Impact of Maternal Obesity on Maternal and Offspring Health

by

Jessica A. Hevener
ID: 917004351
HDE117/Ent117
Longevity

TABLE OF CONTENTS

SUMMARY

This paper is an overview of literature and empirical studies concerning the adverse health effects of obesity on mothers and fetuses during pregnancy and later life. This document is divided into five main sections. The first section introduces the magnitude of maternal obesity. The next section provides background information on the inflammatory pattern and maternal complications in obese individuals. The third section focuses on how adverse intrauterine environments influence fetal programming and prenatal health. The fourth section considers how maternal obesity affects the long-term health of the offspring with a particular emphasis on respiratory health and the Helsinki Birth Cohort. The document ends with a discussion on the importance of early prevention of obesity to improve public health.

INTRODUCTION

The rise of obesity among women of child-bearing age is a public health concern that has reached epidemic-level proportions. Over 60% of women in the United States are either overweight or obese at conception (Godfrey et al., 2017). This percentage continues to rise as individuals consume unhealthy diets and perform a limited amount of exercise. Obesity is a multifactorial health concern characterized by the accumulation of fat in adipose tissue that diminishes one's health (Nurul-Farehah, S., & Rohana, A. J., 2020). Changes in our society's eating habits and environmental conditions continue to contribute to the rise in obesity.

Obesity is measured through the Body Mass Index (BMI) scale, which measures body weight in relation to height. A BMI above 25 is considered overweight, while a BMI above 30 is clinically obese. As BMI increases, individuals will experience a rise in blood pressure, blood sugar, and inflammation. A high BMI increases the risk for serious health complications during pregnancy, which endangers the short-term and long-term health of the mother and the offspring.

The long-term health consequences of developing in an obese intrauterine environment are one of the most widely studied concerns regarding the rise of obesity. A fetus is constantly adapting to the nutrients it receives and is sensitive to the environment that it develops in. Researchers and health professionals are concerned about the long-term health problems caused by developing in an obese intrauterine environment, including insulin resistance, respiratory stress, and cardiovascular disease.

BACKGROUND

Inflammatory Pattern

Obesity is fat accumulation caused by an increase in adipocyte size and number. The primary cause of increased adipocytes is nutrient excess and lack of energy expenditure. Pattern-recognition receptors (PRRs) activate as a response to nutrient excess and trigger metabolic inflammation (Jin & Flavell, 2013). The linear relationship between diet, PRRs, and inflammation are presented in Figure 1. Obese individuals experience a chronic release of pro-inflammatory cytokines, which increases the population of macrophages and promotes the inflammatory response (Tarantal & Berglund, 2014). Living in a chronically inflamed state increases the risk for cardiovascular disease and contributes to insulin resistance.

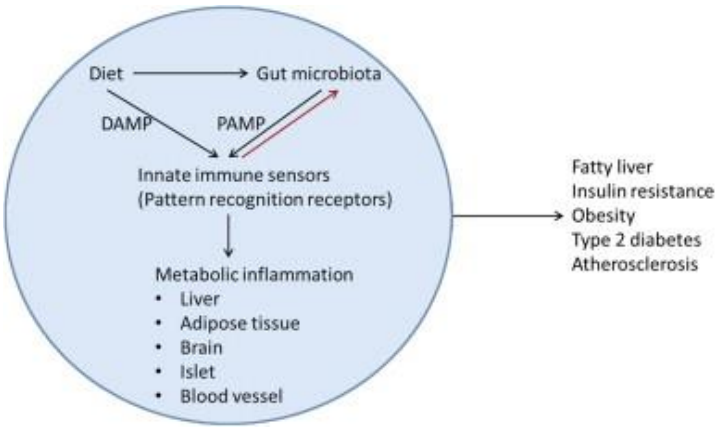

Fig 1. Interactions between diet and gut microbiota activate innate immune sensors that control metabolic inflammation. Pattern recognition receptors sense stress from diet and microbiota, which activates an inflammatory response and promotes obesity (Jin & Flavell, 2013).

Pregnancy is associated with a high-inflammatory state, even in non-obese individuals. In pregnancy, placental growth produces an anti-inflammatory effect to counteract the increased inflammatory response. However, women with a high BMI who start pregnancy with high inflammation will continue to suffer from the health effects of living in an inflamed state. Chronic inflammation increases insulin resistance, which increases the risk of developing gestational diabetes and cardiovascular disorders.

Maternal Complications

Maternal obesity drastically increases the risk of health and pregnancy complications, including gestational diabetes, pre-eclampsia, and venous thromboembolism. There is a direct correlation between a high BMI and developing gestational diabetes. Gestational diabetes is a temporary condition identified by elevated blood glucose levels during pregnancy (Fitzsimons et al., 2009). While this disease is temporary, it increases the long-term risk of developing Type 2 diabetes and high blood pressure later in life (Herring & Oken, 2011). Due to increases in inflammation and insulin resistance in the obese state, women with a high BMI are more likely to develop gestational diabetes than women with a normal BMI (Beloushi et al., 2020). Women with a BMI between 25-29.9, who are clinically overweight, are over two times more likely to develop Gestational diabetes (Table 1). The percentage of Gestational diabetes continues to escalate as BMI increases.

Prevalence of Gestational Diabetes Mellitus in relation to BMI Category

BMI	Category	Gestational Diabetes Mellitus Prevalence (%)
13-18.4	Underweight	0.7
18.5-25	Normal weight	2.3
25-29.9	Overweight	4.8
30-34.9	Obese	5.5
35-64.9	Severely obese	11.5

Table 1. Prevalence of Gestational Diabetes Mellitus based on BMI in a sample of 23,904 women in the United States (Johns et al., 2018).

A mother with a high BMI is more likely to develop pre-eclampsia, which has detrimental short-term and long-term health effects. Pre-eclampsia causes high blood pressure and proteinuria, which increases the risk for impaired organ function, blood clots, and seizures during pregnancy (Fitzsimons et al., 2009). If left untreated, pre-eclampsia will turn into eclampsia, a condition characterized by seizures or comas. Pre-eclampsia is a serious health condition in pregnant women, as it can lead to complications that end in maternal and infant death. After delivery, the symptoms of pre-eclampsia will leave. However, women with pre-eclampsia are likely to suffer from heart disease and have high levels of thyroid-stimulating hormone in later life (Williams, 2011). While the symptoms of pre-eclampsia may end, an individual may still suffer long-term.

Reduced mobility and high blood pressure magnify an obese woman's risk for experiencing venous thromboembolism. Venous thromboembolism refers to blood clots that arise in the veins. Studies have found significant associations between high BMI and an elevated risk for venous thromboembolism (Fitzsimons et al., 2009). These findings demonstrate how complications from obesity build on one another, resulting in fatal health consequences.

PRENATAL HEALTH

In Utero Fetal Programming Hypothesis

Lifestyle and dietary risk factors are widely accepted to cause obesity. However, there is increasing evidence that suggests some metabolic disorders originate before birth. The In-Utero Fetal Programming Hypothesis, also known as the Barker Hypothesis, refers to the link between birth size and the risk of developing chronic disease in later life (Leddy et al., 2008). When researchers restrict nutrition to a mother rat throughout gestation, the offspring develop adult hyperphagia or excessive hunger. The results of the study demonstrate that appetite is pre-programmed during development. Offspring from malnourished mothers are more likely to develop metabolic disorders and obesity in adult life due to their excessive hunger (Breier et al., 2001).

The Barker Hypothesis originally focused on the relationship between low birth weight, malnutrition in fetuses, and the risk of developing health complications as adults. As obesity rises, researchers now use the Barker Hypothesis to study the relationship between obese intrauterine environments and fetal health. Fetuses must adapt to the supply

of nutrients they receive, which may be in abundance or deficit. Fetal adaptations to nutrient excess during development are suspected to permanently change their metabolism and pre-program individuals for metabolic disorders and obesity (Leddy et al., 2008).

Gestational Diabetes

As maternal obesity levels rise, the number of offspring developing in diabetic intrauterine environments continues to increase. To better understand the impacts of development in this environment, researchers study children born from mothers with Gestational diabetes. Children born from mothers with Gestational diabetes tend to have higher birth weight because of excess sugar and insulin (Rooney, 2010). Evidence shows that children born with higher birth weights are more likely to experience childhood obesity, insulin resistance, and circulatory diseases (Johns et al., 2018).

According to the American Diabetes Association, being overweight is the leading risk factor for developing Type 2 diabetes (American Diabetes Association, 2021). As obesity levels rise, there are a higher number of individuals developing in high-glucose and high-insulin environments. Plagemann and his colleagues analyzed the offspring of women with Type 1 diabetes, Type 2 diabetes, and Gestational diabetes to test the fetal programming hypothesis. Plagemann discovered that offspring of mothers with diabetes during pregnancy are more likely to develop impaired glucose tolerance. Longitudinal analysis of children age 1-4 compared to children age 5-9 with diabetic mothers reveals that there is a significant increase of fasting blood glucose with rising age, as seen in Figure 2. This means that even after an overnight fast, children with diabetic mothers during pregnancy are more likely to have increased levels of blood glucose as they age. In contrast, healthy children present stable blood glucose levels with increasing age (Plagemann, 1997). Fetal programming perpetuates the obesity epidemic as individuals who develop in adverse intrauterine environments are more vulnerable to insulin resistance and metabolic disorders. The embryonic exposure to high levels of glucose and insulin reduces the future insulin activity of the offspring.

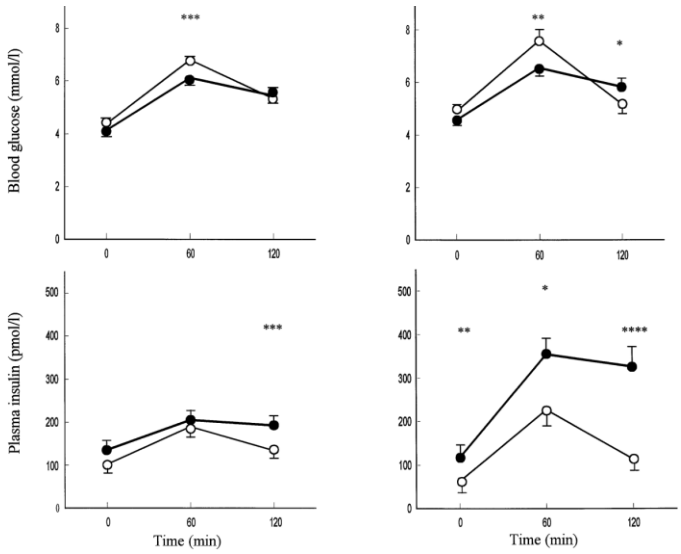

Fig 2. Means of blood glucose and plasma insulin concentrations during oral glucose tolerance tests at (A) 1-4 years of age and (B) 5-9 years of age (Plagemann et al., 1997).

LONG TERM HEALTH OF OFFSPRING

Helsinki Birth Cohort Study

Maternal obesity has long-term effects on the health of the offspring. The Helsinki Birth Cohort Study analyzed birth records of 13,345 men and women born between 1934-1944 in Helsinki, Finland. Researchers used hospital records and national registers to record maternal BMI during pregnancy and report various health consequences among offspring. The cohort study results demonstrate that maternal BMI is positively associated with an increased risk of cancer, cardiovascular disease, and Type 2 diabetes among the offspring (Eriksson et al., 2014). According to these findings, developing in an adverse intrauterine environment with high maternal glucose, insulin, and free fatty acids increases fetal vulnerability to obesity and disease.

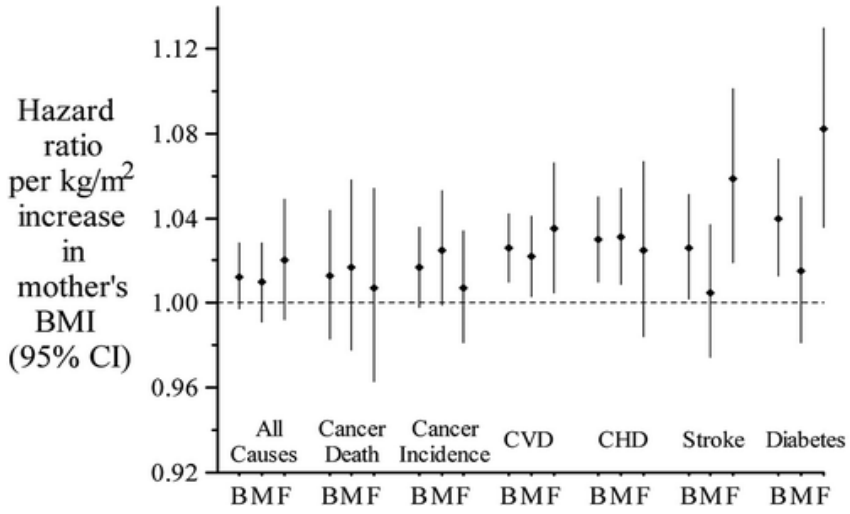

Fig 3. Hazard Ratio per 1 kg/m² increase in maternal BMI in Helsinki Birth Cohort for all-cause mortality, cancer mortality, cardiovascular disease, coronary heart disease, stroke, and diabetes. B column is both males and females. M column is males only. F column is females only. The higher the maternal BMI, the greater the risk for all disease outcomes (Eriksson et al., 2014).

Further research on the Helsinki Birth Cohort Study suggests that disadvantageous body composition is pre-programmed in early life. To understand the mechanisms behind the association between maternal obesity and the long-term consequences on the offspring, Eriksson and colleagues took measurements of body size, composition, and characteristics of 2,003 individuals from the Helsinki Birth Cohort Study. The results of the study demonstrate that maternal BMI is positively associated with BMI in the offspring. The risk for disease in relation to BMI is presented in Figure 3. Mothers with low BMI have offspring with a lower fat percentage. Mothers with high BMI have offspring with a higher body fat percentage (Eriksson et al., 2015). The idea that maternal BMI and offspring BMI are linked supports the hypothesis that fetal programming influences body weight and BMI. The BMI of an individual may be programmed before they are born. This finding emphasizes the adaptability of an embryo to its environment.

Respiratory Health

Maternal obesity during pregnancy has both immediate and long-term consequences on offspring respiratory health. Newborn children who develop in an obese intrauterine environment face a higher risk of respiratory distress syndrome and may require mechanical ventilation. As these children grow up, they experience a higher risk of developing breathing disorders, including asthma, sleep-disordered breathing, and chronic lung disease (McGillick et al., 2017). These respiratory issues continue throughout adulthood and affect the entire lifespan of the individual. A list of these immediate and long-term consequences of maternal obesity on offspring respiratory health are presented in Figure 4.

Inflammation of the immune system during development may contribute to the future development of asthma and respiratory diseases. Immune factors including macrophages and T-cells are critical for regulating asthma and airway inflammation (Hunter Medical Research Institute, 2021). In a meta-analysis of 14 studies, researchers discovered that maternal obesity during pregnancy is associated with an increased risk of asthma in offspring (Forno, et al., 2014). One explanation for this correlation is the high-inflammatory state of obese pregnant women. High levels of pro-inflammatory cytokines circulating in the fetus during an obese pregnancy may influence the development of childhood asthma. Another explanation for this correlation is the decreased amount of adiponectin circulating in obese individuals. Adiponectin is an anti-inflammatory hormone associated with improving asthma control and decreasing airway inflammation (Kattan et al., 2010). Lower amounts of adiponectin in obese mothers reduce the amount of this hormone circulating in the developing fetus, which leads to the development of asthma and other respiratory diseases in later life.

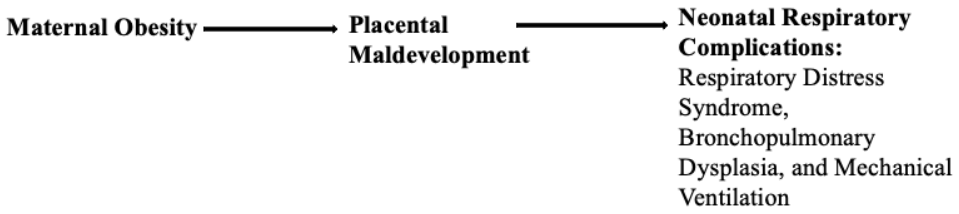

Fig 4. Immediate and Long-Term Consequences of Maternal Obesity (Redrawn from: McGillick, E. et al., 2017).

DISCUSSION

Population-level

The United States is one of the wealthiest nations in the world, yet its public health continues to suffer. While life expectancy has increased, Americans live shorter lives with more illness than people in other high-income countries (Woolf et al., 2013). Possible explanations for this discrepancy include societal design and unhealthy individual behavior. Automobiles and transportation systems decrease physical activity, while the fast-food industry increases food consumption. A society designed for convenience leads to individuals consuming high-caloric diets and expending low amounts of energy, which results in an obese population.

Children who develop in an obese intrauterine environment are more likely to be obese themselves. This cycle of obesity is harmful to public health, as it increases the incidence of cardiovascular disease, Type 2 diabetes, cancer, and osteoarthritis (Visscher & Seidell, 2001). To estimate the progression of the obesity epidemic, Wang and colleagues used previous health records from the National Health Nutrition Examination Study. The results demonstrate that if trends in obesity continue, 78.9% of American adults

will be overweight or obese by the year 2030 (Wang et al., 2012). With most of the population overweight and obese, our society will continue to experience physical health consequences, poorer mental health, and reduced quality of life (Sarwer & Polonsky, 2018). On an individual and population level, we cannot perform our best when our health is suffering.

Importance of Prevention

Findings show that prenatal dietary and lifestyle intervention programs in overweight or obese pregnant women do not decrease gestational weight gain enough to reduce the incidence of gestational diabetes (Hanson et al., 2017). Therefore, it is more beneficial to focus on obesity prevention programs instead of individual weight loss during pregnancy. Pregnancy outcome is related to health before conception, which demonstrates the importance of obesity prevention.

Reducing obesity is a challenge, as it involves multiple variables, including genetics, early life experience, sleep patterns, and stress. However, we can look to other countries with lower obesity rates to find solutions to obesity prevention. Japan has one of the lowest obesity rates in the world. Only 3.6 percent of Japanese citizens are clinically obese, with a BMI over 30. In contrast, 32 percent of Americans are clinically obese (Senauer, 2006). The divide between obesity in Japan and the United States is due to differences in dietary habits and physical activity. In Japan, individuals consume far fewer calories and use walking as a standard form of transportation. While walking everywhere may not be a suitable means of transportation in the United States, individuals must attempt to perform more physical activity. Creating a diet and exercise plan can be a solution for pregnant mothers trying to lose or maintain a healthy weight. Additionally, increasing pregnant mothers' access to fresh foods at restaurants and grocery stores is necessary to promote healthy fetal programming.

Obesity is not just an issue of a lack of self-control. It is a complex problem that requires lifestyle and societal changes. Increases in obesity reflect cultural norms, including large portion sizes, over-consumption of sugar, and limited physical activity. Therefore, reducing maternal obesity will require national efforts to educate the public on the dangers of being overweight and information on how to maintain a healthy weight (Lysnicki, et al. 2001). Our society must understand the serious health effect of obesity on future generations and implement lifestyle changes to stop the cycle.

CONCLUSION

Maternal obesity is a catalyst in the cycle of obesity, a worldwide epidemic with lasting effects on individuals and the population. This epidemic has led to the rise of multiple health issues, including cardiovascular disorders, respiratory disorders, diabetes, and cancer. Maternal obesity causes serious short-term and long-term health conditions in mothers and offspring. While in-utero, the fetus is sensitive and adaptive to its environment. Developing in an obese environment has adverse effects on fetal programming, which leads to a high risk of becoming obese and developing metabolic disorders in later life. Relying on medication for preventable health concerns is not a

reliable treatment for public health. Our population requires lifestyle and community interventions to improve our health and longevity long term.

REFERENCES

ADA. 2021. Know your risk. American Diabetes Association. Retrieved July 22, 2021, https://www.diabetes.org/

Beloushi, M. A., Doshani, A., and Konje, J. C. 2020. Obesity, insulin resistance, and placental dysfunction - fetal growth. *The Lancet Diabetes & Endocrinology* **4:** 191-197.

Breier, B. H., Vickers, M. H., Ikenasio, B. A., Chan, K. Y., and Wong, W. 2001. Fetal programming of appetite and obesity. *Molecular and Cellular Endocrinology*, **185:** 73-79.

Eriksson, J. G., Sandboge, S., Salonen, M. K., Kajantie, E., and Osmond, C. 2014. Long-term consequences of maternal overweight in pregnancy on offspring later health: Findings from the Helsinki Birth Cohort Study. *Annals of Medicine* **46:** 434–438.

Eriksson, J., Sandboge, S., Salonen, M. Kajantie, E., and Osmond, C. 2015. Maternal weight in pregnancy and offspring body composition in late adulthood: Findings from the Helsinki Birth Cohort Study (HBCS). *Annals of Medicine* **47:** 94-99.

Fitzsimons, K.J., Modder, J., and Greer, I. A. 2009. Obesity in pregnancy: risks and management. *Obstetric Medicine* **2:** 52-62.

Forno, E., Young, O., Kumar, R., Simhan, H., and Celedon, J. 2014. Maternal obesity in pregnancy, gestational weight gain, and risk of childhood asthma. *Pediatrics* **134:** 535-546.

Godfrey, K. M., Reynolds, R. M., Prescott, S. L., Nyirenda, M., Jaddoe, V. W., Eriksson, J. G., and Broekman, B. F. 2017. Influence of maternal obesity on the long-term health of offspring. *The Lancet Diabetes & Endocrinology* **5:** 53–64.

Hanson, M.D., Barker, M., Dodd, J.M, Kumanyika, S., Norris, S., Steegers, E., Stephenson, J., Thangaratinam, S., and Yang, H. 2017. Interventions to prevent maternal obesity before conception, during pregnancy, and post-partum. *The Lancet Diabetes & Endocrinology* **5:** 65-76.

Herring, S. J. and Oken, E. 2011. Obesity and diabetes in mothers and their children: Can we stop the intergenerational cycle? *Current Diabetes Reports* **11:** 20-27.

HMRI. 2021. Asthma, respiratory diseases and the immune system research. Retrieved July 22, 2021. https://hmri.org.au/research/viruses-infections-immunity-vaccines-asthma/asthma-respiratory-diseases-immune-system.

Jin, C. and Flavell, R. 2013. Innate sensors of pathogen and stress: Linking inflammation to obesity. *Journal of Allergy and Clinical Immunology*, **132:** 287-294.

Johns, E. C. Denison, F.C., Norman, J.E., and Reynolds, R. M. 2018. Gestational diabetes mellitus: Mechanisms, treatment, and complications. *Trends in Endocrinology & Metabolism*, **29 :**743-754.

Kattan, M., Kumar, R., Bloomberg, G. R., Mitchell, H. E., Calatroni, A., Gergen, P. J., Kercsmar, C.M., Visness, C.M., Matsui, E. C., Steinbach, S. F., Szefler, S. J., Sorkness, C. A., Morgan, W. J., Teach, S. J., and Gan, V.N. 2010. Asthma control, adiposity, and adipokines among inner-city adolescents. *Journal of Allergy and Clinical Immunology*, **125:** 584-592.

Leddy, M. A., Power, M. L., and Schulkin, J. 2008. The impact of maternal obesity on maternal and fetal health. *Reviews in Obstetrics & Gynecology*, **4:** 170–178.

Lyznicki, J., Young, D., Riggs, J. and Davis, R. 2001. *American Family Physician*, **63:** 2185-2197.

McGillick, E. V., Lock, M. C., Orgeig, S., and Morrison, J. L. 2017. Maternal obesity mediated predisposition to respiratory complications at birth and in later life: understanding the implications of the obesogenic intrauterine environment. *Pediatric Respiratory Review*, **21:** 11–18.

Nurul-Farehah, S., & Rohana, A. J. 2020. Maternal obesity and its determinants: A neglected issue? *Malaysian family physician: the official journal of the Academy of Family Physicians of Malaysia*, **15:** 34–42.

Plagemann, A., Harder, T., Kohlkoff, R., Rohde, W., and Dorner, G. 1997. Glucose tolerance and insulin secretion in children of mothers with pregestational IDDM or gestational diabetes. *Diabetologia*, **40:** 1094-1100

Rooney, B. L., Mathiason, M. A., and Schauberger, C. W. 2010. Predictors of obesity in childhood, adolescence, and adulthood in a birth cohort. *Maternal and Child Health Journal* **15:** 1166–1175.

Sarwer, D. B., and Polonsky, H.M. 2016. The psychosocial burden of obesity. *Endocrinology and Metabolism Clinics of North America*, **45:** 677-688.

Senauer, B. and Masahiko, G. 2006. Why is the obesity rate so low in Japan and high in the U.S.? Some possible economic explanations. *University of Minnesota: The Food Industry Center*. https://ageconsearch.umn.edu/record/14321/.

Tarantal, A., and Berglund, L. 2014. Obesity and Lifespan Health—Importance of the Fetal Environment. *Nutrients* **6:** 1725–1736.

Visscher, T. and Seidell, J. 2001. The public health impact of obesity. *Annual Review of Public Health*, **22:** 355-375.

Wang, Y., Beydon, M., Liang, L., Caballero, B., and Kumanyika, S. 2008. Will all Americans become overweight or obese? Estimating the progression and cost of the US obesity epidemic. *Obesity*, **16:** 2323-2330.

Williams, D. 2011. Long-term complications of preeclampsia. *Seminars in Nephrology*, **31:** 111-122.

Woolf, S. and Aron, L, Editors. 2013. U.S Health in International Perspective: Shorter Lives, Poorer Health. *National Research Council*, Washington D.C.