18204	180739	0.1007	0.0009	-0.0013	0.0030	1.01	0.99	1.03
Fourth and greater birth	4673	34991	0.1335	0.0337	0.0298	0.0376	1.34	1.30	1.38

Table3 t-test of environmental related risk factors among different preterm birth outcomes

Environmental related	Not Preterm			Preterm			F-test			t-test			
	N	Mean	SD	N	Mean	SD	DF	F-value	p-value	Method	DF	t-value	p-value
Residual Stability													
Live in same household more than 5 years	303306	0.2191	0.3706	35129	0.2386	0.3863	35128	1.09	<.0001	Satterthwaite	42963	-8.97	<.0001
House tenure													
Owned	303306	0.6659	0.2232	35129	0.6399	0.2238	303305	1.01	0.4964	Pooled	338433	20.60	<.0001
Family owned (among the owned)	302930	0.7587	0.1089	35083	0.7500	0.1085	302929	1.01	0.2709	Pooled	338011	14.16	<.0001
Rent	302930	0.3333	0.2221	35083	0.3592	0.2227	35082	1.01	0.4627	Pooled	338011	-20.68	<.0001
Family rent (among the rent)	303281	0.6255	0.1411	35128	0.6293	0.1338	303280	1.11	<.0001	Satterthwaite	44687	-5.04	<.0001
Live in the house as family (owned and rent)	303306	0.7212	0.1185	35129	0.7144	0.1132	303305	1.09	<.0001	Satterthwaite	44513	10.58	<.0001
Group density (household size)													
1 person	303306	0.2244	0.0885	35129	0.2318	0.0859	303305	1.06	<.0001	Satterthwaite	44219	-15.30	<.0001
2 persons	303306	0.3123	0.0468	35129	0.3072	0.0460	303305	1.04	<.0001	Satterthwaite	43986	19.47	<.0001
3 and 4 persons	303306	0.3470	0.0743	35129	0.3429	0.0696	303305	1.14	<.0001	Satterthwaite	44898	10.41	<.0001
5 and more persons	303306	0.1164	0.0453	35129	0.1181	0.0437	303305	1.08	<.0001	Satterthwaite	44341	-7.10	<.0001

Table 4 ANOVA test of association of residential stability (proportion calculated at the census tract level) and individual and environmental level risk factors

	Residential stability							
Infant demographics	DF	ANOVA SS	Mean Square	F-value	Pr > F	R-Square	coefficient of variation	Root of MSE
Gender	1	0.0416	0.0416	0.30	0.5837	0.0000	168.3624	0.3723
Year of birth	4	25.8500	6.4625	46.64	<.0001	0.0006	168.3169	0.3722
Maternal demographics								
Maternal age	4	1088.8654	272.2163	2010.12	<.0001	0.0232	166.3982	0.3680
Marital status	2	133.6739	66.8369	483.47	<.0001	0.0028	168.1228	0.3718
Race/ethnicity	3	636.2468	212.0823	1550.76	<.0001	0.0136	167.2176	0.3698
Maternal education	3	1018.4730	339.4910	2503.06	<.0001	0.0217	166.5257	0.3683
Delivery payment	1	931.7004	931.7004	6856.48	<.0001	0.0199	166.6825	0.3686
Maternal health related								
Preterm birth history	1	1.5461	1.5461	11.15	0.0008	0.0000	168.3597	0.3723
Adequacy of prenatal care	4	229.0683	57.2671	415.09	<.0001	0.0049	167.9518	0.3714
Maternal smoking	2	336.5753	168.2876	1222.62	<.0001	0.0072	167.7578	0.3710
Maternal alcohol consumption	2	13.3484	6.6742	48.15	<.0001	0.0003	168.3388	0.3723
Order of birth	2	8.80741422	4.4037071	31.77	<.0001	0.000188	168.347	0.3723

Table 5 Correlation of the environmental risk factors and the residential stability

Environmental related	Residential stability					
House tenure	Mean	Std Dev	Pearson Correlation Coefficients	P-value	Spearman Correlation Coefficients	P-value
Owned	0.6632	0.2234	0.1504	<.0001	0.3156	<.0001
Family owned (among the owned)	0.7578	0.1089	0.0905	<.0001	0.2317	<.0001
Rent	0.3360	0.2223	-0.1491	<.0001	-0.3136	<.0001
Family rent (among the rent)	0.6259	0.1404	0.0120	<.0001	0.0691	<.0001
Live in the house as family (owned and rent)	0.7205	0.1180	0.0639	<.0001	0.2084	<.0001
Group density (household size)						
one	0.2252	0.0883	0.0255	<.0001	-0.1739	<.0001
two	0.3117	0.0468	0.1634	<.0001	0.1944	<.0001
threefour	0.3466	0.0738	0.5733	<.0001	0.1829	<.0001
five	0.1166	0.0451	-0.1436	<.0001	-0.0613	<.0001

Table 6 The estimates of the final simple logistic model

Analysis of Maximum Likelihood Estimates							
Parameter	Estimate	Standard Error	OR	OR 95%CI		Wald Chi-Square	Pr > ChiSq
Intercept	-2.090	0.040	0.124	0.114	0.134	2670.94	<.0001
Residential stability	0.357	0.089	1.429	1.201	1.700	16.22	<.0001
PR_PTB	0.369	0.008	1.446	1.424	1.469	2238.44	<.0001
Prenatal care	-0.739	0.021	0.477	0.458	0.498	1226.20	<.0001
Prenatal care	-0.866	0.014	0.421	0.409	0.433	3604.89	<.0001
Prenatal care	1.202	0.011	3.327	3.257	3.399	12159.11	<.0001
Maternal marital	-0.096	0.009	0.908	0.893	0.924	128.05	<.0001
Maternal alcohol	0.080	0.034	1.083	1.014	1.156	5.64	0.0175
Maternal tobacco	0.174	0.011	1.190	1.164	1.217	242.00	<.0001
PARITY	-0.074	0.009	0.928	0.912	0.945	67.83	<.0001
PARITY	0.054	0.013	1.055	1.029	1.083	16.97	<.0001
EDU	0.001	0.009	1.001	0.983	1.019	0.01	0.9125
EDU	-0.088	0.010	0.916	0.898	0.934	73.89	<.0001
RACE	0.320	0.012	1.377	1.345	1.410	683.09	<.0001
RACE	-0.203	0.018	0.816	0.787	0.846	122.55	<.0001
Houseowned	0.006	0.034	1.006	0.941	1.075	0.03	0.8629
Residential stability* houseowned	-0.2893	0.1244	0.748788	0.586769	0.955543	5.41	0.0200

Table7 Logistic model fitness evaluation evidence

Model Fit Statistics		
Criterion	Intercept only	Intercept and covariates
AIC	203273.7	175647.55
SC	203284.4	175828.4
-2 Log L	203271.73	175613.55

Hosmer and Lemeshow Goodness-of-Fit Test		
Chi-Square	DF	Pr > ChiSq
64.4987	8	<.0001

Table8 Logistic model fitness evaluation evidence

Odds Ratio Estimates				
Effect	House tenure quartile	Preterm birth	95% Wald CI	
Residential stability	25%	0.791	0.72	0.86
Residential stability	50%	0.906	0.859	0.956
Residential stability	75%	0.801	0.762	0.842
Residential stability	100%	0.873	0.784	0.972

Table9 Solutions for Fixed Effects of GLIMMIX final model including location as random effect

Solutions for Fixed Effects					
Parameter	OR	OR 95%CI		t Value	Pr > |t|
Residential stability	1.02	1.00	1.05	1.86	0.063
Preterm birth history (Yes)	1.08	1.08	1.09	50.60	<.0001
Preterm birth history (No)	1.00	.	.	.	.
Prenatal care (Adequate-Plus)	0.90	0.90	0.90	-53.13	<.0001
Prenatal care (Adequate)	0.83	0.83	0.83	-103.11	<.0001
Prenatal care (Inadequate)	0.83	0.83	0.84	-149.42	<.0001
Prenatal care (None)	1.00	.	.	.	.
Maternal marital(Yes)	0.98	0.98	0.99	-11.72	<.0001
Maternal marital(No)	1.00	.	.	.	.
Maternal alcohol(Yes)	1.02	1.01	1.03	3.35	0.001
Maternal alcohol(No)	1.00	.	.	.	.
Maternal tobacco(Yes)	1.03	1.02	1.03	13.36	<.0001
Maternal tobacco(No)	1.00	.	.	.	.
PARITY (More than Third)	0.99	0.99	1.00	-3.80	0.000
PARITY (Second & Third)	0.99	0.98	0.99	-7.87	<.0001
PARITY(First)	1.00	.	.	.	.
EDU (At least some college)	1.02	1.01	1.02	10.35	<.0001
EDU (High school degree)	1.01	1.00	1.01	5.25	<.0001
EDU (No high school)	1.00	.	.	.	.
RACE (Hispanic)	1.00	0.99	1.00	-0.42	0.677
RACE (Black)	1.03	1.03	1.04	14.03	<.0001
RACE (White)	1.00	.	.	.	.
Houseowned	1.00	0.99	1.01	-0.53	0.593
Residential stability* houseowned	0.98	0.95	1.02	-1.02	0.310

Table10 Solutions for Fixed Effects of GLIMMIX final model including location as random effect after dropping the interaction term (Residential stability*houseowned)

Solutions for Fixed Effects					
Parameter	OR	OR 95%CI		t Value	Pr > |t|
Residential stability	1.01	1.01	1.02	4.66	<.0001
Preterm birth history (Yes)	1.08	1.08	1.09	50.60	<.0001
Preterm birth history (No)	1.00	.	.	.	.
Prenatal care (Adequate-Plus)	0.90	0.90	0.90	-53.14	<.0001
Prenatal care (Adequate)	0.83	0.83	0.83	-103.12	<.0001
Prenatal care (Inadequate)	0.83	0.83	0.84	-149.42	<.0001
Prenatal care (None)	1.00	.	.	.	.
Maternal marital(Yes)	0.98	0.98	0.99	-11.73	<.0001
Maternal marital(No)	1.00	.	.	.	.
Maternal alcohol(Yes)	1.02	1.01	1.03	3.35	0.0008
Maternal alcohol(No)	1.00	.	.	.	.
Maternal tobacco(Yes)	1.03	1.02	1.03	13.36	<.0001
Maternal tobacco(No)	1.00	.	.	.	.
PARITY (More than Third)	0.99	0.99	1.00	-3.80	0.0001
PARITY (Second & Third)	0.99	0.98	0.99	-7.87	<.0001
PARITY(First)	1.00	.	.	.	.
EDU (At least some college)	1.02	1.01	1.02	10.34	<.0001
EDU (High school degree)	1.01	1.00	1.01	5.23	<.0001
EDU (No high school)	1.00	.	.	.	.
RACE (Hispanic)	1.00	0.99	1.00	-0.42	0.6719
RACE (Black)	1.03	1.03	1.04	14.04	<.0001
RACE (White)	1.00	.	.	.	.
Houseowned	1.00	0.99	1.00	-0.93	0.3521

Table11 Solutions for Fixed Effects of GLIMMIX final model including location as random effect after dropping the interaction term (Residential stability*houseowned) and house tenure

Solutions for Fixed Effects					
Parameter	OR	OR 95%CI		t Value	Pr > |t|
Residential stability	1.01	1.01	1.02	4.56	<.0001
Preterm birth history (Yes)	1.08	1.08	1.09	50.60	<.0001
Preterm birth history (No)	1.00	.	.	.	.
Prenatal care (Adequate-Plus)	0.90	0.90	0.90	-53.13	<.0001
Prenatal care (Adequate)	0.83	0.83	0.83	-103.12	<.0001
Prenatal care (Inadequate)	0.83	0.83	0.84	-149.42	<.0001
Prenatal care (None)	1.00	.	.	.	.
Maternal marital(Yes)	0.98	0.98	0.99	-11.82	<.0001
Maternal marital(No)	1.00	.	.	.	.
Maternal alcohol(Yes)	1.02	1.01	1.03	3.36	0.0008
Maternal alcohol(No)	1.00	.	.	.	.
Maternal tobacco(Yes)	1.03	1.02	1.03	13.36	<.0001
Maternal tobacco(No)	1.00	.	.	.	.
PARITY (More than Third)	0.99	0.99	1.00	-3.81	0.0001
PARITY (Second & Third)	0.99	0.98	0.99	-7.89	<.0001
PARITY(First)	1.00	.	.	.	.
EDU (At least some college)	1.02	1.01	1.02	10.41	<.0001
EDU (High school degree)	1.01	1.00	1.01	5.27	<.0001
EDU (No high school)	1.00	.	.	.	.
RACE (Hispanic)	1.00	0.99	1.00	-0.51	0.6105
RACE (Black)	1.03	1.03	1.04	14.08	<.0001
RACE (White)	1	.	.	.	.