Maternal Gut Microbiome Composition and Gestational Weight Gain in African American Women

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Disclosures

- Author: Sara M. Edwards PhD, MN, MPH, CNM

- Objectives:

  At the conclusion of this presentation, the participants will be able to:
  - Identify the incidence and risk of preexisting and gestational obesity among African American women in the U. S.
  - Summarize the state of the science related to gut microbiome composition in pregnancy
  - Describe the relationship between maternal gut microbiome composition during pregnancy and interval and total gestational weight gain.
  - Examine implications for future research and clinical practice.

- Employer: Emory University

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PI: Elizabeth Corwin and Anne Dunlop

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"Brain-Gut Axis and Its Influence on Gestational Weight Gain"

PI: Sara Edwards

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Importance of the Problem

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2/3 of American women of childbearing age are overweight or obese *(80% of AA)*

Flegal, K.M., et al., *Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010.* JAMA : the journal of the American Medical Association, 2012. **307**(5): p. 491-7.

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Half of pregnant women gain excessive gestational weight (EGW)

Gaillard, R., et al., *Risk factors and outcomes of maternal obesity and excessive weight gain during pregnancy*. Obesity (Silver Spring, Md.), 2013. 21(5): p. 1046-55.
Weight Gain During Pregnancy: Reexamining the Guidelines. Committee to Reexamine IOM Pregnancy Weight Guidelines, Food and Nutrition Board and Board on Children, Youth, and Families., ed. K.M. Rasmussen, Yaktine, A. 2009, Washington, D. C.: National Academies Press.

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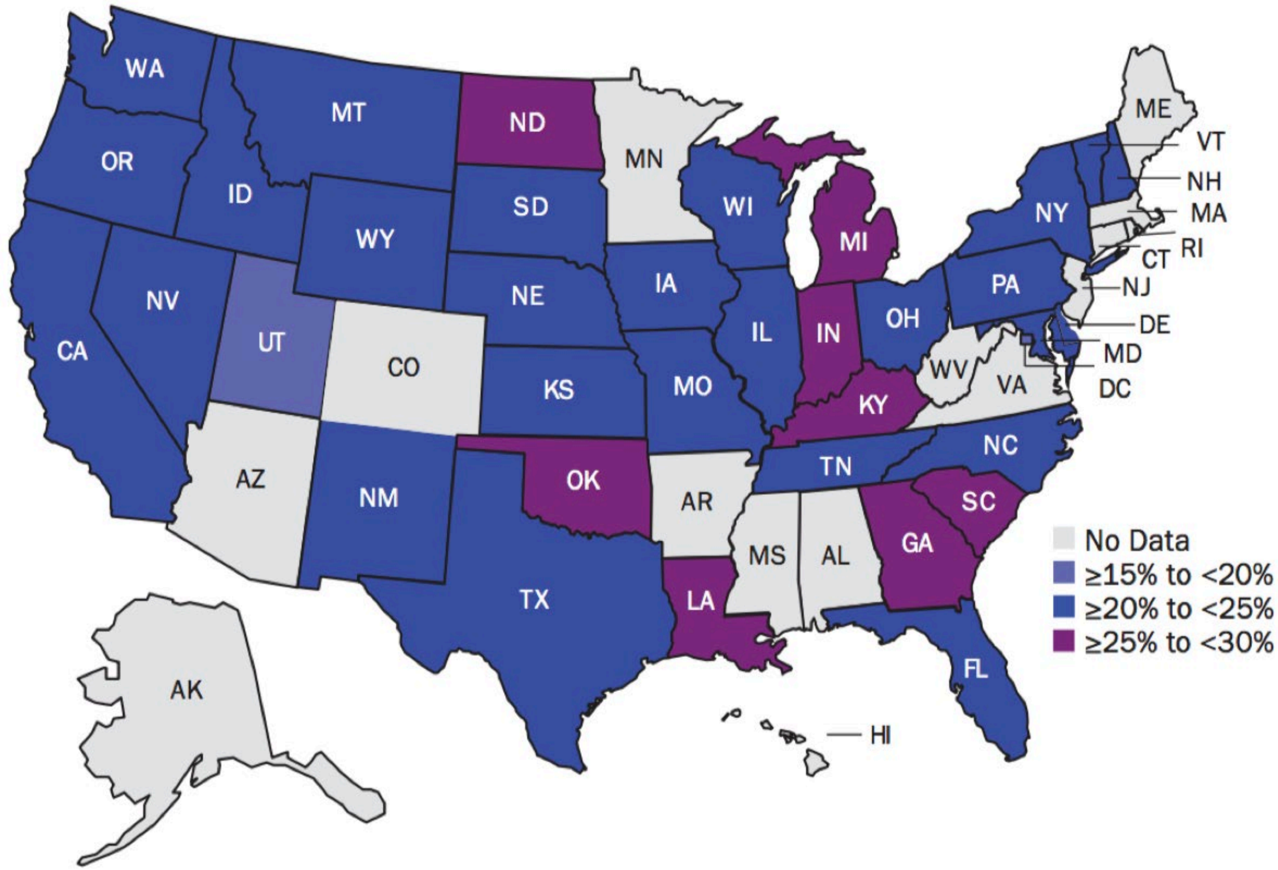
EGW and failure to lose weight postpartum predictors of lifelong obesity

60% women retain 10-20 lbs > 6 months postpartum

Gaillard, R., et al., *Risk factors and outcomes of maternal obesity and excessive weight gain during pregnancy.* Obesity (Silver Spring, Md.), 2013. **21**(5): p. 1046-55.

Percentage of childbearing-age women with obesity, 2011

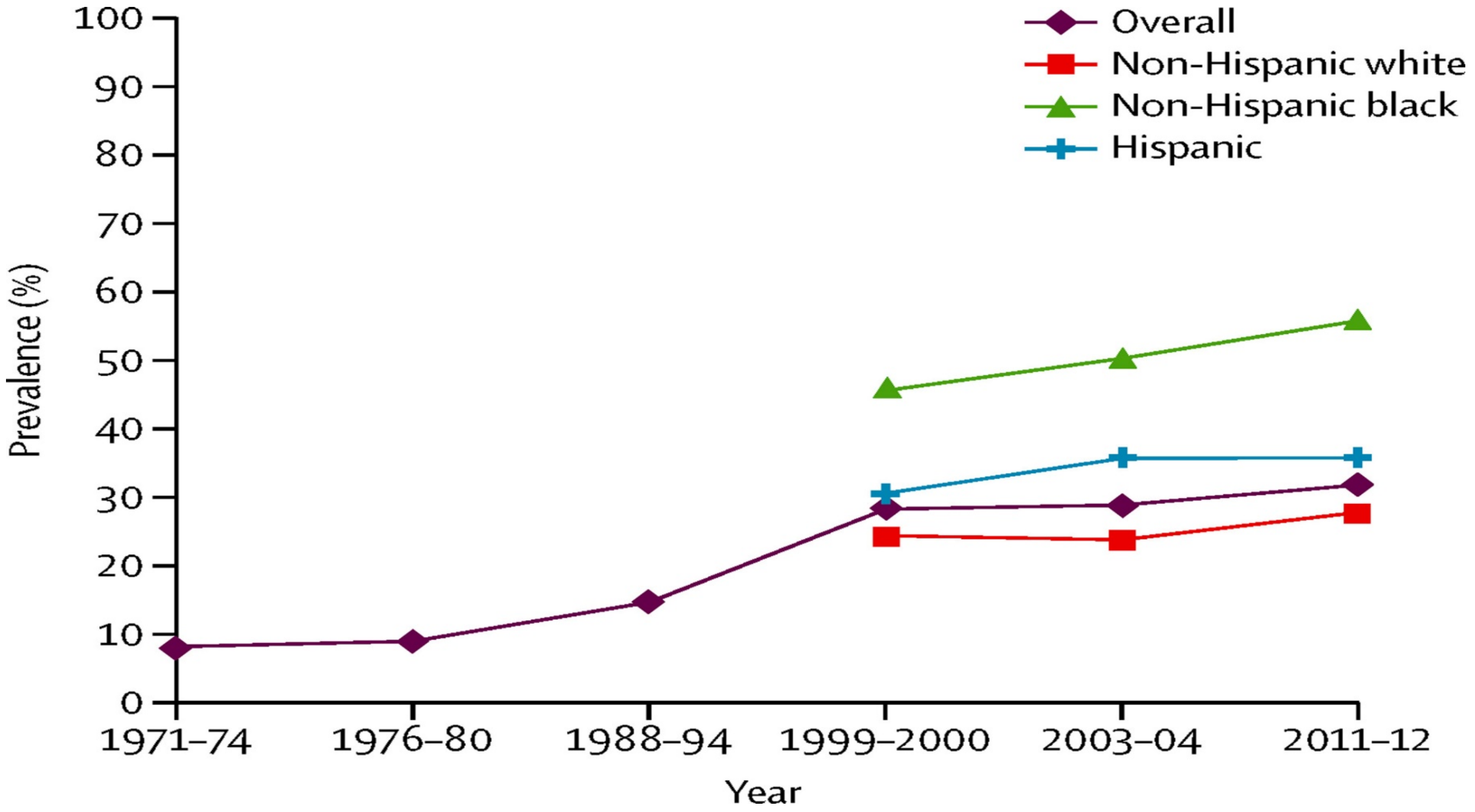
Percent of Women Classified as Obese Prepregnancy by State, 2011



Note: Puerto Rico = 20.5 percent

Source: CDC, National Vital Statistics Reports, U.S. Birth Certificate

Estimated prevalence of maternal obesity in the USA



Poston, L., et al., *Preconceptional and maternal obesity: epidemiology and health consequences.* Lancet Diabetes Endocrinol, 2016. **4**(12): p. 1025-1036.

Gap in the Literature

Gap in the Literature

Weight and Gut Microbiome

Gap in the Literature

Weight and Gut Microbiome

Differences in Gut Microbiome by Race, especially in Pregnancy

Purpose of this Study:

To explore the relationship between gut microbiome composition and gestational weight gain in AA women

Gut Microbiome Composition:

Firmicutes to *Bacteroidetes* *(FTB)* Ratio

Bruce-Keller, A.J. et al (2017). Maternal obese-type gut microbiota differentially impact cognition, anxiety and compulsive behavior in male and female offspring in mice. *PloS one, 12*(4).
Power, S. E., et al. (2014). Intestinal microbiota, diet and health. *The British journal of nutrition, 111*(3), 387-402.
Turnbaugh, P. J., et al. (2006). An obesity-associated gut microbiome with increased capacity for energy harvest. *Nature, 444*(7122), 1027-1031.

Phyla Level

Firmicutes
Gram Positive
Dominant in Obese

Bacteroidetes
Gram Negative
Dominant in Lean

Bruce-Keller, A.J. et al (2017). Maternal obese-type gut microbiota differentially impact cognition, anxiety and compulsive behavior in male and female offspring in mice. *PloS one, 12*(4).
Power, S. E., et al. (2014). Intestinal microbiota, diet and health. *The British journal of nutrition, 111*(3), 387-402.
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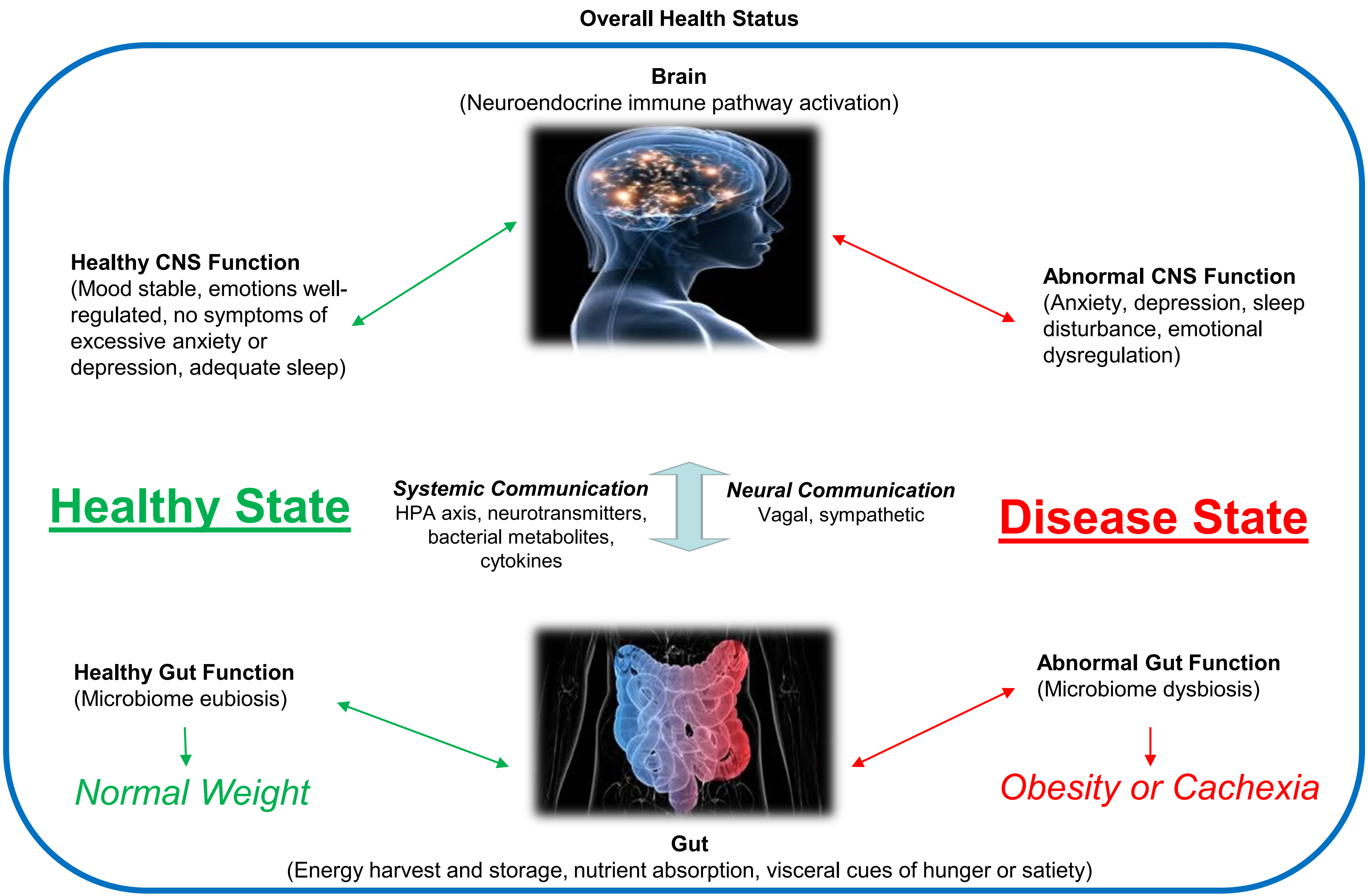
Firmicutes ***Bacteroidetes*** Ratio

Higher Ratio with Obesity, High Stress, and High Fat Diet

Lowers with weight loss

Inconsistent findings with pregnancy (some find lower, some higher as pregnancy advances)



Conceptual Framework of Brain-Gut Axis and Its Influences on Gestational Weight Gain

Sara Edwards PhD, MN, MPH, CNM

Specific Aims

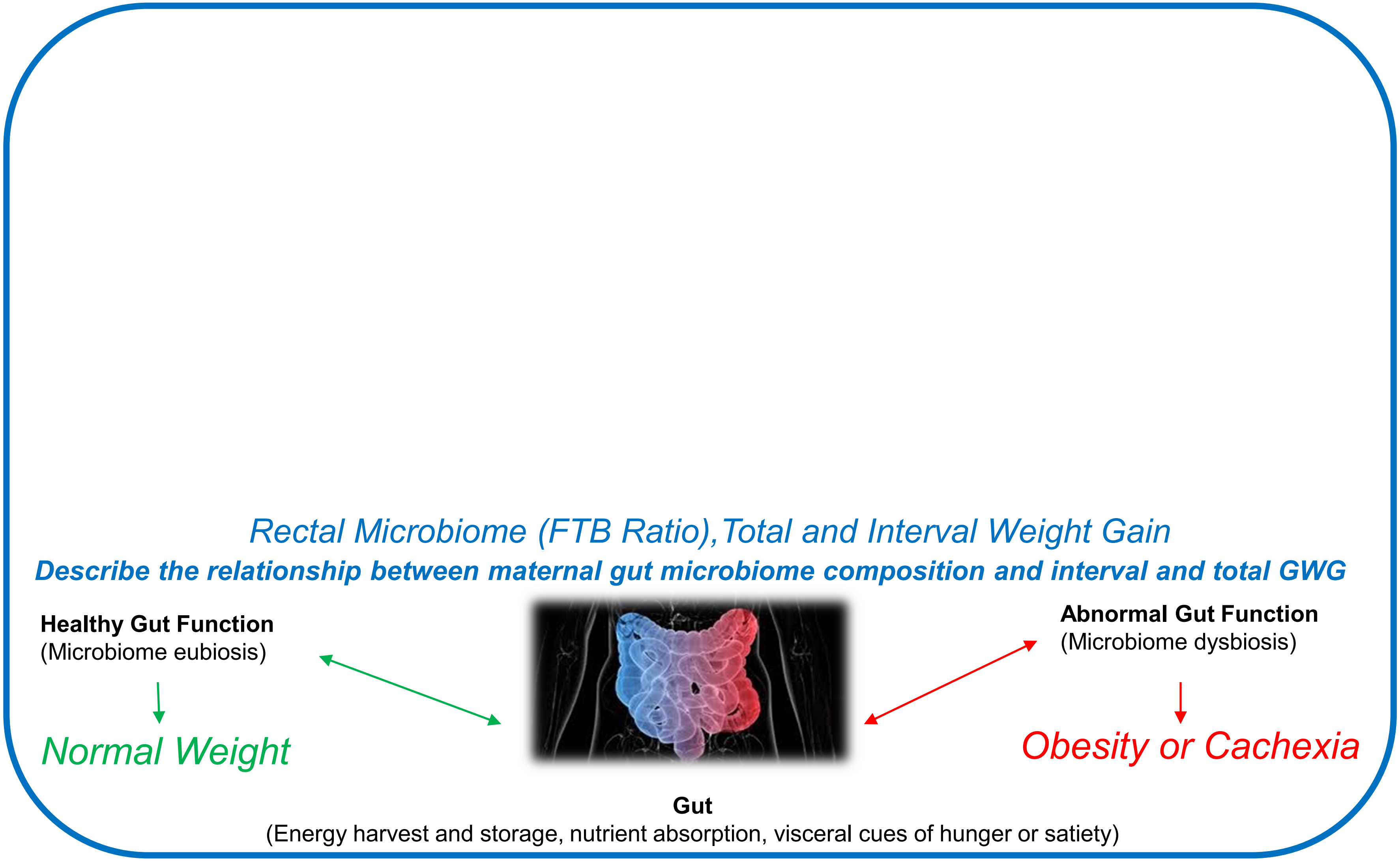
To test the hypothesis, I **enrolled a socioeconomically diverse cohort of healthy pregnant AA women** to consider the following Aim:

Describe the relationship between maternal gut microbiome composition during pregnancy and interval and total gestational weight gain.

Interval and Total Weight

- Most studies of pregnant women have considered pre-pregnant weight and total gestational weight gain, ignoring interval gain.

- Timing of weight gain is relevant to the risk of poor obstetric outcomes and obesity in the mother and child.
  - Early inadequate gains increase risk of preterm birth and fetal growth restriction
  - Early excessive gains increase risk of excessive neonatal body fat



Conceptual Framework of Brain-Gut Axis and Its Influences on Gestational Weight Gain with Aim 1 and Measures of Variables

Research Methods and Design

- Design
- Sample
- Setting
- Inclusion/Exclusion Criteria
- Data Collection and Procedures

Design, Sample, and Setting

- Design: Prospective, longitudinal cohort design, sub-study of the Parent Study, ***"Biobehavioral Influences on the Microbiome and Preterm Birth", IR01-NR014800***
- Sample: socioeconomically diverse cohort of 27 pregnant AA women
- Setting: 2 local area hospitals (Emory Midtown and Grady) in Metro Atlanta and/or home visits

Data Collection and Procedures

- Data collection occurred at 3 time points in the *Parent Study*
  - 8 to 14 weeks gestation
  - 24 to 30 weeks gestation
- This *Sub-Study* added a 3rd time point
  - 35 to 41 weeks
- Compensated $20-30 at each visit
- Chart Review conducted post delivery for select labor and birth variables

Firmicutes

Bacteroidetes

Data Analyses

Data Analyses

I analyzed the data using the planned approach for the hypothesis of this Aim:

Aim: Describe the relationship between maternal gut microbiome composition during pregnancy and interval and total GWG.

Hypothesis: Maternal gut microbiome composition at the 1st and/or 3rd trimester, or the change in composition from the 1st to 3rd, will be associated with interval and/or total GWG.

Sample Characteristics

Sociodemographic Characteristic (N=27)	Distribution
Age, Mean (Range, Min-Max)	25.2 (17, 18-35)
Insurance Type, n (%)	
Medicaid	21 (77.8)
Private	6 (22.2)
Race, n (%)	
Black, African American	27 (100)
Educational Level, n (%)	
HS or less	12 (44.4)
College or greater	15 (55.5)
Marital Status, n (%)	
Married	4 (14.8)
Single	23 (85.2)
Relationship Status, n (%)	
Not in relationship	6 (22.2)
In relationship, no cohabitation	9 (33.3)
In a relationship, cohabitation	12 (44.4)
Parity, n (%)	
0	11 (40.7)
1	9 (33.3)
2 or 3	7 (25.9)

Weight-Related Characteristics

Weight-Related Characteristics	Frequency (Percent)
BMI at First prenatal care visit	
Underweight (<18.5)	1 (3.7)
Healthy Weight (18.5-24.9)	11 (40.7)
Overweight (25-29.9)	3 (11.1)
Obese (30 or more)	12 (44.4)
Gain by recommendation at midpoint of pregnancy	
Inadequate	13 (48.1)
Adequate	8 (29.6)
Excessive	6 (22.2)
Total Gain by recommendation for pregnancy	
Inadequate	9 (33.3)
Adequate	7 (25.9)
Excessive	11 (40.7)

Firmicutes

Bacteroidetes

One-Way Between Groups Analysis of Variance Tests

-Initial BMI Category

-Total Gestational Weight Gain

-Weight Gain at the Midpoint of Pregnancy

BY

-Change in FTB Ratio during the Pregnancy

Firmicutes to *Bacteroidetes* (FTB) Ratio by Initial BMI Category

	Underweight and Healthy Weight (<25), N=12, 44%	Overweight (25-29.9), N=8, 11%	Obese (30 and >), N=12, 44%	One-way, between groups ANOVA
FTB Ratio 1st visit Mean (SD)	1.49 (2.60)	2.45 (1.42	10.57 (23.92)	$F(2,24)=1.00$, $p=.38$
FTB Ratio 3rd visit Mean (SD)	2.14 (1.06)	1.23 (1.06)	2.90 (3.95)	$F(2,24)=0.32$, $p=.73$
FTB Ratio 1st to 3rd visit Mean (SD)	0.66 (0.46)	-1.22 (2.39)	-7.66 (24.55)	$F(2,24)=0.77$, $p=.43$

All ANOVA results with Levene statistic >.05, thus no violation of assumption of homogeneity of variance.

Firmicutes to *Bacteroidetes* (FTB) Ratio by Total Gestational Weight Gain

	Inadequate Gain N=9, 33%	**Adequate Gain N=7, 26%**	**Excessive Gain N=11, 41%**	**One-way, between groups ANOVA**
FTB Ratio 1st visit Mean (SD)	2.19 (3.18)	1.57 (1.98)	11.04 (25.00)	$F(2,24)=1.03$, $p=.37$
FTB Ratio 3rd visit Mean (SD)	4.10 (5.08)	1.98 (2.92)	1.23 (0.64)	$F(2,24)=1.93$, $p=.17$
FTB Ratio 1st to 3rd visit Mean (SD)	1.91 (3.24)	1.23 (0.64)	-9.80 (24.80)	$F(2,24)=1.54$, $p=.24$

All ANOVA results with Levene statistic >.05, thus no violation of assumption of homogeneity of variance.

Firmicutes to *Bacteroidetes* (FTB) Ratio by Weight Gain at mid-gestation

	Inadequate Gain at midpoint N=13, 48%	**Adequate Gain at midpoint N=8, 30%**	**Excessive Gain at midpoint N=6, 22%**	**One-way, between groups ANOVA**
FTB Ratio 1st visit Mean (SD)	2.34 (2.79)	1.18 (1.17)	18.69 (33.08)	$F(2,24)=2.85$, $p=.08$
FTB Ratio 3rd visit Mean (SD)	3.62 (4.49)	1.33 (1.71)	1.09 (0.70)	$F(2,24)=1.76$, $p=.19$
FTB Ratio 1st to 3rd visit Mean (SD)	1.28 (3.27)	0.15 (2.23)	-17.59 (32.68)	$F(2,24)=3.48$, $p=.05$*

(Mid-gestation = 20-25 weeks estimated gestational age)
*Correlation significant at 0.05 level (2-tailed), Eta squared = .22, Tukey HSD revealed Mean difference between inadequate gainers was significantly different from the excessive gainers. Adequate gainers did not significantly differ from either other group.
All ANOVA results revealed Levene statistic >.05, thus no violation of assumption of homogeneity of variance.

Conclusions

No relationships among initial BMI or weight or category of total weight gain and the change in FTB ratio during the pregnancy

The category of weight gain at the midpoint was found to be significantly associated with the change in FTB ratio during the pregnancy (F= 3.48, p = .05)

Additional Findings

Higher FTB ratio initially

Drops steadily during pregnancy

Significant reduction in FTB ratio for overweight and obese versus women at healthy weight who have a slight increase

Limitations

Focus at the Phylum level (FTB ratio) limits conclusions as many species within them are commensal or pathogenic.

Benefit of within-race analysis can be seen as a limitation in terms of generalizability to other races.

Implications for Future Research

Distinct gestational **weight gain patterns** and **specific obstetric risks** more prevalent in AA women could be related to the **intra-racial differences** in the gut microbiome.

Implications for Future Clinical Practice

Certain risks may be ***modifiable*** **if** **prepregnant weights are lowered and weight gain patterns are normalized** to ensure recommended rates by **mid-pregnancy** and at **term**, especially for **AA** women entering pregnancy overweight or obese and harboring a dysbiotic gut microbiome.

Ultimately, the wide racial disparity in obstetric morbidity and mortality must be addressed. Perhaps, the gut microbiome and weight are novel considerations that will one day make a clinical difference in outcomes for AA women and children.

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Alhusen, J. L., Gross, D., Hayat, M. J., Woods, A. B., & Sharps, P. W. (2012). The influence of maternal-fetal attachment and health practices on neonatal outcomes in low-income, urban women. *Research in Nursing and Health, 35*(2), 112-120. doi: 10.1002/nur.21464

Althuizen, E., van Poppel, M. N., Seidell, J. C., & van Mechelen, W. (2009). Correlates of absolute and excessive weight gain during pregnancy. *J Womens Health (Larchmt), 18*(10), 1559-1566. doi: 10.1089/jwh.2008.1275

Bodnar, L. M., Hutcheon, J. A., Platt, R. W., Himes, K. P., Simhan, H. N., & Abrams, B. (2011). Should gestational weight gain recommendations be tailored by maternal characteristics? *American Journal of Epidemiology, 174*(2), 136-146. doi: 10.1093/aje/kwr064

Bodnar, L. M., Siega-Riz, A. M., Simhan, H. N., Himes, K. P., & Abrams, B. (2010). Severe obesity, gestational weight gain, and adverse birth outcomes. *The American journal of clinical nutrition, 91*(6), 1642-1648. doi: 10.3945/ajcn.2009.29008

Bogaerts, A., Van den Bergh, B. R., Ameye, L., Witters, I., Martens, E., Timmerman, D., & Devlieger, R. (2013). Interpregnancy weight change and risk for adverse perinatal outcome. *Obstetrics and Gynecology, 122*(5), 999-1009. doi: 10.1097/AOG.0b013e3182a7f63e

Boghossian, N. S., Yeung, E. H., Lipsky, L. M., Poon, A. K., & Albert, P. S. (2013). Dietary patterns in association with postpartum weight retention. *The American journal of clinical nutrition, 97*(6), 1338-1345. doi: 10.3945/ajcn.112.048702

Bowers, K., Laughon, S. K., Kiely, M., Brite, J., Chen, Z., & Zhang, C. (2013). Gestational diabetes, pre-pregnancy obesity and pregnancy weight gain in relation to excess fetal growth: variations by race/ethnicity. *Diab?tologia, 56*(6), 1263-1271. doi: 10.1007/s00125-013-2881-5

Brooten, D., Youngblut, J. M., Golembeski, S., Magnus, M. H., & Hannan, J. (2012). Perceived weight gain, risk, and nutrition in pregnancy in five racial groups. *Journal of the American Academy of Nurse Practitioners, 24*(1), 32-42. doi: 10.1111/j.1745-7599.2011.00678.x

Bruckner, T. A., Rehkopf, D. H., & Catalano, R. A. (2013). Income gains and very low-weight birth among low-income black mothers in California. *Biodemography and social biology, 59*(2), 141-156. doi: 10.1080/19485565.2013.833802

Cohen, T. R., & Koski, K. G. (2013). Limiting excess weight gain in healthy pregnant women: importance of energy intakes, physical activity, and adherence to gestational weight gain guidelines. *Journal of pregnancy, 2013*, 787032. doi: 10.1155/2013/787032

Cox, L. M., & Blaser, M. J. (2013). Pathways in microbe-induced obesity. *Cell metabolism, 17*(6), 883-894. doi: 10.1016/j.cmet.2013.05.004

Dailey, D. E. (2009). Social stressors and strengths as predictors of infant birth weight in low-income African American women. *Nursing Research, 58*(5), 340-347. doi: 10.1097/NNR.0b013e3181ac1599

Davenport, M. H., Ruchat, S. M., Giroux, I., Sopper, M. M., & Mottola, M. F. (2013). Timing of excessive pregnancy-related weight gain and offspring adiposity at birth. *Obstetrics and Gynecology, 122*(2 Pt 1), 255-261. doi: 10.1097/AOG.0b013e31829a3b86

Davies, G. A., Maxwell, C., McLeod, L., Gagnon, R., Basso, M., Bos, H., . . . Wilson, K. (2010). Obesity in pregnancy. *Journal of obstetrics and gynaecology Canada : JOGC = Journal d'obstetrique et gynecologie du Canada : JOGC, 32*(2), 165-173.

Davies, G. A., Maxwell, C., McLeod, L., Gagnon, R., Basso, M., Bos, H., . . . Gynaecologists of, C. (2010). Obesity in pregnancy. *J Obstet Gynaecol Can, 32*(2), 165-173.

Davies, M. J. (2003). Obesity may confound relation of early pregnancy loss to risk of heart disease. *BMJ, 326*(7399), 1146. doi: 10.1136/bmj.326.7399.1146-a

Davis, E. M., Stange, K. C., & Horwitz, R. I. (2012). Childbearing, stress and obesity disparities in women: a public health perspective. *Maternal and child health journal, 16*(1), 109-118. doi: 10.1007/s10995-010-0712-6

Davis, R. R., Hofferth, S. L., & Shenassa, E. D. (2014). Gestational weight gain and risk of infant death in the United States. *American Journal of Public Health, 104 Suppl 1*, S90-95. doi: 10.2105/ajph.2013.301425

Davis, R. R., Hofferth, S. L. C. I. N. M. C. H. J. M., & author reply, P. (2012). The association between inadequate gestational weight gain and infant mortality among U.S. infants born in 2002. *Maternal and child health journal, 16*(1), 119-124. doi: 10.1007/s10995-010-0713-5 de Jongh, B. E., Paul, D. A., Hoffman, M., & Locke, R. (2013). Effects of Pre-pregnancy Obesity, Race/Ethnicity and Prematurity. *Maternal and child health journal*. doi: 10.1007/s10995-013-1296-8

Dello Russo, M., Ahrens, W., De Vriendt, T., Marild, S., Molnar, D., Moreno, L. A., . . . Siani, A. (2013). Gestational weight gain and adiposity, fat distribution, metabolic profile, and blood pressure in offspring: the IDEFICS project. *International journal of obesity (2005), 37*(7), 914-919. doi: 10.1038/ijo.2013.35

Di Benedetto, A., D'Anna, R., Cannata, M. L., Giordano, D., Interdonato, M. L., & Corrado, F. (2012). Effects of prepregnancy body mass index and weight gain during pregnancy on perinatal outcome in glucose-tolerant women. *Diabetes and Metabolism, 38*(1), 63-67. doi: 10.1016/j.diabet.2011.07.005

Dominguez, T. P. (2011). Adverse birth outcomes in African American women: the social context of persistent reproductive disadvantage. *Social work in public health, 26*(1), 3-16. doi: 10.1080/10911350902986880

Einerson, B. D., Huffman, J. K., Istwan, N. B., Rhea, D. J., & Joy, S. D. (2011). New gestational weight gain guidelines: an observational study of pregnancy outcomes in obese women. *Obesity (Silver Spring, Md.), 19*(12), 2361-2364. doi: 10.1038/oby.2011.67

Facco, F. L. (2011). Sleep-disordered breathing and pregnancy. *Seminars in Perinatology, 35*(6), 335-339. doi: 10.1053/j.semperi.2011.05.018

Ferraro, Z. M., Barrowman, N., Prud'homme, D., Walker, M., Wen, S. W., Rodger, M., & Adamo, K. B. (2012). Excessive gestational weight gain predicts large for gestational age neonates independent of maternal body mass index. *The journal of maternal-fetal & neonatal medicine : the official journal of the European Association of Perinatal Medicine, the Federation of Asia and Oceania Perinatal Societies, the International Society of Perinatal Obstetricians, 25*(5), 538-542. doi: 10.3109/14767058.2011.638953

Flegal, K. M., Carroll, M. D., Kit, B. K., Ogden, C. L. C. I. N. N. R. E. A., & Pmid. (2012). Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010. *JAMA : the journal of the American Medical Association, 307*(5), 491-497. doi: 10.1001/jama.2012.39

Flegal, K. M., Kit, B. K., Orpana, H., Graubard, B. I. C. I. N. J. A., & Pmid. (2013). Association of all-cause mortality with overweight and obesity using standard body mass index categories: a systematic review and meta-analysis. *JAMA : the journal of the American Medical Association, 309*(1), 71-82. doi: 10.1001/jama.2012.113905

Fontaine, P. L., Hellerstedt, W. L., Dayman, C. E., Wall, M. M., & Sherwood, N. E. (2012). Evaluating body mass index-specific trimester weight gain recommendations: differences between black and white women. *Journal of midwifery & women's health, 57*(4), 327-335. doi: 10.1111/j.1542-2011.2011.00139.x

Gibson, K. S., Waters, T. P., & Catalano, P. M. (2012). Maternal weight gain in women who develop gestational diabetes mellitus. *Obstetrics and Gynecology, 119*(3), 560-565. doi: 10.1097/AOG.0b013e31824758e0

Giurgescu, C., McFarlin, B. L., Lomax, J., Craddock, C., & Albrecht, A. (2011). Racial discrimination and the black-white gap in adverse birth outcomes: a review. *Journal of midwifery & women's health, 56*(4), 362-370. doi: 10.1111/j.1542-2011.2011.00034.x

Gold, K. J., DeMonner, S. M., Lantz, P. M., & Hayward, R. A. (2010). Prematurity and low birth weight as potential mediators of higher stillbirth risk in mixed black/white race couples. *Journal of women's health (2002), 19*(4), 767-773. doi: 10.1089/jwh.2009.1561

Goodrich, K., Cregger, M., Wilcox, S., & Liu, J. (2013). A qualitative study of factors affecting pregnancy weight gain in african american women. *Maternal and child health journal, 17*(3), 432-440. doi: 10.1007/s10995-012-1011-1

Gould Rothberg, B. E., Magriples, U., Kershaw, T. S., Rising, S. S., & Ickovics, J. R. (2011). Gestational weight gain and subsequent postpartum weight loss among young, low-income, ethnic minority women. *American Journal of Obstetrics and Gynecology, 204*(1), 52.e51-11. doi: 10.1016/j.ajog.2010.08.028

Headen, I. E., Davis, E. M., Mujahid, M. S., & Abrams, B. (2012). Racial-ethnic differences in pregnancy-related weight. *Advances in nutrition (Bethesda, Md.), 3*(1), 83-94. doi: 10.3945/an.111.000984

Herring, S. J., Henry, T. Q., Klotz, A. A., Foster, G. D., & Whitaker, R. C. (2012). Perceptions of low-income African-American mothers about excessive gestational weight gain. *Maternal and child health journal, 16*(9), 1837-1843. doi: 10.1007/s10995-011-0930-6

Herring, S. J., Nelson, D. B., Davey, A., Klotz, A. A., Dibble, L. V., Oken, E., & Foster, G. D. (2012). Determinants of excessive gestational weight gain in urban, low-income women. *Women's health issues : official publication of the Jacobs Institute of Women's Health, 22*(5), e439-446. doi: 10.1016/j.whi.2012.05.004

Hunt, K. J., Alanis, M. C., Johnson, E. R., Mayorga, M. E., & Korte, J. E. (2013). Maternal pre-pregnancy weight and gestational weight gain and their association with birthweight with a focus on racial differences. *Maternal and child health journal, 17*(1), 85-94. doi: 10.1007/s10995-012-0950-x

Josefson, J. L., Hoffmann, J. A., & Metzger, B. E. (2013). Excessive weight gain in women with a normal pre-pregnancy BMI is associated with increased neonatal adiposity. *Pediatric obesity, 8*(2), e33-36. doi: 10.1111/j.2047-6310.2012.00132.x

Khashan, A. S., Everard, C., McCowan, L. M., Dekker, G., Moss-Morris, R., Baker, P. N., . . . Kenny, L. C. (2014). Second-trimester maternal distress increases the risk of small for gestational age. *Psychological Medicine*, 1-12. doi: 10.1017/s0033291714000300

Klohe-Lehman, D. M., Freeland-Graves, J., Anderson, E. R., McDowell, T., Clarke, K. K., Hanss-Nuss, H., . . . Milani, T. J. (2006). Nutrition knowledge is associated with greater weight loss in obese and overweight low-income mothers. *Journal of the American Dietetic Association, 106*(1), 65-75; quiz 76-69. doi: 10.1016/j.jada.2005.09.047

Kominiarek, M. A., Seligman, N. S., Dolin, C., Gao, W., Berghella, V., Hoffman, M., & Hibbard, J. U. (2013). Gestational weight gain and obesity: is 20 pounds too much? *American Journal of Obstetrics and Gynecology, 209*(3), 214.e211-211. doi: 10.1016/j.ajog.2013.04.035

Krans, E. E., & Chang, J. C. (2012). Low-income African American women's beliefs regarding exercise during pregnancy. *Maternal and child health journal, 16*(6), 1180-1187. doi: 10.1007/s10995-011-0883-9

Krukowski, R. A., Bursac, Z., McGehee, M. A., & West, D. (2013). Exploring potential health disparities in excessive gestational weight gain. *Journal of women's health (2002), 22*(6), 494-500. doi: 10.1089/jwh.2012.3998

Lee, S. Y., & Hsu, H. C. (2012). Stress and health-related well-being among mothers with a low birth weight infant: the role of sleep. *Social science & medicine (1982), 74*(7), 958-965. doi: 10.1016/j.socscimed.2011.12.030

Leslie, W. S., Gibson, A., & Hankey, C. R. (2013). Prevention and management of excessive gestational weight gain: a survey of overweight and obese pregnant women. *BMC pregnancy and childbirth, 13*, 10. doi: 10.1186/1471-2393-13-10

Love, C., David, R. J., Rankin, K. M., & Collins, J. W., Jr. (2010). Exploring weathering: effects of lifelong economic environment and maternal age on low birth weight, small for gestational age, and preterm birth in African-American and white women. *American Journal of Epidemiology, 172*(2), 127-134. doi: 10.1093/aje/kwq109

Macleod, M., Gregor, A., Barnett, C., Magee, E., Thompson, J., & Anderson, A. S. (2013). Provision of weight management advice for obese women during pregnancy: a survey of current practice and midwives' views on future approaches. *Maternal & child nutrition, 9*(4), 467-472. doi: 10.1111/j.1740-8709.2011.00396.x

Medicine, I. I. o. (2010). *Women's Health Research: Progress, Pitfalls, and Promise*. Washington D. C.: The National Academies Press.

Mehta, S. H., Kruger, M., & Sokol, R. J. (2011). Being too large for gestational age precedes childhood obesity in African Americans. *American Journal of Obstetrics and Gynecology, 204*(3), 265.e261-265. doi: 10.1016/j.ajog.2010.12.009

Misra, V. K., & Trudeau, S. (2011). The influence of overweight and obesity on longitudinal trends in maternal serum leptin levels during pregnancy. *Obesity (Silver Spring, Md.), 19*(2), 416-421. doi: 10.1038/oby.2010.172

Nehring, I., Schmoll, S., Beyerlein, A., Hauner, H., & von Kries, R. (2011). Gestational weight gain and long-term postpartum weight retention: a meta-analysis. *The American journal of clinical nutrition, 94*(5), 1225-1231. doi: 10.3945/ajcn.111.015289

O'Dwyer, V., O'Toole, F., Darcy, S., Farah, N., Kennelly, M. M., & Turner, M. J. (2013). Maternal obesity and gestational weight gain. *Journal of obstetrics and gynaecology : the journal of the Institute of Obstetrics and Gynaecology, 33*(7), 671-674. doi: 10.3109/01443615.2013.821461

Okun, M. L., Luther, J., Prather, A. A., Perel, J. M., Wisniewski, S., & Wisner, K. L. (2011). Changes in sleep quality, but not hormones predict time to postpartum depression recurrence. *Journal of Affective Disorders, 130*(3), 378-384. doi: 10.1016/j.jad.2010.07.015

Ouzounian, J. G., Hernandez, G. D., Korst, L. M., Montoro, M. M., Battista, L. R., Walden, C. L., . . . Pmid. (2011). Pre-pregnancy weight and excess weight gain are risk factors for macrosomia in women with gestational diabetes. *Journal of perinatology : official journal of the California Perinatal Association, 31*(11), 717-721. doi: 10.1038/jp.2011.15

Park, S., Sappenfield, W. M., Bish, C., Salihu, H., Goodman, D., & Bensyl, D. M. (2011). Assessment of the Institute of Medicine recommendations for weight gain during pregnancy: Florida, 2004-2007. *Maternal and child health journal, 15*(3), 289-301. doi: 10.1007/s10995-010-0596-5

Paul, K. H., Graham, M. L., & Olson, C. M. (2013). The web of risk factors for excessive gestational weight gain in low income women. *Maternal and child health journal, 17*(2), 344-351. doi: 10.1007/s10995-012-0979-x

Ruchat, S. M., & Mottola, M. F. (2012). Preventing long-term risk of obesity for two generations: prenatal physical activity is part of the puzzle. *Journal of pregnancy, 2012*, 470247. doi: 10.1155/2012/470247

Salihu, H., Mbah, A. K., Alio, A. P., Kornosky, J. L., Whiteman, V. E., Belogolovkin, V., & Rubin, L. P. (2010). Nulliparity and preterm birth in the era of obesity epidemic. *The journal of maternal-fetal & neonatal medicine : the official journal of the European Association of Perinatal Medicine, the Federation of Asia and Oceania Perinatal Societies, the International Society of Perinatal Obstetricians, 23*(12), 1444-1450. doi: 10.3109/14767051003678044

Salihu, H. M. (2011). Maternal obesity and stillbirth. *Seminars in Perinatology, 35*(6), 340-344. doi: 10.1053/j.semperi.2011.05.019

Savitz, D. A., Stein, C. R., Siega-Riz, A. M., & Herring, A. H. (2011). Gestational weight gain and birth outcome in relation to prepregnancy body mass index and ethnicity. *Annals of Epidemiology, 21*(2), 78-85. doi: 10.1016/j.annepidem.2010.06.009

Simas, T. A., Waring, M. E., Liao, X., Garrison, A., Sullivan, G. M., Howard, A. E., & Hardy, J. R. (2012). Prepregnancy weight, gestational weight gain, and risk of growth affected neonates. *Journal of women's health (2002), 21*(4), 410-417. doi: 10.1089/jwh.2011.2810

Singh, K. A., Huston-Presley, L. P., Mencin, P., Thomas, A., Amini, S. B., & Catalano, P. M. (2010). Birth weight and body composition of neonates born to Caucasian compared with African-American mothers. *Obstetrics and Gynecology, 115*(5), 998-1002. doi: 10.1097/AOG.0b013e3181da901a

Stotland, N. E., Cheng, Y. W., Hopkins, L. M., & Caughey, A. B. (2006). Gestational weight gain and adverse neonatal outcome among term infants. *Obstetrics and Gynecology, 108*(3 Pt 1), 635-643. doi: 10.1097/01.AOG.0000228960.16678.bd

Taveras, E. M., Gillman, M. W., Kleinman, K. P., Rich-Edwards, J. W., & Rifas-Shiman, S. L. (2013). Reducing racial/ethnic disparities in childhood obesity: the role of early life risk factors. *JAMA pediatrics, 167*(8), 731-738. doi: 10.1001/jamapediatrics.2013.85

Taylor, P. D., Samuelsson, A. M., & Poston, L. (2014). Maternal obesity and the developmental programming of hypertension: a role for leptin. *Acta physiologica (Oxford, England), 210*(3), 508-523. doi: 10.1111/apha.12223

Torloni, M. R., Fortunato, S. J., Betran, A. P., Williams, S., Brou, L., Drobek, C. O., . . . Menon, R. (2012). Ethnic disparity in spontaneous preterm birth and maternal pre-pregnancy body mass index. *Archives of Gynecology and Obstetrics, 285*(4), 959-966. doi: 10.1007/s00404-011-2102-8

Weight Gain During Pregnancy: Reexamining the Guidelines. (2009). Washington, D. C.: National Academies Press.

Wilkinson, S. A., Poad, D., & Stapleton, H. (2013). Maternal overweight and obesity: a survey of clinicians' characteristics and attitudes, and their responses to their pregnant clients. *BMC pregnancy and childbirth, 13*, 117. doi: 10.1186/1471-2393-13-117

Yu, Z., Han, S., Zhu, J., Sun, X., Ji, C., & Guo, X. (2013). Pre-pregnancy body mass index in relation to infant birth weight and offspring overweight/obesity: a systematic review and meta-analysis. *PloS one, 8*(4), e61627. doi: 10.1371/journal.pone.0061627

Zhao, L. (2013). The gut microbiota and obesity: from correlation to causality. *Nature reviews. Microbiology, 11*(9), 639-647. doi: 10.1038/nrmicro3089