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# Examining childhood and adulthood stressors as risk factors for gestational diabetes mellitus in working pregnant individuals: A prospective cohort study

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ABSTRACT

*Aims:* This study aimed to examine the individual and joint associations of adverse childhood experiences (ACEs) and maternal work and non-work related stressors with the risk of gestational diabetes mellitus (GDM).
*Methods:* Working pregnant individuals (n = 1163) from a United States (U.S.) prospective cohort conducted in South Carolina between 2016 and 2021 were included in the study. ACEs were assessed at study enrollment before 20 gestational weeks (GW), while maternal stressors were assessed in late pregnancy and GDM diagnosis occurred between 24 and 30 GW. Multivariable logistic regressions were performed to assess associations of ACEs and maternal stressors with GDM.
*Results:* Childhood abuse, an ACE subdomain, was associated with an elevated but statistically insignificant risk of GDM (adjusted OR = 1.47; 95 % CI: 0.85–2.53). Only maternal work stressors were associated with an increased risk of GDM (adjusted OR = 2.11; 95 % CI: 1.17–3.79) and the association became much stronger among those with childhood abuse experiences (adjusted OR = 3.80; 95 % CI:1.68–8.60).
*Conclusion:* Among U.S. working pregnant individuals, having work stressors during pregnancy was associated with an elevated risk of developing GDM, particularly among those who had childhood experience of abuse.

## 1. Introduction

Gestational Diabetes Mellitus (GDM) is one of the most common and growing pregnancy complications, affecting 2–10 % of pregnancies in the United States (Centers for Disease Control and Prevention, n.d.). GDM has been linked with elevated risks of adverse health outcomes for both mother and infant (McIntyre et al., 2019). Individuals with GDM are at greater risk of developing Type 2 diabetes as well as cardiovascular disease (CVD) (McIntyre et al., 2019). Short-term adverse health outcomes for infants of GDM-diagnosed individuals include increased risk of macrosomia, hypoglycemia, and respiratory distress (Murray and Reynolds, 2020). Long-term adverse health outcomes for infants include increased risk of obesity and cardiometabolic diseases (Murray and Reynolds, 2020). Thus, identifying modifiable risk factors for GDM is critical for preventing GDM and promoting maternal and child health.

Recent evidence suggests psychosocial factors such as emotional distress and exposure to stressful conditions may play a role in the pathogenesis of Type 2 diabetes, likely through chronic allostatic load involving neuroendocrine, metabolic, and inflammatory pathways (Hackett and Steptoe, 2016; Chen et al., 2016). Furthermore, recent studies have reported that the stressors from different domains during pregnancy were associated with an increased risk of GDM, including financial- and work-related stress (Mason et al., 2016; Versteegen et al., 2021; Lissåker et al., 2022). Finally, findings from the Nurse Health Study II showed that stressful experiences in childhood and adolescent were also associated with a higher risk of GDM (Mason et al., 2016). Despite these findings, research on the interactive role of stress in both childhood and adulthood on GDM, through the life-course perspective,

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is lacking. Emerging evidence suggests that adverse psychosocial experiences during childhood, particularly adverse childhood experiences (ACEs), may moderate the effects of adult stressors on cardiometabolic outcomes, influencing associations between work-related stressors and hypertension and atherosclerosis (Matthews et al., 2022; Westerlund et al., 2012). However, studies specifically focusing on diabetes are lacking.

Thus, we aimed to elucidate the relationship between stressors from different life stages and their implications for GDM risk. We aimed to investigate how childhood stressors (i.e. ACEs) and maternal stressors (both work-related and non-work-related) interact to influence GDM risk in a racially diverse population of pregnant individuals in the United States. We hypothesize that ACEs and maternal stressors would be independently and jointly associated with GDM risk.

## 2. Methods

### 2.1. Study population

Participants from the Centering and Racial Disparities (CRADLE) study who were still working during pregnancy were included in the current study. The CRADLE study was originally designed as a single site, randomized controlled trial to test the effect of group-based prenatal care vs. individual prenatal care on pregnancy and birth outcomes among 2348 medically low-risk pregnant individuals who were aged 14–45 years and enrolled before 21 weeks. The CRADLE study was conducted in Greenville, South Carolina, U.S. between 2016 and 2020 (Chen et al., 2017). The CRADLE study was registered with ClinicalTrials.gov on December 29th, 2015 (NCT02640638). To be eligible in the current study, participants must be aged 18 years or older and were employed outside of the home at the study enrollment, thus yielding a final sample size of 1163 participants (Fig. 1). The study was approved by the institutional review board (Pro00043994).

### 2.2. Exposure measures

ACEs were assessed by a validated questionnaire at enrollment (Survey 1, before 21 weeks gestation). This questionnaire was adapted from the original Centers for Disease Control and Prevention (CDC) ACE study and used in the CDC Behavioral Risk Factor Surveillance System (BRFSS) to assess ACEs (Centers for Disease Control and Prevention, 2014a; Felitti et al., 1998). This ACEs questionnaire retrospectively collects information among adults about their childhood stressful experiences that occurred before age of 18 years (Versteegen et al., 2021; Centers for Disease Control and Prevention, 2020). Of the 11-item questionnaire, two assess physical abuse, three assess sexual abuse, one assesses emotional abuse, and five items assess household challenges, with each item scored 1 if the answer is "Yes" and 0 if the answer is "No" (Supplemental Table S1). The total score of ACEs ranged from 0 to 11.

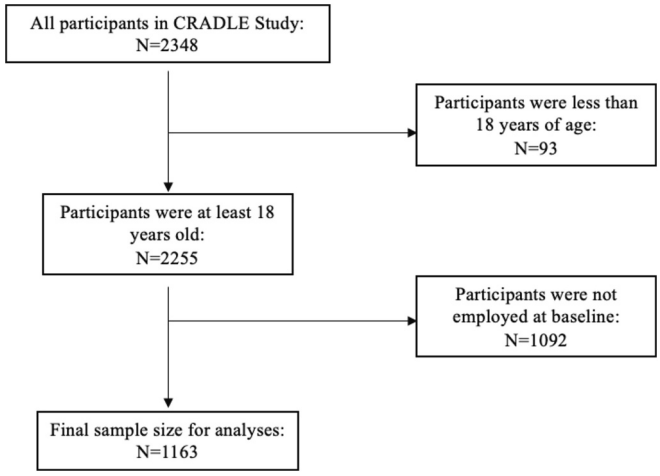


**Fig. 1.** Sample size flowchart for the analysis of employed participants aged 18 years or older from the CRADLE Study in Greenville, South Carolina (2016–2021).

Maternal stressors were measured at Survey 2 (between 30 and 36 weeks of gestation) by a 7-item questionnaire adapted from the CDC Pregnancy Risk Assessment Monitoring System (PRAMS) and included both work-related and non-work related stressors during pregnancy (Centers for Disease Control and Prevention, 2014b). Work stressors were examined using three items (i.e. "Since I became pregnant, I lost my job."). Non-work stress was examined using four items for life stress (i.e. "Since I became pregnant, I lost someone.") (Supplemental Table S1). Participants who experienced at least one work stressor were classified as "Yes" and those who did not experience any work stress were classified as "No". Similarly for maternal non-work stressors, participants who experienced at least one non-work stressor were classified as "Yes" and those who did not experience any non-work stress were classified as "No". A separate "non-response" category was created for participants who responded as "Prefer not to answer".

### 2.3. Ascertainment of GDM

Incidence of GDM was the primary outcome for this study and was diagnosed according to the American College of Obstetricians and Gynecologists (ACOG) recommendation using the two-step approach. Participants were screened for GDM between 24 and 30 weeks gestation with an initial 50 g oral glucose challenge test (GCT) followed by a 100 g oral glucose tolerance test (OGTT) for those with GCT $>$ 140 mg/dl. Individuals were diagnosed with GDM if two plasma glucose values during the OGTT tests were above normal based on the Carpenter and Coustan criteria (i.e., fasting $\geq$ 95, 1-h $\geq$ 180, 2-h $\geq$ 155, or 3-h $\geq$ 140 mg/dl) (*Obstet. Gynecol.*, 2018).

### 2.4. Covariates

Sociodemographic and behavioral information was collected at enrollment during Survey 1, including age, race and ethnicity, education, insurance coverage in the 12 months prior to pregnancy, Medicaid status at delivery, marital status, tobacco use during pregnancy, and employment. Reproductive history and other clinical information were extracted from the medical records. Pre-pregnancy body mass index (BMI) was also extracted from medical records.

### 2.5. Statistical analyses

Since the CRADLE study found group and individual-based prenatal care had similar pregnancy and birth outcomes, participants who were assigned to both prenatal care groups were combined in the current analysis (Crockett et al., 2022).

Descriptive statistics for participants' characteristics by GDM were generated. Differences between GDM groups were compared using *t*-test for continuous variables and Chi-square test (or Fisher's exact test if n is less than 5) for categorical variables. Odds ratios (ORs) and 95 % confidence intervals (CIs) of the individual associations of childhood (i.e., ACE scores) and maternal stressors with GDM were estimated using logistic regression models, both unadjusted and adjusted for covariates. Covariates included in the adjusted models were selected based on their known associations with pregnancy outcomes such as GDM and potential confounding effects (Ben-Haroush et al., 2004; Zhang and Ning, 2011). Covariates adjusted in the multivariable models included age (continuous), pre-pregnancy BMI (continuous), race and ethnicity (Black, Hispanic, White, or Other), Medicaid status at delivery (Medicaid eligible or Other), education (High school graduate or less or College or greater), marital status (married or not married), tobacco use

**Table 1**
Overview of study participants' baseline characteristics in Greenville, South Carolina, 2016–2021 (n = 1163).

| Characteristics | Participants with GDM (n = 69) | Participants without GDM (n = 1094) | *P*-value |
|---|---|---|---|
| Age at enrollment, mean (SD), years | 28.58 (5.34) | 25.14 (4.90) | <0.001 |
| Age category, N (%) | | | <0.001 |
| 18–24 | 16 (23.19) | 613 (56.03) | |
| 25–34 | 44 (63.77) | 429 (39.21) | |
| 35+ | 9 (13.04) | 52 (4.75) | |
| Body mass index, mean (SD), kg/m$^2$ | 35.14 (7.72) | 28.93 (7.25) | <0.001 |
| BMI status, N (%) | | | <0.001 |
| Underweight and Normal weight (<25 kg/m$^2$) | 7 (10.14) | 391 (35.74) | |
| Overweight (25–29.9 kg/m$^2$) | 13 (18.84) | 275 (25.14) | |
| Obese (30 kg/m$^2$ or greater) | 49 (71.01) | 428 (39.12) | |
| Race, N (%) | | | 0.01 |
| African American | 21 (30.43) | 521 (47.62) | |
| White | 28 (40.58) | 387 (35.37) | |
| Hispanic | 18 (26.09) | 170 (15.54) | |
| Other | 2 (2.90) | 16 (1.46) | |
| Marital status, N (%) | | | 0.11 |
| Not married | 35 (50.72) | 678 (61.97) | |
| Married | 17 (24.64) | 175 (16.00) | |
| Missing | 17 (24.64) | 241 (22.03) | |
| Parity, N (%) | | | 0.03 |
| Nulliparous | 24 (34.78) | 524 (47.90) | |
| Parous | 45 (65.22) | 570 (52.10) | |
| Education, N (%) | | | 0.95 |
| High school graduate or less | 52 (75.36) | 819 (74.86) | |
| College or greater | 17 (24.64) | 261 (23.86) | |
| Missing | – | 14 (1.28) | |
| Insurance coverage in the 12 months prior to pregnancy | | | 0.09 |
| No | 28 (40.58) | 429 (39.21) | |
| Yes | 29 (42.03) | 559 (51.10) | |
| Missing | 12 (17.39) | 106 (9.69) | |
| Medicaid status at delivery | | | 0.06 |
| Other | 6 (8.70) | 41 (3.75) | |
| Medicaid eligible | 59 (85.51) | 927 (84.73) | |
| Missing | 4 (5.80) | 126 (11.52) | |
| Tobacco use during pregnancy, N (%) | | | 0.39 |
| No | 54 (78.26) | 900 (82.27) | |
| Yes | 14 (20.29) | 185 (16.91) | |
| Missing | 1 (1.45) | 9 (0.82) | |

GDM: gestational diabetes mellitus; SD: standard deviation.
T-test performed on continuous variables.
Chi-square tests or Fisher's exact test were performed on categorical variables.

during pregnancy (yes or no), employment status (working full-time or working part-time), parity (nulliparous or parous), and prenatal assignment (group-based or individual based). ACEs were first categorized into two groups (i.e., ACE score ≥ 1 for those who experienced at least one ACE vs. ACE score = 0 for those who did not experience any ACEs) to estimate the risk of GDM by childhood stressors. The association of each component of ACE (i.e., physical abuse, sexual abuse, emotional abuse, any childhood abuse, and household challenges) with GDM was then examined. Maternal work stressors (i.e., those who experienced work stressors vs. those who did not) and maternal non-work stressors (i.e., those who experienced non-work stressors vs. those who did not) were separately examined. The joint associations of childhood stressors and maternal stressors with GDM were evaluated by adding an interaction term (i.e., maternal stressor*ACEs (≥1 *or* 0) or maternal stressor*any childhood abuse) and then conducting stratified analyses. Missing covariables (range from 1 to 25 %) were treated as separate categories in the primary analyses (Pedersen et al., 2017).

Sensitivity analyses were performed 1) by categorizing ACE score as <4 or ≥ 4, and 2) by using the complete case analysis as well as multiple imputation of missing exposure and covariate data using the Rubin multiple imputation method (Rubin, 1988). A *P*-value of <0.05 was considered statistically significant for all statistical comparisons except for interaction effects. Interaction effects were considered statistically significant for those with a *P*-value <0.10 (Selvin, 2004; Wasserstein and Lazar, 2016). Analysis was conducted in SAS (SAS Institute Inc. 2020. Release: 9.4 M7 Cary, NC, USA).

## 3. Results

### 3.1. Sample characteristics

Among 1163 participants (46.6 % identified as Black, 35.7 % as White, 16.2 % Hispanic), with the mean (standard deviation [SD]) age of 28 (5) years among participants with GDM and 25 (5) years among those without GDM. Individuals with GDM had a higher pre-pregnancy BMI (mean: 35 kg/m$^2$; SD: 8) compared to those without GDM (mean: 29 kg/m$^2$; SD: 7). Participants with GDM were likely to be White or Hispanic compared to those without GDM. The majority of participants had insurance coverage in the 12 months prior to pregnancy (50.6 %), were Medicaid eligible at delivery (84.8 %), had an education of high school graduate or less (74.9 %), not married (61.3 %) and non-smokers (82.0 %). There were no differences in education between GDM and non-GDM participants, however participants with GDM were also more likely to be married, parous, and tobacco smokers during pregnancy compared to those without GDM (Table 1).

### 3.2. Lifecourse stress (childhood and maternal stress)

Among all 1163 participants, 29 % had an ACE score of 0, 48 % had an ACE score ≥ 1, and 23 % did not respond (Table 2). By ACE domain, 43 % participants reported having experienced at least one abuse in childhood (20 % for physical abuse, 13 % for sexual abuse, and 31 % for emotional abuse) and 48 % reported household challenges during

**Table 2**
Associations of childhood and maternal stressors with GDM among study participants in Greenville, South Carolina, 2016–2021 (n = 1163).

| | Number of exposed participants (%) | Number of GDM/number of exposed participants | Unadjusted model | | Adjusted Model[2] | |
|---|---|---|---|---|---|---|
| | | | ORs (95 % CI) | *P*-values | ORs (95 % CI) | *P*-values |
| Childhood stressors | | | | | | |
| ACE scores | | | | | | |
| ACE score = 0 | 333 (28.63) | 18/333 | 1.00 | – | 1.00 | – |
| ACE score ≥ 1 | 559 (48.07) | 29/559 | 0.96 (0.52–1.75) | 0.89 | 0.89 (0.46–1.71) | 0.72 |
| Non-response | 271 (23.30) | 22/271 | 1.55 (0.81–2.95) | 0.19 | 1.50 (0.74–3.03) | 0.26 |
| Any childhood abuse[1] | | | | | | |
| No | 629 (54.08) | 28/629 | 1.00 | – | 1.00 | – |
| Yes | 505 (43.42) | 38/505 | 1.75 (1.06–2.89) | 0.03 | 1.47 (0.85–2.53) | 0.17 |
| Non-response | 29 (2.49) | 3/29 | 2.48 (0.71–8.68) | 0.16 | 2.09 (0.49–8.97) | 0.32 |
| Household challenges | | | | | | |
| No | 453 (38.95) | 27/453 | 1.00 | – | 1.00 | – |
| Yes | 563 (48.41) | 38/563 | 1.14 (0.69–1.90) | 0.61 | 1.08 (0.62–1.88) | 0.79 |
| Non-response | 147 (12.64) | 4/147 | 0.44 (0.15–1.28) | 0.13 | 0.41 (0.13–1.25) | 0.11 |
| Maternal stressors | | | | | | |
| Work stress | | | | | | |
| No | 615 (52.88) | 27/615 | 1.00 | – | 1.00 | – |
| Yes | 326 (28.03) | 28/326 | 2.05 (1.18–3.54) | 0.01 | 2.11 (1.17–3.79) | 0.01 |
| Non-response | 14 (19.09) | 14/222 | 1.47 (0.75–2.85) | 0.26 | 1.57 (0.41–6.09) | 0.51 |
| Non-work stress | | | | | | |
| No | 550 (47.29) | 30/550 | 1.00 | – | 1.00 | – |
| Yes | 391 (33.62) | 25/391 | 1.18 (0.69–2.05) | 0.55 | 1.06 (0.59–1.93) | 0.84 |
| Non-response | 222 (19.09) | 14/222 | 1.17 (0.61–2.25) | 0.64 | 1.11 (0.29–4.25) | 0.88 |

ACEs: adverse childhood experiences; GDM: gestational diabetes mellitus; OR: odds ratio; CI: confidence interval. Logistic Regression models performed.
[1] Any childhood abuse is a categorical variable that classifies "Yes" to those who experienced physical, sexual, and/or emotional abuse, "No" to those who did not experience any childhood abuse, and "Non-response" to those with missing ACE abuse measures.
[2] Adjusted Model: adjusted for age, education, Medicaid status at delivery, marital status, race, employment status, tobacco use during pregnancy, BMI, parity, and care group.

childhood (Supplemental Table S2). Among all participants, 28 % reported having work stress and 34 % had non-work stress during pregnancy (Table 2).

### 3.3. Associations between childhood stress and GDM

Among 1163 participants, 69 (5.9 %) individuals developed GDM. Participants with ACE score ≥ 1 did not have a higher risk of GDM compared to those with ACE score = 0 in both unadjusted (OR = 0.96; 95 % CI: 0.52–1.75) and adjusted models (adjusted OR = 0.89; 95 % CI: 0.46–1.71) (Table 2). Although participants in the non-response category had an elevated risk of GDM compared to those with ACE score = 0 (adjusted OR = 1.50; 95 % CI: 0.74–3.03), this association was statistically insignificant (*P* = 0.26).

Participants who experienced any household challenges during childhood had a similar risk of GDM compared to those without household challenges (adjusted OR = 1.03; 95 % CI: 0.59–1.80). However, participants who experienced "any childhood abuse" (i.e., physical abuse, sexual abuse, or emotional abuse) in childhood had a 47 % higher odds (adjusted OR = 1.47; 95 % CI: 0.85–2.53) of developing GDM

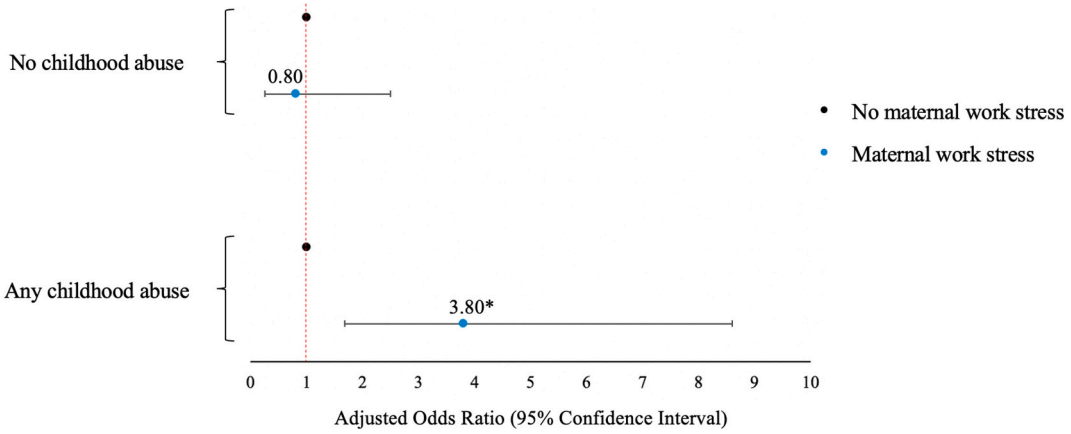


**Fig. 2.** Forest plot of associations between maternal work stress and gestational diabetes, stratified by childhood abuse experience in Greenville, South Carolina 2016–2021.[1]
[1]Logistic regression models adjusted for age, race/ethnicity, education, Medicaid status at delivery, marital status, employment status, care group, tobacco use during pregnancy, prepregnancy BMI, and parity. No maternal work stress is the reference group in each strata of childhood abuse, which is shown in black. Maternal work stress is shown in blue. Any childhood abuse is a categorical variable that classifies "Yes" to those who experienced physical, sexual, and/or emotional abuse and "No" to those who did not experience any childhood abuse. Dots represent adjusted odds ratios with error bars representing 95 % confidence intervals. *P*-value of <0.05 is considered statistically significant and represented in the plot with an asterisk. Dashed line across the plot included to indicate an odds ratio of 1. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

compared to participants who did not experience any childhood abuse. However, the 95 % CI was wide and crossed 1.0. Although participants in the non-response category showed an increased risk of GDM compared to those who did not experience any childhood abuse (adjusted OR = 2.09; 95 % CI: 0.49–8.97), the 95 % CI was very wide and crossed 1.0. Further details of the fully adjusted models of childhood stressors are presented in Supplemental Table S3.

### 3.4. Association between maternal stressors and GDM

Experiencing maternal work stressors was associated with an elevated risk of GDM (adjusted OR = 2.11; 95 % CI: 1.17–3.79), but not maternal non-work stressors (adjusted OR = 1.06; 95 % CI: 0.59–1.93). While participants in the non-response category exhibited a higher risk of GDM compared to those with no maternal work stressors (adjusted OR = 1.57; 95 % CI: 0.41–6.09), this association did not attain statistical significance ($P = 0.51$). Further details of the fully adjusted models of maternal stressors are presented in Supplemental Table S4.

### 3.5. Effect modification of childhood abuse and maternal work stressors on GDM

We observed a statistically significant interaction between childhood abuse and maternal work stressors with GDM as the outcome ($P < 0.10$). We further assessed the association of maternal work stressors with GDM stratified by childhood abuse (Fig. 2). Among participants with childhood abuse, experiencing maternal work stressors was associated with 3.80 times the odds of GDM (adjusted OR = 3.80; 95 % CI: 1.68–8.60) compared to those without exposure to work stressors. Among participants with no childhood abuse, however, experiencing maternal work stressors was not associated with GDM risk (adjusted OR = 0.80; 95 % CI: 0.25–2.50) (Fig. 2).

### 3.6. Sensitivity analyses

In the sensitivity analyses, participants who had ACE scores ≥4 also had a higher GDM risk compared to participants who had ACE scores <4 (Supplemental Table S2; adjusted OR = 1.23; 95 % CI: 0.58–2.58) although the 95 % CIs cross 1.0. When performing multiple imputations or completed case analyses, results remained unchanged. Notably, a positive association remained between experiencing any childhood abuse and GDM risk (adjusted OR = 1.32; 95 % CI: 0.77–2.28) in the multiple imputations or (adjusted OR = 1.33; 95 % CI: 0.54–3.27) in the completed cases. Similarly, participants experiencing maternal work stressors had an increased risk of GDM compared to those without any maternal work stressors (adjusted OR = 1.93; 95 % CI: 1.08–3.47) in multiple imputations or (adjusted OR = 1.33; 95 % CI: 0.53–3.34) in complete case analysis (Supplemental Tables S5). Consistent patterns of association between maternal work stressors and GDM, stratified by childhood abuse, were observed in both complete case analysis participants and after performing multiple imputations (Supplemental Fig. S1).

## 4. Discussion

In this prospective study among racially diverse working pregnant individuals, we found that experiencing childhood abuse and maternal work stressors during pregnancy were independently and jointly associated with an increased risk of GDM. Specifically, participants who reported having maternal work stressors had 2.11 times the odds of developing GDM compared to those without work stressors. Also, participants who experienced childhood abuse (i.e., physical, sexual, or emotional abuse) had 1.49 times the odds of developing GDM compared to those who did not experience childhood abuse. Among individuals who experienced childhood abuse, those with maternal work stressors had 3.80 times the odds of developing GDM compared to working individuals without work stressors.

This examination of the individual and joint associations between childhood stressors and maternal adulthood stressors on GDM risk is an important contribution to the literature. Very few studies have separated pregnancy related stress by domains (Mason et al., 2016; Chen et al., 2020; Schoenaker et al., 2019). Our findings are consistent with results from a large prospective study in Sweden using the Job Exposure Matrix to measure work stress (Lissåker et al., 2022). Pregnant individuals with higher stress levels at work had 36–58 % increased risk of GDM compared to individuals with lower levels (Lissåker et al., 2022). In addition, work-related stress has been associated with a higher risk of T2D (Pena-Gralle et al., 2022) which share some common pathophysiological features with GDM, further corroborating the findings from the current study.

Unlike some other studies (Chen et al., 2020; Hosler et al., 2011; Silveira et al., 2014), we did not find the association between non-work stressors and GDM risk. This is likely due to the different study populations and types of stress captured by different studies. Given the impending re-submission of "work requirements" for Medicaid patients in several states (Sommers et al., 2019), our study provides additional evidence of exacerbated health outcomes for Medicaid beneficiaries working in high-stress occupations. Beyond the broader implications of our findings, it's imperative to recognize the specific impact on predominantly income-eligible Medicaid populations. Individuals in this demographic face unique challenges such as limited access to healthcare services and other socioeconomic factors (Bellerose et al., 2022; Adams et al., 2005). Our study highlights the heightened maternal work stress levels in this population, potentially contributing to an increased risk of GDM. These findings underscore the urgency of developing targeted interventions and policies to improve maternal health outcomes within Medicaid-eligible populations.

Our results on the association between ACEs and GDM risk are consistent with two other cohort studies in the US (Mason et al., 2016; Versteegen et al., 2021). Mason et al. investigated associations of ACE subcategories with GDM and found significant positive associations of physical or sexual abuse with GDM risk using data from the US Nurses' Health cohort (Mason et al., 2016). Another smaller prospective cohort study of 266 pregnant individuals performed by Versteegen et al., also demonstrated a positive association between higher ACE scores and GDM risk (Versteegen et al., 2021).

Although there has been an increased attentiveness on examining long-term, cumulative effects of risk factors on chronic diseases through a life-course framework, studies in psychosocial health and its impact on chronic diseases across the life-course are still limited to hypertension (Repetti et al., 2002), coronary heart disease (Repetti et al., 2002; Lynch and Smith, 2005) and type 2 diabetes (Lynch and Smith, 2005; Ben-Shlomo and Kuh, 2002). This study represents another important contribution to our understanding in this area by examining the GDM risk among working pregnant individuals. By exploring the intricate interplay between childhood abuse, maternal work stressors, and the risk of GDM among a racially diverse cohort of pregnant individuals, our findings shed light on potential pathways underlying these associations. One plausible explanation for the moderating effect of ACEs on the relationship between maternal work stressors and GDM risk is the vulnerability hypothesis (Belsky and Pluess, 2009). According to this hypothesis, individuals who have experienced early life adversity may exhibit heightened vulnerability to the detrimental effects of stressors encountered later in life. Specifically, childhood abuse may expose individuals to the impact of subsequent stressors, such as work-related stressors during pregnancy, thereby amplifying their susceptibility to developing GDM. This vulnerability could manifest through dysregulation of physiological stress response systems, including alterations in neuroendocrine and immune pathways, ultimately contributing to the development of GDM (Phillips and Jones, 2006). Another potential pathway through which ACEs may contribute to the association between maternal work stressors and GDM is via mediation. Adult stressors could

serve as mediators in the pathway from ACEs to GDM. However, our mediation analysis did not support this hypothesis (results not shown but available upon request). Further research exploring the underlying mechanisms through which ACEs heighten the effects of maternal work stressors on GDM risk is warranted to elucidate these pathways and inform preventive interventions targeting vulnerable populations.

Our study has several strengths. First, this is a prospective study and included racially diverse pregnant individuals, particularly Black (47 %) and Hispanic (16 %) pregnant individuals who are under-represented in many other studies. Second, GDM was clinically measured based on laboratory results with high validity (*Obstet. Gynecol.*, 2018). Lastly, we collected extensive sociodemographic and lifestyle information adjusting for several confounders of GDM.

Our study has several limitations worth mentioning. First, it is important to indicate our study is observational in nature. Additionally, while we included many potential confounders, certain lifestyle factors such as physical activity, sleep, and diet, which may also influence GDM risk (Zhang and Ning, 2011), were not assessed or included in our analysis. This omission is acknowledged as a limitation. All reports of ACEs are collected in adulthood thus introducing the potential for recall bias, however evidence has shown the ACEs questionnaire as a valid measure of early life adversity even if collected retrospectively (Hardt and Rutter, 2004). Although we asked participants to report stressors during the pregnancy, the questionnaire was administered around 30 weeks of gestation. Since GDM screening occurred between 24 and 30 weeks gestation, we cannot ascertain the diagnosis of GDM would influence participants' responses. However, given we asked them to report stressful life events during pregnancy and not their perceived stress levels, the influence of GDM diagnosis would be minimal. Furthermore, we had a relatively large number of participants who did not answer questions related to ACEs and maternal stressors, which is common and are likely due to the sensitive nature of the questions. We thus treated "non-response" as a separate category in the data analysis. In our sensitivity analyses, findings did not change substantially after conducting complete case analysis and multiple imputation. In addition, the study sample size may be underpowered to estimate a dose-response relationship between ACE scores and GDM risk given we only had 12 participants with ACE scores equal or above 4 (a more common cutoff applied in other studies). Lastly, the exclusion of non-working participants limits the generalizability of our findings to working pregnant individuals, as our study was specifically designed to examine the risk of GDM in this group, hypothesizing that work-related stressors uniquely impact GDM risk.

Our study underscores the importance of addressing maternal work stressors and childhood adversity in reducing the risk of GDM, particularly among vulnerable populations such as Medicaid beneficiaries. Public health efforts should focus on developing interventions aimed at improving access to affordable healthcare services before and after pregnancy, creating supportive work environments, addressing social determinants of health, and providing education and resources for stress management during pregnancy. Additionally, interventions targeting childhood adversity through early identification and intervention programs may help mitigate the long-term health consequences, including GDM risk. By addressing these psychosocial stressors across the life course, public health initiatives can improve maternal and child health outcomes and reduce the burden of GDM on healthcare systems.

## 5. Conclusion

Among US working pregnant individuals, having maternal work stressors was associated with a higher risk of GDM, which was further moderated by the childhood experience of abuse. Further investigation is warranted to confirm our findings and investigate work-related stressors before pregnancy, as well as strategies to mitigate work-related stress during pregnancy.

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## CRediT authorship contribution statement

**Lizette Mendez:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Jian Li:** Writing – review & editing, Supervision, Funding acquisition, Formal analysis, Conceptualization. **Cheng-Tzu Hsieh:** Formal analysis. **Lu Zhang:** Writing – review & editing, Resources. **Jessica Britt:** Writing – review & editing, Resources. **Amy Crockett:** Writing – review & editing, Resources. **Liwei Chen:** Writing – review & editing, Supervision, Resources, Methodology, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Deidentified study data will be available publicly on the NICHD Data and Specimen Hub (https://dash.nichd.nih.gov) in October 2026, 5 years after study completion.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2024.108163.

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