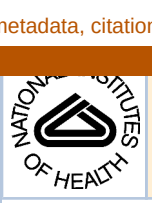

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Racial Differences in C-Reactive Protein Levels During Normal Pregnancy

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Abstract

Objective—Characterization of serum C-Reactive Protein (CRP) levels in a diverse population of healthy pregnant women using a high sensitivity assay.

Study Design—Cross-sectional analysis of a cohort of 775 pregnant women. CRP measured on serum specimens drawn <26 weeks gestation using highly sensitive ELISA kits.

Results—Median CRP was 4.8 mg/L (inter-quartile range 0.63 – 15.7). Black women had higher median CRP values than whites (7.68 mg/L vs 2.59 mg/L, p<.001). Black women demonstrated higher levels of CRP even after controlling for known confounding factors such as smoking and maternal weight.

Conclusion—Pregnancy is an inflammatory stressor. The etiology of racial differences is unclear, but may be important for understanding racial disparities in the incidence inflammatory disorders such as preterm labor and pre-eclampsia.

Keywords

allostatic load; C-reactive protein; CRP; human pregnancy; inflammation; racial disparity

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CONDENSATION:
Pregnancy is an inflammatory stressor as measured by elevations in serum C-reactive protein. Black women have higher levels than white women.

INTRODUCTION

C-reactive protein (CRP) is an acute-phase reactant produced in response to stress, tissue injury and other inflammatory stimuli.[1,2] Recently developed highly-sensitive ELISA assays have lowered the discriminatory range for serum CRP values from 10 mg/L to <1mg/L. Using this new assay, subclinical elevations (>3.0 mg/L) have been identified as markers for endothelial damage, atherogenesis and cardiovascular disease in non-pregnant patients.[3–5] In addition to acute infections and inflammatory processes, there is a well-established relationship between subclinical elevations in serum CRP and obesity, estrogen use, smoking, race and ethnicity.[5–8] In pregnant patients, there has been interest in identifying low-grade systemic inflammation to predict or explain pregnancy-specific conditions such as pre-eclampsia[9–11] and preterm labor.[8,12,13] The importance of maternal inflammation, both in healthy and unhealthy pregnancies, has yet to be fully explored. Therefore, we sought to characterize CRP values in a diverse population of healthy pregnant women using a highly sensitive assay.

MATERIAL AND METHODS

This is a secondary analysis within a cross-sectional prospective study of pregnant women enrolled in a study of oral health in pregnancy. The study was approved by the Duke University Medical Center Institutional Review Board, and all patients provided informed written consent prior to participation in the study. Subjects were enrolled over a 42 month period, beginning in December, 1997. The study design, procedures for patient enrollment, inclusion and exclusion criteria, clinical measurements, data collection methods, medical record abstraction and biological sampling methods have been previously described.[14,15]

Women were excluded if they had a multiple gestation, chronic hypertension, pregestational diabetes, heart murmur or heart valve disease, or human immunodeficiency virus infection. Additionally, patients were required to have ultrasound-confirmed pregnancy dating and to plan on delivering at Duke University Medical Center. Patients who experienced spontaneous pregnancy losses prior to 21 weeks gestational age, elective pregnancy terminations and intrauterine fetal demise were excluded from this analysis. All women were enrolled prior to 26 weeks gestation, at which time they provided demographic information, medical history and behavioral information by interview and written questionnaire. Information on maternal race was collected by patient self-report.

During the study period, 1945 eligible women were identified from the total outpatient obstetric clinic population of 5400 women. Of these, 1069 were successfully enrolled in the original cohort. Serum CRP values were not available for 192 of these women. An additional 102 women were excluded who experienced fetal loss or spontaneous abortion prior to 21 weeks gestation. Our final cohort for this secondary analysis was 775 pregnant women. The sample size was determined by the primary analysis. The current analysis was not considered in estimating sample size or calculating power.

Maternal serum specimens were collected at enrollment. Serum CRP values were determined using commercially available highly-sensitive enzyme-linked immunosorbent assay (VIRGO C-reactive Protein Kit; Hemagen Diagnostics, Waltham MA). The range of this assay is 0.5 to 50 μg/mL, with inter and intra-assay variability of 3% and 15%, respectively. The technique has been previously published.[16] At the time of enrollment, all patients also underwent an oral examination by a trained dental hygienist to assess the presence of periodontal disease, as well as a vaginal examination to evaluate for sexually transmitted infections.

Parametric analysis with Student's T-test and non-parametric analysis with Chi Square test was performed with SAS v 9.1.3 (SAS Institute, Inc. Cary, NC). Our covariates are listed in detail in the results section. CRP levels were examined both as continuous and ordinal values.

Because our inter-quartile range (IQR) for serum CRP values included traditional clinical cut-off of 10 mg/L, we defined elevated CRP values as those above the 75th percentile for our cohort of pregnant women.

RESULTS

The median gestational age at the time of enrollment was 14 weeks (range 4 – 26). Median CRP value at the time of enrollment for all women was 4.8 mg/L (IQR 0.63 – 15.7 mg/L). Demographic information for the cohort is shown in Table 1.

CRP values were plotted against gestational age, and linear regression confirmed a small but significant trend toward increasing serum CRP values with increasing gestational age (R^2=.01, p=.002) in this unadjusted model. Because of the obvious association between increasing gestational age and increasing maternal weight, serum CRP values were also plotted against maternal weight at enrollment. Linear regression confirmed a significant trend toward increasing CRP with increasing maternal weight (R^2=0.12, p<0.001). Believing that the trend toward increasing CRP with increasing gestational age could be a proxy for other characteristics associated with late entry to prenatal care, we sought to further clarify the differences in our population by stratifying women by gestational age at time of enrollment (<14 weeks gestation and ≥14 weeks gestation). Median CRP values <14 weeks (3.95 mg/L, IQR 0.44 – 14.13) were significantly lower compared to those 14–26 weeks (6.24 mg/L, IQR 1.02 – 19.61) (p=.006). Demographic characteristics of women with early entry to prenatal care (<14 weeks) compared with those with late entry (>14 weeks) are presented in Table 1.

Next, we sought to better characterize those women who demonstrated the highest levels of inflammation; those with serum CRP levels above the 75th percentile (15.7 mg/L) for the cohort. The Chi-square Test was employed to identify significant associations between each of our demographic characteristics and elevated serum CRP. We found that black race, maternal weight at enrollment, unmarried status, eligibility for WIC/Food stamps, lack of private insurance and previous preterm delivery were all significantly associated with elevations in serum CRP values above the 75th percentile for the cohort (p≤0.03 for all parameters). Smoking status, which is known to be associated with elevations in serum CRP in non-pregnant patients, did not have a significant association in our population (p=0.58). We also could not identify an association between elevated CRP levels and gestational age, presence of sexually transmitted infections, parity, or alcohol use during the current pregnancy. Using multivariable analysis, maternal weight at enrollment (OR 1.01, CI 1.01 – 1.02 for each 10 pound increase in weight) and black race (OR 2.0, CI 1.4 – 2.8) were the strongest predictors of elevated CRP values, see Table 2.

Because of the strong association we discovered between black race and elevated serum CRP, we stratified our cohort by maternal race for further analysis. As a group, black women had higher median CRP values than white women (7.68 mg/L vs 2.59 mg/L, p<.001). Demographic characteristics are presented in Table 3. Median CRP values were once again calculated for early (<14 weeks) and late (14–26 weeks) pregnancy for both black and white patients. For white women, we identified a trend toward higher serum CRP values with advancing gestational age (1.72 mg/L vs. 3.83 mg/L), but once we adjusted our model for maternal weight at enrollment, this difference did not reach statistical significance (p=0.27). For black women, CRP values did not show the same upward trend with increasing gestational age, even after adjusting for maternal weight (7.61 vs. 7.72, p=1.00). Instead, median values of CRP showed persistent elevations even from the earliest gestational ages. Comparisons of median CRP values for black and white women within both the first and second trimester were highly statistically significant (p < .001), Figure 1.

The Chi-square Test was then employed in order to identify significant associations between each of our demographic characteristics known to be associated with elevated serum CRP and maternal race. We found significantly higher rates of unmarried status, lack of private insurance, and eligibility for WIC/Food stamps among the black women in our cohort.

COMMENT

Limited data have been published on the normal ranges of serum CRP in pregnant women. Initial investigations, using older assays with narrower discriminatory ranges, described a progressive increase in CRP levels with advancing gestational age.[17] A more recent longitudinal study by Belo et al., utilizing the highly sensitive immunoassay, could not identify trends in CRP values. In this study, few women (17%) demonstrated progressive increases throughout gestation, others (30%) had serum CRP values that decreased as gestational age increased, but most (50%) women demonstrated fluctuating CRP levels.[18]

In our cohort of healthy pregnant women, we demonstrate that normal pregnancy is an inflammatory stressor as measured by elevations in serum CRP. Our median value of 4.8 mg/L is above previously published thresholds for sub-clinical inflammation, and our interquartile range of 0.63 – 15.7 mg/L suggests that values above 10 mg/L may be within the normal range for healthy pregnant women. These elevations are evident from even the earliest gestational ages and persist throughout gestation.

This data set is unique in that it includes patient-specific information regarding many of the potential causes of elevated CRP, such as smoking and the presence of sexually transmitted diseases. In addition, all of our patients underwent a complete dental examination, and we therefore had the benefit of knowing periodontal disease status for all of our patients. Most investigators (and clinicians), however, do not have this information. We explored the potential confounding effect of periodontal disease on elevated CRP values by developing our multivariate model both with and without periodontal disease included. The inclusion of periodontal disease changed the odds ratio for the other variables by less than ten percent (data not shown), suggesting that periodontal disease did not confound the relationship between elevations in serum CRP and those patient characteristics identified in Table 2. Because of our desire to present data that would be broadly applicable to a general obstetric population, and because periodontal disease status is rarely available outside of research settings, we elected to omit periodontal disease status from our final model.

It is for similar reason that we elected to include women who eventually went on to develop adverse pregnancy outcomes such as pre-eclampsia and preterm delivery. Although we had the benefit of knowing the pregnancy outcomes for our cohort, those seeking to use CRP values in the routine course of patient case in the first and second trimester would not have access to this information. Excluding these women did not alter any of our findings, and it specifically did not change our findings about the racial differences in serum CRP levels. There were 31 women who developed pre-eclampsia. There were 136 women who delivered prior to 37 weeks gestation; 23 of whom delivered prior to 32 weeks. From our preliminary evaluation of the data, most of these women evidenced serum CRP levels that were below the 75th percentile for the cohort. Further analysis of maternal serum CRP values and other inflammatory mediators in the subsets of women who went on to develop pre-eclampsia or experience preterm delivery is the focus of ongoing research projects.

We did not consider women with early spontaneous pregnancy losses to be part of the normal obstetric population, and excluded them from analysis for this reason. A previous publication from this study cohort found that maternal serum CRP levels were higher in women with normal pregnancies compared to those with spontaneous losses. In that article, the adjusted odds ratio for spontaneous abortion for women with serum CRP >75th percentile was 0.16 (95% CI 0.04

– 0.63), and the authors concluded that perhaps low levels of maternal inflammation are required or produced by normal early placentation.[16]

Our unadjusted cross sectional data on over 700 women suggest that CRP increases with increasing gestational age, but this effect is not longer significant once maternal weight and sociodemographic characteristics are considered. Data from non-pregnant patients have consistently found that markers for obesity, including BMI, waist circumference and fat mass are determinants of serum CRP, a finding that we can confirm from our cohort in which weight accounts for approximately 12% of the variance in serum CRP levels.[19–21] Other authors have reported racial differences in CRP levels, but these previously reported values in non-pregnant subjects do not demonstrate the dramatic differences we found in our cohort.[8,22,23]

The causes and clinical consequences of these observed racial differences in serum CRP levels can be the source of much speculation. Certainly, there may be a role for genetic polymorphisms which differ between black and white women and cause an increased or exaggerated production of proinflammatory cytokines during pregnancy. Another explanation may lie within the broader social and environmental differences observed between racial groups. Indeed, the epidemiologic literature suggests that the categories of race and ethnicity reflect distinct social and environmental influences rather than actual genetic variations between populations.[24–26]

The idea of a burden of Allostatic load, also known as the “weathering hypothesis,” provides one explanation for the ways in which unknown and unmeasured factors (exposure to environmental stressors and triggers for inflammation) seem to play a larger role in serum CRP levels than quantifiable biologic factors (gestational age or weight).[27–29] Namely, elevated serum CRP levels may result from chronic stress caused by socioeconomic disadvantage. As measured by marital status, insurance status, and enrollment in WIC/food stamps, black women in our cohort do appear to have a significantly lower socioeconomic status when compared with their white peers. Over time, the cumulative effects of social inequality may contribute to poor health outcomes described in many minority populations.[28] It is difficult, however, to identify and control for all of the potential confounders. In other words, an individual’s race when considered in isolation from other demographic characteristics cannot adjust for all of the observed “racial differences” within this heterogeneous group.

There are several limitations to our study. First, this is a secondary analysis of data collected for a study of oral health in pregnancy. Ideally, we would have captured additional proxies for sociodemographic status, including information about social support, psychosocial stress, occupational status, diet, education level, and household income. This may have added important information to the interpretation of our data. Second, although our cohort was evenly divided between black and white women, there was a significant difference in the sociodemographic indicators between these two groups. Had our populations been better matched for these characteristics, we may not have observed such dramatic racial differences. Finally, the serum CRP values were only measured once for each patient. Serum CRP values are known to have a large amount of within-individual variability. When used to assess cardiovascular risk, two separate specimens drawn two weeks apart are averaged in order to generate a more stable estimate.[3] Longitudinal assessment through the months of pregnancy, or serial assessment within a more limited time period for each individual patient, may have provided additional insight in our population.

Due to the limitations of our study, specifically the lack of longitudinal or serial CRP measurements, we do not feel that we can propose a normal range for pregnancy. In order to select the women demonstrating the highest levels of inflammation, we elected to consider top quartile of our population as abnormal for the purpose of this study. We did perform ROC analysis, which was not useful in assigning a clear threshold for clinically elevated serum CRP

values. Future projects, using more robust data, would be more appropriate to evaluate weather our value of the top quartile, or another alternative cut-off is more appropriate for use as a clinical range.

The most important implication of our study is to caution investigators and clinicians in their interpretation of serum CRP values in pregnant women, and to illuminate the important influence that sociodemographic characteristics may have on these values. Particularly in the setting of pregnancy-specific conditions with inflammatory components, such as pre-eclampsia and preterm labor, there remain many questions regarding the interactions between pregnancy, inflammation, maternal ethnicity and maternal BMI.[13–15, 26] Future directions for research include well-designed prospective, longitudinal studies that carefully account for the contribution of these important sociodemograhic factors.

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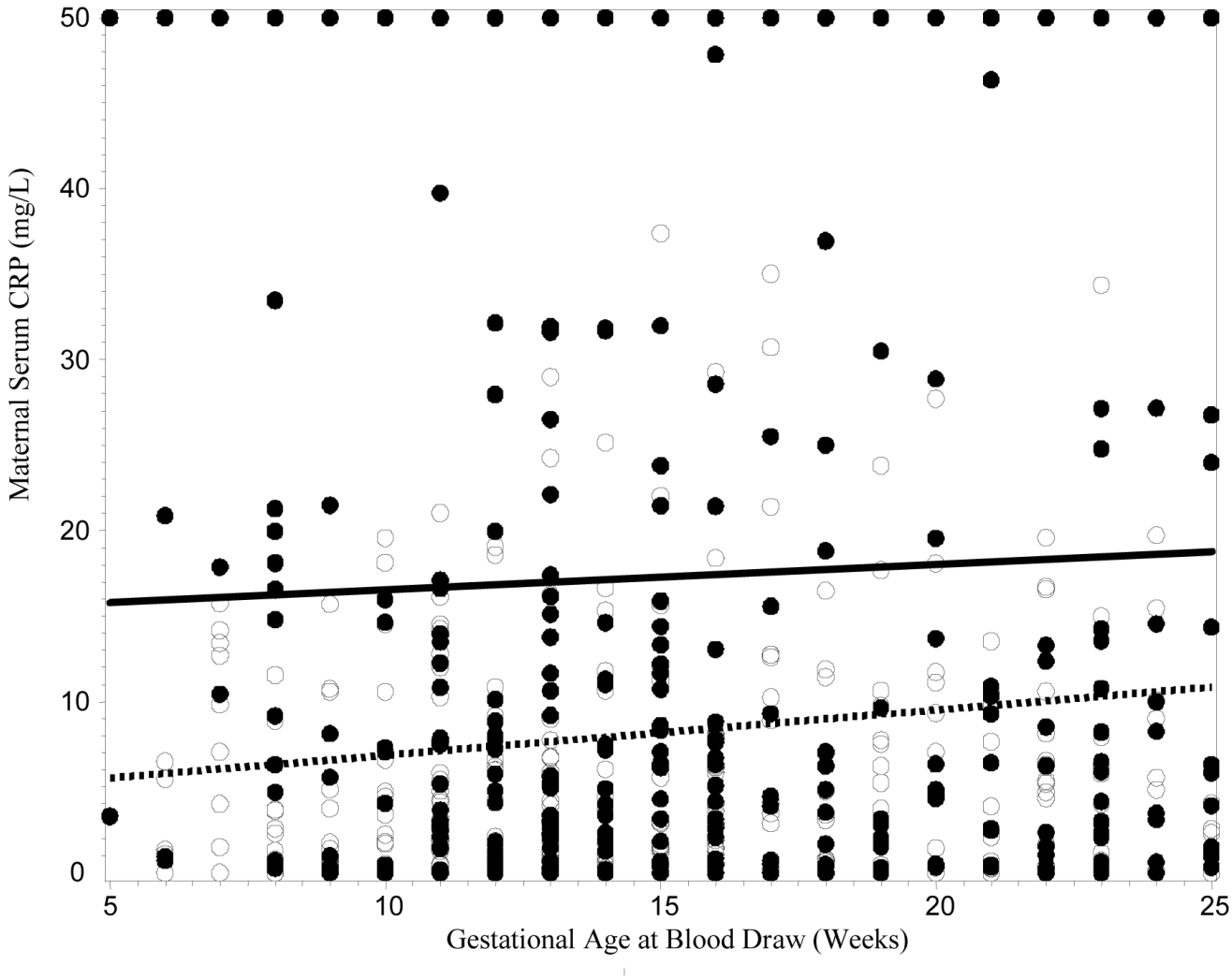

Figure 1. Linear Regression Analysis for Serum CRP Values in Black and White Women by Gestational Age

● Solid Black Circle	Data points representing serum CRP values for Blacks (mg/L)
○ Open Circle	Data points representing serum CRP values for Whites (mg/L)
Solid Black Line	Best-fit linear regression for serum CRP levels in Black women and increasing gestational age ($R^2 < .01$)
Dashed Black Line	Best-fit linear regression line for serum CRP levels in White women and increasing gestational age ($R^2 < .01$)

Brief Description

This figure illustrates the non-significant trend toward increasing serum CRP levels with increasing gestational age. Regression lines for Black and White women are shown separately, which visually represents the racial disparity in serum CRP levels.

Table 1

Demographic Information by Date of Enrollment

Demographic Characteristics	Entire Cohort n = 775	<14 weeks n = 393	≥14 weeks n = 382	p value *
Mean maternal age	28 ± 6.5	28.5 ± 5.8	27.6 ± 6.3	
Mean maternal weight at enrollment (lbs)	162 ± 44.7	162.1 ± 39.7	162.1 ± 43.8	0.98
Maternal Race				
White	374 (48%)	204 (52%)	170 (45%)	0.02
Black	360 (46%)	166 (42%)	194 (51%)	0.03
Other	41 (6%)	23 (6%)	18 (5%)	
Married	394 (51%)	215 (55%)	179 (47%)	0.03
Privately Insured	358 (46%)	193 (49%)	165 (43%)	0.10
Eligible for WIC/Food Stamps	171 (22%)	83 (21%)	88 (23%)	0.52
Primigravida	308 (40%)	157 (40%)	151 (40%)	0.90
Multiparous with previous preterm delivery	133 (28%)	66 (17%)	67 (18%)	0.78
Sexually transmitted disease	97 (13%)	54 (14%)	43 (11%)	0.30
Smoking during current pregnancy	132 (17%)	65 (16%)	67 (18%)	0.71
Alcohol use during current pregnancy	122 (16%)	58 (15%)	64 (17%)	0.45

* for comparison between patients < 14 weeks gestation and ≥ 14 weeks gestation

Table 2

Multivariate Analysis for Associations with Serum CRP Values >75th Percentile

Variable	Odds Ratio	95% CI
Black race	2.1	1.3 – 3.3
Qualify for WIC/Food stamp	2.0	1.3 – 3.1
Lack of private insurance	2.0	1.4 – 2.5
Unmarried	2.0	1.3 – 2.5
Previous preterm birth	1.9	1.2 – 3.0
Maternal weight (per 10 lb. increase)	1.1	1.1 – 1.2
Maternal age (per 5 year increase)	0.8	0.7 – 1.0

Table 3

Demographic Information by Maternal Race

Demographic Characteristics	Black n = 360	White n = 374	p value
Mean maternal age	25.6 ± 5.9	30.3 ± 6.3	0.13
Mean weight (in lbs) at enrollment	167.3 ± 43	150.9 ± 38	0.009
Elevated CRP > 75th percentile	126 (35%)	58 (16%)	<0.001
Married	81 (23%)	278 (74%)	<0.001
Privately Insured	70 (19%)	264 (71%)	<0.001
Eligible for WIC/Food Stamps	129 (36%)	38 (10%)	<0.001
Primigravida	117 (33%)	175 (47%)	<0.001
Multiparous patients with previous preterm delivery	79 (22%)	47 (13%)	<0.001
Sexually transmitted disease	69 (19%)	27 (7%)	<0.001
Smoking during current pregnancy	74 (21%)	57 (15%)	0.06
Alcohol use during current pregnancy	48 (13%)	73 (20%)	0.02