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The relationship between self-report and biomarkers of stress in low-income, reproductive age women

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Abstract

OBJECTIVE—To determine if there is an association between self-reported and biologic measures of stress in low-income, reproductive age women.

STUDY DESIGN—Between 1999 and 2005, randomly selected reproductive age women from the 1998 welfare rolls in Chicago were interviewed yearly to assess psychosocial, socioeconomic, and health characteristics. The association of two stress sensitive biomarkers (Epstein-Barr virus antibody titer (EBV) and C-reactive protein (CRP) level) with self-reported stress was assessed.

RESULTS—Of the 206 women interviewed, 205 (99%) agreed to provide a blood sample. There was no difference in mean EBV or CRP levels based on age, race, parity, employment, marital status, or education. Women who reported a higher degree of perceived stress or reported experiences of discrimination had significantly higher levels of EBV ($p < .05$).

CONCLUSION—Measures of self-reported psychosocial stress are associated with elevated levels EBV antibody in a low-income population of reproductive age women.

Keywords

biomarkers; C-reactive protein; Epstein-Barr virus; low-income women; stress

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Introduction

Psychosocial stress has been proposed as a potential etiology for adverse pregnancy outcomes such as preterm delivery. Three biologically plausible physiologic pathways linking stress and preterm birth have been proposed.¹ First, stress is known to activate the hypothalamic-pituitary-adrenal axis stress response, resulting in a hormonally-mediated cytokine release that stimulates the myometrium.^{2–7} Second, stress, through increased glucocorticoid production, inhibits immune function and increases susceptibility to infection-mediated labor.^{1, 8–13} Third, chronic stress has been reported to up regulate the inflammatory response leading to a chronic pro-inflammatory state.^{14–16}

The epidemiologic evidence linking stress and poor pregnancy outcomes has been intriguing, although somewhat inconsistent. While several studies have shown a link between maternal self-reported stress and low birth weight or preterm birth,^{15, 17–23} others have failed to demonstrate an association.^{24–28} Similarly, it also has been hypothesized that maternal stress may play a role in explaining the racial disparities seen in preterm birth rates in the United States.²⁹ Yet, the available data have not consistently established disparities in stress as the underlying etiology for disparities in preterm birth.

Several factors may explain the inconsistent associations reported between maternal stress and preterm birth. Much of the research conducted to date relies heavily upon self-report measures of stress. In addition, numerous measures of maternal stress have been used with little consistency in the operational definitions across studies. Perhaps most importantly, existing research largely has focused upon acute stress with little emphasis upon chronic stress.³⁰ This is important because chronic stress is a biologically plausible mechanisms linking stress with preterm birth.

Epstein-Barr virus (EBV) antibody and C- reactive protein (CRP) are two examples of biomarkers that increase with chronic stress.^{8, 13, 31–35} However, both have been studied as markers of stress in predominantly older populations with medical co-morbidities.³⁶ The association of elevated EBV and CRP with self-reported chronic stress has been investigated only in a limited fashion in reproductive age women.³⁷ Correspondingly, the objective of this study is to assess the association between self-reported stress and two biologic measures sensitive to chronic stress, EBV and CRP, in a cohort of low-income, reproductive age women.

Materials and Methods

The Illinois Family Study (IFS) is a longitudinal, cohort study that was designed to assess the effects of welfare reform on families in Illinois who were receiving Temporary Assistance for Needy Families (TANF) in 1998. The complete methods for this study have been described elsewhere.¹¹ In brief, the sample population consisted of 1,899 randomly selected TANF grantees who, between 1999 and 2005, completed a yearly interview that included demographic information and questions related to psychosocial stress. The survey was administered in the participant's home by a non-medical, community-based interviewer.

The sample for the current analysis includes the IFS participants from Cook County in 2005. At the time of their yearly interview in 2005, IFS study participants answered several additional survey questions regarding self-reported stress and provided a blood specimen. Given the community setting of the IFS study, blood specimen collection was conducted in participants' homes.³⁸ Specifically, IFS interviewers were trained to collect a dried blood spot specimen from a finger stick. The blood spots were collected on standardized filter paper commonly used for neonatal screening (No. 903, Schleicher and Schull, Keene, NH),

allowed to dry for four hours, and then returned to and stored in a central laboratory at -30°C until batched analysis.

Blood spots were analyzed for C-reactive protein (CRP) and Epstein Barr virus (EBV) antibodies using standardized enzyme immunoassay protocols developed for use with dried blood spot samples.^{39–40} After discs of whole blood were punched from the dried filter paper cards and eluted overnight, the eluate was added to microtiter wells. The quantity of CRP in each sample was determined based on comparison with calibrator values (Dako Corporation, product no.X0923) using a spline-fit standard curve. The EBV antibody protocol utilized an adaptation of a commercially available kit for measuring EBV viral capsid antigen (VCA) IgG antibodies in serum (KC Junior, BioTek, Winooski, VT). The assay quantifies IgG antibodies against the p18 polypeptide, a marker protein containing the immunodominant epitopes of the viral capsid antigen complex. Control and sample values are interpolated from a standard curve using a linear data reduction protocol and reported in ELISA units (Soft-Max Pro, Molecular Devices, Sunnyvale, CA). Previous validation studies indicate a high degree of correlation between results obtained from paired blood spot and serum samples for both CRP³⁹ and EBV antibodies. In the present analysis, subjects with EBV values less than 20 ELISA units were excluded from EBV-related analyses, given that this result is consistent with a non-EBV exposed individual.

Psychosocial factors were grouped into four categories, based on a previously reported conceptual model of chronic stress.^{11, 19} This model posits four domains that are particularly relevant to understanding the actual internal stress experienced by an individual: (1) external stressors (life events, hardships in the home environment, hardships obtaining food, hardships obtaining medical care, having a child with chronic illness in the home, and home crowdedness); (2) enhancers of stress (depression, mental health, and drug or alcohol use); (3) buffers against stress (social support, community group involvement, and coping skills); and (4) perceptions of stress (perceived economic hardship, self-rated health, perceived neighborhood safety, and discrimination). The questions and validated scales from the IFS questionnaire are shown in Table 1.

The relationships between demographic and psychosocial variables and levels of CRP and EBV were investigated. Patients were stratified into “low” or “high” stress categories, as previously described, based on their responses to the stress scales.¹⁷ The serum levels of biomarkers were evaluated for normal distribution using the Kolmogorov-Smirnov test. Continuous variables that were normally distributed were compared using the student t-test and those that were not normally distributed were compared using the Mann-Whitney U test. Pearson analysis was used to assess correlation. All tests were two-tailed and $P < .05$ was used to determine significance. Data analysis was performed using SPSS for Windows, version 16.0 (SPSS Inc, Chicago, IL).

Approval for the study and informed consent was obtained through the institutional review board (IRB) at Northwestern University.

Results

Of the 206 women in Chicago who participated in the IFS, 205 (99%) agreed to provide a blood sample. Two participants did not respond fully to the survey questions assessing external and perceived stressors as well as buffers of stress, and the analysis accordingly did not include their data with regard to these scales. Of the blood samples collected, 187 (91%) met technical standards for analysis (blood spots of sufficient size that was not blotted, smeared, or layered). Non-Hispanic black women accounted for 82.1% of the study population, 10.2 % were Hispanic, 5.1% were non-Hispanic white, and 2.6% were classified

as “other.” The women ranged from 19 to 47 years of age, with approximately 15% younger than 22 years, 69% between 23 and 34 years, and 15% more than 35 years. The participants reported having had between 1 and 11 children, with 32% reporting 5 or more children. Eighty-four percent of the participants were not married, 49% of the sample was not employed, and 30% reported they had not graduated from high school or received a GED. The reported mean household income was \$18,816.

The CRP levels, which were not normally distributed ($P < 0.01$), ranged from .02 to 35.54 mg/L with a median (interquartile range) of 1.8 (0.6–5.5) mg/L. Four EBV samples were less than 20 ELISA units and therefore excluded from the analysis. The remaining specimens ($N = 183$) yielded EBV levels that were normally distributed ($P = 0.12$) and ranged from 22.69 to 303.39 ELISA units, with a mean of 136.84 ± 71.70 ELISA units. EBV and CRP levels were found to be significantly correlated ($p < 0.001$).

Maternal CRP and EBV levels stratified by maternal characteristics are presented in Table 2. Levels did not differ by any demographic factor. Conversely, EBV levels were found to be significantly associated with some indicators of chronic stress. These data are presented in Table 3. For example, women who reported a higher degree of perceived stress had significantly higher mean EBV levels than women who reported a lower degree of perceived stress (140.1 ± 72.5 vs. 101.4 ± 58.4 , $p = 0.04$). In addition, significantly higher mean EBV levels were found in women reporting experiences of discrimination compared to women reporting no experiences of discrimination, (mean 160.6 ± 69.3 vs. mean 131.0 ± 71.3 ELISA units, $p = 0.03$). The associations of CRP with the measures of stress are presented in Table 4. Higher levels of CRP were seen in women with the fewest buffers against stress, although this result did not reach statistical significance ($p = 0.08$).

Comment

In this study, CRP and EBV antibody levels, two markers reflective of chronic stress, were not associated with maternal demographic factors, including maternal race or indicators of relative socioeconomic status (e.g., employment status, income). There was discernable evidence, however, that EBV antibody levels were associated with some measures of stress, and in particular perceived stress and discrimination. Though the highest CRP levels were found in women with the fewest buffers against stressful events, this relationship did not reach statistical significance.

Elevated CRP levels have been associated with self-reported stress.^{36–37} Similarly, elevated CRP levels have been associated with preterm birth.^{31, 34–35} Yet, there have been no prospective studies that have linked stress, CRP levels, and preterm birth, and the relevance of CRP as a biomarker of stress relevant to reproductive-age women and to adverse obstetric outcomes has not been established. Indeed, in this prospective study, CRP levels were not strongly associated with multiple domains of an individual’s experience of stress.

However, EBV antibody levels were significantly associated with measures of stress. This relationship is of particular interest, given that the relationship of EBV antibodies with chronic stress has not been well studied in reproductive-age or pregnant women. EBV antibodies, however, have been widely studied among other populations and shown to be associated with negative life events, academic stress, strained social relationships, and emotional distress.^{8, 13, 32–33, 41–44} Indeed, in one meta-analysis, EBV antibodies were identified as one of the most consistent and strongest measures of stress.⁹

In this study of low-income, predominantly African-American women, we found elevated EBV antibody levels to be most strongly associated with elevated perceived stress and experiences of discrimination. Measures of perceived stress and discrimination have been

associated with increased rates of low birth weight infants and preterm birth in African-American women. For example, Collins et al. reported that African-American mothers' perceptions of increased stress were significantly associated with increased odds of having a very-low birth weight (VLBW) child. Additionally, it was noted that African-American women who reported higher exposure to racism had significantly increased odds for very low birth weight (VLBW) infants even when controlling for demographic, biomedical, and behavioral variables.⁴⁵ The association of racial discrimination with adverse pregnancy outcomes, as well as with higher levels of EBV antibodies, is of particular relevance given the known racial disparity in preterm birth, the lack of an accepted etiology of the disparity, and the inability of traditional socioeconomic variables (e.g. economic differences) to fully account for this disparity.

This study also provides evidence that blood specimens, obtained in a community setting with a high degree of subject acceptance, can allow analysis of potentially relevant stress biomarkers. It has previously been shown that community-based research may more effectively overcome issues of trust, ease of access, and follow-up than hospital-based specimen collection, particularly in low-income populations.^{46–48} Community-based data collection may achieve higher rates of participation and retention and therefore diminish selection bias that may be associated with hospital-based data collection.

Limitations of our study should be noted. The size of the study population may have limited the ability to elucidate associations between biomarkers and survey measures of stress. Also, the detection of an association depends upon the ability to discern the stress that an individual is experiencing, and the best method or instrument to assess chronic stress remains uncertain. It may be that stress is best defined not by measurement from single instruments, but by a more elaborate combination of measures from different domains and instruments. Not all measures of stress used in surveys may be equally valid or reliable for different populations. For example, stressors experienced by low-income women living in an urban setting may need to be assessed differently than for women who have other socioeconomic or racial backgrounds. Nevertheless, the measures used in this study are well established and assess different domains of stress. Finally, women in the study all had a significant degree of economic deprivation which reduced any potential confounding by economic status. This population was chosen because chronic stress was likely to be more prevalent and greater in magnitude. Yet, it is also possible that the choice of this population limited the possibility of finding an association, as the overall levels of the stress biomarkers were higher and the distribution of these biomarkers was narrower than in a random sample of the entire population. In this case, a “ceiling effect” could have impaired the ability to discern associations between chronic stress and the biomarkers under study.

This study adds to the growing body of literature focused on the ramifications of stress in reproductive age women. Additional research needs to determine which biomarkers and which psychometric assessments best capture the stress that an individual experiences, as well as the exact relationship between self-reported stress, stress biomarkers and reproductive health outcomes such as preterm birth. In addition, prospective cohort studies may elucidate the importance of the gene-environment interaction with respect to stress and adverse pregnancy outcomes.

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Table 1

Questions and scales included in the interview and assigned to the chronic stress model.

Variable Name	Question or Scale
<i>External stressors</i>	
Hardships in the home environment	Home Hardship Scale ⁴⁹ Questions directed at determining issues such as household plumbing/heat/telephone problems, rodent or insect infestation, or having had to borrow money from friends or family to pay bills
Food insecurity	USDA Household Food Security Scale ⁵⁰ Questions directed at determining ability to afford the needed food for a household
Child with chronic illness in the home	Do any of the children living in your home have a chronic illness?
Home crowdedness	Number of persons sleeping in the home divided by number of bedrooms. (>2.25 persons/room = crowdedness)
Unemployed	Are you currently working for pay?
Hardship obtaining medical care	Have you had difficulty obtaining medical care in the last year that you felt that you or your family needed?
Stressful life events	Life Events Scale ⁵¹ 13 events grouped into 4 categories: emotional, financial, partner-related and traumatic.
<i>Buffers of stress</i>	
Social support	Social Support Scale ⁵²
Coping skills	State Hope, Goals, Coping Scale ⁵³
Community group involvement	Do you participate in any community groups or volunteer groups?
Attend church	Do you attend religious services? How often?
<i>Enhancers of stress</i>	
Depression	Center for Epidemiological Studies Depression Scale (CES-D) ⁵⁴
Needed treatment for mental health issues in the last year	Have you felt that you needed treatment for mental health issues in the last year?
<i>Perceived stress</i>	
Perceived economic hardship	Perceived Economic Hardship Scale ⁵⁵ Questions directed at determining the status of an individuals' financial situation, such as whether she worries about having enough money in the future or can generally afford to buy the things she needs
Self-rated health	SF-36 Health Survey ⁵⁶ Poor or Fair health versus Good or Very Good or Excellent Health
Perceived neighborhood safety	Do you perceive your neighborhood is safe at night?
Perceived discrimination	Krieger Discrimination Scale ⁵⁷

USDA, United States Department of Agriculture.

Table 2

Serum analyte levels stratified by maternal characteristics.

	N	CRP (mg/L)	P	EBV (ELISA units)	P
Race / ethnicity					
Non-Hispanic Black	153	1.7 (0.6–5.1)	0.67	140.9 ± 73.3	0.11
other	34	2.2 (0.5–5.7)		119.2 ± 62.4	
Age					
≤25	75	1.2 (0.5–4.7)	0.09	139.8 ± 68.8	0.65
>25	112	2.3 (0.8–5.6)		134.9 ± 73.8	
High school graduate					
yes	53	1.8 (0.7–5.5)	0.43	150.8 ± 76.3	0.09
no	133	1.7 (0.5–4.3)		130.9 ± 69.5	
Parity					
≤ 4 children	127	1.6 (0.6–5.1)	0.78	139.5 ± 67.7	0.46
> 4 children	60	2.1 (0.6–5.1)		131.1 ± 80.0	
Marital status					
single	158	1.5 (0.6–4.8)	0.05	136.9 ± 71.0	0.98
married	29	3.4 (0.7–8.0)		136.5 ± 76.5	
Employed					
yes	96	1.3 (0.5–4.2)	0.11	130.0 ± 71.9	0.18
no	91	2.5 (0.8–5.9)		144.1 ± 71.9	

All data presented as medians (interquartile range) or as means ± standard deviations

CRP, C-reactive protein; EBV, Epstein-Barr virus antibodies.

Table 3

Epstein-Barr virus antibody levels (ELISA units) stratified by psychosocial stressors.

	N	Mean EBV (ELISA units)	P
External stressors			
External stress index			
high	23	141.7 ± 74.0	0.74
low	158	136.3 ± 71.8	
Buffers of stress			
Buffers of stress index			
low	15	136.4 ± 75.7	0.99
high	166	136.3 ± 71.8	
Enhancers of stress			
Enhancers of stress index			
high	12	128.0 ± 82.4	0.66
low	171	137.5 ± 71.1	
Perceived stressors			
Perceived stressors index			
high	15	140.1 ± 72.5	0.04
low	166	101.4 ± 58.4	
Perceived discrimination			
yes	36	160.6 ± 69.3	0.03
no	147	131.0 ± 71.3	

All values presented as means ± standard deviations

EBV, Epstein-Barr Virus antibodies

Table 4

C-reactive protein levels (mg/L) stratified by psychosocial stressors.

	N	CRP (mg/L)	P
External stressors			
External stress index			
high	23	1.7 (0.6–5.2)	0.83
low	162	1.6 (0.5–5.5)	
Buffers of stress			
Buffers of stress index			
low	15	2.9 (0.9–9.5)	0.08
high	170	1.6 (0.6–5.0)	
Enhancers of stress			
Enhancers of stress index			
high	12	1.3 (0.5–2.8)	0.48
low	175	1.8 (0.6–5.5)	
Perceived stressors			
Perceived stressors index			
high	15	1.7 (0.6–5.5)	0.69
low	170	2.1 (0.9–3.5)	
Perceived discrimination			
yes	36	1.8 (0.6–5.5)	0.33
no	151	1.1 (0.3–5.2)	

All values presented as means $\pm$ standard deviations.

CRP, C-reactive protein