Spring 2020

Factors Influencing Both Maternal and Infant Body Composition at Two Years Postpartum

Samantha Henry
Western Kentucky University, sjh0318@outlook.com

FACTORS INFLUENCING BOTH MATERNAL AND INFANT BODY COMPOSITION AT TWO YEARS POSTPARTUM

A Thesis
Presented to
The Faculty of the School of Kinesiology, Recreation, and Sport
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
Of the Requirements for the Degree
Master of Science

By
Samantha Henry

May 2020

FACTORS INFLUENCING BOTH MATERNAL AND INFANT BODY COMPOSITON AT TWO YEARS POSTPARTUM

Date Recommended June 30, 2020

Rachel Tinius

Rachel Tinius, Director of Thesis

Danilo Tolusso

Danilo Tolusso

Sarah L Herrick

Sarah Herrick

T. Scott Lyons

Scott Lyons

Ranjit T. Koodali Digitally signed by Ranjit T. Koodali
Date: 2020.07.27 13:40:49 -05'00'

Associate Provost for Research and Graduate Education

Acknowledgements

This project would not have been half of what it is if it were not for the help of others. I would like to first and foremost thank my thesis advisor, Dr. Rachel Tinius, for the irreplaceable support and encouragement she has provided me throughout this process. I am also beyond grateful for all of the support from my committee, Dr. Danilo Tolusso, Dr. Sarah Herrick, and Dr. Scott Lyons. I would like to thank Brenna Menke for assisting with data collection and always having a helpful suggestion and Catie Duchette for her help picking up tasks when she was needed. Additionally, I would like to thank the Western Kentucky University Graduate School for funding this study. Last, but not least, I would like to thank the entire Kinesiology program for being the best support system and always providing me with something to laugh about.

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Directed by Rachel Tinius, Danilo Tolusso, Sarah Herrick, and Scott Lyons

School of Kinesiology, Recreation, and Sport Western Kentucky University

Maternal body composition (BC) and physical activity (PA) level during pregnancy both contribute to infant body composition; however, few studies follow children beyond the early weeks to determine the longer-term implications of maternal lifestyle on offspring health. The purpose of this study was threefold: 1) Determine the role of maternal obesity on offspring BC at 2 years of age; 2) Determine the role of PA during pregnancy on maternal and infant BC at two years postpartum; and 3) Determine whether BC at birth (assessed via air displacement plethysmography [PEA POD]) is related to BC at two years of age (assessed via air displacement plethysmography BOD POD). Participants were recruited from a larger observational study. BC (assessed via air displacement plethysmography, PA (assessed via accelerometer), and other lifestyle factors (assessed via validated surveys) were collected for both mother and infant. Twelve mother-infant pairs completed study visits. Kendall's Tau-b correlation coefficients (R > 0.07 small, > 0.2 moderate, > 0.35 large, > 0.5 very large, > 0.7 nearly perfect) were used to investigate the relationships between maternal and toddler variables due to violation of assumptions and the small sample size. At two years postpartum, maternal body fat percentage positively correlated with offspring BMI (R=0.200). Maternal body fat percentage during pregnancy showed a moderate positive correlation with offspring body fat percentage at two years of age (R=0.222). Maternal light physical activity during pregnancy also showed a moderate positive correlation with offspring body fat percentage at two years of age (R=0.286). Maternal sedentary and light physical activity at two years postpartum showed a large and very large positive correlation with toddler sedentary and light physical activity at two years of age (R= 0.418 and R= 0.564, respectively). Finally, a moderate negative correlation was observed between offspring body fat percentage at birth and at two years of age (R= -0.286). These findings suggest that women who are of a healthy BC and participate in regular PA during late pregnancy are more likely to have children who are also active and have a healthy body composition. Overall, this study demonstrates the importance of healthy lifestyle choices during and after pregnancy.

Introduction

Obesity rates are at an all-time high in America, and this puts the population at high risk for various related cardiovascular and metabolic diseases (CDC 2020). Although there are non-modifiable factors that contribute to the development of many of these diseases (e.g. age and family history), it is crucial to put efforts towards decreasing risk through modifiable lifestyle factors (e.g. diet and exercise). Previous work shows that often these factors are harder to modify later in life (Whitaker et al. 1997). Findings ways to combat this epidemic at an early age in future generations may allow us to start the process of creating a healthier society.

Currently, 17% of children living in the United States suffer from childhood obesity (Ogden et al. 2014), and this number continues to climb each year (CDC 2016). The earlier a child becomes overweight or obese, the more likely they are to suffer from obesity in adulthood (Whitaker et al. 1998). With this, childhood obesity also puts the child at a greater risk of developing high blood pressure, high cholesterol, insulin resistance, and type 2 diabetes later in life. Aside from these health conditions, mental illnesses such as anxiety, depression, and low self-esteem can also result from children growing up obese or overweight with a poor body image (CDC 2016). While research efforts dealing with already existing obesity are worthy of merit, it seems to be equally beneficial to consider ways to prevent the disease from occurring.

Excess weight gain in any stage of life is known to be caused by a positive energy balance resulting from higher caloric intake than expenditure. Specifically, in the first year of life, when physical activity is not yet a significant contributor to caloric expenditure, it is easy for infants to fall into this calorie surplus state (Clapp et al., 1998).

The home environment plays a significant role in a child's overall activity level. It has been found that older children are more active when they are put in environments that support outdoor play, but for younger toddlers, it is not as easy due to their lack of motor skill development (CDC 2016). Because of this lack of motor skills, and the continued growth of technology, the amount of sedentary activities available for younger children are increasing. It is common for this population to spend large amounts of time participating in sedentary activities, typically in the form of screen time (CDC 2016). Hnatiuk et al. found that infants who spend more time being physically active with their mothers at nine months had higher physical activity levels when retested at 19 months (Hnatiuk et al. 2013). Creating home environments that encourage more physical activity for the children may help decrease their risk of being or becoming overweight or obese as children.

Even before the home environment comes into play, the intrauterine environment may have an important impact on child body composition, not only at birth but into the early years of life. Research has shown that offspring born to overweight or obese mothers are likely to have higher birth weights (Mudd et al. 2015). With this, higher birth weights have previously been related to higher body fat percentages later in life (Zhou et al. 2019). Few studies have examined the effects of maternal exercise during pregnancy and its effect on fetal growth, but even fewer follow those participants to look at the long term effects exercise during pregnancy may have on maternal or offspring body composition (Hopkins et al. 2010).

Previous research shows a focus on how childhood nutrition and physical activity my affect childhood obesity but lacks information relating maternal diet and activity to the child (Kong et al. 2016). More longitudinal studies are needed to better understand the impact of maternal and toddler lifestyle factors on toddler body composition. Furthermore, studies that quantitatively assess toddler activity levels and how they relate to important health outcomes may bring us one step closer to being able to create these recommendations for this population.

Purpose

To our knowledge, few studies have examined body composition at delivery to determine whether it can predict body composition at later time points. *Therefore, this study aims to accomplish three main goals*: 1) Determine the role of maternal obesity on offspring body composition at 2 years of age; 2) Determine the role of physical activity during pregnancy on maternal and infant body composition at two years postpartum; and 3) Determine whether body composition at birth is related to body composition at two years of age.

Literature Review

The Problem of Obesity

Obesity is a chronic illness that affects all generations. The percentages of children who classify as overweight or obese is consistently increasing around the world, being recognized as a public health concern (Gale et al. 2007). Childhood obesity not only puts the child at a greater risk for adulthood obesity, but also increases risk for other various health complications such as asthma, type 2 diabetes, and cardiovascular disease (Gale et al. 2007; Mattran et al. 2011), all of which are leading causes of morbidity and mortality (Must 1999). On top of this, childhood obesity that develops into adulthood obesity has a tendency to be more severe and have greater adverse effects than those who develop obesity later in adulthood (Paliy et al. 2014).

It is thought that obesity status at ages one or two is not highly predictive of adulthood obesity, but the older a child becomes while continuing to fall into the obese weight category, the higher the probability they will carry that obesity into adulthood (Whitaker et al. 1997). The older one gets, the less common it is for a person to have the ability to maintain a significant amount of weight loss (Whitaker et al. 1997). This is why it is so important to continue to find ways to catch and reverse the chance of obesity as early in the lifespan as possible.

Obesity and over nutrition during pregnancy

Obesity during pregnancy has been linked to increased risk for offspring obesity (Mudd et al., 2015). Mothers with higher fat mass at the time of conception are thought to have decreased insulin sensitivity throughout pregnancy. This may allow for more glucose and leptin availability for the fetus causing the offspring to have a higher fat mass at birth (Gale et al. 2007). One study found the largest difference in weight status of children born to overweight/ obese or healthy mothers to occur in the offspring's fourth year of life (Téllez-Rojo et al. 2019). However, when looking further into the individual effect of these weight differences, researchers concluded that less than 50% of the variation could be attributed to factors other than family and nutritional habits (Téllez-Rojo et al. 2019).

Although body mass index (BMI) is not a gold standard measurement for assessing body composition, studies that do use both reliable body composition measures and BMI calculations have found associations between higher pre-pregnancy BMI and rapid infant weight gain in early life (Bernhardsen et al. 2019). This is subsequently associated with higher offspring adiposity throughout childhood (Bernhardsen et al., 2019). A study done by Gale et al., suggests that it may not be excessive maternal weight gain that influences excessive infant adiposity, but rather maternal over- or under-nutrition both prior to and during pregnancy that have a greater impact (Gale et al. 2007).

Fetal development may be altered if the fetus' nutrient supply line is affected by maternal gestational hypertensive disorders and/or maternal over nutrition (Golab et al., 2018; Paliy et al., 2014). Maternal over-nutrition during pregnancy has the possibility of imposing fetal growth restrictions which could influence the offspring's glucose metabolism and development of adipose tissue and therefore increase their risk for obesity later in life (Golab et al., 2018; Paliy et al., 2014). A positive relationship exists between over-caloric intrauterine environments and obesity status in the offspring through early adulthood (Téllez-Rojo et al. 2019). Thus, not only should maternal weight status and nutritional habits be considered for infant health after birth and throughout childhood, but they may have an important role prior to and during pregnancy as well.

Fetal and Genetic Programming

Fetal programming is a general term used to describe the events that occur in utero that influence the offspring's disease risk later in life (Barker 1990). By comparing infant mortality to mortality caused by cardiovascular disease, researchers realized that the neonatal environment may be more important in determining disease risk than the home environment after birth (Barker 1990). Events that are thought to have negative consequences (e.g., fetal endocrine and metabolic changes) on the fetal environment include unhealthy maternal body composition, maternal dietary intake, uteroplacental blood flow, placental transfer, and the fetal genome (Bauer et al., 2020). The goal of understanding fetal programming is to find and prevent "turning-points" in determining the offspring's risk for disease (Godfrey and Barker 2001; Bauer et al. 2020).

The intrauterine environment plays a vital role in developing many aspects of human health throughout the lifespan (Crozier et al. 2010). Researchers believe the third trimester may be an important time for the fetus' programming of fat mass accumulation. Intrauterine environments that are exposed to healthy nutrition and exercise may develop more favorable fetal growth and allow for more favorable body composition and overall health status for the offspring later in life (Crozier et al. 2010).

DNA methylation is believed to be a major route for the intrauterine environment to affect offspring adiposity. DNA methylation can arise from both genetic and environment influences (Mendelson et al. 2017; Lin et al. 2017). Lin et al., reported that methylation in umbilical cord genes that had previously been associated with adulthood adiposity also had associations with infant weight and adiposity (Lin et al., 2017). It was also found that genetic variation and methylation in adiposity-linked genes influenced offspring birth weight and weight status through the first two years (Lin et al., 2017). If occurring in the correct genes, methylation could cause changes in energy balance and/or lipid metabolism, indirectly affecting weight status (Mendelson et al., 2017). Being as though DNA methylation is potentially influenced by poor maternal diet and exercise habits, it is essential for these factors to be a priority when considering management of offspring body composition and overall health outcomes.

Gestational Weight Gain

Excessive gestational weight gain during pregnancy has been identified as a modifiable risk factor for the offspring to develop childhood obesity (Gillman et al. 2008). A study done by Gillman et al., found this to be true when following up with mother-child pairs at three years postpartum and found over half of the children born to mothers who experience excess gestational weight gain were classified as overweight at the follow-up (BMI > 95th percentile) (Gillman et al. 2008). It is possible that inadequate gestational weight gain may cause the fetus to develop poor regulation of appetite and cause the offspring to have a higher BMI throughout life. On the other hand, it is possible that excess gestational weight gain may allow for greater adipocyte number and therefore also leaving the offspring with higher fat mass accumulation throughout life (Crozier et al. 2010). Mothers who are considered overweight or obese prior to conception are more likely to show excess gestational weight gain (Crozier et al. 2010).

The Institute of Medicine (IOM) has set guidelines for gestational weight gain based on the mother's pre-pregnancy BMI status. As of 2009, the IOM recommends

12.5-18 kg for underweight mothers, 11.5-16 kg for normal weight mothers, 7-11.5 kg for overweight mothers, and 5-9 kg for obese mothers (Crozier et al. 2010) (11(7)). In a study of 948 mothers, almost half (49%) gained more weight during pregnancy than recommended by the IOM and 21% of mothers gained less weight that what is recommended (Crozier et al. 2010). In the same study, children of mothers who had excess gestational weight gain had higher fat mass measurements at birth, four years, and six years of age when compared to children of mothers who had appropriate gestational weight gain (according to the IOM) (Crozier et al. 2010). Thus, not only is excessive gestational weight gain common, but it is linked to short and long-term outcomes for the offspring.

Gestational Diabetes

Gestational diabetes (GD) effects 10-25% of all pregnancies (Golab et al. 2018). GD is particularly common for mothers who carry higher amounts of fat mass into their pregnancy. GD and maternal obesity, both during and prior to pregnancy, put both mom and baby at higher risks for complications throughout pregnancy, labor, and delivery, as well as negative fetal development (Litwin et al. 2020). Because of this, pre-pregnancy obesity, along with GD, are considered risk factors for not only offspring obesity, but also other health concerns such as other cardiovascular or metabolic diseases (Litwin et al. 2020).

A study done by Litwin et al., found that mothers diagnosed with gestational diabetes had less gestational weight gain compared to non-diabetic mothers. At a 6 -year follow-up, researchers found no differences in offspring body weight or body composition between diabetic and non-diabetic mothers (Litwin et al. 2020). This shows the children of overweight or obese mothers have a higher risk for increased adiposity regardless of their exposure to GD. Researchers seem to agree that exercise, specifically aerobic exercise, and its effects on glucose tolerance are one of the main reasons exercise is so important and beneficial during pregnancy for both the mother and offspring (Owe et al. 2009). It is still unclear whether gestational diabetes has an effect on offspring obesity without there also being a presence of excess gestational weight gain (Golab et al. 2018).

Exercise during Pregnancy

Maternal exercise during pregnancy can provide a number of benefits for not only the mother but the offspring at birth and potentially later into the offspring's life. Continuing physical activity throughout pregnancy has been shown to help lower gestational weight gain and risk for developing gestational diabetes, two factors known to influence offspring birth weight (Kong et al. 2016). While maternal exercise during pregnancy may be vital in regulating fetal growth due to its ability to alter placental substrate utilization less is known about the long-term effects of maternal exercise during pregnancy on postnatal child outcomes (Clapp, 2006). Additionally, it is still unclear as to what type, intensity, or when exercise during pregnancy is most beneficial for the offspring (Clapp, 2006).

A review noted a study that looked at resistance exercise during pregnancy and found that weight bearing exercise in early pregnancy improved fetal growth rate but decreased the growth rate when performed in mid-late pregnancy (Clapp et al. 2000; Bauer et al. 2020). The same review also noted that several studies have shown maternal aerobic physical activity during pregnancy to increase umbilical cord blood flow, causing an improvement in placental circulation (Katz et al. 1988; Rafla and Beazely 1991; Bauer et al. 2020). Light to moderate exercise, regardless of exercise mode, throughout pregnancy has shown benefits for both maternal and offspring outcomes, including decreasing the risk of the offspring developing excess weight within the first year of life (Perales et al. 2020).

Most studies seems to agree on the idea that third trimester exercise and/or leisure time physical activity (LTPA) is most likely to have noticeable effects on offspring outcomes, both at birth and later in life (Clapp et al. 1998; Mattran et al. 2011; Mudd et al. 2015, 2019). However, some divergent findings have been reported as to the effects of maternal physical activity during pregnancy on toddler body composition. One study found lower offspring body fat percentages in those birthed from an active female and the other saw no change in body composition in children from mothers with different activity levels (Clapp 1996; Clapp et al. 1998). This difference is thought to be attributed to the difference in environments, specifically feeding practices of the participants, which could be due to the fact that one study was looking at an urban population and the other more rural (Clapp et al., 1998).

Women who are regular exercisers before pregnancy are more likely to continue exercising throughout their pregnancy (Owe et al. 2009). Clapp et al. found that women who carried exercise through into late pregnancy gave birth to offspring who remained leaner into their fifth year of life (Clapp et al., 1998). In another study from Mudd et al, higher levels of physical activity in the third trimester had positive effects on offspring body composition at five years. However, it was speculated that this activity may need to be of a higher volume or intensity to show benefit (Mudd et al., 2015). A theory behind this is the third trimester is where that majority of fetal weight gain occurs and potentially when they begin the process of programing for adipose accumulation. Increasing, or continuing a high level of activity through this time period may allow for improved metabolic mechanisms to reduce fat storage at birth and throughout the early years (Mudd et al., 2019).

Mudd et al., performed a study looking at maternal physical activity and its effects not only on child body composition, but also child LTPA. Data from this study showed trends of maternal inactivity associating with offspring obesity regardless of child activity status (Mudd et al., 2015). Conversely, they also saw that maternal LTPA associated with higher offspring LTPA but not necessarily lower child body composition (Mudd et al., 2015). Though, this could indirectly provide benefit to child body composition later in life. Looking at the effect in older children (7-10 years), Kong et al. examined pre- and mid-pregnancy LTPA and found no relationship with lower childhood adiposity in children of active vs non-active mothers, further showing the importance of continuing exercise into the third trimester (Kong et al. 2016). Exercise throughout pregnancy may be an important preventative strategy for those who have predispositions for offspring obesity, such as higher pre-pregnancy BMI (Bernhardsen et al. 2019).

Parental Influence

Parental obesity is considered one of the most significant early predictors of childhood obesity (Téllez-Rojo et al. 2019). When asked to report on their offspring's diet, overweight or obese mothers tend to report their children consume higher caloric diets than what healthy weight mothers report of their offspring (Téllez-Rojo et al. 2019). Considering the effect of parental diet influencing the diet of their offspring, especially in early childhood, this shows a direct link to high calorie diets and higher offspring weight statuses (Téllez-Rojo et al. 2019).

One study found children of obese parents to be less active than children of healthy weight parents (Crozier et al. 2010). Researchers believe that infants have high amounts of fat accretion, due to minimal amounts of physical activity and high calorie diets. This fat is not lost until the child becomes fully ambulatory (Clapp et al., 1998). Taken together, if overweight or obese mothers give birth to offspring with higher caloric diets and lower levels of physical activity than those born to healthy weight mothers, their risk for developing obesity is significantly increased.

Whitaker et al. found that although body composition of a one or two-year-old was not predictive of their chance for adulthood obesity, the best way to predict this was through parent obesity status. If one parent is obese during the offspring's childhood, the child is put at a higher risk for adulthood obesity and having two overweight or obese parents doubles this risk (Whitaker et al. 1997; Téllez-Rojo et al. 2019).

Some researchers believe the effect parental influence has on a child's weight status is more affected by the environment the family places the child in, such as food availability and if the landscape promotes physical activity (Téllez-Rojo et al. 2019). Whitaker suggests that this parental influence effect holds true past the one or two year mark of the child's life, possibly through the age of ten, because of the shared environment of a family (Whitaker et al. 1997). It is possible that higher levels of parental physical activity following pregnancy could create a learned habit for the offspring and increase their physical activity levels throughout life.

Child Leisure Time Physical Activity

Not only does weight status affect the presence of chronic disease throughout the lifespan, but physical activity levels in the ages close to birth may also play a role (Gillman et al. 2008). Child LTPA has been found to be inversely related to child body size (Mudd et al., 2015). Mudd et al. found that even if a mother was active throughout pregnancy, children with lower activity levels had higher body composition measurements than more active children (Mudd et al., 2015).

Previous research has confirmed that obese children are less physically active than their healthy weight counterparts (Moore et al. 2003). It has also been shown that more active children accumulate less body fat over time (Moore et al. 2003). One study found that objectively measured moderate physical activity throughout life reduced the effects of higher infancy and childhood fat mass in subjects at a 30 year follow-up (Kolle et al. 2017). Considering this, researchers believe that there are particular time points throughout childhood that affect adipose development more than others, causing lifestyle and body composition during these periods to be more critical in predicting adulthood obesity (Moore et al. 2003). Further research, such as this study, is warranted to help develop physical activity guidelines for this age group to help improve health outcomes.

Long term implications of birth weight and infant body composition

Birth weight is one of the most common factors used to determine a child's risk for obesity. Higher birth weights are almost always associated with higher weight statuses later in life (Zhou et al. 2019). A recent systematic review identified high pregnancy BMI, excessive gestational weight gain, prenatal tobacco use, high infant birth weight, and rapid weight gain in the first days following birth as being the main influencing factors on offspring obesity during the first two years of life (Woo Baidal et al. 2016).

Evidence has shown birth weight to share similar genetic determinants with some obesity related metabolic diseases (Lin et al. 2017). Therefore, if physical activity during pregnancy is able to regulate birth size and/or birth weight, it can also be a potential mechanism to positively modulate offspring body composition throughout the lifespan (Mattran et al. 2011). Studies using direct measures of body composition found increased birth weight to be associated with higher amounts of lean mass but not necessarily lower amounts of fat mass at birth (Mudd et al., 2015). Researchers have also found that toddlers who fall into higher weight or BMI categories at two years of age are at high risks for carrying obesity into their later life (Gale et al. 2007). These comparisons show the importance of paying attention to an infant’s body weight and body composition. Being able to classify different weight status’ for disease risk at such a young age can help guide obesity prevention interventions for future generations.

Materials and Methods

Study Design and Participants

This study serves as a follow-up to a larger study looking at the effects of maternal exercise during pregnancy on infant body composition at birth. (Tinius et al. 2020). Once participants completed the previous study, they were included on a mailing list for this ongoing study. Mother-child pairs were all contacted by the study team to return for the present study. Exclusion criteria for the present study were if the mother was pregnant again with another child, or if the child and/ or mother had any ongoing injury or illness that affected their current physical activity status. All study procedures were approved by the Western Kentucky University Institutional Review Board (IRB ID 16-229).

As part of the previous study, extensive data were collected on mothers during pregnancy. These data include dietary information, physical activity assessments, metabolic responsiveness to a high-fat meal, fasted and postprandial biomarkers assessing lipids (cholesterol, triglycerides, free fatty acids), insulin resistance, inflammation, and maternal anthropometrics. In addition, data on infant body composition using air displacement plethysmography via PEA POD (COSMED USA, Inc., Concord, CA), was taken at delivery, as well as cord blood to assess biomarkers in the infant.

Protocol

As a participant's child approached two years of age, mothers were contacted for participation in this follow-up study. They were informed the study would consist of similar body composition assessments, physical activity measurements, and surveys as the previous study in which they participated. All women who agreed were consented for participation including assent for the child (Appendix A) and were compensated $20.00 once after completing body composition measurement and again after completing a survey packet. All measurements were taken within a 2-month window following the child's second birthday (2 years-0 days through 2 years, 2 months).

Body Composition Measurement

Once consented, both the mother and child were asked to visit the Western Kentucky University Body Composition Laboratory to have their body composition assessed using air displacement plethysmography via BOD POD and BOD POD pediatric option, respectively (Figure 1) (COSMED USA, Inc., Concord, CA). Air displacement plethysmography measurements were chosen because it has previously been validated for both adult females and children of our age group (Fields et al. 2000; Fields and Allison 2012). All assessments were performed by certified technicians following standard procedures (Fields and Allison 2012). The only difference between the maternal and infant BOD POD assessment is the use of the pediatric chair and pediatric calibration cylinder. Mothers were all tested first, to help ease the anxiety of the toddler before being tested. The BOD POD was calibrated between maternal and toddler measurements to ensure accuracy of switching to the pediatric option. After the body composition measurements were completed, each participant was compensated half of the total study compensation.

Figure 1: Toddler and BOD POD Pediatric Option

Physical Activity Assessment

At the end of the visit, both the mother and child were instructed to wear an Actigraph triaxial accelerometer to assess their physical activity level. Mothers were given an Actigraph GT9X Link Accelerometer (ActiGraph LLC, Pensacola, FL) (Figure 2) and instructed to wear it on their non-dominant wrist for seven full days. Toddlers were given an Actigraph wGT3X-BT Accelerometer (ActiGraph LLC, Pensacola, FL) (Figure 2), and had it placed on their left ankle with non-removable, hospital-grade wristbands. They were asked to wear the monitor for 24 hours on a day representative of typical activity levels. Both accelerometers sampled at 30-100 Hertz. These monitors recorded wear time validation, sleep time, and heart rate and activity status. The main differences between the monitors chosen for the toddlers is the hospital grade wrist band used to prevent the toddler from removing the device early and the lack of a screen for safety reasons. After the mother's monitor stopped recording (7 days), monitors were collected from the participants and analyzed. From this, data on average caloric expenditure/day, percent of time spent in moderate or vigorous physical activity, and percentages of time spent in sedentary, light, moderate, vigorous, and very vigorous activity intensities were collected.

Figure 2: Maternal (left) and toddler (right) accelerometers

Statistical Analysis

Kendall's Tau-b correlation coefficients were used to investigate the relationships between maternal and toddler variables due to violation of assumptions and the small sample size. The correlation coefficient cut-off values were converted from Pearson values (Walker 2003) (Table 2). All data were stored in REDCap electronic data management software. Statistics were analyzed using SPSS Statistics 25.0 (IBM, 2009). The α-level value was set at 0.05 to denote statistical significance.

Table 1: Kendall's Tau-b converted R-values

	Pearson	Kendall's Tau
Small	>0.1	0.07
Moderate	>0.3	0.2
Large	>0.5	0.35
Very Large	>0.7	0.5
Nearly Perfect	>.9	0.7

Results

To date, fifteen of the forty-four eligible women from the previous study (Tinius et al. 2020) have become eligible for follow-up. Of those fifteen, twelve mother-child pairs have consented and completed participation in this study (Figure 3) (Tables 2 and 3). Unfortunately, remaining scheduled follow-ups were cancelled due to COVID-19 research restrictions.

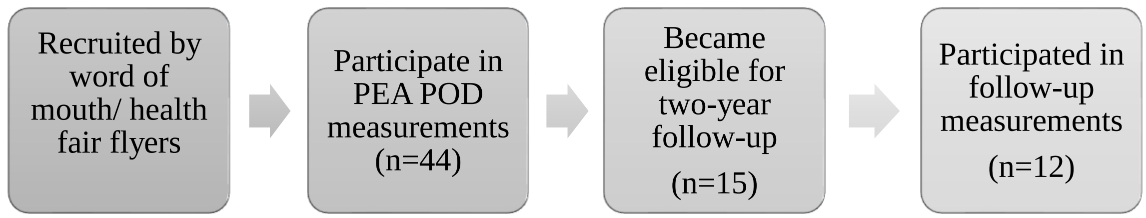
Table 2: Maternal characteristics

Variables	**N=12** **Mean ± SD or # (%)**
Age	33.92 ± 3.5
Height (cm)	162.56 ± 11.66
Weight (kg)	77.55 ± 18.18
Ethnicity (% white)	12 (100%)
Education *High school diploma* *College degree* *Post-graduate degree*	 1 (8.33%) 3 (25.00%) 8 (66.67%)
Household income	$146,250 ± $49,911

Table 3: Offspring characteristic

Variables	**N=12** **Mean ± SD or # (%)**
Age (years)	2
Gender *% Male* *% Female*	 (7) 58.30% (5) 41.70%
Height (cm.) (n=11)	84.93 ± 3.74
Weight (kg) (n=11)	12.89 ± 1.58
Ethnicity (% white)	100%
Breast feeding duration (months)	12.5 ± 7.44
Daycare (% in attendance)	(6) 50%

Figure 3: Participant follow-up eligibility and retention



Ancillary Finding: The relationship between maternal and toddler activity levels at 2 years postpartum

Although it was not an aim of the present study, interesting relationships emerged between maternal and offspring physical activity behaviors, which is noteworthy and includes our only statistically significant finding based on p-values. Specifically, maternal sedentary time at two years postpartum showed a large, positive correlation with offspring sedentary time at two years of age (r_τ = 0.418, p=0.073) (Figure 4). Similarly, maternal light physical activity at two years postpartum showed a statistically significant, very large, positive correlation with offspring light physical activity (r_τ = 0.564, p= 0.016) (Figure 5).

Figure 4: The relationship between maternal and offspring sedentary time at two years postpartum

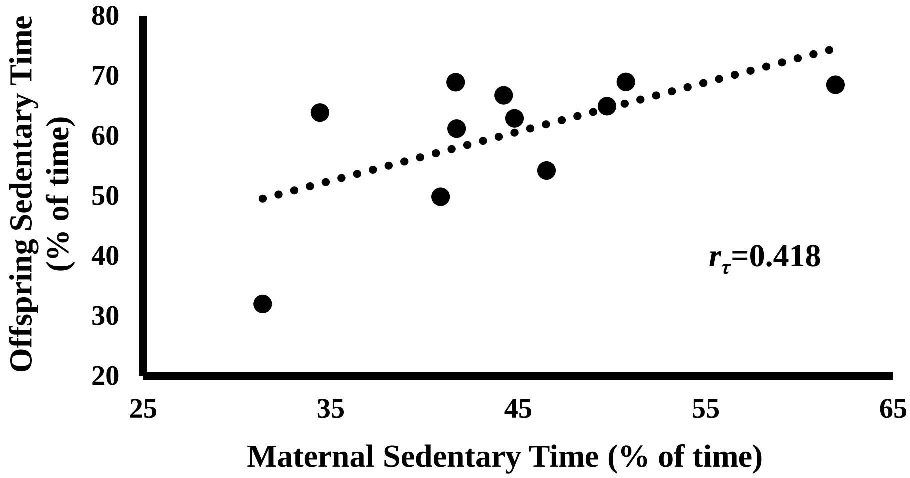
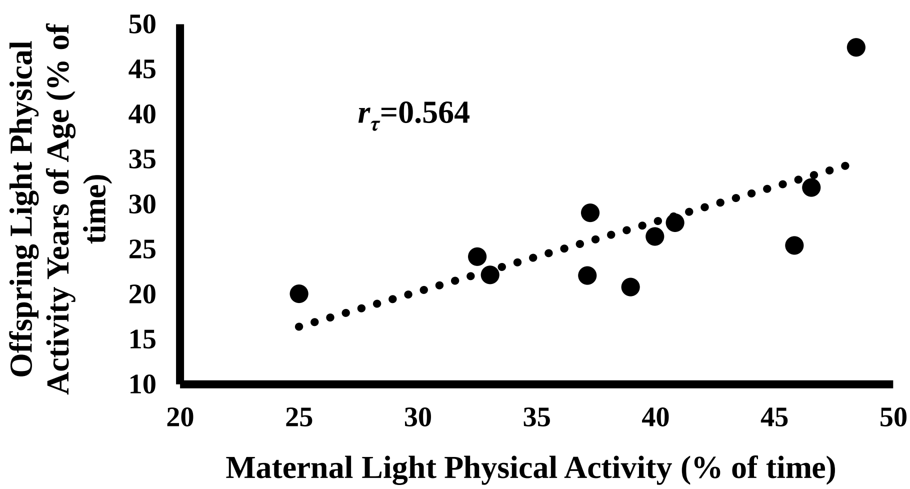


Figure 5: The relationship between maternal and offspring light physical activity at two years postpartum



Aim 1: Determine the role of maternal obesity on offspring body composition at 2 years of age

A small- to-moderate, positive correlation was found between maternal body fat percentage at two years postpartum and offspring BMI at two years of age (r_τ =0.200, *p*=0.421) (Figure 6) and maternal body fat percentage during pregnancy and offspring body fat percentage at two years of age (r_τ =0.222, *p*=0.404) (Figure 7). Maternal body fat percentage at two years postpartum and offspring body fat percentage at two years of age were not correlated (r_τ =0.056, *p*=0.835)

Figure 6: The relationship between maternal body fat percentage at two years postpartum and offspring BMI at two years of age

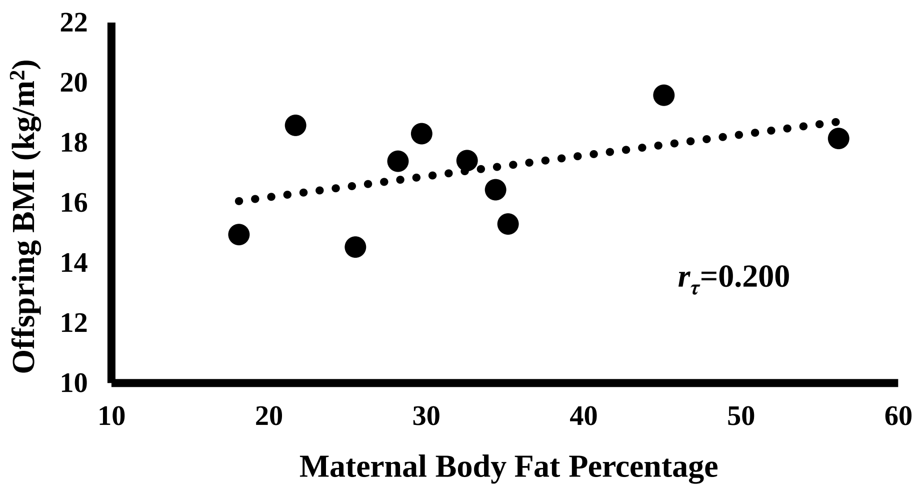
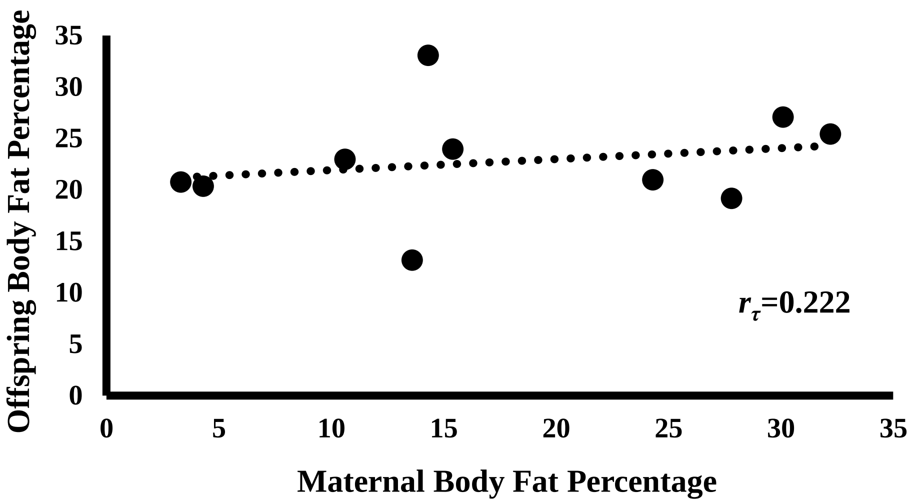
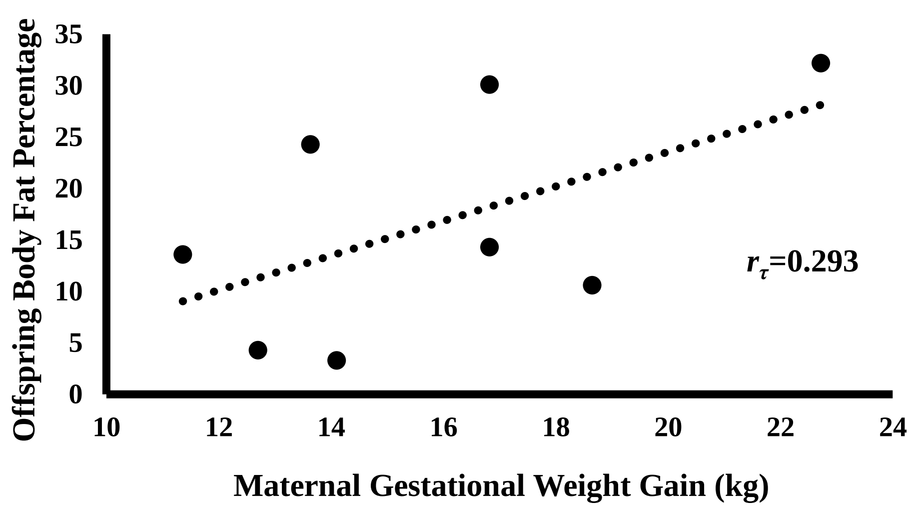


Figure 7: The relationship between maternal body fat percentage during pregnancy and offspring body fat percentage at two years of age.



Maternal gestational weight gain showed a moderate, positive correlation with offspring body fat percentage at two years of age (r_τ = 0.293, p=0.458) (Figure 8).

Figure 8: The relationship between maternal gestational weight gain and offspring body fat percentage at two years of age

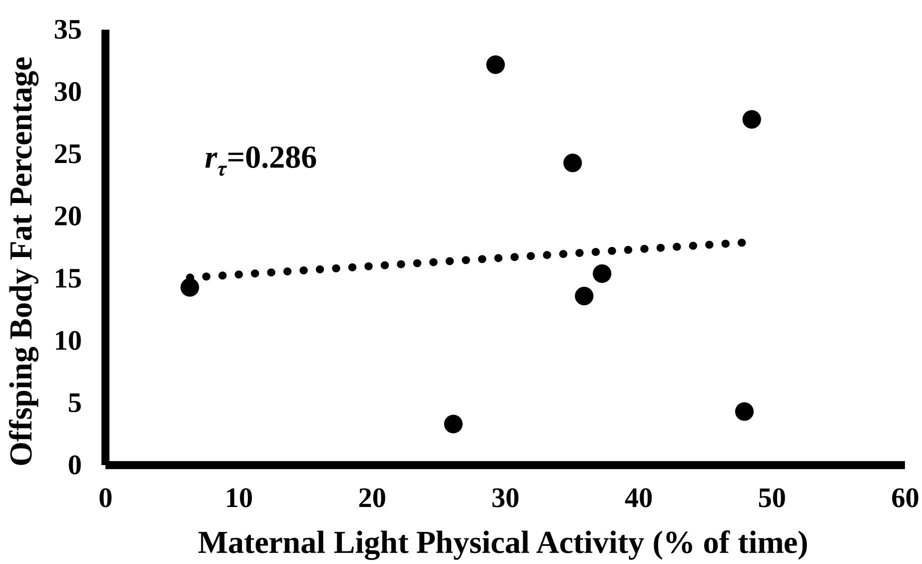


Aim 2: Determine the role of physical activity during pregnancy on maternal and infant body composition at two years postpartum

Maternal sedentary time, measured via accelerometer, during pregnancy showed small to no correlations with offspring body fat percentage at two years of age (r_τ=0.000, *p*=1.0), maternal body fat percentage (r_τ =0.127, *p*=0.586), or maternal BMI at two years postpartum (r_τ =0.091, *p*=0.697).

Maternal light physical activity during pregnancy showed a moderate, positive correlation with offspring body fat percentage at two years of age, but there is not enough evidence to consider this statistically significant (r_τ=0.286, *p*=0.322) (Figure 9). No correlation was found between maternal light physical activity during pregnancy and maternal BMI at two years postpartum (r_τ= -0.055, *p*=0.851). No correlation was found between maternal light physical activity and maternal body fat percentage at the two-year follow-up (r_τ= -0.091, *p*=0.697).

Figure 9: The relationship between maternal light physical activity during pregnancy vs. offspring body fat percentage at two years of age



Maternal moderate physical activity during pregnancy showed a moderate, negative correlation with maternal body fat percentage at two years postpartum (Figure 10) (r_τ= -0.236, *p*=0.312) and a small, negative correlation with maternal BMI at two years postpartum (r_τ=-0.200, *p*=0.392). Maternal moderate activity during pregnancy also showed a large, positive correlation with maternal moderate physical activity at two years postpartum (r_τ=0.382, *p*=0.102) (Figure 11). No correlation was found between maternal moderate physical activity during pregnancy and offspring body fat percentage at two years of age (r_τ= -0.071, *p*=0.805).

Figure 10: The relationship between maternal moderate physical activity during pregnancy and maternal body fat percentage at two years postpartum

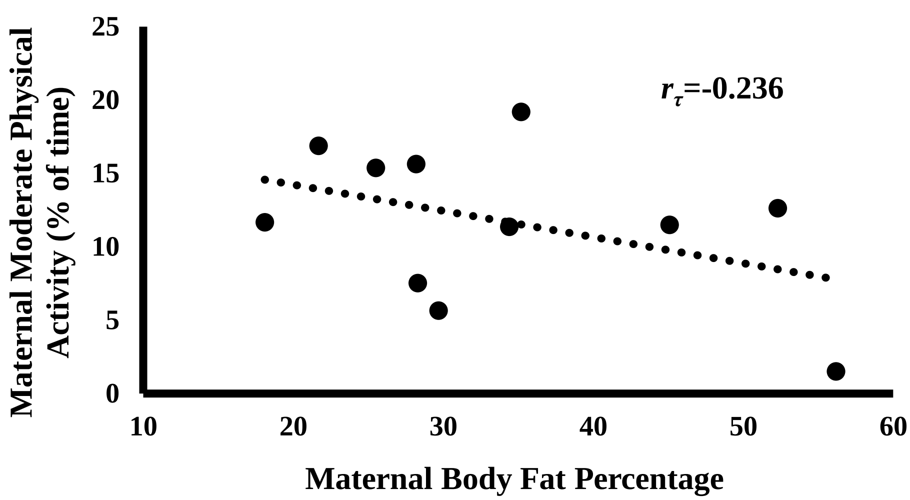
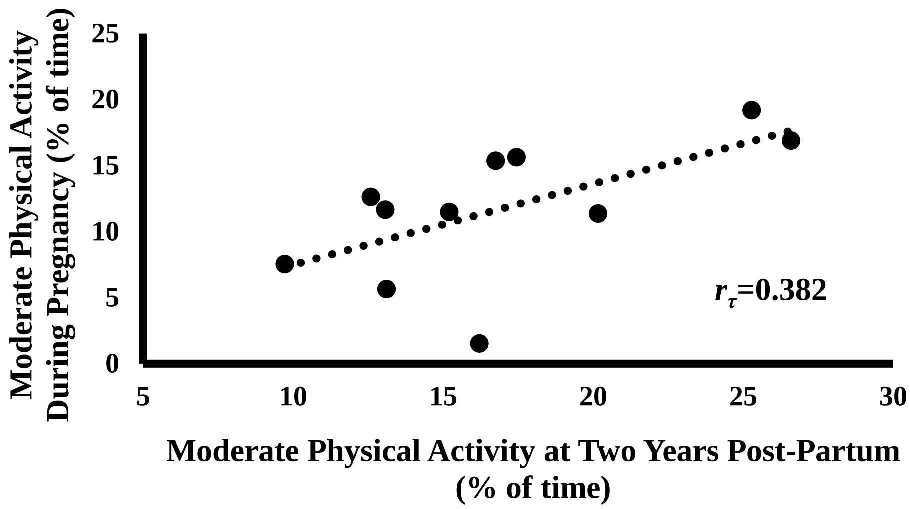


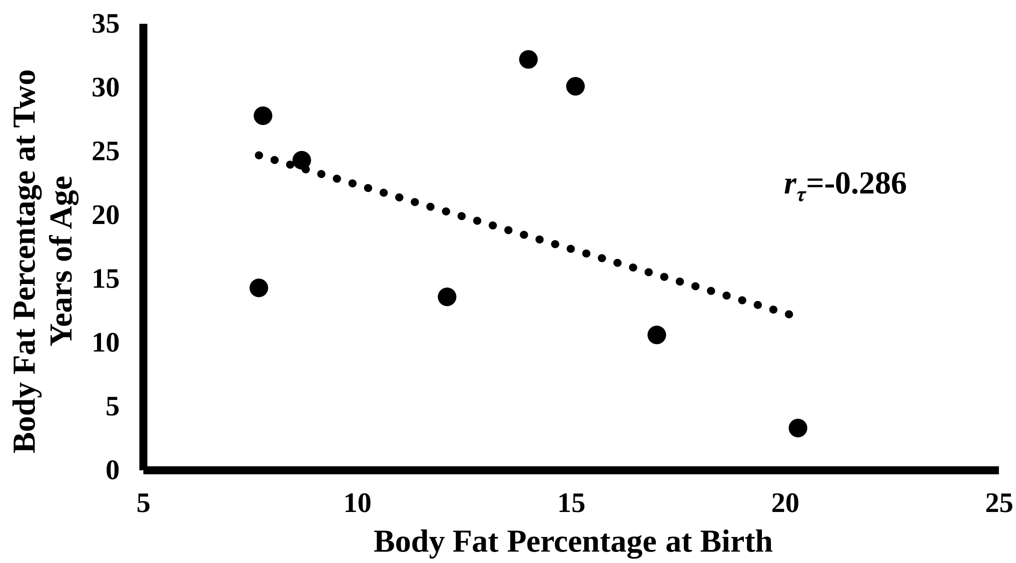
Figure 11: Maternal moderate physical activity during pregnancy vs. maternal moderate physical activity at two years postpartum



Aim 3: Determine whether body composition at birth is related to body composition at two years of age

Bodyfat percentage of the offspring at birth, showed a small, negative correlation with offspring body fat percentage, at two years of age (r_τ= -0.286, p=0.322) (Figure 12). There is not enough evidence to consider this statistically significant.

Figure 12: The relationship between offspring body fat percentage at birth and offspring body fat percentage at two years of age



Discussion

This study aimed to determine the longer-term effects maternal body composition and physical activity during pregnancy have on both maternal and infant body composition and physical activity levels at two years postpartum. Research has shown benefits of maternal physical activity during pregnancy on both maternal and infant outcomes at birth, but few studies have been done to see how these effects are carried on past the initial days following birth. This study also assessed whether body composition at birth was associated with offspring body composition at two years of age when assessed via air displacement plethysmography. Overall, the results of this study suggest a relationship between maternal body composition both during pregnancy and at two years postpartum and offspring body composition at two years of age. Relationships were also seen between maternal physical activity during pregnancy on both offspring body composition at two years of age and maternal body composition and physical activity at two years postpartum. A small relationship was found between offspring body composition at birth and offspring body composition at two years of age. A statistically significant relationship was seen between maternal light physical activity at two years postpartum and toddler light physical activity at two years of age, and a similar trend was observed between maternal and toddler sedentary time at two years postpartum. Although most results of this study were not statistically significant, the fact that some relationships were seen despite the small sample size shows potential for future studies to dive deeper into these topics to develop a more thorough understanding of the potential mitigating role of maternal behaviors during and after pregnancy on important infant anthropometric outcomes.

Aim 1: Determine the role of maternal obesity on offspring body composition at 2 years of age

Higher pregnancy body weight/body mass index has a negative effect on offspring body composition (Mudd et al., 2015). Our results suggest positive correlations between maternal body fat percentage both during pregnancy and at two years postpartum on offspring BMI and body fat percentage at two years of age, respectively. These findings support the theory that having an overweight or obese mother increases a child's risk for becoming overweight or obese themselves (Bernhardsen et al. 2019). This higher offspring weight status at two years postpartum may be a result of higher offspring weight status at birth coming from factors that occurred during pregnancy and/or due to the shared environment with a mother who is overweight or obese. A positive relationship was also observed between gestational weight gain and offspring body composition at two years of age. Our findings are consistent with Gillman et al. who found that children born to mothers with excess gestational weight gain have higher BMI at a three year follow-up (BMI > 95th percentile) (Gillman et al. 2008). Implementing a healthy diet and exercise routine during or even after pregnancy could be beneficial in both reducing gestational weight gain and the consequential effects (e.g. potential increased offspring birth weight) while also creating healthy habits for the environment the offspring is being brought into. Previous studies have suggested that the environment, such as food availability and offspring exposure to physical activity, play a vital role in determining future behaviors that may influence offspring body composition (Whitaker et al. 1997; Téllez-Rojo et al. 2019). Together these results show that offspring of overweight or obese mothers are likely to have a higher weight status at two years of age.

Aim 2: Determine the role of physical activity during pregnancy on maternal and infant body composition at two years postpartum

Relationships were found between maternal light physical activity during pregnancy and offspring body composition at two years of age. Also, maternal moderate physical activity during pregnancy showed relationships with maternal body composition and BMI at the two year follow up. These results are similar to data reported by Perales et al., who found light-to-moderate exercise during pregnancy had beneficial effects on offspring weight status throughout the first year of life (Perales et al. 2020). Although we did not detect a relationship between moderate physical activity and offspring body composition, the previous study had prescribed specific exercises to participants whereas we simply measured their typical activity levels. The previous study also monitored intensity based on age-predicted heart rate intervals, whereas this study measured intensity through accelerometer cut points.

Although not directly part the project aims, the ancillary findings showed some interesting and important relationships were noted between maternal and toddler physical activity levels at two years postpartum. Maternal sedentary time at two-years postpartum correlated with offspring sedentary time at two-years of age. Further, there was a statistically significant relationship between maternal light physical activity and offspring light physical activity at the two-year follow-up. This demonstrates an important potential impact of parental lifestyle behaviors to influence the child’s activity status, which in turn could contribute to energy balance and weight status (McMurray et al. 1993). This is consistent with previous work that found that parental sedentary behavior and physical activity levels can have a major impact on activity levels in children of preschool age (Xu et al. 2018). Another study found that higher amount of mother-baby interactions, although not specified as "physical activity" interactions, during infancy led to higher physical activity levels throughout toddlerhood and that more positive parent-child interactions showed increased developmental skills and a reduced risk for obesity (Hager et al. 2017). These results suggest the importance of parental influence on offspring behaviors promoting a healthy lifestyle.

Aim 3: Determine whether body composition at birth is related to body composition at two years of age

Although not statistically significant, a small relationship was noted between offspring body composition at birth and at two years of age. Previous studies have documented relationships between birth body composition and body composition later in life (Whitaker et al. 1997; Mudd et al. 2015; Woo Baidal et al. 2016; Zhou et al. 2019). These studies have used different, less accurate assessment techniques and have studied offspring at timepoints past two years of age during childhood. One study followed-up with offspring at 7-10 years postpartum and found relationships in both fat and fat free mass when compared to birth weight (Zhou et al. 2019). Another study suggested that lower birth weights may be more dependent on higher amounts of lean mass rather than lower amounts of fat mass, which shows the importance of using true body composition analysis rather than relying on birth weight or BMI for these predictions (Mudd et al., 2015). These factors, along with our small sample size, may have played a role in the strength of our results. Being able to predict toddler body composition from body composition at birth can help parents intervene earlier for at-risk infants, possibly by considering physical activity and dietary interventions for infants to prevent the future development of overweight and obesity.

Limitations and Future Research

An important limitation for this study is its small sample size. Due to time constraints, only fifteen mother-child pairs from the previous study became eligible for follow-up during the data collection period due to the timing of the offspring's second birthday. Of these fifteen, four mother-child pairs were lost in follow-up, leaving this study with a total number of twelve participants. Thus, continuing data collection with this sample of mother-child pairs or creating a future intervention with a larger sample may yield different results. Additionally, the previous study was compiled of a group of mothers who showed little diversity. Reducing that sample for this study further reduced the amount of diversity among our participants. With 100% of participants being white and 66.67% of them having completed a post-graduate degree, we may have seen different results had we assessed more diverse mothers in terms of ethnicity and educational attainment. A suggestion for future research is to not only look at maternal characteristics but also include body composition and physical activity levels on the father or partner. The father may have a genetic influence on the offspring, as well as an environmental/lifestyle influence. Any partners of members of the household may also have an environmental impact; however, this was not assessed.

Another limiting factor pertains to the gender distribution of the offspring as nearly 60% of the offspring were male. Previous research has suggested that male toddlers tend to have higher physical activity levels and therefore show stronger relationships when comparing their body composition with maternal factors (Bernhardsen et al. 2019). Previous work also suggests the relationships between mother and infant variables may be influenced by offspring gender (Xu et al. 2018). Again, increasing the sample size and attempting to equalize the offspring gender ratio may make the results of this study more generalizable. Future studies with larger sample sizes may also want to consider stratifying the sample by infant gender to further explore these relationships and how they may differ by gender. Similarly, all the offspring had been breastfed for some amount of time during infancy. This experience may influence body composition differently than infants who are not able to breast feed (Li et al. 2005). Future interventions should look to include offspring who have not been breastfed to again make their results more generalizable.

A limitation pertaining to the study methods involves the use of the BOD POD with pediatric option. The study team recently acquired this equipment and had to learn the most productive strategies to work with toddlers and getting them to agree to the use of the BOD POD was a limitation within the first few participants we tested. Although all study team members were BOD POD and BOD POD with pediatric option certified administrators, each toddler brought a new personality and new challenges to overcome. We did address this concern to the best of our abilities by creating a welcoming environment in the lab and allowing for playtime with the toddler to make them feel more comfortable. We also were able to calibrate the BOD POD with a toy or electronic device, such as a cellphone, inside to help their comfort level during the assessment. Future studies may investigate best approaches for calming toddler anxiety during a BOD POD assessment.

Conclusion

This research provides important insight into how maternal lifestyle choices surrounding body composition and physical activity can impact not only their own but also their offspring's health at birth and in the two years to follow. It also begins to help us understand how body composition at birth can be used to predict future body composition. Although mostly small relationships were found, this study adds an additional positive argument that exercise during and after pregnancy can benefit both maternal and offspring health outcomes. More studies like this are needed to build on information needed to develop guidelines for safe and effective toddler physical activity.

Obesity is a growing problem, and we hope with this study and future research can find ways to combat this epidemic in future generations before it begins. We believe the best way to do this is to start as early as the time of conception. This study was one small step towards better understanding the relationships between maternal lifestyle factors (namely, physical activity and weight status) and offspring outcomes at two years of age.

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APPENDIX A

IRB Stamped Informed Consent

WESTERN KENTUCKY UNIVERSITY

Institutional Review Board
Continuing Review Report

INFORMED CONSENT DOCUMENT

Project Title: Factors influencing maternal and offspring body composition at 2 years postpartum

Investigator: Dr. Rachel Tinius, School of Kinesiology, Recreation, and Sport, (270) 745-5026

You are being asked to participate in a study conducted through Western Kentucky University. The University requires that you give your signed agreement to participate in this project.
You must be 18 years old or older to participate in this research study.

The investigator will explain to you in detail the purpose of the study, the procedures to be used, and the potential benefits and possible risks of participation. You may ask any questions you have to help you understand the study. A basic explanation of the study is written below. Please read this explanation and discuss with the researcher any questions you may have.

If you have decided to participate in the study, please sign this form in the presence of the person who explained the project to you. You will be given a copy of this form to keep for your records.

1. **Nature and Purpose of the Project:**
While pregnant, you participated in a study investigating the role of physical activity during pregnancy on infant body composition. The present study will follow-up with you and your child at 2 years postpartum to assess infant and maternal body composition. Our goal is to see if physical activity during pregnancy has an impact on body composition of the child at 2 years, and also to test whether or not body composition at birth can predict body composition at 2 years of age.

2. **Explanation of Procedures**
Similar to the previous study, you will be asked to wear an activity monitor on your non-dominant wrist to assess your current physical activity levels for one week. We will also ask that your child wears a monitor on their left ankle for a 24-hour period that is indicative of their normal daily activity level.

   Within 2 months of your child's 2nd birthday, you and your child will be asked to come to WKU's Body Composition Laboratory on WKU's main campus. You and your child will have your body fat percentage assessed via the BodPod (mother) and BodPod with pediatric option (child). All assessments will be performed by a certified technician and will require the subject to sit in an egg-shaped machine for approximately 3 minutes. Your child will be able to see you through a window throughout the entire measurement. We will also assess body composition on both you and your child using skinfold calipers. In addition, a number of surveys will be given regarding lifestyle habits, such as diet and exercise, of you and your child.

WKU IRB# 16-229
Approval - 6/27/2019
End Date - 1/02/2020
Full Board
Original - 12/14/2015

3. **Discomfort and Risks:**

Skin fold measurements:
There is no risk of harm from this measure. You or your child may briefly experience some very mild discomfort resulting from the light pinch of skin with the caliper. The pinching sensation is the same as if you were to lightly take a pinch of skin between your fingers.

BodPod Measurement:
There are no risks with this measure. However, being in the enclosed space may cause some anxiety for those who are uncomfortable in tight, enclosed spaces. Toys and/or an electronic device can be given to the child to take in the machine to help ease their anxiety and keep them occupied during the test. If at any time you want to stop the test, you will be able to reach a button that will open the machine and stop the test immediately.

4. **Benefits:**
You will not benefit directly from being in the study. However, you will learn information about you and your child's health status. We also hope the knowledge we gain will help us understand lifestyle factors that influence health outcomes. You will be paid $20 for your participation in this study and $20 for your child's participation after measurements are taken and surveys are completed and returned ($40 total).

5. **Confidentiality:**
To help protect your confidentiality, we will keep your information private and protected. Your research file will contain identifiable information such as your name, patient ID#, and birthday. Protected Health Information (PHI) will be created by the study team. Study PHI will be kept in your research record and only the research team will have access to the information. The data obtained from this study will be kept confidential. Patients are assigned a study specific identifying number (PID) upon entry to the study, after which all medical information is referenced by this number. Databases that contain private health, medical or research information are behind firewalls, require password/username for access, are maintained using the PID, and only the PI and Co-PIs, have access to the code that matches the PID with other patient identifiers. All hardcopy data records are stored in locked file cabinets and kept in a locked office. If we write a report or article about this study or share the study data set with others, we will do so in such a way that you cannot be directly identified

6. **Refusal/Withdrawal:**
Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time with no penalty.

WESTERN KENTUCKY UNIVERSITY

Institutional Review Board
Continuing Review Report

You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

______________________________________ ______________
Signature of Participant Date

______________________________________ ______________
Witness Date

Informed Assent for Child

My child's participation in this project is voluntary, and I have been told that I may stop his/her participation in this study at any time. I give permission for my child to participate in this study.

____
(Child's name – printed)

___________________________________ __________________________
(Signature of Parent/Guardian) (Date)

___________________________________ __________________________
(Name of Parent/Guardian- printed) (Relationship to participant – printed)

THE DATED APPROVAL ON THIS CONSENT FORM INDICATES THAT
THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY
THE WESTERN KENTUCKY UNIVERSITY INSTITUTIONAL REVIEW BOARD
Robin Pyles, Human Protections Administrator
TELEPHONE: (270) 745-3360

WKU IRB# 16-229
Approval - 6/27/2019
End Date - 1/02/2020
Full Board
Original - 12/14/2015