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**Author Manuscript** 

Matern Child Health J. Author manuscript; available in PMC 2013 January 1.

# Published in final edited form as:

Matern Child Health J. 2012 January ; 16(1): 109–118. doi:10.1007/s10995-010-0712-6.

# Childbearing, stress and obesity disparities in women: a public health perspective

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# Abstract

The perinatal period, from early in the first trimester to 1 year postpartum, provides opportunities for novel public health interventions to reduce obesity disparities. We present a unifying sociobiological framework to suggest opportunities for multidisciplinary research and public health approaches to elucidate and target the mechanisms for the development of maternal obesity and related disparities. The framework illustrates the interplay of the social, cultural and physical environment; stress appraisal and response; and coping behaviors on short-term outcomes (e.g. allostatic load and gestational weight gain), the intermediate outcomes of persistent insulin resistance and post-partum weight retention, and longer term outcomes of obesity and its disease consequences. Testing the proposed relationships may provide insights into how childbearing risk factors such as gestational weight gain, postpartum weight retention and parity contribute to obesity, which are needed to inform public health policies and clinical care guidelines aimed at reducing obesity and improving the health of women.

# Keywords

Obesity; racial disparity; pregnancy weight gain; postpartum weight retention; maternal stress

# INTRODUCTION

# Obesity remains a public health challenge

Obesity affects one out of every three adults in the US and remains a public health challenge.<sup>1</sup> 112,000 lives are lost each year due to obesity and its related illnesses (e.g. heart disease, diabetes, cancers).<sup>2</sup> Many of the current community and clinical interventions have been effective for short-term weight loss (1–3 years). Long-term non surgical weight loss interventions have been discouraging. Thus, obesity prevention has been a desirable focus and many preventive programs have targeted children and high-risk young adults. Obesity

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Conflict of Interests: There are no financial or conflicts of interests for any of the authors.

prevention and intervention programs have been culturally tailored to target high-risk groups, such as African-American and Hispanic women.<sup>3–7</sup> However, the childbearing period is one area that deserves further attention and exploration for obesity risk reduction.

#### A focus on childbearing-related obesity

According to a recent Institute of Medicine (IOM) report, the increasing rate of maternal overweight and obesity before, during and after pregnancy is a serious health problem for both mothers and children.<sup>8</sup> Maternal obesity contributes to prenatal diseases (i.e. gestational diabetes);<sup>9, 10</sup> operative and premature deliveries;<sup>10, 11</sup> fetal injury during delivery<sup>12</sup>; intrauterine mortality,<sup>12</sup> and shorter duration of breast-feeding.<sup>13</sup> The long-term outcomes of maternal obesity include chronic diseases (e.g. diabetes, cardiovascular disease), premature death as well as adverse complications in the next pregnancy for mother and baby.<sup>12, 14, 15</sup>

Childbearing women, particularly African-American, Hispanic and socioeconomically disadvantaged women, bear a disproportionate burden of obesity and its sequelae.<sup>1</sup> Obesity rates for US women of childbearing ages, 12–19 years and 20–39 years, have tripled 5% to 16% and 9% to 29% respectively over the past several decades.<sup>16</sup> Racial/ethnic differences in these obesity rates begin in early adolescence and widen throughout the childbearing period.<sup>17</sup> African-American women have the highest obesity rates at 29% (ages 12–19 years) and 47% (ages 20–39 years), followed by Hispanic –American women at 18% (ages 12–19 years) and 40% (20–39 years) and non Hispanic white women at 15% (ages 12–19 years) and 31% (ages 20–39 years).<sup>1, 18</sup> Likewise, women with less than a high school education or who have income ≤ 130% of poverty threshold have twice the obesity rates as women of higher socioeconomic status.<sup>19</sup>

The five-year risk of developing obesity for women giving birth to at least one child was 3.5 times that of women who had never given birth; this risk was particularly greater for African-American, Mexican-American and socioeconomically disadvantaged women.<sup>20</sup> Our analyses of the diverse US National Longitudinal Survey of Youth cohort showed that only 11% of women with a normal pre-pregnancy BMI who become obese postpartum returned to a normal pre-pregnancy weight; 89% remained significantly overweight (BMI > 27) and obese in the 5 years after childbirth.<sup>20</sup> Childbearing risk factors such as young maternal age, pre-pregnancy overweight, excessive pregnancy weight gain, postpartum weight retention and high parity are associated with long-term overweight and obesity.<sup>21–24</sup> The prevalence of maternal overweight at the start of pregnancy almost doubled from 24% to 44% from 1983 to 2007.<sup>8, 25</sup> More than 40% of women gain weight during pregnancy that exceeds the amount recommended by the IOM, and excessive pregnancy weight gain is likely to be retained after childbirth.<sup>21–23, 26–29</sup> Thus, maternal weight retention six months to a year postpartum contributes to long-term major weight gain and obesity.<sup>12,13,16,22</sup>

An unequal distribution of these childbearing risk factors among minority and low income women contribute to the high rates of overweight/obesity before and after pregnancy seen in these select subgroups.<sup>8, 29–31</sup> African-American and socioeconomically disadvantaged women have greater pre-pregnancy weight, postpartum weight retention and parity. Interestingly, African-American women who were normal weight at the start of pregnancy and have pregnancy weight gain within the range recommended by the IOM were twice as likely as non-Hispanic white women to retain 14 to 20+ pounds 10 to18 months postpartum, even after adjusting for age, SES, parity, birth interval, height, and birth weight.<sup>29</sup> The racial/ethnic and SES differences in childbearing risk factors associated with obesity and in later life obesity rates raises concern for poor maternal health outcomes as well as questions for further investigation into causes for the persistent obesity disparity among women.

Obesity and health disparities are two vitally important health issues that require broadening our understanding of the influence of events throughout the lifecourse. The childbearing period is a critical time when many women either become overweight/obese or their level of overweight increases substantially. The perinatal period, from early first trimester to a year after childbirth, is a time of considerable psychological and physiological stress for many women.<sup>32</sup> Major psychological, physical and social adjustments are required by new mothers attempting to balance their new roles and responsibilities while recuperating physically. For some women already living with chronic daily stress, an unintended pregnancy can generate even greater stress exposure which if not suitably buffered may contribute to health problems for both mother and baby.

#### Consideration of under-appreciated modifiable factors: role of maternal stress and obesity

Our framework proposes consideration of novel modifiable risk factors, such as maternal stress. Much of the research on the detrimental effects of maternal stress has focused on infant health outcomes such as poor cognitive development, behavior, low birth weight, and prematurity.<sup>33–37</sup> This work provided evidence of prenatal stress in disrupting the hypothalamic-pituitary-adrenal axis system (HPA), a system involved in eating behavior and weight control, resulting in lifelong problems in behavioral and neuro-cognitive development for the infant; this work has also raised concerning questions regarding maternal health outcomes.<sup>38</sup>

Chronic stress exposure not adequately mitigated by one's biological adaptive systems or supportive social and environmental resources may contribute to the development of weight problems for the mother. Chronic stress exposure disrupts the HPA system which influences eating behaviors and the metabolic profile in animals and humans. <sup>39–43</sup> Evidence for the relationship between stress and weight gain is gradually developing. Few studies have shown a decrease in body weight with exposure to stress and others have shown an increase depending on the type of stress exposure -- acute vs. chronic.<sup>41–44</sup> Reasons for the inconsistent relationship may be due to the variety of studies (animal vs. human), methods (cross-sectional vs. longitudinal), and measurements and definitions of stress (acute vs. chronic) used. Thus, whether men are more affected then women or pregnant women vs. non pregnant women has not yet been fully determined. However, pregnant women with stressful life events or pregnancy complications have higher cortisol levels and greater HPA dysfunction, which promotes the increase in nutrient dense food and central fat distribution.<sup>32, 42, 45</sup> African-American women who experience perceived stress have greater dysfunction in their HPA and abdominal obesity.<sup>46</sup>

Although the relationship between maternal stress exposure and excessive pregnancy weight gain or retention is unclear, we do know that women with greater life stress and stress reactivity have higher body mass indices and waist- to- hip ratio (e.g. abdominal obesity) compared to women with lower stress levels.<sup>45</sup> African-American, Hispanic and socioeconomically disadvantaged women disproportionately experience additional chronic stress related to social disadvantages (e.g. discrimination, single parenthood and poverty)<sup>46, 47</sup> which may enhance their risk for poor health outcomes (e.g. Obesity). Thus, exploring the complex interplay of stress and the stress response systems during pregnancy may provide a new understanding of mechanisms for obesity development. Likewise, if the exposure of chronic stress is higher and the stress reactivity more detrimental for minority and socioeconomically disadvantaged women it may help explain differences in obesity outcomes.

#### A conceptual framework for maternal obesity development

The Institute of Medicine's recent report titled, "Bridging the Evidence Gap in Obesity Prevention; A Framework to Inform Decision Making" aims to broaden the thinking and set a new direction for future obesity prevention research.<sup>48</sup> The report calls for a systematic approach involving interdisciplinary investigation that can provide new theoretical frameworks that build upon existing evidence by proposing a vision for new testable non-linear relationships and measurement techniques.<sup>48</sup> In line with this initiative, our sociobiological stress, pregnancy and obesity conceptual framework (Figure 1) synthesizes existing lines of evidence with new hypotheses into a theory for the development of pregnancy-related obesity disparities in women. Each domain in the framework represents a body of evidence that varies in depth, quality and type of research. Our framework builds upon previous research frameworks <sup>40, 44, 49–53</sup> by uniquely integrating into one comprehensive conceptual framework the contributions of social, environmental, genetic, behavioral and biological determinants of obesity in the setting of pregnancy.

The principal theory underlying our framework is that disparities in health outcomes, in this case obesity, are due in part to a combination of genetic risk, suboptimal living environment (e.g. social and physical), differential exposure and response to chronic stress, coping ability, and health risk behaviors.<sup>50, 54</sup> It is important to note that the framework sits within a specific moment within a women's lifecourse; although the model appears linear it is represents a multistate process in which women transition in and out of the different domains (see panel A in figure) of the framework over her lifecourse, from birth until death. We focus on one moment—childbearing, which is represented in the expanded section of the time line above the framework (see Figure 1). We focus on this time period because maternal obesity is receiving greater attention due to increasing rates and is now an important public health concern for both mother and child.

#### Determinants of maternal stress exposure

Panel A (Figure 1) displays the hypothesized relationships of genetics, health status, race/ ethnicity, socioeconomic status, and environment in creating a stressful milieu. To date, genetic research, mainly animal and twin human studies, have provided evidence for the role of genes in appetite, eating behavior, energy metabolism, energy expenditure, adipogenesis, fat distribution, and predisposition to chronic diseases (e.g. diabetes).<sup>54–59</sup> For example, catecholamine and glucocorticoids promote ob gene expression thereby regulating appetite and glucose metabolism, particularly under stressful conditions.<sup>40, 54</sup> The role of genes in the numerous biological pathways involved in homeostasis and energy balance predisposes some women to weight gain and obesity which can affect general health status. Susceptibility to obesity is determined by the interaction between a polygenetic predisposition and environmental factors.<sup>60</sup> To our knowledge, only three small clinical studies have examined the genetic determinants of pregnancy weight gain and postpartum retention.<sup>61–63</sup> These human studies assert that primiparous women who are homozygous carriers of the G protein β3 825T allele have an increased risk of pregnancy weight gain, postpartum weight retention and obesity especially in the absence of physical activity.<sup>61, 63</sup> More genetic studies of weight change during the peri-partum period are needed.

Genetics predispose women to other non-obesity related medical problems that will also influence their general health status. General health in the framework represents the presence of medical problems a woman has entering pregnancy that may create or perpetuate stressful life experiences. A woman's social, cultural and physical environment will also influence her health, also a potential source of chronic stress. Race/ethnicity and socioeconomic status predisposes some women to stressful life experiences. While we acknowledge that biological features of race may exist, such as some genetic determinants for physical appearance, to a degree, and the development of certain diseases (e.g. sickle cell and cystic fibrosis)<sup>64</sup> the discussion of race and genetics is beyond the scope of the paper. Race in our framework represents a self-identifying category of ancestry and is intended to capture the social and cultural meaning or experience critical to societal patterns of bias in the US. In this context, race is a social construct that considers how ones social standing, treatment and acceptance contributes to stressful life experiences and sources of chronic daily stress <sup>65–68</sup> For example, numerous studies have documented the association between individual racism, institutional racism, and discrimination with poor mental health (e.g. stress) and chronic health problems in African Americans and Hispanics.<sup>65, 66, 69–71</sup> Additionally, race-related cultural beliefs, experiences and expectations can also influence health outcomes.<sup>71–74</sup>

Similar to race/ethnicity, low socioeconomic status, traditionally determined by level of education, occupational prestige, and income is associated with discrimination, limited access to healthcare, and poor health outcomes. <sup>75, 76</sup> For example, living in resource-poor environments lacking in high quality educational systems, social organizations, high quality food stores, sanitation, and healthcare facilities has adverse mental and physical health consequences (such as pregnancy at a young age).<sup>7778</sup> Thus, we suggest the interconnectedness of being an underrepresented minority and/or socioeconomically disadvantaged creates stressful life experiences and chronic daily stressors because of the social experiences and limitations imposed.

To summarize Panel A, we propose that genetic susceptibility, general health, race/ethnicity and SES, in the context of suboptimal social, cultural and physical environments creates a stressful milieu both externally (e.g. stressful life experiences) and internally (e.g. activation of the stress response system). If not sufficiently buffered, chronic stress exposure can overburden and ultimately impair one's biological adaptive systems.<sup>79</sup>

#### Stress appraisal and response

Panel B depicts how stressful life experiences contribute to biological and behavioral changes. Stress is the vehicle by which social, physical, psychological, and environmental stressors are appraised and internalized ("gets under the skin") to activate the stress response systems.<sup>80</sup> Chronic stress influences a woman's health outcome depending on her ability to appraise stressful events, her biological stress response, her emotional and behavioral coping ability, as well as the availability of social and environmental resources to mitigate the effects of stress.<sup>46</sup> Hypothetically, pregnant women who demonstrate positive coping skills and health behaviors, such as maintaining a healthy diet, good sleep habits, regular exercise, meaningful relationships, and abstinence from smoking and alcohol consumption are able to buffer the effects of chronic stress. We reason then that under-representative minority status and/or having limited financial and social resources, maladaptive coping and poor health behaviors are potential risk factors for chronically high stress levels and associated affects.

#### Impaired biological adaptation to stress

Panel B to C represents impaired allostasis, which is the inability, through the body's physiological and behavioral adapted efforts, to maintain homeostasis (i.e. a state of equilibrium) in response to chronic stress exposure. <sup>40</sup> Evidence from over forty years of basic science and clinical research shows that chronic stress disrupts the complex neuro-endocrine pathways in the human stress response system which impedes the ability to maintain homeostasis.<sup>40, 42, 44, 79, 81–83</sup> Chronic stress exposure initiates this complex biological response system through a coordinated network of neuro-endocrine signals that

influence appetite, eating behavior, energy balance and fat distribution.<sup>84</sup> Chronic stress exposure repeatedly activates the hypothalamic-pituitary-adrenal axis (HPA) which chronically elevates cortisol levels. Elevated cortisol levels promote insulin resistance, central fat storage (abdominal obesity) and increase intake of nutrient dense foods creating an energy imbalance, which overtime results in obesity. <sup>42, 4542, 43</sup> Central fat compared to peripheral fat has more glucocorticoid receptors and is sensitive to the fat – accumulating effects of circulating cortisol and thus responds by increasing in size.<sup>45</sup> The impairment in the ability to maintain homoeostasis is the underlying dysfunction in biology upon which negative health behaviors (poor diet, sedentary, poor sleep hygiene) are superimposed; this further contributes to an energy imbalance by either the promotion of increase in energy intake and/or decrease in energy expenditure. <sup>41, 42, 45, 82, 85</sup> Theoretically, pregnant women under chronic stress, particularly minority and low socioeconomic women, would have HPA dysfunction and neuroendocrine changes that elevate cortisol and impair energy balance predisposing to high pre-pregnancy weight, excessive pregnancy weight gain, postpartum weight retention and ultimately obesity. (Panel B to E).

#### Pregnancy weight gain, postpartum weight retention and obesity outcomes

Panel C to E depicts three important clinical outcomes. The first outcome, excessive pregnancy weight gain, is defined as total maternal weight gain that exceeds the IOM 1990 recommended pregnancy weight gain guidelines.<sup>21, 27, 86–88</sup> The second outcome is postpartum weight retention which appears to be an essential factor in the development of obesity.<sup>23, 89</sup> The average postpartum weight retention is 3.3 lbs to 3.7 lbs at 6 months to one year <sup>21, 22, 27</sup> with a range of up to 20+ lbs.<sup>23</sup> There is no consensus as to how much postpartum weight retention is too much; however, Rooney and colleagues suggest women retaining six pounds or more by six months postpartum experience major long-term weight gain.<sup>90</sup> Third, is the long-term outcome of obesity as defined by the World Health Organization criteria.<sup>9, 91</sup>

We propose that the relationship between excessive pregnancy weight gain and postpartum weight retention may involve insulin resistance. In the latter half of a normal pregnancy, the mother becomes insulin resistant to ensure adequate energy substrates for the fetus.<sup>91</sup> This insulin resistant state is mediated by placental secretion of human placental lactogen, progesterone, cortisol, prolactin, tumor necrosis factor alpha (TNF $\alpha$ ), and leptin and is usually reversed after delivery of the placenta.<sup>92</sup> High serum insulin concentrations during pregnancy are associated with a 3.5 fold increased risk of excess pregnancy weight gain and a 2.6 fold increased risk of excess postpartum weight retention.<sup>9</sup> Prospective evidence suggests that insulin resistant obese women with gestational diabetes do not lose weight postpartum.<sup>21, 23</sup> Additional research is needed to determine whether a persistent insulin resistant postpartum state is occurring in obese women without gestational diabetes and how chronic stress contributes to insulin resistance postpartum. An inability to lose weight postpartum may further contribute to insulin resistance promoting further weight gain postpartum (Panel D to E).

Finally, Panel D to E depicts a hypothetical trajectory for women with greater postpartum weight retention, high parity (having more than two children) and short inter-pregnancy intervals. These women may be more likely to experience cumulative weight gain overtime leading to a greater incidence of obesity. We know from two prospective studies done in the US that women who retain weight six months after childbirth were more likely to begin the second pregnancy heavier and have considerably more weight gain (18.3lb vs. 5.3lbs) over the next 10 years..<sup>51, 92, 93</sup> Postpartum weight retention appears to facilitate weight accumulation with subsequent pregnancies and predispose to later life obesity.

The postpartum period is a critical time when women are experiencing weight change and stress exposure. Mothers may desire to lose weight postpartum but are often challenged emotionally and physically with caring for a new infant, themselves, and other family members while working and/or maintaining a household, which limits their participation in conventional weight loss interventions.<sup>94–98</sup> Thus, focusing on obesity prevention in postpartum women has great potential to alter the obesity trajectories.

# CONCEPUTAL FRAMEWORK TESTING AND PUBLIC HEALTH IMPLICATIONS

Our stress, pregnancy and obesity framework offers a testable unifying multidisciplinary framework for the development of obesity disparities in women. Our framework is timely in that it accomplishes several of the IOM report's stated objectives which include synthesizing evidence and new hypotheses into a theoretical framework of two important health issues-obesity and health disparities, and proposing a perspective on new measureable and modifiable factors and relationships to examine using an interdisciplinary systems approach. <sup>48</sup>

#### Implications for research

Theories such as, *The Thrifty Gene* <sup>40</sup> and *Selfish Brain* <sup>53</sup> guide basic science research in understanding the role of the gene-environment interaction in obesity, energy metabolism and neuro-endocrine regulation. Other theories such as the *Cultural Tolerance of Fatness Theory*<sup>49</sup> and the *Health Belief Model*<sup>52</sup> propose pathways for the influence of cultural, social-psychological, and behavioral factors on obesity. The models of stress by Scott and Howard, <sup>79, 81</sup> Allostatic load by McEwen <sup>50</sup> and Weathering by Geronimus <sup>99, 100</sup> unify psychosocial and biological perspectives by relating the stressful effects of social, environmental and biological influences to the development of poor health outcomes. Our framework builds on these previous models by integrating the multiple determinants of obesity into a single framework and grounding the framework in the setting of pregnancy. The framework includes latent variables, which are abstract concepts, such as coping that are unobservable or not objectively measured but can be assessed using reliable questionnaires to study mediating and moderating effects of these variables by path analyses and structural equation modeling.<sup>89, 95, 97, 101, 102</sup>

Empirically testing the framework using prospective human and animal studies will help clarify the mechanisms involved in the development of obesity as well as define the essential components and optimal time-points for weight management interventions for women after childbirth. The first level of studies would consist of both animal studies and human physiologic studies that focus on elucidating the genetic differences, metabolic and hormonal changes that affect weight change during and after pregnancy, especially in populations experiencing high stress levels. The physiologic studies should investigate the longitudinal changes in maternal body composition during and after pregnancy and further elucidate the role of placental hormones in eating behavior, weight change and insulin resistance. The second level of clinical and population-based studies should focus on determining modifiable risk factors that best characterize and predict which women will experience excessive pregnancy weight gain and/or postpartum weight retention. To conduct such studies, databases and surveillance systems will need to be expanded (e.g. birth certificate) or created to include detailed perinatal variables as well as sufficient samples of minority and economically disadvantaged women. Additionally, advanced statistical methods to analyze these databases will be required. Importantly, longitudinal and crosssectional studies will need to investigate the differences and similarities in risk factors and outcomes among mothers of various racial and socioeconomic backgrounds. Our conceptual

framework guides thinking about the differences and offers a reason for why the relationships depicted are expected to differ by race and socioeconomic levels. The third level of studies should consist of intervention studies aimed at reducing postpartum weight retention. To date, the six rigorous randomized controlled weight-reduction trials that have targeted pregnant and postpartum women have been minimally successful in getting these women to lose weight after childbirth.<sup>89, 95, 97, 98, 101, 102</sup> These postpartum weight loss interventions had high attrition rates and focused primarily on modification of diet and physical activity with some adjunct behavioral intervention.<sup>85, 98</sup> Qualitative studies are necessary for understanding what facilitates a woman's ability to lose weight after childbirth and how to successfully implement weight reduction strategies into a new mom's busy lifestyle. Qualitative studies that identify the ethnic and socioeconomic differences in women's opinions, beliefs, and competing demands that influence weight management postpartum are valuable.

The framework encourages the deep consideration of the complexity of the relationships among stressful life events, the bio-psychosocial environment, behavior and the biological response. Understanding this complexity will influence future study designs and analytical techniques. At all levels the studies described above will require (i) the use of rigorous study designs with sufficient recruitment and retention of minority and low socioeconomic women; (ii) the development of valid and reliable anthropometric measures for pregnant women, especially of body composition; and (iii) the simultaneous incorporation of social, behavioral, environmental, and biological measures into statistical models.

#### Implications for public health policy and clinical practice

Previous maternal weight gain guidelines have primarily focused on optimizing infant health outcomes.<sup>21, 85, 103</sup> However, over 40% of women gain more than the 1990 Institute of Medicine pregnancy weight gain guidelines and a significant amount of these women remain considerably heavier after childbirth increasing their risk for obesity and adverse health outcomes.<sup>104</sup> The increasing maternal obesity problem has prompted the Institute of Medicine to review and revise the 1990 pregnancy weight gain guidelines.<sup>8, 104</sup> In reviewing the current state of evidence for the impact of maternal weight gain on maternal outcomes, the committee called for a conceptual framework that would guide further research into reducing pregnancy-related weight gain while optimizing maternal and infant health outcomes. Our framework offers insights for optimizing maternal health outcomes by directing greater attention to potentially modifiable risk factors and time-points that affect maternal health both antepartum and postpartum. The framework highlights potential pathways for the development of adverse weight-related health outcomes in an effort to stimulate targeted-funding opportunities to support surveillance and research. We hope the framework stimulates clinical and public health consideration of the pathways for maternal weight gain and postpartum weight retention by reminding physicians and community workers to assess stressful life events, social support, coping ability, and conditions of the physical environment of pregnant women. Until effective and available interventions can be delivered in the healthcare system or are covered by insurance, teaming up with community programs and organizations is important. These organizations have the infrastructure, devoted time and resources to serve their community. Many of these resources are underutilized because people do not know about them or are not referred. Additionally, tighter research and referral links between the healthcare system and community programs and organizations are needed to effectively address these public health issues. Due to frequent physician-patient encounters, physicians are well positioned to connect pregnant patients with community resources and social services that can increase the social capital particularly of women with ineffective coping behaviors to buffer chronic stress exposure. Pregnant women may also need assistance with identifying and effectively using their social

networks as another means of support and buffer of chronic daily stress. Finally, if the hypotheses in the framework are realized, future pre- and post- natal care plans can be adapted to incorporate weight management and stress-reduction strategies as well as screening for insulin resistance and potentially other metabolic precursors to prevent postpartum weight retention and future obesity-related chronic illness.

# CONCLUSION

Our framework provides insight for interdisciplinary investigation of the determinants and pathways for the obesity disparities in women. The framework integrates insights from the basic, clinical, and population sciences as well as other relevant theoretical perspectives, and provides novel hypotheses for potential mechanisms for excessive pregnancy weight gain and weight retention after childbirth. Additionally, the framework proposes that part of the racial/ethnic and socioeconomic disparities in later life obesity may result from differences in the response to elevated chronic stress levels and pregnancy experience. This multidisciplinary framework provides a systems approach to identify high-risk women, modifiable factors and time points, as well as for designing and tailoring obesity prevention efforts after childbirth. We hope the framework will focus funding agencies, researchers, healthcare providers and physicians on the perinatal risk factors for the development of obesity in efforts to discover novel perinatal public health and clinical interventions.

#### Acknowledgments

This research was supported by an NIH 5 R25 CA9-355 grant from the National Cancer Institute and Harold Amos Medical Faculty Award from Robert Wood Johnson Foundation, by a Family Medicine Research Center grant from the American Academy of Family Physicians and by a Clinical Research Professorship from the American Cancer Society.

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#### Figure 1.

Conceptual Model of Postpartum Weight Retention and Development of Obesity in Later Life