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Review Article

Pathways to maternal health inequities: Structural racism, sleep, and physiological stress

Lisa M. Christian [a,*], Ryan L. Brown [b], Judith E. Carroll [c], Julian F. Thayer [d], Tené T. Lewis [e], Shannon L. Gillespie [f], Christopher P. Fagundes [g,h]

[a] Department of Psychiatry & Behavioral Health and the Institute for Behavioral Medicine Research and The Institute for Behavioral Medicine Research, The Ohio State University Wexner Medical Center, Columbus, OH, USA
[b] Department of Psychiatry and Behavioral Sciences, University of California, San Francisco, San Francisco, CA, USA
[c] Cousins Center for Psychoneuroimmunology, Department of Psychiatry & Biobehavioral Sciences, Semel Institute for Neuroscience & Human Behavior, University of California, Los Angeles, USA
[d] Department of Psychological Science, University of California at Irvine, Irvine, CA, USA
[e] Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, GA, USA
[f] Martha S. Pitzer Center for Women, Children and Youth, College of Nursing, The Ohio State University, Columbus, OH, USA
[g] Department of Psychological Sciences, Rice University, Houston, TX, USA
[h] Department of Psychiatry & Behavioral Sciences, Baylor College of Medicine, Houston, TX, USA

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ABSTRACT

Racial inequities in health are vast and well-documented, particularly regarding maternal and infant health. Sleep health, including but not limited to duration and quality, is central to overall health and well-being. However, research has not adequately addressed how racism embedded in structures and systems, in addition to individual experiences, may affect maternal health by impacting sleep. In this critical review, we aim to 1) synthesize findings, emphasizing collaborative studies within our group, 2) highlight gaps in knowledge, and 3) propose a theoretical framework and methodological approach for moving the field forward. Specifically, we focus on findings and future directions linking perinatal sleep, cardiovascular and immune function, and racial disparities in maternal health. Because too few studies look beyond individual-level determinants of sleep deficiencies among Black Americans, we assert a critical need for research that bridges multiple levels of analysis (e.g., individual, community, society) and provides recommendations for specific health parameters that researchers in this area can target. Although the need to understand and address perinatal health disparities is clear, the goal of identifying multilevel mechanisms underlying how racism in one's environment and daily life may interact to affect health extends far beyond pregnancy research.

1. Introduction

Substantial and persistent racial inequities in health among Black versus White Americans are well documented, including significant disparities in maternal and infant morbidity and mortality (Centers for Disease Control and Prevention, 2020). It is increasingly recognized that "racial" health inequities are largely due to the biological embodiment of the cumulative effects of racism that persist across structures, systems, and individual interactions (Webb et al., 2022; Alvidrez et al., 2019; Hardeman et al., 2018; Boyd et al., 2020). For example, even current socioeconomic differences among individuals within various racial groups represent inequities in opportunities and access that are embedded within structures and propagated across generations. Racial segregation was formalized and legalized for approximately 100 years through the Jim Crow laws, which affected the right to vote, opportunities for employment and education, and access to public spaces, including pools, restrooms, dining facilities, and even hospitals (Krieger et al., 2014). In addition, racist policies have been enacted, including racially restrictive deed covenants on homes and redlining practices whereby areas in which Black residents lived were deemed as "risky investments" for home loans (Wallace et al., 2015; Blankenship et al., 2023). Racist policies affected the ability of Black veterans to fully take

* Corresponding author at: Institute for Behavioral Medicine Research, The Ohio State University Wexner Medical Center, Room 112, 460 Medical Center Drive, Columbus, OH 43210, USA.
E-mail address: Lisa.Christian@osumc.edu (L.M. Christian).

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advantage of low-cost mortgages offered to veterans via the GI Bill after World War II because banks would not extend loans in Black neighborhoods. Such benefits, which also extended to college tuition and low-interest loans for starting businesses, positively affected economic well-being among White but not Black service members.

Several recent studies have documented associations between aspects of institutional racism, such as Black male incarceration rates (Dyer et al., 2019) as well as overpolicing (Hardeman et al., 2021) and adverse birth outcomes among Black Americans. However, there is still limited work on the *within-group* dynamics that emerge among Black Americans because of racism embedded across one's environment and lifespan (Sealy-Jefferson et al., 2015, 2019–2021; Jahn et al., 2020; Seaton and Zeiders, 2021). As discussed throughout this paper, most research focuses on differences in health between White and Black people and/or individual-level predictors that obfuscate the reality of the racism that persists across structures, systems, and individual interactions. Thus, the biological mechanisms underlying how racism, at multiple levels, affects maternal health remain understudied, representing an emerging topic of investigation that is critical to designing equitable models of care and achieving equitable health.

Sleep, the focus of the current review, is a key causal factor implicated in racial health inequities, including complications of pregnancy (Lu et al., 2021). Indeed, maternal sleep health during pregnancy, as well as postpartum, have wide-ranging implications beyond perinatal outcomes (e.g., preterm birth and low birth weight). Reviewed elsewhere in detail (Christian et al., 2019; Carroll et al., 2019), these include effects on maternal health during pregnancy and postpartum, child health and development, as well as women's long-term health beyond the perinatal period. Sleep deficiencies can be defined and measured in several ways, with duration of sleep and subjective sleep quality being two critical aspects. Substantial differences in sleep are consistently noted among Black versus White Americans, with exposure to racism hypothesized to be an important mechanism. For example, recent Centers for Disease Control and Prevention data shows that 33 % of adults who self-identify as White sleep less than seven hours per night as compared to 46 % of adults who self-identify as Black (Liu et al., 2016). Numerous studies now show that independent of socioeconomic status, Black Americans have significantly higher rates of short sleep and poorer subjectively reported sleep quality than White Americans or Americans of any other racial or ethnic group (Hall et al., 2009; Petrov and Lichstein, 2016; Ruiter et al., 2011).

In this critical review, we aim to 1) synthesize findings, emphasizing collaborative studies within our group, 2) highlight gaps in knowledge, and 3) propose a theoretical framework and methodological approach for moving the field forward. We provide a review of sleep health among pregnant US-born individuals of African or other ancestry who self-identify as Black American. We describe normative changes in sleep during pregnancy before turning to racial disparities related to sleep during pregnancy. Then, we identify the cardiovascular and immune markers affected by poor sleep, and how sleep health may help us understand racial disparities in these areas. Finally, we delineate the limitations of our current knowledge and highlight promising areas for future research, with the goal of spurring stakeholder-informed, multilevel, within-group analyses that would meaningfully advance this critical area of research.

2. Pregnancy and sleep

2.1. Pregnancy as a physical stress test

Pregnancy is a period of dynamic physiological adaptation. As such, it provides a "natural experiment" or a physical "stress test" to examine the body's ability to respond adequately to extreme physical demands (Bohrer and Ehrenthal, 2015; Tutino et al., 2020). Changes include a 40–50 % increase in blood volume, a 10–30 beat per minute increase in resting heart rate, a 30–50 % increase in cardiac output, and a 30 % decrease in vascular resistance by the third trimester (Sanghavi and Rutherford, 2014). Heart rate variability (HRV), which is vagally mediated, also decreases – the most substantial difference is noted during the second half of pregnancy (Stein et al., 1999). Driven by placental production, corticotrophin-releasing hormone increases by 1,000–10,000-fold and cortisol levels increase by 2- to 3-fold (Thomson, 2013). Localized inflammatory responses are also essential to successful implantation (Mor et al., 2011), with healthy pregnancy characterized by progressive increases in serum inflammatory markers (e.g., IL-6, TNF-α, IL-1β) and innate immune responsiveness by maternal white blood cells (Christian and Porter, 2014; Gillespie et al., 2016; Hantsoo et al., 2019).

As evidenced by data from our team and others, the ability to undergo such adaptations while maintaining sympathetic-parasympathetic balance and avoiding excessive inflammatory responses is critical for maternal-infant health (Hantsoo et al., 2019; Blair et al., 2015). Moreover, as a potent physical "stress test," pregnancy is increasingly understood as a critical window of development with implications for health across the lifespan for both mother and child. Impairments in maternal cardiovascular and immune adaptation to pregnancy have been linked with a greater risk for poor birth outcomes as well as worse cardiometabolic health decades later among the maternal-infant dyad (Bohrer and Ehrenthal, 2015; Tutino et al., 2020).

2.2. Pregnancy as a period of risk for sleep deficiencies

Deficiencies in sleep duration and quality differ by gender, with the odds of experiencing insomnia approximately 1.5 higher in women than men (Roth et al., 2011). Pregnancy further exacerbates sleep disturbances. Women report poorer sleep quality, more nighttime waking, and more napping, beginning in the first trimester and progressively worsening through late pregnancy (Christian et al., 2019; Okun and Coussons-Read, 2007; Facco et al., 2010). Hormonal changes contribute to prenatal sleep deficiencies, as estrogen and progesterone substantially affect sleep beginning in early pregnancy (Sowers et al., 2008; Lee et al., 2000). Pregnancy itself is also physically demanding and can affect sleep, particularly during late pregnancy. In this context, pressure is exerted on the maternal lungs and bladder by the developing fetus, leading to difficulty taking deep breaths, frequency of urination, and overall discomfort (Christian et al., 2019). For many, stress and depressive and anxiety symptoms related to prenatal adjustments, preparing for childbirth, and anticipating major financial, lifestyle, and relationship changes can add to the mental health burden, contributing to sleep deficiencies (Blair et al., 2015). These unique factors that arise during pregnancy can also occur in the context of pre-existing stressors and psychological distress, with evidence suggesting that stress and distress are exacerbated by exposure to structural, systemic, and individual racism (Grobman et al., 2016; Gillespie et al., 2021; Hailu et al., 2022; Alson et al., 2021).

3. Race and sleep during pregnancy

Considerable evidence shows effects of race and racial discrimination on sleep health in pregnancy as well as among non-pregnant adults (Slopen et al., 2016). In a study of over 7000 adults, Grandner and colleagues found that perceived racial discrimination was associated with increased risks of sleep disturbance (OR = 2.62) and daytime fatigue (OR = 2.07) (Grandner et al., 2012). Perceived racial discrimination is also linked with differences in sleep architecture (less slow-wave sleep) among African Americans (Tomfohr et al., 2012). Among 600 Black American women, greater exposure to racial discrimination predicted poorer self-reported sleep quality during early and mid-pregnancy (p values $\leq$ 0.002). Further, gendered racial stress was associated with poorer sleep quality at both time points, effects that remained after adjusting for depressive symptoms and socioeconomic status (Cohen et al., 2022). In studies of pregnant individuals, in a cohort

of 640 people, everyday discrimination predicted poorer self-reported sleep quality (Francis et al., 2017). Further, data from multiple cohorts enrolled in the ECHO study, non-Hispanic Black race predicted shorter sleep duration as well as greater sleep disturbances during pregnancy (Lucchini et al., 2022).

Data from our group also show that Black Americans have shorter sleep durations and poorer sleep quality than White Americans during pregnancy. In one study, 133 women (77 Black Americans, 56 White Americans) completed the Pittsburgh Sleep Quality Index (PSQI) in each trimester and at early postpartum. Among the full sample, 88 % reported clinically disturbed sleep during at least one assessment during pregnancy (Christian et al., 2019). Despite these high rates of sleep disturbance across all women in this sample, Black Americans reported significantly poorer subjective sleep quality and sleep efficiency and significantly greater sleep disturbance than White Americans (Christian et al., 2019). Multiparous women also reported significantly worse sleep quality than nulliparous women during early and mid-pregnancy, reflecting sleep interference associated with childrearing (Christian et al., 2019).

In additional data from our group (under review), among a separate cohort of women, wrist-actigraphy data revealed longitudinal changes in sleep across week-long periods during the third trimester, and at one, four, eight, and twelve months postpartum (n = 65; 24.6 % Black American). Black American women exhibited significantly shorter sleep duration at the first four assessments, with mean sleep durations between 6.1–6.6 h among Black Americans versus 6.8–7.3 h among White Americans. Sleep duration per wrist-actigraphy was moderately correlated with self-reported sleep duration at each time point (r values 0.27–0.48, p values < 0.05; unpublished data). This is consistent with prior studies showing modest correlations between subjective and objective indices of sleep. Unfortunately, comprehensive data on sleep in Black American women across pregnancy is currently unavailable.

4. Race, sleep, and maternal biology

4.1. Immune parameters

Poorer sleep quality promotes immune dysregulation (Okun and Coussons-Read, 2007; Irwin, 2019; Okun et al., 2007), which may be one mechanism underlying racial disparities in health outcomes. While there is limited work considering the relationship between sleep and immune parameters in samples of Black women, the broader literature on sleep and health highlights inflammation and accelerated cellular aging as key biological mechanisms that are responsive to disturbed sleep (Carroll et al., 2019; Okun et al., 2009; Okun, 2019).

In a cohort of 138 women (79 Black American, 53 White American) assessed at mid-pregnancy, poorer subjective sleep quality (per the PSQI) was associated with higher serum pro-inflammatory cytokine IL-8 levels among Black Americans (r = 0.30, p = 0.01) but not White Americans (r = 0.13, p = 0.35), an effect not accounted for by age, education, income, or body mass index (Blair et al., 2015). The authors extended these findings in a separate postpartum sample of 69 women (46.4 % Black American) who completed the PSQI at 7–10 weeks after giving birth (Christian et al., 2018). In this study, lipopolysaccharide-stimulated peripheral blood mononuclear cell (PBMC) cytokine production capacity was assessed using *ex vivo* methods, quantifying the maternal immune response to bacterial challenge. Controlling for maternal age, income, and body mass index, Black but not White Americans demonstrated positive associations among poorer sleep quality, shorter sleep duration, greater sleep disturbance, and higher stimulated production of IL-6 and IL-8 (p values ≤ 0.04). These findings suggest that sleep-induced immune dysregulation is more pronounced among Black versus White Americans.

Recently, we examined associations among sleep deficiencies and peripheral leukocyte gene expression among 103 pregnant women (33 Black American, 70 White American) assessed at mid-pregnancy (Carroll et al., 2020). Promoter-based analysis of genes differentially expressed among those with (PSQI > 9) versus without (PSQI ≤ 5) significant sleep disturbances showed greater activation of nuclear factor κ B (NF-κB), activator protein-1 (AP-1), and cAMP response element-binding protein (CREB) among Black Americans. When these analyses were repeated among White women with versus without sleep disturbance, greater activation of AP-1 but not NF-κB was observed, while CREB activity was reduced. Racial differences in the association between sleep and glucocorticoid receptor (GR) activity were also observed. Black women with versus without sleep disturbance demonstrated lower GR activity ($p < 0.05$), while White women with versus without sleep disturbance exhibited a trend suggesting the potential for greater GR activity (p = 0.11). Similarly, interferon response factor (IRF) activity was reduced in Black Americans but enhanced in White Americans with versus without sleep deficiencies (p values ≤ 0.05). These highly novel data showed that sleep deficiencies in pregnancy predict greater breadth and magnitude of change in the expression of genes pertinent to pro-inflammatory and antiviral pathways among Black versus White Americans, with a full reversal of the direction of association in some instances. It will be important to elucidate the factors affecting longitudinal changes and within-group variability in these effects among Black American women.

Also of note, more than 90 % of adults in the United States are infected with Epstein-Barr virus (EBV) (Jones and Straus, 1987). Once an individual is infected, they carry the virus for life (McDade et al., 2000). Typically kept in a latent state by cell-mediated immunity, EBV can become reactivated when the immune system is suppressed, including under conditions of stress, causing a release of viral antigens and activation of the humoral immune response (McDade et al., 2000; Prosch et al., 2000; Glaser et al., 1985). While partial latent EBV reactivation generally causes little to no symptoms among healthy individuals (Hess, 2004); it is a sensitive measure of stress-induced cellular immune dysregulation (Van Rood et al., 1993). We examined the effects of race and racial discrimination on the reactivation of latent EBV longitudinally during pregnancy among White American (n = 18) and Black American (n = 38) women with highly similar demographic characteristics and health behaviors. Black American women had significantly higher EBV IgG antibody titers against the virus capsid antigen during each trimester of pregnancy and postpartum (p values $\leq$ 0.001) (Christian et al., 2012). This effect was most pronounced in Black Americans endorsing high (n = 17) versus low (n = 21) racial discrimination [p = 0.03 (first trimester), p = 0.04 (second trimester), p = 0.12 (third trimester), p = 0.06 (postpartum)]. These data demonstrate the effects of both racial minority status and individual exposure to discrimination on the viral immune response.

4.2. Cardiovascular parameters

As noted above, pregnancy is associated with profound and complex cardiovascular adjustments. Blood pressure decreases during pregnancy and this decrease in blood pressure is due primarily to reductions in vascular resistance (Tkachenko et al., 2014). There are widely documented racial differences in hypertensive disorders of pregnancy, such that Black women are disproportionately impacted relative to other racial/ethnic groups. Studies have found associations between reports of stress related to structural racism (e.g., financial stress, neighborhood crime) as well as vicarious exposure to racism as a child, with BP in pregnancy among Black mothers (Hilmert et al., 2008; Hilmert et al., 2014).

In addition to blood pressure changes, heart rate increases and vagally-mediated heart rate variability decreases (Voss et al., 2006). Vagally mediated heart rate variability (HRV) is a sensitive index of neural control of the parasympathetic nervous system. HRV reflects the beat-to-beat variation in the cardiac R-R interval. Time and frequency domain analyses of these R-R intervals provide information on the relative contributions of sympathetic and parasympathetic regulation of the heart and heart rate (HR). Thus, higher HRV is associated with better

cardiovascular health and reduced mortality risk (Fagundes and Wu, 2020). However, in pregnancy, relatively higher HRV is considered deletious as it is associated with abnormal uterine perfusion (Voss et al., 2006). Emerging evidence also suggests that racial minoritized status plays a significant role in HRV as well as blood pressure, especially vascular resistance (Hilmert et al., 2014; Thayer et al., 2010; Schuster et al., 2016; Jarczok et al., 2019). Of importance in the context of pregnancy, HRV serves as an indicator of overall autonomic nervous system (ANS) activity, and ANS dysfunction is implicated causally in maternal and neonatal disorders, including hypertensive disorders and fetal growth (Sharifi-Heris et al., 2023).

Meta-analyses demonstrate remarkably greater vagally-mediated HRV among Black than White individuals as well as substantially higher total peripheral resistance (TPR: a measure of vascular resistance) (Voss et al., 2006; Hill et al., 2015; Brownlow et al., 2020) This pattern of higher HRV and higher TPR has been termed the "cardiovascular conundrum" as higher HRV should be associated with lower TPR (Hill and Thayer, 2019; Thayer et al., 2021). For example, one study noted that greater HRV was associated with lower TPR six years later in White individuals, but HRV was not a significant predictor of TPR in Black individuals (Williams et al., 2021).

Pregnancy is a potent endogenous vasodilatory stimulus. During normal pregnancy, mean arterial pressure (MAP) decreases starting in the first trimester (Chapman et al., 1998). The decrease in MAP is primarily due to a decrease in TPR (Chapman et al., 1998). In addition, HRV is also reduced starting early in the pregnancy (Voss et al., 2000). These autonomic nervous system (ANS) changes occur to support a healthy pregnancy. Elevated MAP is associated with the serious pregnancy related condition known as preeclampsia. Similarly, a failure to reduce HRV during pregnancy is associated with poorer birth outcomes (Voss et al., 2006). Of health importance, recent findings from our group provide novel evidence of impaired vasodilation in pregnancy among Black versus White American women. Hemodynamics [mean arterial pressure (MAP), cardiac output (CO), and total peripheral resistance (TPR)] and high-frequency heart rate variability (HRV) were examined during a seated waking period in 40 pregnant women (20 Black American, 20 White American) and matched non-pregnant controls ($n = 40$) (Christian et al., 2020). Women also completed the Experiences of Discrimination Scale (Krieger et al., 2005). Independent of race, pregnancy was associated with decreased MAP [$t(68) = 3.72$, $p < 0.001$]. However, pregnant and non-pregnant Black Americans showed impaired vasodilation compared to White Americans, as indicated by greater TPR [$t(63) = 3.06$, $p = 0.001$] despite higher high-frequency HRV [$t(66) = 1.52$, $p = 0.06$]. Thus, these results replicate the cardiovascular conundrum pattern. In Black but not White Americans, fewer experiences with discrimination were associated with greater TPR [$r = -0.35$, $p = 0.04$]. While this finding seems paradoxical, prior data suggest that low reports of discrimination may be indicative of suppressing one's experiences (Dorr et al., 2007; Rosati et al., 2021). Finally, the high-frequency HRV of White but not Black Americans was inversely related to infant birth weight ($r = -0.76$ and $r = 0.18$, respectively). This study provides new evidence of impaired vasodilation in the context of an endogenous vasodilatory stimulus (i.e., pregnancy) among Black versus White Americans, with findings of potential importance to the understanding of intergenerational transmission of cardiovascular risk.

5. Major limitations of the current knowledge base

Research on the causes of sleep deficiencies in Black Americans has focused predominantly on individual level determinants, with exposure to violent and non-violent racism-related events associated with poorer sleep quality and perceived racial discrimination identified as a risk factor for sleep disturbance, impaired sleep architecture, poorer perceived sleep quality, and daytime fatigue (Grandner et al., 2012; Tomfohr et al., 2012; Francis et al., 2017; Beatty et al., 2011; Bethea et al., 2020; Hoggard and Hill, 2018; McKinnon et al., 2022). In fact, in a 2016 systematic review of 17 studies assessing discrimination and sleep, 15 focused on individual experiences of discrimination (Slopen et al., 2016). A more recent 2019 review of 39 studies yielded comparable results (Lewis and McKinnon, 2019) Similarly, in a study of 90 National Institute of Minority Health and Health Disparities (NIMHD)-funded R01s, most studies (91 %) assessed one or more individual-level determinants of sleep but only 64 %, 50 %, and 27 % assessed one or more interpersonal, community, or societal-level determinant of sleep, respectively (Alvidrez et al., 2019). However, systemic racism affects the distribution of social determinants of health at the individual, interpersonal, community, and societal levels and across the behavioral, physical, and sociocultural domains. Greater consideration of broader social determinants of health (e.g., wealth accumulation, nonstandard work hours) is needed in disparities research.

Moreover, while differences in sleep between White and Black Americans are well-documented, studies addressing the antecedents and consequences of sleep deficiencies *among* Black Americans are few. It is now recognized that "comparison studies, however necessary to establish inequities, are insufficient to advance the science of diversity." (Whitfield et al., 2008) In actuality, the social construct of "race" is entangled in multiple complex and interrelated exposures that cannot be meaningfully discerned through comparative analyses. Evidence suggests that differential exposures that accompany the social construct of "race" are qualitatively similar across groups. Thus, studies addressing health inequities have increasingly employed a within-disparity group design. As stated by Corwin and colleagues: "in order to understand and eliminate health disparities, researchers must first look *within the disparity group* to identify the within race norms and the risk and protective factors experienced by the population." (Corwin et al., 2017).

Beyond needing more granular work delineating the effects of racism, at multiple levels, on within-group processes among Black Americans, the intersectional effects of race and gender contribute to gendered racism (i.e., racism and sexism intersecting to create a distinct experience (Lewis and Neville, 2015; Perez et al., 2023; Thomas et al., 2008; Patterson et al., 2022) warrant attention. For example, at least one study has documented associations between gendered racial microaggressions and poor sleep in non-pregnant Black women (Erving et al., 2023) Pregnancy itself represents a unique identity. Racialized pregnancy stigma is observed in the form of stereotypes of Black motherhood, including negative assumptions, judgments, and devaluation of Black pregnancies (Mehra et al., 2020). The role of stigma may be further amplified among *young* Black women (OjiNjideka Hemphill et al., 2023). Ultimately, intersectional identities related to race, gender, and age affect stigma, which contributes to both maternal stress and reduced quality of care, together affecting maternal and child health outcomes (Patterson et al., 2022; Mehra et al., 2020; OjiNjideka Hemphill et al., 2023; Bohren et al., 2024).

Women exhibit different ways of coping with exposure to intersectional stigma. Of particular relevance, the superwoman schema framework (Woods-Giscombe et al., 2019) reflects the race-gender role that may develop among Black women to cope with the oppression of gendered racism (i.e., feeling an obligation to present as "strong," suppress emotions, not be vulnerable, and an intense motivation to succeed even in the face of limited resources). Of importance, the superwoman schema is associated with upregulation of the sympathetic nervous system as well as inflammatory dysregulation (Woods-Giscombe et al., 2019; Allen et al., 2019; Bond et al., 2022).

6. Future directions

We propose that future studies focused on sleep deficiencies among Black Americans, including during pregnancy, apply a model of assessment adapted from the NIMHD Social Determinants of Health Research Framework. This framework, inspired by the NIMHD Research Framework (National Institute on Minority Health and Health Disparities,

2017), highlights the need to assess multilevel (i.e., individual, interpersonal, community, societal) and multidomain (i.e., behavioral, physical environment, sociocultural environment) influences on sleep health. Using a within-group design and applying the primary components of the NIMHD Research Framework to study social determinants of health, the data gained would inform targeted content and delivery methods for novel interventions. An effective intervention strategy necessitates understanding influences at the individual, interpersonal, community, and societal levels to inform the *design* and disseminate future interventions and related research findings. As shown in Fig. 1, in addition to assessment of individual level functioning and subjective perceptions, assessment of geographic location, governmental policy, neighborhood safety/violence and aspects of the built environment including walkability, access to nature, availability of public transportation, accessibility of healthy foods, access to medical care directly affect health and are modifiable.

To undertake such an endeavor, the most appropriate combinations of educational and therapeutic approaches must be considered. Key stakeholders such as social networks, healthcare providers, families, and individual patients must be engaged to ensure acceptability and accessibility. As an example, participants in a recent randomized clinical trial completed either an automated internet-delivered version of cognitive behavioral therapy-based intervention for insomnia (CBT-I) or the same CBT-I intervention that was stakeholder-informed and culturally tailored. While participants in both groups experienced reductions in insomnia severity, study completion (a key predictor of intervention effectiveness) was significantly enhanced among those in the tailored arm.

From a measurement and modeling perspective, studies on individual determinants will ideally use both questionnaires and daily diaries across pregnancy to capture within-subject variation in behavioral factors and better understand physical and sociocultural environmental supports and constraints (see Fig. 1). Most research on social stress utilizes retrospective recall of the previous weeks or months (Almeida, 2005). In contrast, daily diary methods provide greater ecological validity, reduce memory effects, and permit examination of within-person changes (Almeida, 2005). Relatedly, there is a gap in the literature regarding the longitudinal assessment of both actigraphy-based and self-reported sleep across pregnancy among Black American women, as these assessments tend to be only moderately correlated (Okun et al., 2021) and actigraphy-based measures may better predict inflammation (Irwin et al., 2016). Further, self-report approaches that utilize a multidimensional lens, such as the RU SATED tool (Ravyts et al., 2021; Chung et al., 2021; Buysse, 2014), warrant attention. In addition, it will be critical to evaluate and extend current models of pregnancy stress to identify the distinct effects of gendered racism on biopsychosocial stress processes through pregnancy.

In terms of future directions related to biological mechanisms, preliminary data link race, racial discrimination, and sleep deficiencies with inflammation and viral reactivation in perinatal women as indicated by serum biomarker levels, including pro-inflammatory cytokines and antibody titers (Gillespie et al., 2016; Blair et al., 2015; Christian et al., 2012; Christian et al., 2018; Christian et al., 2013). Advances in RNA sequencing now permit the examination of cellular mechanisms underlying these downstream observations. For example, transcriptomics data generated by RNA sequencing provide remarkable precision and sensitivity. The field of social genomics uses transcriptomics to examine patterns of up and down-regulation of genes in association with psychosocial exposures. In particular, there is a pattern of gene expression coined the "conserved transcriptional response to adversity (CTRA)," which is characterized by up-regulation of pro-inflammatory transcription with concurrent down-regulation of antiviral and antibody-related transcription (Cole, 2009). These studies provided a molecular framework for the cellular mechanisms underlying the previously puzzling epidemiological observation that social stress increases the risk for diseases marked by immune function that is both up-regulated (i.e., in the context of inflammatory diseases) and down-regulated (i.e., in the context of reduced vaccine efficacy and greater risk for viral infections) (Cole et al., 2007). The CTRA pattern has subsequently been identified in the context of diverse stressor exposures, including social stress, conflict, and loneliness (Cole, 2009; Cole et al., 2007; Miller et al., 2008; Cole et al., 2011; Chen et al., 2009; Irwin and Cole, 2011) and, per our recent paper, sleep deficiencies in pregnancy (Carroll et al., 2020). Thus, future studies of sleep-related changes in inflammation during pregnancy may benefit from examining whether the CTRA pattern corresponds with sleep deficiencies in pregnancy generally and when examining multilevel and multidomain parameters.

In addition, from a physiological perspective, data on sleep HRV in pregnancy are lacking. Sleep HRV (sHRV) provides a quantitative measure of autonomic nervous system activity during a prolonged period of *physiological restoration* that is critical to health maintenance and well-being. Few studies examining race and HRV have been in women, and fewer still have evaluated HRV during sleep, despite its importance to cardiovascular health. One of the few available studies reported that Black and Chinese American women had greater cardiac parasympathetic control (high-frequency HRV) during sleep compared to White Americans (Hall et al., 2013). Conversely, low-frequency HRV, and the low frequency/high frequency ratio were higher during sleep in

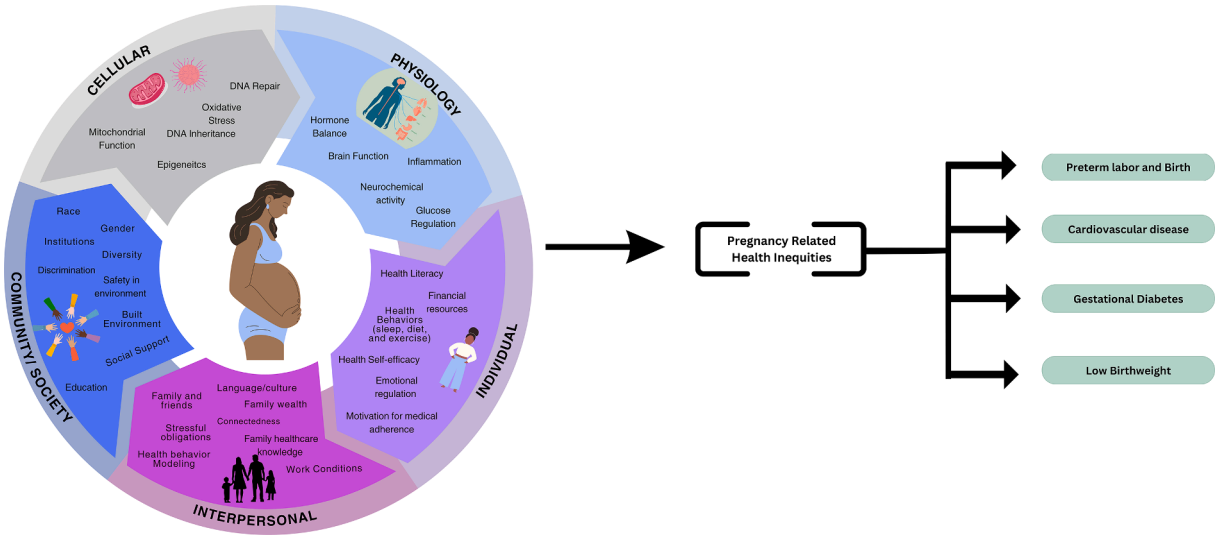

Fig. 1.

White American women compared with Black and Chinese American women. Future assessments of sHRV can directly inform understanding of the relative sympathetic versus parasympathetic control of cardiovascular function during sleep.

7. Conclusions

Herein, we reviewed sleep as a restorative behavior that is critical to health and well-being but often marked by deficiencies, particularly among women versus men, during pregnancy versus non-pregnancy, and among Black versus White Americans. While sleep science has gained traction in recent years, there is a scarcity of robust data on self-reported and objective sleep parameters over time, particularly among pregnant Black American women. Moreover, sleep has primarily been evaluated at the individual level, leaving important questions unanswered regarding the effects of interpersonal, community, and societal contexts. These gaps are a critical limitation to the study of racial health disparities. Indeed, systemic racism affects exposures to social determinants of health, the physical and sociocultural environments in which we are born, live, learn, work, play, worship, and age. Such deficits in knowledge are important targets of future research that would promote more equitable models of prenatal care. Sleep is a key example of a complex behavior that may significantly affect health and well-being if better understood and clinically optimized, particularly among pregnant Black Americans.

CRediT authorship contribution statement

Lisa M. Christian: Writing – review & editing, Writing – original draft. **Ryan L. Brown:** Writing – original draft, Writing – review & editing. **Judith E. Carroll:** Writing – review & editing, Writing – original draft, Conceptualization. **Julian F. Thayer:** Writing – review & editing, Writing – original draft, Conceptualization. **Tené T. Lewis:** Writing – review & editing. **Shannon L. Gillespie:** Writing – review & editing. **Christopher P. Fagundes:** Writing – review & editing, Writing – original draft, 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

No data was used for the research described in the article.

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