THE ASSOCIATIONS BETWEEN PHYSICAL ACTIVITY AND ANTEPARTUM AND POSTPARTUM DEPRESSION

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ABSTRACT

Zewditu Demissie: The Associations Between Physical Activity and Antepartum and Postpartum Depression
(Under the direction of Dr. Anna Maria Siega-Riz)

Background: Depression is a disease of great public health concern as it is responsible for a significant amount of disability and morbidity, and millions of Americans are depressed in any given year. Antepartum and postpartum depression confer health risks for the mother and her family. Research has indicated that physically active individuals may be less likely to experience depression, however, few studies have used pregnancy and postpartum samples.

Methods: Data from the third and postpartum phases of the Pregnancy, Infection, and Nutrition (PIN) Study were used to determine the association between moderate-to-vigorous physical activity (MVPA) and depressive symptoms among pregnant and postpartum women. The PIN3 Study was a prospective cohort of 2006 pregnant women in North Carolina enrolled between January 2001 and June 2005. The PIN Postpartum Study followed a subset of the PIN3 women with in-home visits at 3 and 12 months postpartum. Physical activity recall was assessed by telephone at 17-22 and 27-30 weeks' gestation of pregnancy and at 3 months postpartum. Self-reported depressive symptoms were assessed by the Center for Epidemiologic Studies-Depression Scale at <20 and 24-29 weeks' gestation, while postpartum depressive symptoms were assessed using the Edinburgh Postnatal Depression Scale at both home visits.

Results: Active women with ≤2.67 hours/week of total MVPA at 17-22 weeks' gestation had almost half the odds of having high depressive symptoms at 24-29 weeks' gestation as

compared to women with no MVPA. However, total MVPA at 3 months postpartum was associated with a doubling of the odds of elevated depressive symptoms at 12 months postpartum. Adult and child care and indoor household MVPA were associated with increased odds of elevated depressive symptoms in both pregnancy and postpartum. No benefit from recreational activity on depressive symptoms was found at any time point. No significant associations were found between MVPA and depressive symptoms when examining the association between MVPA during pregnancy and 3-month depressive symptoms.

Conclusion: Associations between physical activity and depressive symptoms differ by domain of MVPA. Future studies with higher statistical power should explore potential differences by domain of physical activity.

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BMI	body mass index
CES-D	Centers for Epidemiologic Studies-Depression (Scale)
CI	confidence interval
EPDS	Edinburgh Postnatal Depression Scale
MVPA	moderate-to-vigorous physical activity
OR	odds ratio
PIN	Pregnancy, Infection, and Nutrition (Study)
U.S.	United States
WIC	Special Supplemental Nutrition Program for Women, Infants, and Children

CHAPTER I

BACKGROUND

A. Study Rationale

Depression is an important mental health issue with more than 340 million people in the world afflicted with the condition (Greden, 2001). Depression is the leading cause of disability in the developed world (Lopez et al, 2006) and is projected to become the second leading cause in the developing world by 2020 (Murray and Lopez, 1997). Women are more likely to be diagnosed with major depressive disorder than men; in the United States (U.S.), the gender ratio is approximately 2:1 (Weissman et al, 1993). The mean age of onset for women in the US is 28.2 years, during the childbearing years (Weissman et al, 1993).

Pregnancy can make women susceptible to the onset or return of depression with some women developing depression for the first time while they are pregnant while those with pre-existing symptoms may experience recurrence, continuation, or worsening of their condition (Bennett et al, 2004). Approximately 15% of women have their initial onset of depression during pregnancy (Gaynes et al, 2005). The pregnancy and postpartum periods are especially important times to prevent and control depression as not only does the disease pose threats to the woman's health, but has implications for the health of her newborn and family (Lusskin et al, 2007). Though the most common treatments for depression are antidepressant medications and psychotherapy, research is now focusing on the utility of physical activity as a tool to prevent and manage depression during pregnancy and postpartum since medication and therapy may not be desirable to these women due to concerns over side effects, stigma, time and financial costs (Teychenne et al, 2008b; U.S.

Department of Health and Human Services [U.S. DHHS] 2007; Hammond and Crozier 2007; Bowen and Muhajarine 2006; Daley et al, 2007).

B. Depression Epidemiology

1. Introduction

Depression is characterized by the following symptoms: depressed mood, marked diminished interest or pleasure in activities, weight loss, insomnia/hypersomnia, psychomotor agitation or retardation, fatigue or loss of energy, feelings of worthlessness or excessive guilt, and thoughts of death or suicide (American Psychiatric Association, 2000). The Structured Clinical Interview for the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) is considered the gold standard for depression assessment (Sanchez-Villegas et al, 2008). To be diagnosed with major depression, an individual must exhibit at least five of these symptoms for two weeks or more, and one of the symptoms must be either depressed mood or loss of interest/pleasure (American Psychiatric Association, 2000). Minor depression is defined similarly but only 2-4 of the symptoms must be present (American Psychiatric Association, 2000). The criteria for diagnosing antepartum and postpartum depression do not differ from general depression; the only difference is the time period at which it happens (Bowen and Muhajarine, 2006; Seehusen et al, 2005). Depression is classified postpartum if it occurs within the first year after birth (Lusskin et al, 2007). Treatments for depression include psychotherapy, social support, antidepressant medications, bright light therapy, and electroconvulsive therapy (Bowen and Muhajarine, 2006; Leahy-Warren and McCarthy, 2007).

2. Depression statistics

Over 340 million people in the world are afflicted with depression (Greden, 2001). In the U.S., 9.5% of the population or 20.9 million Americans are affected by depressive

disorders in any given year (National Institute of Mental Health, 2003). The one-year prevalence of major depression in adult women ranges between 7.1% and 13% (Bennett et al, 2004). A systematic review determined that 18.4% of women experience depression during pregnancy based on clinical interview or assessment (Gaynes et al, 2005). The authors also reported that the estimated prevalence of depression during pregnancy was 11.0%, 8.5%, and 8.5% for the first, second, and third trimesters respectively (Gaynes et al, 2005). Almost 50% of postpartum women become depressed in the first 12 months after birth and it is estimated that 500,000 American women experience postpartum depression (PPD) each year (Gaynes et al, 2005; Wisner et al, 2002). However, PPD is undiagnosed in more than 50% of American women who have the condition (Beck et al, 2001).

3. Health effects of depression during pregnancy and postpartum

Depression during the pregnancy and postpartum periods has consequences to the mother, her child, and family (Lusskin et al, 2007). There is evidence of antepartum depression resulting in pregnancy and obstetric complications (Larsson et al, 2004; Bennett et al, 2004), poor health behaviors (Bennett et al, 2004), and risk-taking behaviors (Bennett et al, 2004). Depressed mothers are more likely to be noncompliant with prenatal care (Lusskin et al, 2007; Lee and Chung, 2007), smoke (Lusskin et al, 2007; Bowen and Muhajarine, 2006; Hammond and Crozier, 2007; Brown and Solchany, 2004), use alcohol or drugs (Lusskin et al, 2007; Bowen and Muhajarine, 2006; Hammond and Crozier, 2007; Brown and Solchany, 2004; Lee and Chung, 2007), sleep poorly (Lusskin et al, 2007), eat poorly (Lusskin et al, 2007; Brown and Solchany, 2004), and have poor weight gain (Lusskin et al, 2007) during pregnancy. Depressed mothers are also more likely to contemplate or attempt suicide during pregnancy or the postpartum period (Lusskin et al, 2007; Bowen and Muhajarine, 2006). Pregnancy complications include bleeding during gestation (Lusskin et al, 2007; Bowen and Muhajarine, 2006; Hammond and Crozier, 2007), preeclampsia

(Lusskin et al, 2007; Hammond and Crozier, 2007), and pregnancy-induced hypertension (Bowen and Muhajarine, 2006). Obstetric complications that may result from depression include spontaneous abortion (Lusskin et al, 2007; Hammond and Crozier, 2007), caesarean section (Lusskin et al, 2007; Brown and Solchany, 2004; Lee and Chung, 2007), and preterm labor (Hammond and Crozier, 2007; Lee and Chung, 2007). Women with untreated antepartum depression are also at increased risk of developing irritable bowel syndrome and cardiovascular problems (Bowen and Muhajarine, 2006). Women with PPD are also significantly more likely to experience depression later in life (Phillips & O'Hara, 1991).

Research shows that depression may impact the child from the fetal stage through childhood. Babies born to depressed women are more likely to be born preterm (Lusskin et al, 2007; Bowen and Muhajarine, 2006), have low birth weight (Lusskin et al, 2007; Hammond and Crozier, 2007; Lee and Chung, 2007), be small-for-gestational age (Lusskin et al, 2007; Hammond and Crozier, 2007), be admitted to the neonatal care unit (Lusskin et al, 2007; Bowen and Muhajarine, 2006; Hammond and Crozier, 2007; Brown and Solchany, 2004), have smaller head circumferences (Lusskin et al, 2007), and score low on the Apgar test (Lusskin et al, 2007; Hammond and Crozier, 2007). PPD can influence the physical, emotional, behavioral, and cognitive development of children (Lee and Chung, 2007). Offspring born to depressed mothers are found to score lower on development scales (Bowen and Muhajarine, 2006), have decreased motor tone and activity (Bowen and Muhajarine, 2006), demonstrate more stress behaviors (Bowen and Muhajarine, 2006), exhibit behavioral problems (Hammond and Crozier, 2007; Lusskin et al, 2007), have language problems (Hammond and Crozier, 2007), sleep poorly (Bowen and Muhajarine, 2006), and be more irritable (Bowen and Muhajarine, 2006). In later life, these children may also exhibit criminal behavior (Hammond and Crozier, 2007).

Antepartum and postpartum depression may also influence the relationship between the mother and child. Women with antepartum depression are likely to have negative feelings and perceptions of her child and may feel negatively about being a mother (Brown and Solchany, 2004). Depression may result in reduced attachment and parent-child bonding (Hammond and Crozier, 2007; Lusskin et al, 2007). Depressed mothers are also less likely to breastfeed their infants (Bowen and Muhajarine, 2006).

Maternal depression can also impact the fathers. Depressed mothers report poorer partner satisfaction and if a woman is depressed, there is a 40-50% risk that the child's father will also develop depression (Appolonio and Fingerhut, 2008; Lee and Chung, 2007).

4. Factors associated with depression during pregnancy and postpartum

Personal and family health history, socioeconomic conditions, psychosocial factors, pregnancy factors, and health behaviors are associated with diagnoses of antepartum and postpartum depression. Personal and family history of depression is an important risk factor for the development of antepartum depression (Brown and Solchany, 2004; Lusskin et al, 2007; Bowen and Muhajarine, 2006). Women who had depression before pregnancy are 4.9 times more likely to have high depression scores during pregnancy (Brown and Solchany, 2004). First-degree relatives of depressed individuals are 1.5-3 times more likely to develop depression themselves (Lusskin et al, 2007). A myriad of personal and interpersonal factors play a role in the development of antepartum depression. Risk factors for antepartum depression are listed in Table 1.1.

Antepartum depression is itself a risk factor for PPD (Lusskin et al, 2007; Beck, 2001). Women with antepartum depression at 32 weeks of gestation have 6.5 times the risk of developing persistent PPD as compared to non-depressed women (Heron et al, 2004). Risk factors for PPD are generally similar to those found for antepartum depression. These factors and additional risk factors are listed in Table 1.2.

TABLE 1.1. Factors associated with depression during pregnancy.*

Factor	Direction & Strength	Reference(s)
Personal history of depression	++	Bowen and Muhajarine, 2006; Bowen et al, 2009; Brown and Solchany, 2004; Lusskin et al, 2007; Marcus, 2009; Marcus et al, 2003; Rich-Edwards et al, 2006
Antepartum anxiety	++	Lancaster et al, 2010; Leigh and Milgrom, 2008
Family history of depression	++	Lusskin et al, 2007; Ryan et al, 2005
Poorer overall health	+	Ryan et al, 2005; Marcus et al, 2003
Poverty/low socioeconomic status	+	Brown and Solchany, 2004; Leigh and Milgrom, 2008; Lau and Keung, 2007
Education	-	Brown and Solchany, 2004; Marcus et al, 2003; Ryan et al, 2005
Age	Inconsistent	Lancaster et al, 2010; Lau and Keung, 2007; Rich-Edwards et al, 2006; Ryan et al, 2005
Parity	Inconsistent	Lancaster et al, 2010; Ryan et al, 2005
Employment status	-	Brown and Solchany, 2004; Lau and Keung, 2007; Marcus et al, 2003; Ryan et al, 2005
Social support	--	Bowen and Muhajarine, 2006; Bowen et al, 2009; Brown and Solchany, 2004; Lancaster et al, 2010; Lee et al, 2007; Leigh and Milgrom, 2008; Lusskin et al, 2007; Ryan et al, 2005
Domestic violence	+	Bowen and Muhajarine, 2006; Brown and Solchany, 2004; Lancaster et al, 2010; Ryan et al, 2005; Tam and Chung, 2007
Not married/partnered	++	Bowen and Muhajarine, 2006; Brown and Solchany, 2004; Rich-Edwards et al, 2006; Ryan et al, 2005
Marital satisfaction	-	Bowen and Muhajarine, 2006; Lusskin et al, 2007; Ryan et al, 2005
Life events	+	Leigh and Milgrom, 2008; Lusskin et al, 2007

TABLE 1.1. Concluded.

Factor	Direction & Strength	Reference(s)
Life stress	++	Bowen and Muhajarine, 2006; Lancaster et al, 2010; Lau and Keung, 2007; Tam and Chung, 2007
Self-esteem	-	Lee et al, 2007; Leigh and Milgrom, 2008
Unplanned pregnancy	+	Bowen and Muhajarine, 2006; Lancaster et al, 2010; Lau and Keung, 2007; Lusskin et al, 2007; Ryan et al, 2005; Tam and Chung, 2007
Ambivalent/negative feelings about pregnancy or unwanted pregnancy	++	Bowen and Muhajarine, 2006; Lee et al, 2007; Lusskin et al, 2007; Rich-Edwards et al, 2006; Ryan et al, 2005
Smoking	+	Brown and Solchany, 2004; Marcus, 2009; Marcus et al 2003; Ryan et al, 2005; Tam and Chung, 2007
Alcohol use	Inconsistent	Brown and Solchany, 2004; Lancaster et al, 2010; Marcus et al; 2003
Drug use	Inconsistent	Bowen and Muhajarine, 2006; Lancaster et al, 2010; Ryan et al, 2005; Tam and Chung, 2007

* += Small positive association; ++= Moderate positive association; -=Small negative association; --=Moderate negative association. Based on Cohen (1992) cutpoints for effect sizes and Camm et al (2006).

TABLE 1.2. Factors associated with depression during postpartum.*

Factor	Direction	Reference(s)
Antepartum depression	++	Beck, 1996; Beck, 2001; Dennis and Ross, 2006; Friedman and Resnick, 2009; Lee and Chung, 2007; Lusskin et al, 2007; Mallikarjun and Oyebode, 2005; Rich-Edwards et al, 2006; Robertson et al, 2004
History of depression	++	Beck, 1996; Beck, 2001; Lee and Chung, 2007; Mallikarjun and Oyebode, 2005; Marcus, 2009; McCoy et al, 2008; McCoy et al, 2006; Milgrom et al, 2008; Robertson et al, 2004
Prenatal anxiety	++	Beck, 1996; Beck, 2001; Friedman and Resnick, 2009; Lee and Chung, 2007; Leigh and Milgrom, 2008; Mallikarjun and Oyebode, 2005; Robertson et al, 2004
Maternity blues	+	Beck, 1996; Beck, 2001; Mallikarjun and Oyebode, 2005
Poverty/low socioeconomic status	+	Beck, 2001; Lee and Chung, 2007; Leigh and Milgrom, 2008; Marcus, 2009; McCoy et al, 2006; Milgrom et al, 2008; Robertson et al, 2004
Age	Inconsistent	McCoy et al, 2006; Milgrom et al, 2008; Robertson et al, 2004
Social support	--	Beck, 1996; Beck, 2001; Lee and Chung, 2007; Friedman and Resnick, 2009; Leigh and Milgrom, 2008; Lusskin et al, 2007; Mallikarjun and Oyebode, 2005; Milgrom et al, 2008; O'Hara and Swain, 1996; Robertson et al, 2004; Tam and Chung, 2007
Not married/partnered	+	Beck, 2001; Marcus, 2009, Milgrom et al, 2008
Marital satisfaction	--	Beck, 1996; Beck, 2001; Lee and Chung, 2007; Lusskin et al, 2007; O'Hara and Swain, 1996; Robertson et al, 2004
Life events	+	Lee and Milgrom, 2008; Lusskin et al, 2007; Mallikarjun and Oyebode, 2005; Milgrom et al, 2008; O'Hara and Swain, 1996; Robertson et al, 2004
Life stress	++	Beck, 1996; Beck, 2001; Lee and Chung, 2007

Table 1.2 Concluded.

Factor	Direction	Reference(s)
Self-esteem	-	Beck, 2001; Leigh and Milgrom, 2008
Negative cognitive style	+	Leigh and Milgrom, 2008; O'Hara and Swain, 1996
Unplanned pregnancy	+	Beck, 2001; Lusskin et al, 2007; Patel et al, 2008; Warner et al, 1996
Obstetric/birth complications	+	O'Hara and Swain, 1996; Robertson et al, 2004
Not breastfeeding	+	McCoy et al, 2006; Patel et al, 2008; Warner et al, 1996
Childcare stress	+	Beck, 1996; Beck, 2001
Smoking	+	McCoy et al, 2008; McCoy et al, 2006

* += Small positive association; ++= Moderate positive association; -=Small negative association; --=Moderate negative association. Based on Cohen (1992) cutpoints for effect sizes and Camm et al (2006).

C. Physical Activity Epidemiology

1. Definitions/Terminology

Physical activity is defined as any bodily movement conducted by the skeletal muscles that results in calorie expenditure (Welk, 2002). This is in contrast to the concepts of exercise and physical fitness (Welk, 2002). Exercise is defined more narrowly as any planned, structured, repetitive physical activity that results in the improvement or maintenance of physical fitness. Physical fitness is a set of outcomes or traits that indicate one's ability to perform physical activity. Physical activity can be measured in many different ways (Welk, 2002). Measurements can examine the type, intensity, frequency, and duration of activity. Researchers can also investigate different domains (i.e. recreational versus occupational) of activity, continuous versus intermittent activity, and weight-bearing versus non-weight-bearing activity. A measurement that enables the comparison of various activities on a standard scale is metabolic equivalents (METS). One MET equals the energy expended at rest, approximately 3.5 ml/kg/min of oxygen consumption; the more vigorous the activity, the more oxygen is consumed (Welk, 2002). Activities are assigned MET values based on their amount of oxygen consumption as compared to rest; a MET of 2 means that twice the amount of oxygen required at rest is consumed.

2. Physical activity recommendations

The U.S. DHHS (2008) recommends that adults perform at least 150 minutes of moderate-intensity a week, or 75 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of both intensities. They also recommend that this activity be performed in bouts of at least 10 minutes and preferably spread throughout the week. It is recommended that pregnant women who are not regularly active or who engage in low intensity activity participate in at least 150 minutes/week of moderate-intensity activity while women who are highly active can continue at their pre-pregnancy activity levels (U.S.

DHHS, 2008). Postpartum women are recommended to participate in at least 150 minutes of moderate-intensity aerobic physical activity, and those with uncomplicated pregnancy/delivery can be physically active soon after delivery (US DHHS, 2008; Scott, 2006).

3. Health benefits of physical activity

Physical activity is a major component to living a healthy life, influencing mortality, disability, physical and mental health, and behaviors. Being physically active during adulthood reduces the risk of premature death (Warburton et al, 2006; WHO, 2003; U.S. DHHS, 2008). It is estimated that physical inactivity is responsible for 1.9 million deaths worldwide (WHO, 2002). Physical inactivity also contributes to 19 million disability-adjusted life-years (WHO, 2002). Physical activity promotes reduced risks of hypertension (U.S. DHHS, 2008; WHO, 2003; Warburton et al, 2006), cardiovascular diseases (U.S. DHHS, 2008; WHO, 2003; Warburton et al, 2006; Chen and Millar, 1999), diabetes (U.S. DHHS, 2008; WHO, 2003; Warburton et al, 2006), some cancers (U.S. DHHS, 2008; WHO, 2003; Warburton et al, 2006), obesity (U.S. DHHS, 2008; WHO, 2003; Warburton et al, 2006), osteoporosis (Warburton et al, 2006), and low back pain (WHO, 2003). Being physically active on a regular basis can also help build healthy bones, muscles, and joints and increase stamina (U.S. DHHS, 2008; WHO, 2003). Physical activity also has health benefits for well-being (WHO, 2003), stress (WHO, 2003), anxiety (WHO, 2003) and depression (U.S. DHHS, 2008; Warburton et al, 2006; Chen and Millar, 1999). Those who are regularly physically active are less likely to participate in risky behaviors such as smoking, alcohol and substance abuse, eating an unhealthy diet, and violence (WHO, 2003).

A study of the effects of physical activity in pregnancy demonstrates that activity also benefits preeclampsia, gestational diabetes, body image, self esteem, general well-being, insomnia, anxiety, and depression (Pivarnik et al, 2006). Physical activity also confers many

health benefits for the mother; improves satisfaction with life, motherhood, and partner; and has been found to have no negative influence on breast milk quality or the breastfeeding experience (US DHHS, 2008; Pivarnik et al, 2006; Scott, 2006; Sampselle et al, 1999; Larson Meyer, 2002).

4. Physical activity levels in pregnancy and postpartum

Intensity and duration of physical activity generally decreases going from the pre-pregnancy period to pregnancy and over the course of pregnancy (Poudevigne and O'Connor, 2006). Pregnant women also shift to performing activities that they consider to be safer (Poudevigne and O'Connor, 2006). Pregnant women are less active than non-pregnant women (Evenson et al, 2004). Among women who participated in the 2000 Behavioral Risk Factor Surveillance System, 65.6% of the pregnant women had been physically active while 73.1% of non-pregnant women were active in the past month. Evenson and Wen (2010) examined self-reported physical activity levels among pregnant women using 1999-2006 National Health and Nutrition Examination Survey data. Almost a quarter (22.8%) of the women reported any transportation activity, 54.3% reported any moderate-to-vigorous household activity, and 56.6% reported any moderate-to-vigorous leisure activity, in the past month. Over this period, 22.9% of the women participated in at least 150 minutes of aerobic activity in the past week. Pre-pregnancy, pregnancy, and postpartum physical activity was assessed in a Spanish study of 80 women planning to conceive (Cucó et al, 2006). Considerable leisure activity, defined as at least 30 min of activity for four days in the week, was found to be highest in pre-pregnancy (21.3%). It decreased consistently throughout pregnancy (17.5% to 2.5%) and then increased to 11.3% in the postpartum period. In contrast, never participating in activity was lowest in pre-pregnancy (63.8%), increased at each pregnancy assessment (72.5% to 90%), but then decreased to 83.8% in the postpartum. In a retrospective study of postpartum women

(Symons Downs and Hausenblas, 2004), METS of strenuous, moderate, and mild exercise all decreased from pre-pregnancy to pregnancy. Moderate and mild exercise continued to decline into the postpartum period, however, vigorous exercise increased some. Oken et al (2007) assessed physical activity at six months postpartum. They found that postpartum women participated in a mean (standard deviation) of 0.7 (0.07) hrs/day of walking, 0.2 (0.3) hrs/day of moderate activity, and 0.2 (0.3) hrs/day of vigorous activity.

Borodulin et al (2009) reported total and domain-specific physical activity levels among women participating in the Pregnancy, Infection, and Nutrition Study during pregnancy and postpartum. Among these women, total physical activity decreased over pregnancy, but increased during the postpartum period. The mean MET hrs/wk (standard deviation) values were 24.7 (26.8) at 17-22 weeks' gestation, 19.1 (18.9) at 27-30 weeks' gestation, 25.7 (29.3) at 3 months postpartum, and 26.7 (31.5) at 12 months postpartum. The participants reported more adult and child care and recreational activity and less indoor household activity during postpartum when compared to pregnancy.

D. Physical Activity and Depression

1. Proposed mechanisms

a. Overview

Depressed individuals undergo many physiological changes. Brain imaging shows that the brains of those depressed are different than the non-depressed. Depressed individuals have abnormal functioning in the parts of the brain that regulate mood, thinking, sleep, appetite, and behavior (U.S. DHHS, 2007). This corresponds with the diagnostic criteria for depressive disorder. This abnormal functioning is a result of neurotransmitters being out of balance (U.S. DHHS, 2007). Depressed individuals have high levels of cortisol (a glucocorticoid) which results from abnormalities in the hypothalamic-pituitary-adrenal circuit (Leonard, 1986). Glucocorticoids play a role in stress management (Bowen, 1998).

Biogenic amine neurotransmitters control the pituitary hormone releasing factors in the hypothalamus (Leonard, 1986). The monoamines noradrenaline, dopamine, and serotonin are at reduced levels for those with depression (North et al, 1990; Craft and Perna, 2004). Depressed individuals also have decreased thyroid stimulating hormone (TSH) response to thyroid releasing hormone (TRH). This may be influenced by abnormalities in monoamine transmitters as TRH release from the hypothalamus is regulated by noradrenaline, dopamine, and serotonin (Leonard, 1986). Growth hormone secretion is reduced in depressed individuals and is also influenced by low levels of dopamine and serotonin (Leonard, 1986). A reduction in immune response is also of concern with depressed individuals (Leonard, 1986).

It has been found that women have a higher risk of depression than men (Weissman et al, 1993). Though women demonstrate more positive health-seeking attitudes and higher levels of health care utilization (Mackenzie et al, 2006; Koopmans & Lamers, 2007), there are biological differences between men and women that may contribute to the disparity. Since the sex gap is found over the approximate span of the reproductive years (Kessler et al, 1993), this increased risk may be due to ovarian hormone regulation (Deecher et al, 2008). This difference may also be due to sex differences in hormone changes, thyroid function, neurotransmitter activity, and the effects of estrogen on the neurotransmitters (National Alliance on Mental Illness [NAMI], 2003). Endocrine function changes can produce unpredictable and dramatic swings in ovarian hormone levels which can predispose women to the development of depressive symptoms (Deecher et al, 2008). Estrogen is a neuromodulator that alters the activities of neurotransmitter systems, including systems that are involved in major depression (Deecher et al, 2008). Progestins also affect many neurotransmitter systems and neural receptors (Deecher et al, 2008). Estrogen affects serotonergic systems by modulating serotonin neuronal firing, increasing serotonin synthesis, decreasing serotonin degredation, altering serotonin reception subtypes, and

densensitizing serotonin autoreceptors (Deecher et al, 2008). Estrogen affects noradrenergic systems by increasing available norepinephrine, increasing norerpinephrine synthesis, altering adrenergic receptor gene expression, and decreasing norepinephrine turnover (Deecher et al, 2008).

There are many physiological responses to exercise- both short-term and long-term. Systems affected are the musculoskeletal, cardiovascular, respiratory, endocrine, and immune systems (U.S. DHHS, 1996). Short term cardiovascular changes include increased cardiac output, blood flow, blood pressure, oxygen extraction from arterial blood, capillary density on the ventricular myocardium, myocardial contractibility, and wall stress. Increase in pulmonary ventilation is a short term effect in the respiratory system. Short term skeletal muscle changes include increases in lactate in the muscle (resulting in lower pH in the muscle and blood), metabolic rate, maximal oxygen uptake, and lactate threshold. There are myriad of short term hormonal responses to exercise. Notably, catecholamines (such as epinephrine), growth hormones, cortisol, TSH, testosterone, estradiol, and progesterone levels are all increased after exercise. Moderate exercise improves the function of certain immune systems components acutely. However, high intensity, long duration, and excessive training may have adverse short term effects on immune function. Long term adaptations of the skeletal muscle and bone include increase in fiber cross-sectional area, transitions in fiber type, and an increase in the number of capillaries in trained muscle, and stronger ligaments and tendons. Increased mitochrondrial size and number, oxidative enzyme activity, oxygen storage in muscle fibers, and the capacity to store glycogen in skeletal muscle are all long term metabolic adaptations to exercise. Long term cardiovascular adaptations include increased stroke volume, increased ventricular dilatation, and hypertrophy of cardiac muscle fibers. Long term respiratory adaptations include increases in both the maximal pulmonary function rate and pulmonary diffusion at maximal work rates.

There are many proposed mechanisms for the association between physical activity and depression. As both depressed individuals and exercisers experience similar endocrine changes, an endocrine focused hypothesis is one of the most promising mechanisms. Both psychological and physiological/biochemical mechanisms are theorized to explain the effects of physical activity on depression. It is likely that a combination of mechanisms influence the physical activity-depression association (Craft and Perna, 2004).

b. Psychological mechanisms

The cognitive-behavioral hypothesis is one of the most frequently proposed mechanisms for the physical activity's antidepressant effect (North et al, 1990). The hypothesis suggests that activity releases positive thoughts and feelings that interrupt a negative thought-negative behavior cycle that leads to depression. Related components that possibly mediate this mechanism are increased skill mastery, increased self-efficacy, feelings of success, and increased locus of control. When a person masters a difficult task, they experience increases in self-confidence, self-efficacy, and ability to cope with personal problems.

Self-efficacy is the belief that one has the skills to complete a task and the confidence that the desired outcome will result from performing the task (Craft and Perna, 2004). Depressed individuals tend to have low self-efficacy for bringing about positive outcomes in their lives and coping with personal issues which results in negative self-evaluations, negative ruminations, and faulty thinking. Positive physical activity experiences may enhance self-efficacy in depressed persons through mastery.

It is also proposed that the physical changes that result from physical activity (i.e. weight loss, increase in muscle tone) are positive cues towards a sense of achievement that produces an antidepressant effect (Daley et al, 2007).

The social interaction hypothesis proposes that the social group interaction, pleasure, or attention that one receives while exercising is responsible for its antidepressant effects. It is thought that this hypothesis may be more relevant when one starts and exercise program (since it is an external motivator) and its effect is diminished as exercise rewards are internalized (North et al, 1990).

The time out/distraction hypothesis suggests that activity distracts individuals from their daily worries and thoughts and can result in decreased depressive symptoms (North et al, 1990; Craft and Perna, 2004). Physical activity can be a useful strategy to prompt depressed individuals to focus on events other than their life circumstances (Daley et al, 2007).

c. Physiological/biochemical mechanisms

Cardiovascular fitness can contribute to the antidepressant effect of physical activity. The cardiovascular fitness hypothesis is proposed since as both the length of exercise program and number of exercise sessions increase there is a greater decrease in depression (North et al, 1990). It is not likely that this mechanism accounts for the short-term effect of physical activity on depression, but may contribute overall to the effect (North et al, 1990).

The amine hypothesis may be the most promising physiological mechanism for explaining physical activity's effect on depression (Craft and Perna, 2004). The levels of monoamine neurotransmitters- serotonin, dopamine, norepinephrine – are found to be lower in depressed individuals (North et al, 1990; Craft and Perna, 2004). After exercise, these neurotransmitter levels are increased in urine and plasma (Craft and Perna, 2004). This hypothesis is all supported by the fact that tricyclic antidepressants, monoamine oxidase inhibitors, and electroconvulsive therapy (current and effective treatments for depression) all increase amine transmission (North et al, 1990).

The endorphin hypothesis suggests that exercise influences depression through an increased secretion of β-endorphins (Craft and Perna, 2004; Daley et al, 2007). Endorphins relieve pain, can produce a euphoric state and positive mood, and improve sense of well-being (North et al, 1990; Craft and Perna, 2004; Daley et al, 2007).

The thermogenic hypothesis proposes that the rise in core temperature that results from physical activity influences depression through feelings of relaxation and a decrease in muscle tension (Craft and Perna, 2004).

d. Potential relationships between mechanisms

Depression affects a person's mood, concentration, sleep, activity level, interests, appetite, and social behavior (NAMI, 2003). There are also some gender differences in the degree of symptomatology with women reporting more anxiety, somatization (experiencing aches and/or pains without a physiological cause), weight gain, appetite increase, oversleeping, anger, and hostility (NAMI, 2003). The cognitive-behavioral, self-efficacy, physical change, and cardiovascular fitness hypotheses may all be related. Self-efficacy is noted as a mediator in the cognitive-behavioral hypotheses. Cardiovascular fitness results in internal physiological changes as well as external body changes. These external changes may provide more reinforcement for women as they report more weight gain and appetite increases than men. When an individual experiences increases in cardiovascular fitness, this may make them more self-efficacious and self-confident as they can see that their behavior is having positive results. Amines are involved in mood, drive, and motivation (Leonard, 1986). Therefore, the amine hypothesis may also be related to the cognitive-behavioral and self-efficacy hypotheses. The influence of mood indicated in the endorphin hypothesis may be related to the positive thoughts included in the cognitive-behavioral hypothesis.

2. Literature on physical activity and depression

e. General

There is a strong positive benefit of physical activity on depression, and the benefits may be long-lasting (U.S. DHHS, 2008; Craft and Perna, 2004). Studies have found that increasing levels of both occupational and leisure-time activity result in a reduction of depressive symptoms (Dunn et al, 2001). Participation in light, moderate, and vigorous activity each contribute to decreased depression symptomatology (Dunn et al, 2001). Both resistance training and aerobic exercise affect depression (Dunn et al, 2001). Though Dunn et al (2001) concluded that there is little evidence of a dose-response effect of physical activity on depression, however, some recent studies indicate that there may be one (Galper et al, 2006; Goodwin, 2003; Kull, 2002). Galper et al (2006) categorized participants into groups of inactive, insufficiently active, sufficiently active, and highly active individuals by walking, jogging, and running miles/week. The most benefit of physical activity was found in the sufficiently active group. Goodwin (2003) found a significant ($p < 0.0001$) dose-response between self-reported frequency of physical activity and current major depression. Among fertility-aged women in Estonia (Kull, 2002), mean depressive symptoms scores consistently increased with lower leisure-time physical activity and frequency of depression increased as inactivity increased.

f. Pregnancy physical activity and antepartum depression

Few studies have been conducted on the association between physical activity and antepartum depressive symptoms. Poudevigne and O'Connor (2006) conducted a review of the relationship between physical activity and psychological health, including studies of mood, fatigue, and depression. The authors concluded that inactivity is associated with worse mood in pregnancy, but only three of the six studies they included investigated the association between physical activity and depression.

A total of eight studies have investigated the association between physical activity and depressive symptoms during pregnancy. The majority of these studies of have followed pregnant women prospectively, however, Koniak-Griffin (1994) conducted a self-selected trial of healthy, pregnant adolescents. She found significant decreased depressive symptomatology for women who participated in the exercise intervention, but only a small change in symptoms for the comparison group. Mixed results were found in the observational studies. In a sample of Black women, it was found that women with low depressive symptoms were significantly more likely to exercise during pregnancy than those with elevated symptoms (Orr et al, 2006). Haas et al (2004) found that women who did not exercise during pregnancy had increased odds of having high depressive symptoms. Da Costa et al (2003) found that women participating in any leisure-time physical activity had significantly less depressed mood in the first and second trimesters of pregnancy. In a sample of Jamaican women, low frequency (≤1 day/week) of exercise was associated with significantly less depressive symptoms and lower odds of having elevated depressive symptoms than non-exercisers (Pottinger et al, 2009). However, women exercising 2 or more days/week did not differ significantly from non-exercisers. Three studies found no association between physical activity (total or exercise) and depressive symptoms (Symons Downs, et al 2008; Poudevigne and O'Connor, 2005; Goodwin et al, 2000). Details on the populations, measures, and results of these studies can be found in Table 1.3.

g. Postpartum physical activity and postpartum depression

There has been more research into the effects of postpartum physical activity on postpartum depressive symptoms. Daley et al (2007) recently conducted a review of the role of physical activity in treating postpartum depression. They concluded that physical activity may be beneficial to women suffering from postpartum depression.

TABLE 1.3. Summary of the literature on the association between physical activity during pregnancy and antepartum depression.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Pottinger et al (2009)	Prospective cohort of 452 pregnant women in Jamaica.	Frequency of exercise in days/week assessed in each trimester.	Edinburgh Postnatal Depression Scale (EPDS) assessed at each trimester: continuous and categorical (13+= elevated depressive symptoms)	Women exercising ≤1 day/week had significantly lower odds of having elevated depressive symptroms than non-exercisers and have significantly lower mean EPDS scores. There was no significant difference between women exercising 2+ days/week and non-exercisers. <u>≤ 1 day/week exercisers</u> Odds Ratio [OR] (95% Confidence Interval [CI])= 0.51 (0.30, 0.85) Linear regression β (95% CI)= -0.7 (-1.3, -0.2)
Symons Downs et al (2008)	Prospective cohort of 230 pregnant women in Central Pennsylvania.	Leisure-Time Exercise Questionnaire (LTEQ) Self-reported 15-min bouts of strenuous, moderate, or mild leisure activity performed in the past week. Total scores are measured in metabolic equivalents and activity time. Assessed during the first and second trimesters.	Centers for Epidemiological Studies-Depression Scale (CES-D) assessed during second and third trimesters.	No significant association between exercise and depressive symptoms. <u>β from linear hierarchical regression</u> 1st trimester LTEQ and 2nd trimester CES-D: -0.11 2nd trimester LTEQ and 3rd trimester CES-D: 0.02

TABLE 1.3. Continued.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Orr et al (2006)	Prospective cohort of 1163 pregnant Black women in Baltimore; 922 in final sample	Participation in strenuous and non-strenuous activity. Asked if they were active for at least 20 minutes, 3 times per week. Retrospectively ascertained pre-pregnancy levels and prospectively ascertained levels at first prenatal visit.	CES-D at first prenatal visit.	Women with a CES-D score <16 were significantly more likely to exercise during pregnancy (65.9%) than those with a CES-D score of 16+ (51.8%), p=0.011.
Poudevigne and O'Connor (2005)	Prospective matched case-control study of 12 pregnant women and 12 non-pregnant / non-lactating women in Georgia, United States.	Interviewer-administered 7-day recall of physical activity in the last week. Participants reported time spent in sleep, moderate, hard or very hard activity. Remaining activities were classified as light activity. Reported at 12, 16, 20, 24, 28, 32, 36 weeks' gestation.	Profile of Moods States (POMS) at 12, 16, 20, 24, 28, 32, 36 weeks gestation.	There were no statistically significant correlations between changes in physical activity and changes in depressed mood for either group.
Haas et al (2004)	Prospective cohort of 1,809 women in the San Francisco Bay area; 1,641 had complete data during pregnancy. Project WISH.	Frequency and duration of physical activity at 24-28 and 32-26 weeks' gestation.	CES-D at <20, 24-28, and 32-36 weeks' gestation. Score of >10 represented high depressive symptoms.	No exercise during pregnancy was associated with increased odds of high depressive symptoms. OR (95% CI) <u>Group vs. >2 hrs/week of exercise</u> None: 1.80 (1.22, 2.64) ≤2 hrs/week: 1.21 (0.84, 1.75)

TABLE 1.3. Continued.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Da Costa et al (2003)	Prospective cohort of 230 pregnant women in Montreal; 180 had complete data	Leisure-time physical activity during the prior month assessed through structured interviews in each trimester. Frequency, form, and duration were reported. Classified into exercisers and non-exercisers.	Lubin depression adjective checklist given monthly starting in 3rd month of pregnancy.	Exercisers had significantly less depressed mood in first and second trimesters. Lubin score ± standard deviation <u>Exercisers vs. non-exercisers</u> Trimester 1: 11.6 ± 5.5. vs. 8.5 ± 4.7, difference=0.61 Trimester 2: 10 ± 4.4 vs. 8 ± 3.4, difference=0.51 Trimester 3: 10.2 ± 4.4 vs. 8.7 ± 4.0, difference=0.36
Goodwin et al (2000)	Prospective cohort of 65 nulliparous pregnant women in Melbourne, Australia.	Women were classified as exercisers or non-exercisers based on reporting from a study-developed exercise history questionnaire. To be classified as an exerciser, women must have reported an average of at least 2 bouts of activity per week during the prior 4 weeks.	General Health Questionnaire-28 assessed at 30 weeks of gestation.	No group difference for depression.

TABLE 1.3. Concluded.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Koniak-Griffin (1994)	Self-selected trial of 58 healthy pregnant adolescents recruited from a residential maternity home in Los Angeles.	35 women agreed to participate in a 6-week aerobic exercise program (AEP). The program consisted of supervised activity for 45 min/session 2 times/week. The other 23 women refused to exercise and comprise the comparison group.	CES-D given pre-test and post-test.	Depressive symptoms decreased for the AEP group while there was a small, non-significant change for the comparison group. CES-D score ± standard deviation by group Pre-test vs. Post-test AEP: 27.4 ± 13.2 reduced to 22.0 ± 11.4, $p \leq 0.05$ Comparison: 26.2 ± 13.2 reduced to 25.7 ± 13.7

A total of 10 studies have examined associations between physical activity and depressive symptoms during the postpartum period. The majority of these studies have been trials of relatively small size (Da Costa, 2009, Heh et al, 2008, Daley et al, 2008; May, 2005; Armstrong and Edwards, 2004; Armstrong and Edwards, 2003; Koltyn and Schultes, 1997). One study examined the acute effects of physical activity by randomizing 20 mothers to either 60 minutes of exercise or quiet rest (Koltyn and Schultes, 1997). Participants in both groups experienced less depressed mood after the trial and there was no significant group effect. An exercise trial of sedentary women experiencing PPD in Scotland found that participation in the trial resulted in reduced depressive symptoms scores, but there was no control group (May, 2005). Four of the other trials found that their exercise interventions were effective at reducing depressive symptoms using comparison groups (Da Costa et al, 2009; Heh et al, 2008; Armstrong and Edwards, 2004; Armstrong and Edwards, 2003). Da Costa et al (2009) additionally found that baseline Edinburgh Postnatal Depression Scale (EPDS) moderated the exercise intervention trials effect on depressive symptoms with opposite influences suggested by baseline EPDS status. Daley et al (2008) found that EPDS scores did not differ between women with PPD randomized to either an exercise intervention or usual care. All three prospective cohort studies found associations between physical activity and depressive symptoms. Herring et al (2008) found that women experiencing only PPD walked significantly less than women that did not experience either antepartum or postpartum depression. In a cohort of women from the San Francisco area, women participating in no exercise postpartum had increased odds of having elevated depressive symptoms (Haas et al, 2004). Craike et al (2010) found that increased leisure-time MVPA was associated with less depressive symptoms among mothers of infants aged 3-19 months in Australia. Details of these studies can be found in Table 1.4.

TABLE 1.4. Summary of the literature on the association between physical activity during postpartum and postpartum depression.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Craike et al (2010)	Prospective cohort study of mothers in Australia with infants aged 3-19 months. Wave 1 of the Longitudinal Study of Australian Children (LSAC) Wave 1 n=5107 4720 women included in analysis	Frequency (days/week) of moderate or vigorous leisure-time activity that was performed for at least 30 minutes.	K6 Scale	There was an inverse association between leisure-time physical activity and depressive symptoms. Hierarchical regression β=-0.06, p<0.01 The authors also found an interaction between leisure-time physical activity and life stress.

TABLE 1.4. Continued.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Da Costa et al (2009)	Randomized clinical trial of 88 women with depressed mood (≥10 on the Edinburgh Postnatal Depression Scale [EPDS]) postpartum in Montreal.	Women were randomly assigned to a 12-week home-based exercise program or usual care. Exercise program: 4 meetings with an exercise physiologist, individualized exercise prescription.	EPDS Hamilton Rating Scale for Depression (HAM-D) Assessed at 3 months and 6 months post-baseline.	Baseline EPDS score modified the change in EPDS score. In pooled analysis, the intervention group had significantly lower HAM-D score. The intervention effect was significant for 3 months post-baseline only. β (95% Confidence Interval) of the intervention effect <u>EPDS (pooled for 3 and 6 months)</u> Baseline EPDS ≤13: 2.77 (0.50, 5.05) Baseline EPDS >13: -4.06 (-6.61, -1.51) <u>HAM-D</u> 3 months: -1.83 (-3.41, -0.24) 6 months: -0.26 (-1.78, 1.26) HAM-D mean score difference (95% Confidence Interval), pooled for 3 and 6 months <u>Usual Care- Intervention</u> 1.83 (0.24, 3.41), p=0.02

TABLE 1.4. Continued.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Heh et al (2008)	Controlled trial of 80 primiparas with an EPDS score > 10 at four weeks postpartum in Taiwan. 63 women actually finished the program.	Exercise support program: 1 hr/week at the hospital and 2 sessions/week at home for 3 months. 45 min stretching program with warm-up and cool down. Control group: standard care.	EPDS score at 5 months postpartum.	At 5 months postpartum, the experimental group was less likely to be depressed than the control group. <u>EPDS > 10 by group</u> Experimental: 39.4% Control: 66.7% χ^2= 4.68, p=0.01 The experimental group had a greater reduction in depressive symptoms over time than the control group. EPDS score ± standard deviation by group <u>4 weeks vs. 5 mo postpartum</u> Experimental: 16.5 ± 2.6 vs. 10.2 ± 3.6, within group t=15.0, p=0.0000 Control: 16.3 ± 3.2 vs. 12.7 ± 3.9, within group t=6.1, p= 0.0000 Between group t=2.64, p=0.001
Daley et al (2008)	Randomized controlled trial of 38 women with postpartum depression in the United Kingdom; 31 completed the study.	Women were randomized to an exercise intervention or usual care. Intervention: 2 one-on-one exercise consultations (at baseline and at 4 weeks), follow-up support phone calls at weeks 3 and 9.	EPDS at baseline at 12 weeks post-randomization.	EPDS scores did not differ between the groups. Mean difference in scores (95% Confidence Interval) 1.2 (-5.2, 2.8)

TABLE 1.4. Continued.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Herring et al (2008)	Prospective cohort of 850 pregnant women in eastern Massachusetts. Project Viva.	Hours/week spent walking on average in the past month at 6 months postpartum.	EPDS at mid-pregnancy and 6 months postpartum. Score of >12 indicated probable depression.	Women with only postpartum depression walked significantly less than women with no antepartum or postpartum depression. Mean (standard deviation) of hours/week walked 0.59 (0.7), p<0.05
May (2005)	Trial of 20 sedentary women experiencing postpartum depression in Scotland. No control group.	Group-based weekly exercise classes focused on muscle toning, stretching, and relaxation.	EPDS at baseline and post-program.	Participating in these exercise classes resulted in reduced final EPDS scores (no data shown).
Haas et al (2004)	Prospective cohort of 1,809 women in the San Francisco Bay area; 1,476 had complete data at postpartum. Project WISH.	Frequency and duration of physical activity at 8-12 weeks postpartum.	Centers for Epidemiological Studies-Depression (CES-D) scale at 8-12 weeks postpartum. Score of >10 represented high depressive symptoms.	No exercise post-delivery was associated with increased odds of high depressive symptoms. Odds Ratio (95% Confidence Interval) Group vs. >2 hrs/week of exercise None: 1.62 (1.04, 2.54) ≤2 hrs/week: 0.91 (0.58, 1.43)

TABLE 1.4. Continued.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Armstrong and Edwards (2004)	Randomized controlled trial of 24 women who gave birth in the past 12 months living in the Gold Coast region of Queensland with an Edinburgh Postnatal Depression Scale score of ≥12 at the screening phase.	Exercise intervention group versus social support group. Exercise intervention: Pram walking 2 times a week with a group and one time independently for approximately 40 minutes at a moderate pace. 12-week intervention period.	EPDS measured at pre-test/week 1, week 6, and week 12.	Pram walking group had reduced symptomatology over study period. The support group had no significant reduction. EPDS score ± standard deviation <u>Pram walking group vs. support</u> Pretest: 17.25 ± 4.00 vs. 17.17 ± 4.45 Week 6: 10.22 ± 3.19 vs. 15.00 ± 5.91 Week 12: 6.33 ± 3.67 vs. 13.33 ± 7.66
Armstrong and Edwards (2003)	Randomized controlled trial of 20 women with a child between the ages of 6 weeks and 12 months living in the Gold Coast region of Queensland with an Edinburgh Postnatal Depression Scale score of ≥12 at the screening phase.	Intervention group: group walking three times per week for 30–40 minutes at a moderate intensity. Non-intervention group: usual routine. 12-week intervention period.	EPDS, The 12-item General Health Questionnaire (GHQ 12), and the Depression Anxiety Stress Scale (DASS) measured at pre-test/week 1, week 6 and week 12.	For each tool used, depression symptomatology was lower for the intervention group than the control group. EPDS Scores ± standard deviation <u>Intervention vs. Control</u> Pre-test: 17.40 ± 4.65 vs. 18.40 ± 4.77 Week 6: 7.20 ± 4.32 vs. 13.50 ± 4.53, $p< 0.01$ Week 12: 4.60 ± 3.34 vs. 14.70 ± 7.66, $p< 0.01$

TABLE 1.4. Concluded.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Koltyn and Schultes (1997)	Randomized controlled trial of 20 postpartum women in Texas.	60-minute exercise class vs. 60-minute quiet rest period.	Profile of Mood States (POMS) before and after either the exercise or rest session.	POMS score decreased significantly following both exercise and quiet rest. There was a significant trials effect ($F_{1, 18}=8.27$, $p<0.01$). There was no significant group or group x trials interaction.

h. Pregnancy physical activity and postpartum depression

Four studies have examined the association between physical activity during pregnancy and postpartum depressive symptoms. Each has suggested that physical activity during pregnancy may have some benefit for depressive symptoms (Ersek and Brunner Huber, 2009; Symons Downs et al, 2008; Nordhagen and Sundgot-Borgen, 2002; Abraham et al, 2001). Norhangen and Sundgot-Borgen (2002) found that women who participated in 60+ minutes per week of moderate to high intensity activity in the third trimester of pregnancy had significantly fewer postpartum depressive symptoms when compared to less active women. Abraham et al (2001) found that women who participated in low-intensity exercise as a means of controlling weight or shape during months 3 and 4 of their pregnancy had less postpartum depressive symptoms than women who did not. Two studies found mixed results depending on which measure of physical activity was used. A prospective cohort of Pennsylvania women indicated that women participating in more exercise over the pregnancy period experienced lower depressive symptoms at 6 weeks postpartum than less active women (Symons Downs et al, 2008). However, third trimester exercise alone did not significantly predict postpartum depressive symptoms. Ersek and Brunner Huber (2009) did not find a significant association between physical activity during the last trimester of pregnancy and postpartum depressive symptoms among women who had given birth in the last 2 to 6 months, but found that being active both before and during pregnancy was associated with reduced odds of feeling depressed. Details of these studies can be found in Table 1.5.

3. Summary of overall gaps in the literature

There are a number of issues in physical activity-depression research conducted in the general population. Population-based studies vary in size, population, and the way they assess physical activity (Otto et al, 2007). It is also difficult to determine causation in many

TABLE 1.5. Summary of the literature on the association between physical activity during pregnancy and postpartum depression.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Ersek and Brunner Huber (2009)	Population-based surveillance system of North Carolina women who had given birth to a live infant in the past 2 to 6 months. The Pregnancy Risk Assessment Monitoring System. 2,169 women included for 2004-2005.	Frequency of physical activity/exercise for at least 30 minutes in a week during the last 3 months of pregnancy.	Frequency of feeling down, depressed, or hopeless. Frequency of having little interest or pleasure in doing things.	No significant association between physical activity in the last trimester and 1) feeling depressed or down and 2) having little interest/pleasure. Women who were active pre-pregnancy and during pregnancy had lower odds of having little interest or pleasure when compared to non-active women. Odds Ratio (95% Confidence Interval) <u>Last trimester activity (yes vs. no)</u> Depressed/down: 1.21 (0.95, 1.55) Lack of interest: 0.83 (0.65, 1.06) <u>Active both pre-pregnancy and last trimester (both vs. none)</u> Depressed/down: 1.01 (0.75, 1.36) Lack of interest: 0.66 (0.49, 0.87)

TABLE 1.5. Concluded.

Authors (year)	Design and Study Population	Physical Activity	Depression	Results
Symons Downs et al (2008)	Prospective cohort of 230 pregnant women in Central Pennsylvania	Leisure-Time Exercise Questionnaire (LTEQ) Self-reported 15-min bouts of strenuous, moderate, or mild leisure activity performed in the past week. Total score was measured in metabolic equivalents and activity time. Assessed during each trimester.	Centers for Epidemiological Studies- Depression Scale (CES-D) assessed at 6 weeks postpartum.	Third trimester exercise was not significantly associated with postpartum depressive symptoms. A higher score on the cumulative pregnancy exercise index (using data from all trimesters) was significantly associated with lower depressive symptoms. <u>β from linear hierarchical regression</u> 3rd trimester LTEQ: -0.11 Cumulative LTEQ: -0.27 ($p<0.01$)
Nordhagen and Sundgot-Borgen (2002)	Prospective cohort of 203 pregnant women in Norway.	Frequency, duration, and type of physical activity during each trimester of pregnancy. Categorized as minutes/week of moderate/high intensity activity.	Hospital Anxiety and Depression Scale-Depression (HADS-D) at 6 weeks postpartum.	Women participating in ≥60 minutes per week of moderate/high intensity activity had significantly fewer depressive symptoms than less active women ($p<0.01$).
Abraham et al (2001)	Retrospective cohort of 181 healthy women with singleton births in Sydney, Australia.	Participation in low-intensity exercise for reasons of shape or weight was assessed for pre-pregnancy, months 3-4 of pregnancy, and months 6-7 of pregnancy retrospectively during the postnatal week.	Edinburgh Postnatal Depression Scale (EPDS) score measured in the postnatal week.	Participation in low-intensity exercise for reasons of shape or weight at months 3-4 of pregnancy was associated with EPDS score in the final regression model. $\beta = -2.099$, $p = 0.001$

of the studies due to their design. Determining directionality is of concern with physical activity-depression studies since not only can physical activity influence depressive symptoms but depressed women may be less likely to exercise (Otto et al, 2007). Most studies examined depressive symptoms rather than an actual diagnosis of depression. Some depressive symptoms overlap with other mood disorders and may render it difficult to make clear conclusions (Otto et al, 2007). Furthermore, different diagnostic criteria may be used to determine depression. Dunn et al (2001) has reported that a number of studies on physical activity and general depression only examine the acute effects of physical activity versus the chronic effects. However, depression is not an acute condition and it is likely that it will take an extended period of time for physical activity to have an effect on depressive state. Studies also differ widely in the range of depressive symptoms that are included. Some studies include both non-depressed and depressed individuals while others only consist of depressed persons. These issues make it difficult to compare study results.

The issues identified for general depression research also apply to research conducted during the pregnancy and postpartum periods. The main issue in reviewing the literature on physical activity and depression in pregnancy and postpartum is the paucity of studies conducted thus far. A total of 20 studies on this topic using these populations have been conducted. Studies are difficult to compare for multiple reasons. Different physical activity and depressive symptoms measures were used in both the pregnancy and postpartum research. Even when the same measure is used, different classifications were employed. For example, some studies analyzed depressive symptoms on a continuous scale while others categorized symptom level, using different cutpoints. The studies consist of varied populations (depression status, demographics, etc). All but one of the trials of the association between pregnancy physical activity and antepartum depression included depressed women. Past research has also been limited in sample size; only five studies recruited at least 250 women. As with general depression research, many of the studies

used physical activity assessments without established psychometrics (i.e. validity, reliability). This makes it hard to assess the quality of the study and draw appropriate conclusions. Few dose-response investigations were conducted as physical activity was generally dichotomized in the studies. For the intervention studies, only one exercise prescription was assigned with no variation in physical activity level. Some interventions combined exercise with social support, an important factor related to depressive symptoms. A control group may or may have been included, but sometimes the control group was not the most appropriate (i.e. a support group versus a standard care group). One trial in pregnancy also had participants self-select into the intervention, which could have resulted in self-selection bias. In the observational studies, various aspects of physical activity may have been assessed yet the women were mainly categorized dichotomously. Though past research has shown that the association between physical activity and depression may differ by domain (McKercher et al, 2009; Teychenne et al, 2008a), previous studies among pregnant and postpartum women have failed to examine these potential differences (i.e. leisure versus occupational). Observational studies have focused on either recreational or total physical activity or walking. Lastly, only three observational studies have examined the association between physical activity and depressive symptoms in postpartum. These observational studies are important for understanding how these factors are associated under real world circumstances. Further research into the associations between physical activity and depression in pregnancy and postpartum is necessary to address these issues and allow for comparisons and aggregation.

This investigation addressed some of these issues. This study used more than 1,000 women in the pregnancy analysis and approximately 500 women in the postpartum analyses. The large sample size allowed for control of a number of confounders. By not limiting our sample to women with depression, we are able to observe a range of depressive symptoms. By looking at the association between physical activity at an earlier timepoint

and later depression, the temporality issue is of less concern and the chronic effect of physical activity on depression can be examined. However, pre-pregnancy depressive symptoms status was not available; therefore, we are unable to conclude that women with elevated depressive symptoms were new cases. The physical activity measure used in this investigation assessed frequency, intensity, duration, and type of physical activity using a validated measure. Assessing all these domains not only will make this investigation more comprehensive, but assessing all these domains has been found to improve recall accuracy (Poudevigne and O'Connor, 2006). Physical activity was categorized into more than two categories when possible.

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CHAPTER II

SPECIFIC AIMS

Depression is the leading cause of disability in the developed world (Lopez et al, 2006). In any given year, depression affects over 20 million Americans (National Institute of Mental Health, 2003), most of whom are women as the gender ratio is about 2:1 for females:males (Weissman et al, 1993). The childbearing years are a particularly vulnerable period for the development of depression with 14.5% of women experiencing their first depressive episode while they are pregnant and 18.4% experiencing new or recurrent depression during pregnancy (Gaynes et al, 2005). Almost 50% of postpartum women become depressed in the first 12 months after birth and it is estimated that 500,000 American women experience postpartum depression (PPD) each year (Gaynes et al, 2005; Wisner et al, 2002). Depression during pregnancy and postpartum is especially important to focus on since the consequences of depression during this time not only affect the mother, but her new infant, any other children, her husband, and their relationships having potentially profound and long-lasting effects (Lusskin et al, 2007; Leigh and Milgrom, 2008). There is increasing evidence of a beneficial effect of physical activity on depression, but few studies have examined the association during pregnancy and the postpartum period. The goal of this investigation was to conduct a more extensive analysis of the association between physical activity and depression in pregnant and postpartum women.

Aim 1: Determine if moderate-to-vigorous physical activity (MVPA) in mid-pregnancy (17-22 weeks' gestation) is associated with depressive symptoms in later pregnancy (24-29 weeks' gestation).

Aim 2: Determine if MVPA in mid-pregnancy (17-22 weeks), MVPA in later pregnancy (27-30 weeks), and change in MVPA from mid- to later pregnancy are associated with depressive symptoms at 3 months postpartum.

Aim 3: Determine if MVPA at 3 months postpartum is associated with depressive symptoms at 12 months postpartum.

For all three aims, we explored if the association between physical activity and depressive symptoms differed by domain of activity reported (recreational, occupational, child and adult care, indoor/outdoor household activities, and transportation). Additionally, for Aim 1, we investigated if the association between physical activity and depressive symptoms differs when using perceived intensity (somewhat hard, hard/very hard activity) as compared to absolute intensity (MET-hours/week) measures of physical activity for total and domain-specific MVPA.

These aims were accomplished through secondary analysis of Pregnancy, Infection, and Nutrition (PIN) Study data. We obtained data from the third (PIN3) and postpartum (PIN Postpartum) phases of the study. PIN3 was a prospective cohort of pregnant women, recruited by the 20th week of gestation from prenatal clinics at the University of North Carolina (UNC) Hospitals during January 2001 and June 2005. A total of 2006 women were recruited for this phase of the study. PIN Postpartum followed a subset of these women through their first postpartum year, the first of the follow-up visits occurring in 2003.

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CHAPTER III

STUDY DESIGN AND METHODS

A. The Pregnancy, Infection, and Nutrition Study- Parent Study

The PIN Study was a prospective cohort of pregnant women conducted in four main phases from 1995 to 2005. The third and fourth phases of the study were called PIN3 and PIN3plus. Since the protocols for PIN3 and PIN3plus were common for most participants, they are referred to together as PIN3 and cover the period from 2001-2005. A subset of PIN3 mothers was also re-contacted during the postpartum period at 3 and 12 months to comprise the PIN Postpartum study sample. The objectives of the PIN3 study were to investigate whether physical activity or stress are associated with preterm birth. The postpartum study focused on the role of diet, physical activity, and stress related to postpartum weight retention.

The PIN3 study recruited 2006 women from prenatal clinics at UNC Hospitals if they were at less than or equal to 20 weeks' gestation. Data collection was completed in December 2005. Potential participants for PIN3 were identified through medical chart reviews of new prenatal patients at the UNC Hospitals. Women were excluded if they were younger than 16 years of age, non-English speaking, were not planning to continue care or give birth at the study site, carrying multiple gestations, or did not have a telephone to complete the phone interviews.

The data were collected using a multitude of methods. Participants had two research clinic visits (at <20 and 24-29 weeks' gestation), two telephone interviews (at 17-22 and 27-30 weeks' gestation), and two self-administered questionnaires which were given at

each of the clinic visits and mailed back to study staff. During the second clinic visit, a food frequency questionnaire was also administered to assess diet during the second trimester of pregnancy. After delivery, women completed an in-hospital questionnaire, and medical charts were abstracted. In the self-administered questionnaires, psychosocial factors, family history of cardiovascular disease, and safety of physical activity were assessed. During the telephone interviews, general health, additional psychosocial measures, demographic information, occupational information, physical activity, reproductive history, sexual health, community characteristics, food security, and health behaviors were assessed.

The PIN Postpartum Study sample is derived from the 2006 expectant mothers who were recruited into the PIN3 Study. Women who agreed to be contacted after delivery were phoned at around 6 weeks postpartum to introduce the postpartum study. To be eligible for the PIN Postpartum Study, the women must have delivered a live-born infant at UNC Hospitals between October 2002 and December 2005 and lived in the study's catchement area so that in-home visits could be conducted. These criteria produced 1169 eligible women. If the mother agreed to participate in the study, an in-home visit was scheduled for around 3 months postpartum. A total of 689 mothers agreed to participate and completed a 3-month visit. At the 3-month home interview, women were asked about infant health and feeding, current health status, eating attitudes, vitamin and supplement use, tobacco and drug use, psychosocial measures, demographics, occupation, physical activity, body image, neighborhood characteristics. Physical measurements were also taken at this visit and women were given a food frequency questionnaire to assess diet during the previous three months. Women who remained eligible and continued in the study were again interviewed at 12 months postpartum and asked questions from the 3-month interview, as well as a revised restraint scale and food security assessment.

B. Current Study

The PIN3 study recruited 2006 women. A total of 375 women became ineligible or dropped out of PIN3. Reasons for incomplete follow-up/ineligibility include: lost pregnancy (n=33), requesting to drop out or have no future contact (n=159), moving out of the area or lost contact (n=45), not completing the first telephone interview (n=84), delivering multiple births (n=4), not delivering at UNC Hospitals (n=42), and having medical problems at delivery (n=8). The sample for pregnancy analysis was restricted to mothers with a known date of delivery, singleton birth, and those with non-missing data for physical activity, depressive symptoms, and covariates.

Of the 2006 women eligible for PIN3, only 1169 were eligible for PIN Postpartum. Those 375 women that became ineligible or dropped out of PIN3 were also considered ineligible for PIN Postpartum. There were also 462 women who delivered before PIN Postpartum recruitment began. Of the women initially considered eligible, an additional 480 women became ineligible or refused due to medical constraints (n=24), being unreachable (n=153), timing/scheduling issues (n=116), and refusal (n=187). This resulted in 689 mothers agreeing to participate in the first home interview at 3-months. Between the 3-month and 12-month postpartum home interviews, 139 mothers became ineligible or dropped out of the study: 45 became pregnant, 73 were unreachable or moved, 11 requested to leave the study, and 10 were ineligible for other reasons. This results in 550 women with a 12-month home interview. For both postpartum analyses, analysis was restricted to women with non-missing data for physical activity, depressive symptoms, and covariates.

A flowchart of the PIN3 and PIN Postpartum attrition is presented in Figure 3.1.

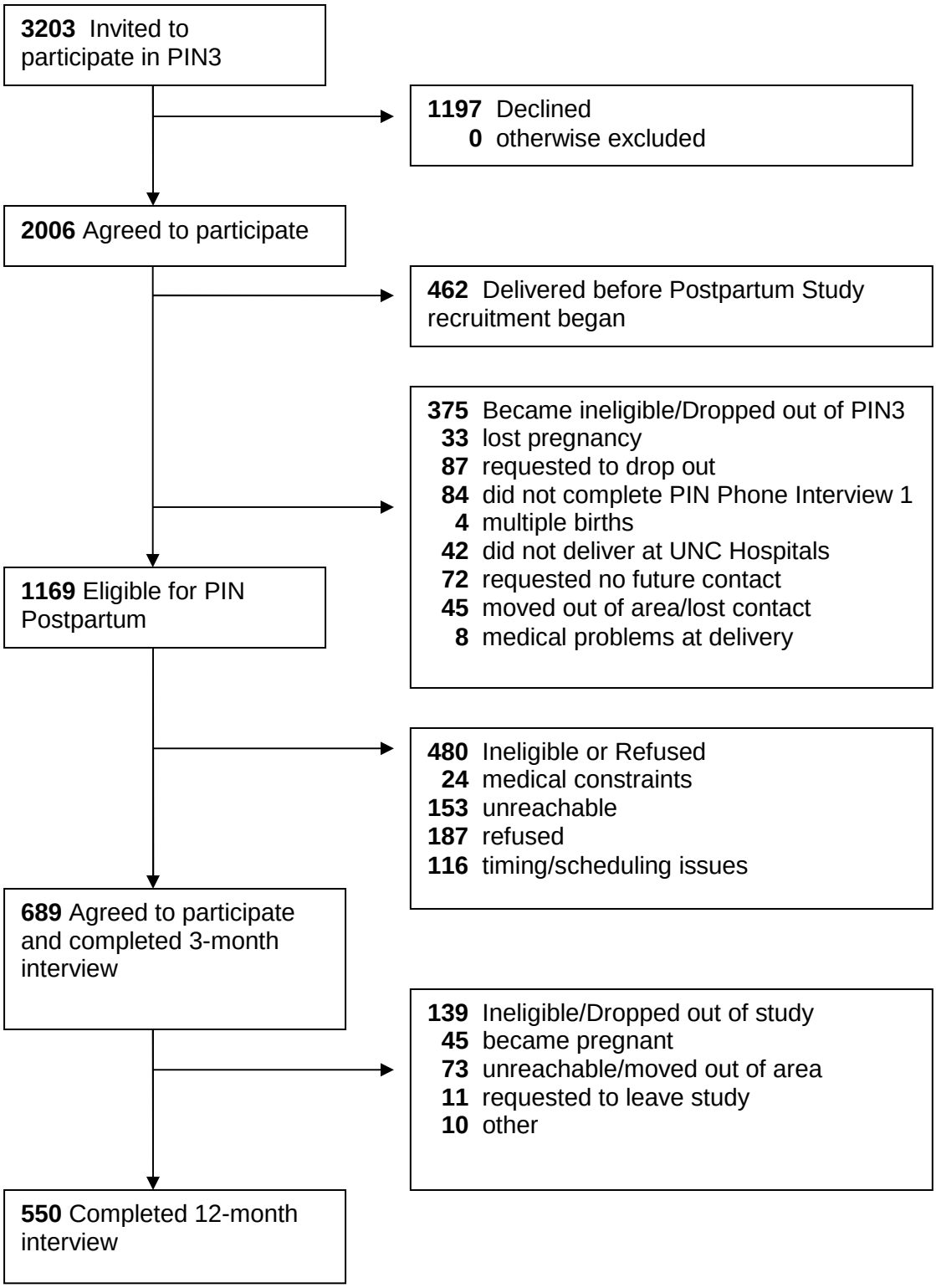

FIGURE 3.1. Flowchart of Pregnancy, Infection, and Nutrition (PIN) 3 Study and PIN Postpartum attrition.

C. Physical Activity Assessment

A structured recall of physical activity performed during the past seven days was recorded during the two telephone interviews over the pregnancy (17-22 and 27-30 weeks' gestation) and during both home interviews conducted postpartum (3 and 12 months). For this investigation, both measurements during pregnancy and the 3-month postpartum were used. Assessments of occupational, recreational, household, child and adult care, transportation activity, and stair climbing were performed at each time point. Frequency, duration, and intensity of each activity type were determined. For each type of activity, participants were first asked if they performed that activity in the past week to a level that caused at least some increase in breathing and heart rate. If they responded in the affirmative, the women were asked to list all the types of domain-specific activities they performed. Subsequently, they were asked to report the number of sessions, average duration per session, and perceived intensity level of each activity type. Perceived intensity was assessed based on the Borg scale- fairly light, somewhat hard, and hard or very hard (Borg and Linderholm, 1974). Self-report of activities that were "fairly light" corresponded with light activity, "somewhat hard" corresponded to moderate activity, and "hard or very hard" corresponded to vigorous activity.

For each analytical aim, physical activity was restricted to activities of moderate to vigorous intensity and was characterized in minutes/week. Minutes per week is calculated by multiplying the number of times a participant performs an activity by the number of hours she performs it and transforming it to the minute scale. Minutes per week can then be aggregated by intensity and domain. For aim 1 and 3 analysis, MVPA was also characterized as MET-hours per week. MET-hours per week is calculated by multiplying the number of times the participant performs the activity by the number of hours it is performed and then multiplying by the compendium-established MET value for the activity (Ainsworth et al, 2000; Ainsworth et al, 1993). Documentation on how these MET values were assigned

in the PIN Study is available at the study website (Pregnancy, Infection, and Nutrition Study, 2007). For adults aged 20-39 years, MET values of 4.8-7.1 are classified as moderate intensity and values of 7.2+ are classified as vigorous activity, following standards for 20 to 39 year old adults (Pollock et al, 1998). The MET-hours values were summed across activity type to establish a total MVPA MET-hours/week value.

Both validation and reliability studies of the physical activity instrument were conducted in this population (Evenson and Wen, 2010). The rating scale developed by Landis and Koch (1977) was used to determine agreement level: 0-0.2 poor, 0.2-0.4 fair, 0.4-0.6 moderate, 0.6-0.8 substantial, and 0.8-<1.0 almost perfect. For the validation portion, a subset of 177 participants was asked to wear an accelerometer and keep a physical activity diary for seven days to compare these levels to the interview-reported values. Agreement with the diary and accelerometer was calculated using Spearman correlation coefficients (SCC) and intraclass correlation coefficients (ICC). Agreement between the questionnaire and diary was in the moderate range for total minutes per week of moderate activity (ICC 0.43, 95% CI 0.27, 0.60), total minutes per week of moderate to vigorous activity (ICC 0.48, 95% CI 0.29, 0.68), and total MET minutes per week of moderate to vigorous activity (ICC 0.44, 95% CI 0.26, 0.60). Agreement was even better when SCCs were calculated. SCC values for those same physical activity measures were 0.61, 0.67, and 0.61 respectively. The agreement between the diary and total minutes per week of vigorous activity was also substantial (ICC 0.74, 95% CI 0.31, 0.91). Agreement between the questionnaire and accelerometer fell into the fair to poor range when using cutpoints developed by Swartz et al (2000). The SCCs were as follows: total minutes per week of moderate activity (0.33, 95% CI 0.15, 0.48), total minutes per week of moderate to vigorous activity (0.34, 95% CI 0.18. 0.46), total MET minutes per week of moderate to vigorous activity (0.08, 95% CI 0.02, 0.16). Agreement when using Hendelman et al (2000) cutpoints were similar. As compared to Swartz et al (2000), the cutpoint for moderate

activity was lower, but the cutpoint for vigorous activity was higher. When using Freedson et al (1998) cutpoints, agreement between the questionnaire and accelerometer was lower. As compared to Swartz et al (2000), both the cutpoints for moderate and vigorous activity were higher.

For the reliability analysis, a subset of 109 participants repeated their physical activity recall within 48 hours of the initial assessment. In general, the assessments had substantial agreement. The ICC for total number of minutes of moderate and vigorous perceived activity was 0.84 (95% CI 0.77-0.89) and the total number of MET minutes per week of activity was 0.84 (95% CI 0.78-0.89).

For Aim 1, physical activity was categorized into three levels: no MVPA, ≤ median of non-zero values, and > median of non-zero values for both perceived and absolute intensity. The sample size was greatly reduced in the PIN Postpartum Study, therefore, physical activity was dichotomized as no MVPA and any MVPA.

D. Depression Assessment

1. Centers for Epidemiologic Studies-Depression Scale

The CES-D (Center for Epidemiological Studies-Depression) Scale (Radloff, 1977) was used to assess depression during pregnancy. The scale measures depressive symptoms, particularly depressed mood in the general population. The CES-D is as a short, structured self-administered questionnaire. The 20-item scale uses Likert response categories to assess feelings and activities the respondent experienced during the past week. Components of scale include depressed mood, feelings of guilt and worthlessness, feelings of helplessness and hopelessness, psychomotor retardation, loss of appetite, and sleep disturbance. Questions are posed in both the positive and negative direction; therefore, some questions require reversed coding. Each response is given a score of 0 to 3. A composite score is calculated summing responses and the score ranges from 0 to 60.

A variety of cutoff scores have shown associations with a clinical diagnosis of depression, with a score of 16+ suggested as an appropriate positive screen for depression (Gaynes, et al. 2005; Radloff, 1977; Weissman, 1977). In this analysis, a cutoff of 17 was used as CES-D scores for pregnant women may be higher due to overlap between depressive and pregnancy symptoms (Hoffman and Hatch, 2000; Orr and Miller, 1995; Klein and Essex, 1994/1995). This cutpoint of 17 was compared to a method suggested by Hoffman and Hatch (2000) where the four scale items related to pregnancy are removed and the remaining items inflated so the scale range remains 0-60 and the 16 cutpoint is still used. The scores calculated by each method were highly correlated with each other (Pearson's r=0.98) and the women were largely categorized into the same binary depressive symptoms category (χ^2=849.64, p<0.0001). When these re-categorized depressive symptoms scores were used in modeling, they performed similarly to our original scoring method.

The CES-D has high internal consistency, adequate test-retest reliability, and has been found to be a valid tool for assessing depressive symptoms (Radloff, 1977). Internal consistency in the general population was approximately 0.85. For psychiatric in-patients, the internal consistency is approximately 0.90 (Radloff, 1977). In a study of differences in internal consistency reliability of the CES-D (Roberts, 1980), coefficients ranged from 0.83-0.91 among English speakers (Roberts, 1980). Most of the test-retest reliability correlations were in the moderate range, ranging between 0.32 and 0.67 (Radloff, 1977). The correlation for individuals with no life events was 0.54 (Radloff, 1977). The CES-D has been found to correlate with clinical ratings of depression, with other variables related to depression, and with other self report tools (Radloff, 1997; Weissman et al, 1977). The sensitivity when compared to the Raskin Depression Score ranged from 74-99% and specificity ranged from 56-86%. The CES-D scale also detects changes in depressive symptoms over time (Weissman et al, 1977; Husaini, 1980), differentiates between patient

and community populations (Weissman et al, 1977), distinguishes between patient groups (Husaini, 1980), and distinguishes symptom severity among depressed patients (Husaini, 1980).

The outcome of interest for the pregnancy analysis was depressive symptoms at 24-29 weeks' gestation. Depressive symptoms at <20 weeks was included as a covariate. When examining the association between pregnancy MVPA and postpartum depressive symptoms, depressive symptoms both time points were considered covariates: <20 weeks measure for mid-pregnancy MVPA analysis and 24-29 weeks for later pregnancy analysis.

2. Edinburgh Postnatal Depression Scale

The Edinburgh Postnatal Depression Scale (EPDS) (Cox et al, 1987) was used to assess postpartum depressive symptoms. The EPDS is a 10-item postpartum depression screening questionnaire that has been used extensively in research (Gaynes et al, 2005). The scale assesses the woman's mood during the past week using 4-point response categories. As questions are both positively and negatively written, reverse coding of some responses is necessary. A composite score is then calculated by summing across items. A threshold score of 12/13 has been shown to indicate depression of various severities and persons needing further assessment (Cox et al, 1987).

A cutpoint of 13 was used in this analysis. The EPDS has been found to have satisfactory sensitivity, specificity, and positive predictive value (PPV) at this cutpoint (Cox et al, 1987; Gaynes et al, 2005). In a study of 84 mothers, the EPDS score was compared to the Research Diagnostic Criteria from Goldberg's Standardised Psychiatric Interview (Cox et al, 1987). The sensitivity was 86%, the specificity was 78%, and the PPV was 73%. In analysis of a subset of 60 of the mothers, the sensitivity was 85%, specificity 77%, PPV 83%, split-half reliability 0.88, and standardized alpha–coefficient 0.87. Pooled analysis from a systematic review produced a sensitivity point estimate of 0.54 (95% confidence interval

[CI]= 0.39, 0.70) and a specificity estimate of 0.91 (95% CI, 0.88, 0.94) for detecting minor and major depression.

We examined the association between MVPA at 3 months postpartum and EPDS score at 12 months postpartum and the associations between MVPA during pregnancy and 3-month postpartum EPDS score.

E. Covariates

An extensive assessment of potential covariates was conducted by the PIN investigators. The covariates discussed here are variables that are considered potential confounders of the physical activity and depressive symptoms association found through review of previously-published literature. These variables are those that have been found to be associated with both physical activity and depression (in general and during the pregnancy or postpartum periods) or may be factors that were adjusted for in previous analyses examining the association. A summary of how these measures were collected and the rationale for their inclusion is presented in Table 3.1.

1. Sociodemographic variables

Age. Participants were asked to provide their date of birth in order to calculate their age at the start of pregnancy. Birth date was assessed during the first telephone interview. Maternal age was categorized as: ≤24, 25-29, 30-34, and 35+ years.

Socioeconomic Status. Household percent of poverty for 2001 will be used as an indicator of the women's socioeconomic status. This variable takes into account an individuals' income and the number of adults and children residing in the household (Proctor and Dalaker, 2002). A value of 100 is equivalent to being at the poverty line. Poverty is assessed during

TABLE 3.1. Description of covariates and timing of measurement.

Factor	Timing of Assessment and Categorization*	Potential Confounder for Which Aims	Rationale
Maternal age	PI1 and T Age in years: ≤24, 25-29, 30-34, 35+	Aim 1, Aim 2, Aim3	There is some evidence of age being associated with depression with most indicating that younger adults are more vulnerable. Age is associated with physical activity. Age is almost always included as a covariate in physical activity and depression research. (Teychenne et al, 2008; Sanchez-Villegas et al, 2008; Galper, 2006; Wise, 2006; Ryan et al, 2005; Belza and Warms, 2004; Evenson et al, 2004; Goodwin, 2003; Zhang and Savitz, 1996)
Body mass index (BMI)	Pre-pregnancy: Recruitment screener. Adjustments made to pre-pregnancy weight after medical abstracts were completed Postpartum: HI1, HI2 Institute of Medicine categories: 1= BMI < 19.8 (low) 2= 19.8 <= BMI < =26.0 (normal) 3= 26.0 < BMI < =29.0 (overweight) 4= BMI >29.0 (obese)	Pre-pregnancy BMI- Aim 1, Aim 2 Postpartum BMI- Aim 3	BMI has shown to be associated with depression. Has been reported that obesity increases prevalence of major depression and dysthymia in lifetime and past year. Those with a higher BMI report less physical activity. BMI is a significant predictor of change in physical activity. Obesity is associated with decreases in physical activity in middle-aged adults. BMI has been repeatedly controlled for in studies of physical activity and depression. (Lim et al, 2008; Petry et al, 2008; Rosemann et al, 2008; Sanchez-Villegas et al, 2008; Brown et al, 2007; LaCoursiere et al, 2006; Wise, 2006; Brown et al, 2005; Carter, 2000)

TABLE 3.1. Continued.

Factor	Timing of Assessment and Categorization*	Potential Confounder for Which Aims	Rationale
Race	PI1 and T White, Black, Other	Aim 1, Aim 2, Aim 3	Some indication that race is associated with depressive disorders. A national surveillance study has shown a 25-fold difference in rates of depression among racial/ethnic groups among those with diabetes. Whites seem to be more at risk for major depression. Non-white women are less likely to participate in physical activity. (Baker and Oswalt, 2008; Li et al, 2008; Keita 2007; Stewart et al, 2007; Ning et al, 2003)
Marital Status	PI1 and T, but also updated at PI2, HI1, HI2 Married, Unmarried	Aim 1, Aim 2, Aim 3	Women without partners in pregnancy are more likely to develop depression. Being married or partnered has been to shown to be associated with lower levels of physical activity. Marital status is typically controlled for in studies of physical activity and depression. (Sanchez-Villegas et al, 2008; Lau and Keung, 2007; Lee and Chung, 2007; Wise, 2006; Brown et al, 2005; Belza and Warms, 2004; Goodwin, 2003; Ning et al, 2003)
Education	PI1 and T, updated HI1 and HI2 Pregnancy: ≤12, 13-15, 16, and 17+ years Postpartum: ≤12, 13-16, and 17+ years	Aim 1, Aim 2, Aim 3	Educational attainment is frequently shown to be associated with depression. Lower education is associated with decrease in physical activity in middle-aged adults. Those with less education are less active. (Brown et al, 2007; Orr et al, 2006; Kahan et al, 2005; Ryan et al, 2005; Marcus et al, 2003; Giles-Corti and Donovan, 2002; Zhang and Savitz, 1996; Gotlib et al, 1989)

TABLE 3.1. Continued.

Factor	Timing of Assessment and Categorization*	Potential Confounder for Which Aims	Rationale
Poverty status	PI1, HI ≤185% of the poverty line 185% of the poverty line	Aim 1, Aim 2, Aim 3	Rates of depression correlated with socioeconomic status. Poverty in particular has been showed to be associated with depression. Those with more income are more likely to be active. (Kinyanda et al, 2009; Talala et al, 2009; Brown et al, 2007; Belza and Warms, 2004; Bennett et al, 2004; Ning et al, 2003)
Parity	PI1 0, 1, 2+ children	Aim 1, Aim 2, Aim 3	Increased parity and those with more children at home are at increased risk of depression in pregnancy and postpartum. Women with previous children are less likely to exercise during pregnancy. (Ryan et al, 2005; Larsson et al, 2004; Giles-Corti and Donovan, 2002; Zhang and Savitz, 1996; Gotlib et al, 1989)
Smoking	PI2, HI1, HI2 Smoker, Non-smoker	Aim 1, Aim 2, Aim 3	There is evidence that smoking is associated with depression. Quitting smoking has been associated with a decrease in depressive symptoms score. Mixed results on if there is a dose-response effect of smoking on depression. Smoking is inversely related to physical activity. Smoking is frequently included as a covariate when investigating the association between physical activity and depression. (Bottomley and Lancaster, 2008; Cranford et al, 2008; Kaczynski et al, 2008; Munafò et al, 2008; Sanchez-Villegas et al, 2008; Wise, 2006; Brown et al, 2005)

TABLE 3.1. Continued.

Factor	Timing of Assessment and Categorization*	Potential Confounder for Which Aims	Rationale
General Health	PI1 Excellent/Very good, Good, Fair/Poor	Aim 1, Aim 2	Some evidence that those with poorer overall health are more likely to be depressed. Those with poor self perceived health status perform no or few leisure physical activities. Pregnant women with good or excellent health are more likely to participate in any leisure activity. Health variables (i.e. physical illness, presence of any severe disease, existing health conditions, etc) typically considered as covariates in studies of physical activity and depression. (Sanchez-Villegas et al, 2008; Galper, 2006; Wise, 2006; Brown et al, 2005; Kahan et al, 2005; Brown and Solchany, 2004; Evenson et al, 2004; Goodwin, 2003)
Vaginal Bleeding	PI1, PI2	Aim 1, Aim 2	Vaginal bleeding may be a sign of an at-risk pregnancy. Leisure time physical activity has been found to be associated with increased risk of miscarriage. Physical discomforts during pregnancy may be associated with antepartum depression. (Hasan et al, 2010; Karaçam and Ançel, 2009; Madsen et al, 2008)
Gestational Diabetes	Medical record abstraction Present, Not present	Aim 1, Aim 2	Exercise is a treatment for gestational diabetes. Gestational diabetes has been shown to be associated with depression in pregnancy. (Cheung, 2009; Kozhimannil et al, 2009; Marquez et al, 2009; Serlin and Lash, 2009)

TABLE 3.1. Continued.

Factor	Timing of Assessment and Categorization*	Potential Confounder for Which Aims	Rationale
Negative Life Events	PI1, SAQ2 Sarason's Life Experiences Survey: 0- <1, 1- <4, 4+.	Aim 1, Aim 2	Experiencing traumatic life events is a risk factor for depression. Life events since delivery show an association with postpartum depression. Life change events affect participation in physical activity. Those experiencing life events are more likely to become inactive. (Allendar et al, 2008; Ho-Yen et al, 2007; Brown and Trost, 2003; O'Hara et al, 1984)
Social Support Scale	SAQ1 MOS Social Support Scale: 0- <78, 78- <89, and 89+.	Aim 1	Lack of social support is considered one of those most important risk factors for depression. Social support has been considered an overwhelming predictor of physical activity. (Bowen and Muhajarine, 2006; Ryan et al, 2005; Belza and Warms, 2004)
Partner Support	PI2, HI1, HI2 A lot, Some, Not much/None	Aim 2, Aim 3	Lack of social support is considered one of those most important risk factors for depression. Social support has been considered an overwhelming predictor of physical activity. (Bowen and Muhajarine, 2006; Ryan et al, 2005; Belza and Warms, 2004)
Sleep Quality	SAQ2, HI1, HI2 Excellent, Good, Fair/Poor	Aim 2, Aim 3	Physically active women have better sleep quality than sedentary women. Sleep disturbances and depressive symptoms score are associated. Insomnia predicts later higher depressive symptoms score. Sleep quality in early pregnancy predicts depressive symptoms in later pregnancy. (Buysse et al, 2008; Jansson-Fröjmark and Lindblom, 2008; da Castro Toledo Guimares et al, 2008; Goyal et al, 2007)

TABLE 3.1. Concluded.

Factor	Timing of Assessment and Categorization*	Potential Confounder for Which Aims	Rationale
Work Status	PI1, PI2, HI1, HI2 Working, Not working	Aim 1, Aim 2, Aim 3	There is an indication that housewife status and unemployment are associated with depression. Among middle aged women, those with part-time employment are more active than those with full-time employment. Occupation variables have been controlled for in studies of physical activity and depression. (Marchesi et al, 2009; Brown et al, 2007; Wise, 2006; Brown et al, 2005; Ryan et al, 2005; Gotlib et al, 1989)
Breastfeeding Practice	HI1, H12 Current, stopped, and never breastfed	Aim 3	Mothers have expressed concerns that exercise negatively affects their breastfeeding, which may make them less like to be active. Women with persistent depressive symptoms were more likely to have breastfed for less than a month. The decision to continue breastfeeding correlates with regular physical activity. Women with elevated postpartum depressive symptoms are more likely to have negative breastfeeding practices and experiences than those with low symptoms. (Sandes et al, 2007; Pippins et al, 2006; Rich et al, 2004)

* T=Tracking file, PI1= Telephone interview 1 (17-22 weeks' gestation), PI2= Telephone interview 2 (27-30 weeks' gestation), SAQ1= Self-administered questionnaire 1 (<20 weeks' gestation), SAQ2= Self-administered questionnaire 2 (24-29 weeks' gestation), HI1= 3-month postpartum home interview, HI2= 12-month postpartum interview.

pregnancy and postpartum. The variable was dichotomized at the Women, Infants, and Children program income guideline cutpoint, which is 185% of the U.S. poverty level (U.S. Department of Agriculture, 2009).

Race. Maternal race was assessed during the first telephone interview during pregnancy. Participants could choose between White, African-American, American Indian, Asian/Pacific Islander, and other. A participant would then provide a description for "other." A constructed variable for race was created by coding race into 18 categories incorporating Hispanic ethnicity and accounting for multi-racial status. Race was categorized into three levels: White, Black, and Other.

Education. Education was assessed during the first telephone interview and asks for the highest year of education the women have completed. Education status in pregnancy was categorized into four levels: ≤12, 13-15, 16, and 17+ years. Postpartum education status was categorized as: ≤12, 13-16, and 17+ years.

Marital Status. The women were asked to indicate if they were single, married, separated, divorced, or widowed. This was updated during the pregnancy and at postpartum. Marital status was dichotomized as married and unmarried.

Parity. The count of live births and stillbirths was used to ascertain participant's parity level. This was assessed during the first telephone interview during pregnancy. This variable was categorized as: 0, 1, and 2+.

2. Physical Health

Body Mass Index. Self-reported height and pre-pregnancy weight were collected at PIN3 Study recruitment. These height and weight values were used to calculate pre-pregnancy

body mass index (BMI). Pre-pregnancy BMI was grouped into Institute of Medicine (1990) categories: <19.8 (low), 19.8-26 (normal), >26-29 (overweight), and >29 (obese) kg/m^2. BMI was also calculated for 3 and 12 months postpartum using measurements from home interviews. Postpartum BMI was categorized into National Heart, Lung and Blood Institute guidelines (U.S. DHHS, 1998) groupings: <18.5 (low), 18.5-24.9 (normal), 25-29.9 (overweight), or 30+ (obese) kg/m^2 (obese). Pre-pregnancy and 3-month BMI were considered covariates.

Vaginal Bleeding. The number of vaginal bleeding episodes was assessed at both telephone interviews during pregnancy and was categorized as any or no bleeding.

Gestational Diabetes. Gestational diabetes status was abstracted from medical records post-pregnancy and was classified as present or not present.

General Health. During the first telephone interview during pregnancy, the women were asked to indicate if their health in general was: excellent, very good, good, fair, or poor. The variable was collapsed to: excellent/very good, good, fair/poor.

Smoking. Women were asked to indicate the average number of cigarettes smoked/day for each month up to month 6 of pregnancy. A study constructed variable averaged the number of cigarettes smoked for months 1-6. The average number of cigarettes smoked per day for months 1-3 and 1-12 of postpartum were also assessed. Pregnancy and 3-month postpartum smoking behavior were considered potential confounders and were categorized as any smoker and non-smoker.

3. Psychosocial Health

Social Support. Social support was assessed during the first self-administered questionnaire during pregnancy with the MOS Social Support Scale. The scale assesses the availability of perceived social support in four categories. It uses a five-category Likert response for 19 items. In this study, the question of how many close friends and close relatives the woman had was separated into two questions to see if her support network was more family based or friend based. Reliability measures for 14 definitions of health concepts were in the 0.74 to 0.93 range using Cronbach's alpha (Sherbourne & Stewart, 1991). The 19 items are scaled into an overall score and into four subscales: tangible or instrumental support, affectionate, positive social interaction, and a combination category of emotional/informational support. The sum all items was examined in this study and the variable was categorized according to PIN3-suggested categories: 0- <78, 78- <89, and 89+.

Partner Support. Partner support was also investigated as a potential confounder. Partner support was assessed with a single item about the amount of emotional support the woman receives from the man acting as the child's father and was categorized as: a lot, some, not much/none. This was assessed during the second telephone interview during pregnancy and at both postpartum home interviews. The pregnancy and 3-month postpartum measurements were considered potential covariates.

Life Events. Life events were assessed in the first telephone interview with the Life Experiences Survey (LES; Sarason et al, 1978). An update of the LES was included with the second self-administered questionnaire. The LES examines both acute and chronic life stresses. It provides a composite score of life events and the impact of those events. Women are asked if events occurred since the start of pregnancy and, if so, they are asked to report the impact of each item as having a positive (+1 to +3), negative (-1 to -3), or no

impact (0). Incorporating the impact eliminates the use of a preconceived assessment of what is a positive or negative life event since impact is contextual. This allows for the calculation of a composite impact score of positive events, negative events, or all events using absolute values. The LES was modified by eliminating the item asking whether the respondent experienced a pregnancy, and combining husband and boyfriend (details of marital status, cohabitation, and relation with the father of the baby are obtained elsewhere), resulting in 39 items from the original 57 in the LES. Test-retest reliability studies were conducted with reliability coefficients of.53 for the positive impact score, .88 for the negative impact score, and .64 for the total score (Behnke and Eyler, 1997). The sum of all negative impact scores will be included in this analysis and categorized according to PIN-suggested categories: 0- <1, 1- <4, 4+.

4. Other Factors

Sleep quality. In the second self-administered questionnaire and at both postpartum home interviews, women were asked to report how they rated the quality of sleep on most nights: fair, poor, good, or excellent. In analysis, this was collapsed to: fair/poor, good/excellent. The pregnancy and 3-month assessments were considered as covariates.

Work status. Participants were asked if they had worked any for pay since one month prior to becoming pregnant and if they were still working during the first telephone interview during pregnancy. A chance to update work status was given during the second telephone interview of PIN3 and at both home interviews during postpartum. The study constructed variable categorized work status as currently working or not working. Work status at mid-pregnancy, later pregnancy, and 3 months postpartum were investigated as potential confounders.

Breastfeeding practice. During postpartum home interviews, women were asked if they ever breastfed their infant and if they were still breastfeeding. Breastfeeding status at 3 months postpartum was considered a covariate and was categorized as current, stopped, and never.

F. Data Analysis

1. Overview

Analysis was conducted using SAS, Version 9 (SAS Institute, Inc., Cary, NC) and STATA 11 (StataCorp, College Station, TX). PIN data underwent extensive data management and quality control procedures. Range checks, completeness and data consistency were conducted. We examined the association between total and domain-specific MVPA during pregnancy and postpartum and depressive symptoms during either pregnancy or postpartum. Analysis included data exploration of univariate distributions, bivariate associations, and multivariate adjusted regression. Complete case analysis was used to handle missing data in regression analysis. Observations that were missing values for the exposure, outcome, or any covariates included in the model were dropped when the estimates were calculated.

2. Confounding

Factors found to be associated with both physical activity and depression in previous research and factors adjusted for in previous analyses were considered potential confounders. Confounding was initially assessed at the crude level, but then determine at the adjusted level in models. The first step in determining potential confounding status was to check to see if these variables were associated with both physical activity and depressive symptoms in our sample. Crude associations between the potential confounders and physical activity and depressive symptoms were examined with contingency tables using the

categorized forms of each variable. When the p-values from the Chi-square analysis were ≤ 0.20, the covariate was considered a potential confounder and subsequently investigated in the modeling stage. Model building started with the model including all the potential confounders. Confounding was assessed through the change-in-estimate method and backwards deletion (Rothman and Greenland, 1998). Potential confounders will be deleted one-by-one at each step. The odds ratio (OR) from the model without the covariate and the OR from the model with the covariate were compared as such: ln(OR with covariate/OR without covariate). Those deletions resulting in a more than 10% change in estimate were considered confounders and retained in the model. It was determined *a priori* that the previous measurement of depressive symptoms would be included in the models because previous history of depression is a major risk factor for both antepartum and postpartum depression (Marcus, 2009) and is expected to be associated with previous activity given previous literature.

3. Regression modeling

We examined the prospective associations between (1) total and domain-specific MVPA in mid-pregnancy and depressive symptoms at later pregnancy, (2) total and domain-specific MVPA in mid-pregnancy and 3-month postpartum depressive symptoms, (3) total and domain-specific MVPA in later pregnancy and depressive symptoms at 3 months postpartum, and (4) total and domain-specific MVPA at 3 months postpartum and depressive symptoms at 12 months postpartum. Logistic regression was used to model the associations between MVPA and depressive symptoms. Logistic regression models the log-odds of the outcome with the intercept and regression parameters of the explanatory variables. Proc logistic in SAS was used. Due to the reduced sample size in the PIN Postpartum Study, exact logistic regression modeling was utilized to calculate ORs and 95% confidence intervals (CIs) for aims 1 and 2. Also for aims 2 and 3, Heckman modeling

(Heckman, 1978; Heckman, 1979) was used to determine if there was selection bias in our final model sample as compared to the women eligible for the PIN Postpartum Study. The heckprob procedure was used in STATA. For aim 1, logistic B-spline regression analysis (Gregory et al, 2008) was conducted to explore if other forms of the physical activity variables would be informative in describing the association between total physical activity and depressive symptoms; however, it did not contribute over and above the logistic model so the results were not presented.

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CHAPTER IV

MANUSCRIPT 1: PHYSICAL ACTIVITY AND DEPRESSIVE SYMPTOMS AMONG PREGNANT WOMEN: THE PIN3 STUDY

A. Abstract

Prenatal depression confers health risks for both mother and family. Physical activity may promote better mental health; however, few studies have examined the influence of physical activity on prenatal depression. Data from 1220 women enrolled in the third Pregnancy, Infection, and Nutrition Study (2001-2005) was used to examine the associations between overall and domain-specific moderate-to-vigorous physical activity (MVPA) and depressive symptoms during pregnancy. Self-reported, past week physical activity assessed at 17-22 weeks' gestation was modeled in logistic regression with self-reported depressive symptoms assessed by the Center for Epidemiologic Studies-Depression Scale at 24-29 weeks' gestation. Active women with ≤2.67 hours/week of total MVPA had almost half the odds of having high depressive symptoms as compared to women with no MVPA (odds ratio [OR]=0.56, 95% confidence interval [CI]= 0.38, 0.83). Increased odds of elevated depressive symptoms were found for women participating in some but ≤2.25 hours/week of adult and child care MVPA (OR=1.84; 95% CI=1.08, 3.11) and >1 hours of indoor household MVPA (OR=1.63, 95% CI=0.99, 2.70) when compared to women with no MVPA. While overall MVPA may play a role in reducing the odds of developing elevated depressive symptoms, adult and child care and indoor household activities may increase it.

B. Introduction

Women are approximately twice as likely to be diagnosed with major depressive disorder than men in the United States (U.S.) (Weissman et al, 1993). One in five American women will be diagnosed with depression over her lifetime with a mean age of onset at 28 years, during the childbearing years (Kessler et al, 1993; Weissman et al, 1993). As hormones have been shown to influence emotions and mood, certain life changes (i.e., puberty, pregnancy, menopause) can make women particularly vulnerable to the onset or return of depressive symptoms (National Institute of Mental Health [NIMH], 2008; Bennett et al, 2004). Approximately 15% of pregnant women have their initial onset of depression during pregnancy (Gaynes et al, 2005). A systematic review determined that 18.4% of pregnant women experience depression during pregnancy based on clinical interview or assessment (Gaynes et al, 2005). The authors also reported that the estimated prevalence of depression during pregnancy was 11.0%, 8.5%, and 8.5% for the first, second, and third trimesters respectively (Gaynes et al, 2005).

Depressive symptoms include sad mood, loss of interest in activities, feelings of helplessness and hopelessness, decreased energy, decision-making difficulties, sleep problems, restlessness, irritability, changes in eating patterns, suicidal ideations or attempts, and persistent physical symptoms that do not respond to treatment (NIMH, 2007). When this occurs during pregnancy, the disease poses threats to the mother's health and has implications for the health of her newborn and family (Lusskin et al, 2007; Bowen and Muhajarine, 2006). There is evidence of antenatal depression resulting in pregnancy and obstetric complications (Bowen and Muhajarine, 2006; Larsson et al, 2004; Bennett et al, 2004), poor health behaviors (Bennett et al, 2004), and risk-taking behaviors (Bowen and Muhajarine, 2006; Bennett et al, 2004). Depressed mothers-to-be are also less likely to attend regular prenatal visits (Lusskin et al, 2007; Lee and Chung, 2007; Bowen and Muhajarine, 2006). Maternal depression may impact the child from the fetal stage through

childhood, influencing birth outcomes, mother-infant relations, development, and behavior (Lusskin et al, 2007; Bowen and Muhajarine, 2006; Hammond and Crozier, 2007; Brown and Solchany, 2004).

The most commonly employed treatments for depression are antidepressant medication and psychotherapy though these may not be desirable among pregnant women due to concerns over side effects, stigma, time and financial costs (NIMH, 2007; Hammond and Crozier, 2007; Bowen and Muhajarine, 2006; Daley et al, 2007). This prompts incentive to investigate other treatments for depression (Hammond and Crozier, 2007). Several studies have reported on the association between physical activity and depression in non-pregnant populations, mostly finding that being physically active is associated with better mental health (Teychenne et al, 2008). Research is now focusing on the utility of physical activity as a tool to prevent and manage depression (Teychenne et al, 2008). Some studies have shown that physical activity can be as effective a treatment for depression as medication and therapy (Dunn et al, 2005; Craft and Perna, 2004; Martinsen, 2008).

The risks of participating in moderate intensity physical activity during pregnancy are considered low and may contribute to health benefits for both mother and fetus (Vladutiu et al, In Press; U.S. Department of Health and Human Services [DHHS], 2008; Pivarnik et al, 2006). It is recommended that pregnant women who are not regularly active or who engage in low intensity activity participate in at least 150 minutes/week of moderate-intensity activity while women who are highly active can continue at their pre-pregnancy activity levels (U.S. DHHS, 2008).

Though the role of physical activity in the development and treatment of depression has been studied extensively in general populations, research on pregnant populations is limited. To date, research on pregnant women has focused on total and recreational physical activity. In a number of studies, participation in physical activity was associated

with lower levels of depressive symptoms (Pottinger et al, 2009; Orr et al, 2006; Haas et al, 2004, Da Costa et al, 2003; Koniak-Griffin, 1994). However, other studies have found primarily no associations between total or recreational physical activity and depressive symptoms (Goodwin et al, 2000; Poudevigne and O'Connor, 2005; Symons Downs et al, 2008). These studies have also primarily focused on cross-sectional associations between physical activity and depression, not examining potential longitudinal associations.

The objective of this investigation was to expand previous research and examine the association between overall and domain-specific moderate-to-vigorous physical activity (MVPA) and depressive symptoms during pregnancy.

C. Methods

1. Setting and population

This investigation used data from the third phase of the Pregnancy, Infection, and Nutrition Study (PIN3), a prospective cohort of pregnant women. The main objectives were to investigate whether physical activity or stress are associated with preterm birth. Women were recruited between January 2001 and June 2005 from prenatal clinics at the University of North Carolina (UNC) Hospitals in Chapel Hill, NC. The Institutional Review Board of the UNC School of Medicine approved the study protocols.

2. Procedures

Potential participants for PIN3 were identified through medical chart reviews of new prenatal patients at the UNC Hospitals. Written informed consent was obtained from each participant. Women were asked to participate in two research clinic visits (at <20 and 24-29 weeks' gestation), two telephone interviews (at 17-22 and 27-30 weeks' gestation), and two self-administered questionnaires which were given at each of the clinic visits and mailed back to study staff. Most psychosocial factors were assessed on the self-administered

questionnaires. During the telephone interviews, general health, additional psychosocial measures, sociodemographic information, occupational information, physical activity, reproductive history, and health behaviors were assessed. Medical charts were abstracted after delivery to obtain information on pregnancy complications and outcomes.

3. Participants

The PIN3 Study recruited women who were less than or equal to 20 weeks' gestation at their second prenatal visit. Women were excluded if they were younger than 16 years of age, non-English speaking, were not planning to continue care or give birth at the study site, carrying multiple gestations, or did not have a telephone to complete the phone interviews. Out of 3203 eligible participants, 2006 (63%) women were recruited. Women were allowed to participate in the PIN3 Study for more than one pregnancy. However, this analysis was restricted to the first PIN3 pregnancy, eliminating 274 pregnancies. Women were also excluded if they had no known delivery date (n=57) or no data on physical activity (n=2), depression (n=335) or both (n=117). Additionally, one woman's physical activity level was considered an outlier so her data was also excluded. This resulted in a total of 1220 participants available for analysis. When compared to the 455 women excluded for incomplete data, our sample was composed of more White (73% vs. 55%) and married (77% vs. 54%) women. The included women were also older (29 vs. 27 years), had more education (16 vs. 14 years), were better off financially (426% vs. 319% of the poverty line), and had higher parity (0.9 vs. 0.7 pregnancies). P-values for these differences were all less than 0.0001.

4. Physical activity assessment

Structured recall of physical activity performed during the past seven days was recorded during a telephone interview at 17-22 weeks' gestation with documented validity

and reliability (Evenson and Wen, 2010). Assessments of occupational, recreational, household, child and adult care, and transportation activity were performed at each time point. Frequency, duration, and intensity of each activity type were determined. For each type of activity, women were first asked if they participated in that activity in the past week that caused at least some increase in breathing and heart rate. If they responded in the affirmative, the women were asked to list all the types of domain-specific activities they performed. Subsequently, they were asked to report the number of sessions, average duration per session, and perceived intensity level of each activity type. Perceived intensity was assessed based on the Borg scale- fairly light, somewhat hard, and hard or very hard (Borg and Linderholm, 1974). Self-report of activities that were "fairly light" corresponded with light activity, "somewhat hard" corresponded to moderate activity, and "hard or very hard" corresponded to vigorous activity.

Physical activity for this analysis was restricted to moderate and vigorous activities and was characterized in two ways: hours/week and metabolic equivalent (MET)-hours per week, based on perceived and absolute intensity, respectively. Hours per week was calculated by multiplying the number of times a participant reported an activity by the number of hours she reported, focusing only on activities that were reported as "somewhat hard" or "hard or very hard." Hours per week of activity was then aggregated by intensity and domain. MET-hours per week was calculated by multiplying the number of times the participant reported the activity by the number of hours it is reported and then multiplying by the MET value for the activity. The activities were coded based on compendium-established intensities (Pregnancy, Infection, and Nutrition Study, 2007; Ainsworth et al, 2000; Ainsworth et al, 1993). For adults aged 20-39 years, MET values of 4.8-7.1 are classified as moderate intensity and values of 7.2+ are classified as vigorous activity, following standards for 20 to 39 year old adults (Pollock et al, 1998). The MET-hours values were summed across activity type to establish a total MVPA MET-hours/week value. The exposures of interest for

this analysis were total and all domain-specific physical activity measures that were of moderate-to-vigorous intensity at 17-22 weeks' gestation.

5. Depression assessment

The Center for Epidemiological Studies-Depression (CES-D) Scale (Radloff, 1977) was used to assess depression during pregnancy at <20 and 24-29 weeks' gestation. The scale measures depressive symptoms, particularly depressed mood in the general population; however, the results of the scale can not be used to make a diagnosis of depression. The CES-D is a 20-item, structured self-administered questionnaire. Each response was given a score of 0 to 3. A composite score is calculated summing responses and the score ranges from 0 to 60. A variety of cutoff scores have shown associations with a clinical diagnosis of depression, with a score of 16+ suggested as an appropriate positive screen for depression (Gaynes et al, 2005; Radloff, 1977; Weissman, 1977). In this analysis, a cutoff of 17 was used as CES-D scores for pregnant women may be higher due to overlap between depressive and pregnancy symptoms (Hoffman and Hatch, 2000; Orr and Miller, 1995; Klein and Essex, 1994/1995). The outcome of interest was depressive symptoms at 24-29 weeks' gestation. Depressive symptoms at <20 weeks was included as a covariate.

6. Covariates

Factors previously found to be associated with both physical activity and depression in previous research and factors adjusted for in previous analyses were considered potential confounders. This includes sociodemographic variables such as age (≤ 24, 25-29, 30-34, and 35+ years), race (White, Black, or other), and marital status (married or unmarried). Indicators of socioeconomic status included were: education (≤12, 13-15, 16, and 17+), employment status at time of first phone interview (yes, no), and poverty status (≤185% or

>185% of the poverty line). Poverty status considers an individual's income and the number of adults and children that live in the home (Proctor and Dalaker, 2002). The value of 100 is equivalent to being at the poverty line. The 185% cutpoint is used as it is the Women, Infants, and Children income guideline cutpoint (U.S. Department of Agriculture, 2009). Health indicators included were: parity (0, 1, and 2+), pre-pregnancy body mass index (Institute of Medicine 1990 categories: <19.8, 19.8-26, >26-29, and >29 kg/m^2) based on pre-pregnancy height and weight reported at recruitment, smoking status for first six months of pregnancy (any smoking or nonsmoker), general health status (poor/fair, good, and very good/excellent), vaginal bleeding (any or none), and gestational diabetes (indicated in medical chart or not).

Psychosocial factors include number of negative life events and social support. Life events were assessed in the first telephone interview with the Life Experiences Survey (LES) which examines both acute and chronic life stresses (Sarason et al, 1978). It provides a composite score of life events and the impact of those events. Women are asked if events occurred since the start of pregnancy and, if so, they are asked to report the impact of each item as having a positive (+1 to +3), negative (-1 to -3), or no impact (0). The LES was modified by eliminating the item asking whether the respondent experienced a pregnancy, and combining husband and boyfriend (details of marital status, cohabitation, and relation with the father of the baby are obtained elsewhere), resulting in 39 items from the original 57 in the LES. The composite score of the impact of negative events was examined as a covariate and was categorized as 0- <1, 1-<4, and 4+. Social support was assessed during the first self-administered questionnaire with the Medical Outcomes Study Social Support Scale which assesses the availability of perceived social support in four categories (Sherbourne and Stewart, 1991). It uses a five-category Likert response for 19 items. The overall score was used as a covariate and was categorized as 0- <78, 78- <89, and 89+.

7. Data analysis

Analysis was performed using version 9.1 of the SAS statistical software (SAS Institute Inc, Cary, NC). Univariate analysis was conducted to describe sample characteristics of potential covariates and physical activity. A covariate was considered a confounder in this analysis if it was associated with both physical activity and depressive symptoms (using Chi-square analysis) and changed the estimate of the physical activity-depressive symptoms association by ≥10% in the modeling stage using backwards deletion (Rothman and Greenland 1998). This was performed separately by physical activity domain. It was determined *a priori* that depressive symptoms at <20 weeks would be included as a covariate in all adjusted models, as previous history of depression is one of the most significant predictors of later depression (Brown and Solchany, 2004; Lusskin et al, 2007; Bowen and Muhajarine, 2006) and is expected to be associated with physical activity given previous literature. For each domain-specific model, additional adjustment for other MVPA was also performed to assess potential confounding.

Logistic regression modeling was utilized to calculate odds ratios (OR) and 95% confidence intervals (CI). Regression models were restricted to participants that had complete data for exposure, outcome, and the covariates of interest that were determined to be potential confounders (n=1077). Depressive symptoms were considered high if the CES-D score was at or above 17; otherwise, it was considered low. Physical activity was modeled as a three-level variable: none (reference), ≤ the median of non-zero values, and > the median of non-zero values. Estimates of the ORs were collapsed for adult and child care activity measured in METS-hours/week due to the precision and because the estimates and the 95% CIs were the same. Logistic B-spline regression analysis (Gregory et al. 2008) was conducted to explore if other forms of the physical activity variables would be informative in describing the association between total physical activity and depressive symptoms, but it did not contribute over and above the logistic model so the results were not presented.

D. Results

1. Sample characteristics

Among the 1220 PIN3 participants with physical activity and depressive symptoms data, 26% of the women were classified as having elevated depressive symptoms at 24-29 weeks' gestation. CES-D scores ranged from 0 to 55 with a median value of 10 and an interquartile range (IQR) of 5-17. Table 4.1 presents selected sample characteristics overall and by depressive symptoms status. The majority of the women were Whites (73%). Approximately one-third (34%) of the women belonged to the age group 30-34 years and 31% were of the age 25-29 years. Over three-quarters (77%) of the participants were married. The sample of women was highly educated, with 63% of the women completing at least 16 years of education. A low proportion of low income women were enrolled in this study sample; 19% of the women met the WIC income eligibility criteria. Most of the women, 53%, were within the normal range of BMI before becoming pregnant. Women with elevated depressive symptoms were younger, had less education, were poorer, and were more likely to be non-White, unmarried, and multiparous than women with non-elevated depressive symptoms.

Participation in MVPA was examined descriptively among the women in the study sample who had complete data on the physical activity measures and depressive symptoms. A total of 409 (33.5%) women participated in no perceived, self-reported MVPA in hours/week. Median activity levels were 1.17 hours/week with IQR of 0-3.5. The highest proportion of women reported participating in moderate-to-vigorous recreational activity; 43.2% of women participated in recreational activity in hours/week. Women were least likely to participate in outdoor household activity according to hours/week (6%). Figure 4.1 presents the distribution of domain-specific activities by quartile of total MVPA in hours/week. For women with the highest levels of MVPA, recreational activity comprised the lowest proportion of their total activity as compared to women in other quartiles.

Focusing on absolute intensity in MET-hours/week, 742 (60.8%) of the women participated in MVPA; median activity levels and IQR values were all 0. Women were most likely to participate in recreational activity (23.7%) and least likely to participate in adult and child care activity (3%) when assessed in absolute intensity. All women were considered as having no transportation MVPA when using MET-hours/week because walking and biking for transportation have MET values of 4, below the threshold of 4.8 for moderate activity.

2. Physical activity associations with depressive symptoms

Crude and adjusted models for the associations between perceived MVPA (hours/week) and depressive symptoms are shown in Table 4.2. Significant associations between total MVPA and depressive symptoms were found in both the crude and adjusted models. In the final model, women who participated in above zero and ≤2.67 total MVPA had a reduced odds of depressive symptoms as compared to inactive women (OR=0.56, 95% CI=0.38, 0.83). There were slight increases in the odds of having elevated depressive symptoms for those active at work as compared to women with no work MVPA. After adjustment, women who participated in any activity but ≤ 2.25 hours/week of adult and child care activity had 1.84 times the odds of elevated depressive symptoms than those who did not (95% CI=1.08, 3.11). Women who spent more than 1 hour/week in indoor household MVPA had 1.63 times the odds of high depressive symptoms than women with indoor household MVPA (0.98, 2.70). There were no associations between outdoor household or transportation activity and depressive symptoms for crude and adjusted models.

Crude and adjusted models for the association between absolute MVPA (MET-hours/week) and depressive symptoms associations are presented in Table 4.3. In the adjusted model, women with >9 MET-hours/week of total activity were 31% less likely to have elevated depressive symptoms than those with less activity (OR=0.69, 95% CI=0.46, 1.06); this was in the opposite direction from the crude model. There was no association

between work MVPA, recreational MVPA, and outdoor household MVPA with depressive symptoms in adjusted models. The association between adult and child care activity showed a larger inverse association when adjusted as compared to the crude model, but it was still non-significant and precision was poorer. Participation in more than 6 hours/week of indoor household activity was significantly associated with depressive symptoms in the adjusted model (OR=3.00, 95% CI=1.34, 6.72). There was no association between outdoor physical activity and depressive symptoms in either the crude or adjusted models.

For domain-specific measures of both perceived and absolute intensities, we re-ran all adjusted models, adding a covariate for MVPA outside of the specific domain of interest to account for this potential confounding. For example, the recreational activity model was adjusted for total activity subtracting out recreational activity. The models did not substantially change when other domains were included as covariates.

For both intensity types, we combined participation levels of work, adult and child care, indoor household, outdoor household, and transportation activities into one measure to represent non-elective (vs. recreational) activity. For those participating in some MVPA but less than or equal to the median (2 hours) of non-elective MVPA, the odds of developing elevated depressive symptoms compared to women with no MVPA was 0.69 (95% CI=0.46, 1.06). However, those with more than 2 hours of non-elective MVPA were more likely to develop high depressive symptoms (OR=1.73, 95% CI=1.17, 2.56). There was a null association between non-elective activity in METS and depressive symptoms among women with any MVPA but less than or equal to the median of 4.89 METS (OR=0.96, 95% CI=0.55, 1.66), but those with more than the median METS of non-elective activity had 1.77 times the odds of developing elevated depressive symptoms (95% CI=1.08, 2.88).

E. Discussion

We found few associations between total and domain-specific MVPA at 17-22 weeks' gestation and depressive symptoms at 24-29 weeks' gestation. Total perceived MVPA was associated with reduced odds of elevated depressive symptoms. Associations between recreational activity and depressive symptoms, the mostly frequently investigated physical activity domain, produced estimates close to the null in adjusted modeling. Women participating in perceived adult and child care MVPA had increased odds of having high depressive symptoms. Women participating in high amounts of indoor household activity had increased odds of having high depressive symptoms. Increased odds of elevated depressive symptoms were found with participation in more than median levels of non-elective MVPA for both perceived and absolute intensities.

There has been limited previous research into associations of physical activity with depression in pregnant populations. Most studies reported cross-sectional associations between physical activity and depressive symptoms or mood, failing to examine the longitudinal associations between physical activity and subsequent depression. Associations have been found with total or recreational activities and depressive symptoms and depressed mood among pregnant adolescents self-selected to participate in a trial in Los Angeles (Koniak-Griffin, 1994) and cross-sectional analysis of pregnant Canadian women (Da Costa et al, 2003), pregnant California women (Haas et al, 2004), pregnant African-American women in Baltimore (Orr et al, 2006), and pregnant women in Jamaica (Pottinger et al, 2009). In each study, active women were less likely to have depressive symptoms than inactive women; however, Pottinger et al. (2009) found decreased odds for occasional exercise, but not frequent exercise. Other studies have found primarily no associations between total or recreational physical activity and depressive symptoms (Goodwin et al, 2000; Poudevigne and O'Connor, 2005; Symons Downs et al, 2008).

Symons Downs et al. (2008) was the only previous study reporting on the association between physical activity during the second trimester and depressive symptoms during the third trimester. They found no association for leisure-time physical activity, which corresponds with our reported findings on the association between recreational MVPA and depressive symptoms. We also found increased odds of high depressive symptoms with adult and child care MVPA and indoor household MVPA. These tasks are associated with home-keeping. A study of pregnant Italian women found that being a housewife was associated with increased odds of minor depression as compared to being a student, unemployed, or employed (Marchesi et al, 2009). We found that higher levels of non-elective MVPA (participation in work, adult and child care, indoor household, outdoor household, and transportation activities) was associated with increased odds of developing elevated depressive symptoms. In comparison to recreational activities, these activities are not usually performed for enjoyment or electively and may be considered burdensome. Molarius et al. (2009) found that the odds of being moderately or extremely depressed or anxious increased as the more burdensome the participants rated their domestic work. Simply higher participation levels in housework may be considered burdensome for women, which may explain why women with those with low levels of both indoor and household MVPA have a slightly reduced odds of having elevated depressive symptoms while those with higher than median levels have increased odds.

Strengths and Limitations

There are some limitations in our study. First, self-report depression scales such as the CES-D measure depressive symptoms. Clinical assessment is needed to diagnose depression. However, clinical assessments in population studies are costly and timely. Depression screening tools are frequently used in depression research involving large samples. The CES-D is a commonly used, reliable, and valid measurement of depressive

symptoms that correlates well with clinical ratings (Radloff, 1997; Weissman et al, 1977). Overall, investigating depression during pregnancy is difficult. Self-reported screening tools tend to focus on somatic symptoms, including symptoms that overlap between pregnancy and depression, which makes determining depression status difficult in a pregnant population (Ryan et al, 2005; Brown and Solchany, 2004; Misri, 2007; Klein and Essex, 1994). To address this, we used a slightly higher threshold for high depressive symptoms than used in the general population. This cutpoint of 17 was compared to a method suggested by Hoffman and Hatch (2000) where the four scale items related to pregnancy are removed and the remaining items inflated so the scale range remains 0-60 and the 16 cutpoint is still used. The scores calculated by each method were highly correlated with each other (Pearson's r=0.98) and the women were largely categorized into the same binary depressive symptoms category (χ^2=849.64, p<0.0001). When these re-categorized depressive symptoms scores were used in modeling, they performed similarly to our original scoring method.

Determining if physical activity is a causal factor of elevated depressive symptoms is not possible in this study. We did not assess levels of depressive symptoms or diagnoses of depressive disorders for the pre-pregnancy period. Therefore, our case group is a mix of individuals with incident, recurrent, and persistent elevated symptoms. However, we did control for depressive symptoms at <20 weeks in all adjusted models. Furthermore, depression is not an acute condition; it is likely that it takes an extended period of time for physical activity to have an effect on depression. The physical activity and depressive symptoms measures in our study may be too close together in time; two weeks separated the end of the physical activity assessment and the start of the depressive symptoms assessment.

Physical activity assessment was more extensive than conducted in previous pregnancy studies. From self-reported data of frequency and duration of various activities

and compendium-established MET values, we were able to calculate activity levels of both perceived and absolute intensity and examine differences the associations with depressive symptoms by domain. Another concern is that the MET values used for determining absolute intensity are not specific to pregnant populations, and pregnancy increases a woman's resting metabolic rate by 15-20% (Clapp, 2002). Another concern is that physical activity was only assessed during the past week. Physical activity behavior can change from week to week and the reported values may not be representative of usual behavior.

Despite these limitations, there are several strengths of our study. It is a large, prospective cohort study that measured a variety of factors relevant to the health of pregnant women. The longitudinal design of the study allowed us to examine the association with earlier physical activity with later depressive symptoms. Reliable and valid assessment tools were used to measure physical activity (Evenson and Wen, 2010), depression (Radloff, 1977; Weissman et al, 1977; Husaini, 1980), and a number of the covariates (Sarason et al, 1978; Sherbourne and Stewart, 1991). The physical activity assessment was comprehensive- collecting data on duration, frequency, intensity, and domain. Previous research has only investigated leisure-time or total activity. Data collection was extensive which allowed for good control for confounders; however, as in any observational study, there may still be residual confounding.

F. Conclusion

This study investigates how the association between physical activity and depressive symptoms differs by domain of activity in a pregnant population. We found that participation in total MVPA reduces the odds of high depressive symptoms, but that participation in adult and child care MPVA and indoor household MVPA may heighten depressive symptoms rather than be beneficial. Future research should explore how the association between physical activity and depressive symptoms differs by domain. Furthermore, studies should

investigate differences in association by intensity of activity (perceived vs. absolute and including light activities vs. MPVA). There has been an increased focus on the potential for physical activity to serve as a non-drug treatment for depression as antidepressant use concerns both mother and health providers (Hammond and Crozier, 2007; Bowen and Muhajarine, 2006; Manber et al, 2002). Physical activity is a good candidate as it has minimal side effects, is cost-effective, and has been shown to be as effective as antidepressants and psychotherapy in non-pregnant populations (Daley et al, 2007; Dunn et al, 2005; Craft and Perna, 2004; Martinsen, 2008). Given adequate evidence from studies using pregnant populations, physical activity may be a useful treatment for depression.

Table 4.1. Selected characteristics of women enrolled in the third phase of the Pregnancy, Infection, and Nutrition Study with non-missing values for physical activity at 17-22 weeks' gestation and depression at 24-29 weeks' gestation overall and by depressive symptoms status (<17 score on the Center for Epidemiological Studies-Depression [CES-D] scale versus ≥ 17 score on the CES-D) (n=1220).

		CES-D		
	Total (n=1220) n (%)	**<17 (n=905) n (%)**	**≥ 17 (n=316) n (%)**	**χ^2 (p-value)**
Age (years)				34.27 (<.0001)
≤ 24	241 (20)	143 (16)	98 (31)	
25-29	373 (31)	289 (32)	84 (27)	
30-34	416 (34)	323 (36)	93 (29)	
35+	190 (16)	149 (16)	41 (13)	
Race[a]				11.47 (.0029)
White	895 (73)	686 (76)	209 (66)	
Black	202 (17)	134 (15)	68 (22)	
Other	122 (10)	83 (9)	39 (12)	
Marital status				58.27 (<.0001)
Married	945 (77)	749 (83)	196 (62)	
Single	231 (19)	131 (14)	100 (32)	
Widowed, Divorced, Separated	44 (4)	24 (3)	20 (6)	
Education (years)				103.79 (<0.0001)
≤12	225 (18)	117 (13)	108 (34)	
13-15	228 (19)	148 (16)	80 (25)	
16	361 (30)	291 (32)	70 (22)	
17+	406 (33)	348 (39)	58 (18)	
Working at time of first phone interview				13.77 (.0002)
Yes	381 (31)	256 (28)	125 (40)	
No	839 (69)	648 (72)	191 (60)	
Income (percent of the poverty line)[b]				44.34 (<.0001)
≤ 185	222 (19)	127 (14)	95 (32)	
>185	952 (81)	750 (86)	202 (68)	
Parity				14.20 (.0008)
0	678 (56)	524 (58)	154 (49)	
1	361 (30)	265 (29)	96 (30)	
2+	181 (15)	115 (13)	66 (21)	

Table 4.1. Concluded

	Total (n=1220) n (%)	CES-D <17 (n=905) n (%)	CES-D ≥ 17 (n=316) n (%)	χ^2 (p-value)
Pre-pregnancy body mass index (kg/m^2)[c]				28.92 (<.0001)
<19.8	169 (14)	139 (16)	30 (10)	
19.8-26	642 (53)	497 (56)	145 (46)	
>26-29	126 (10)	89 (10)	37 (12)	
>29	270 (22)	169 (19)	101 (32)	
Smoked at least once in first 6 mo pregnancy[d]				58.02 (<.0001)
Yes	126 (11)	59 (7)	67 (22)	
No	1052 (89)	821 (93)	231 (78)	

[a] Missing data on 1 woman
[b] Missing data on 46 women
[c] Missing data on 13 women
[d] Missing data on 42 women

Table 4.2. Odds ratios (OR) and 95% confidence intervals (CI) from logistic regression analysis of the association between total and domain-specific moderate-to-vigorous physical activity (MVPA) of somewhat hard and hard/very hard perceived intensity (hours/week) at 17-22 weeks' gestation and depressive symptoms at 24-29 weeks' gestation among women enrolled in the PIN3 Study (n=1077).[a]

		Crude Model		Final Adjusted Model	
	n (%)	**OR**	**95%CI**	**OR**	**95% CI**
Total MVPA (hrs/wk)[b]					
0	356 (33.1)	1.00	--	1.00	--
≤ median	370 (34.4)	0.52	0.37, 0.73	0.56	0.38, 0.83
> median	351 (32.6)	0.63	0.45, 0.88	0.73	0.50, 1.07
Work MVPA (hrs/wk)[c]					
0	967 (89.8)	1.00	--	1.00	--
≤ median	60 (5.6)	1.37	0.77, 2.42	1.47	0.76, 2.84
> median	50 (4.6)	1.95	1.08, 3.52	1.38	0.68, 2.78
Recreational MVPA (hrs/wk)[d]					
0	598 (55.5)	1.00	--	1.00	--
≤ median	271 (25.2)	0.72	0.51, 1.02	0.93	0.62, 1.38
> median	208 (19.3)	0.94	0.66, 1.35	1.29	0.85, 1.98
Adult and Child Care MVPA (hrs/wk)[e]					
0	914 (84.9)	1.00	--	1.00	--
≤ median	90 (8.4)	3.05	1.95, 4.75	1.84	1.08, 3.11
> median	73 (6.8)	2.54	1.55, 4.16	1.46	0.81, 2.61
Indoor Household MVPA (hrs/wk)[f]					
0	843 (78.3)	1.00	--	1.00	--
≤ median	128 (11.9)	1.15	0.74, 1.76	0.77	0.46, 1.28
> median	106 (9.8)	2.64	1.74, 4.00	1.63	0.98, 2.70

Table 4.2. Concluded.

		Crude Model		Final Adjusted Model	
	n (%)	**OR**	**95%CI**	**OR**	**95% CI**
Outdoor Household MVPA (hrs/wk)[b]					
0	1009 (93.7)	1.00	--	1.00	--
≤ median	42 (3.9)	0.95	0.46, 1.97	0.65	0.28, 1.49
> median	26 (2.4)	1.62	0.71, 3.67	2.08	0.83, 5.24
Transportation MVPA (hrs/wk)[b]					
0	979 (90.9)	1.00	--	1.00	--
≤ median	46 (4.3)	1.48	0.79, 2.79	1.19	0.57, 2.50
> median	52 (4.8)	0.92	0.47, 1.78	0.76	0.35, 1.62

[a] Median values for activity are: 2.67 (total), 1.49 (work), 2 (recreational), 2.25 (adult and child care), 1 (indoor household), 1.5 (outdoor household), 0.97 (transportation).
[b]Adjusted for depressive symptoms at <20 weeks' gestation.
[c]Adjusted for depressive symptoms at <20 weeks' gestation, social support.
[d]Adjusted for depressive symptoms at <20 weeks' gestation, social support, body mass index, smoking.
[e]Adjusted for depressive symptoms at <20 weeks' gestation, negative life events.
[f]Adjusted for depressive symptoms at <20 weeks' gestation, social support, negative life events, smoking.

Table 4.3. Odds ratios (OR) and 95% confidence intervals (CI) from logistic regression analysis of the association between total and domain-specific physical activity of absolute moderate and vigorous intensity (MET-hours/week) at 17-22 weeks' gestation and depressive symptoms at 24-29 weeks gestation' among women enrolled in the PIN3 Study (n=1077).[a]

		Crude Model		Final Adjusted Model	
	n (%)	OR	95%CI	OR	95% CI
Total MVPA (MET-hrs/wk)[b]					
0	640 (59.4)	1.00	--	1.00	--
≤ median	224 (20.8)	0.76	0.48, 1.19	0.71	0.42, 1.18
> median	213 (19.8)	1.14	0.80, 1.63	0.69	0.46, 1.06
Work MVPA (MET-hrs/wk)[b]					
0	991 (92.0)	1.00	--	1.00	--
≤ median	48 (4.5)	0.51	0.23, 1.15	0.65	0.26, 1.63
> median	38 (3.5)	1.38	0.68, 2.77	1.76	0.79, 3.90
Recreational MVPA (MET-hrs/wk)[b]					
0	808 (75.0)	1.00	--	1.00	--
≤ median	146 (13.6)	0.65	0.42, 1.01	1.20	0.73, 1.98
> median	123 (11.4)	0.42	0.25, 0.72	0.91	0.50, 1.63
Adult and Child Care MVPA (MET-hrs/wk)[c]					
0	1045 (97.0)	1.00	--	1.00	--
> 0	32 (3.0)	0.69	0.20, 2.44	0.44	0.15, 1.30
Indoor Household MVPA (MET-hrs/wk)[d]					
0	998 (92.7)	1.00	--	--	--
≤ median	46 (4.3)	0.87	0.43, 1.78	0.86	0.38, 1.94
> median	33 (3.1)	2.94	1.46, 5.91	3.00	1.34, 6.72
Outdoor Household MVPA (MET-hrs/wk)[d]					
0	1030 (95.6)	1.00	--	--	--
≤ median	26 (2.4)	0.93	0.37, 2.33	0.67	0.23, 1.95
> median	21 (2.0)	2.81	1.18, 6.68	2.44	0.88, 6.75

[a] Median values for activity are: 9 (total), 4 (work), 10.5 (recreational), 6 (indoor household), 5.5 (outdoor household).
[b]Adjusted for depressive symptoms at <20 weeks' gestation, education.
[c]Adjusted for depressive symptoms at <20 weeks' gestation, social support, smoking.
[d]Adjusted for depressive symptoms at <20 weeks' gestation.

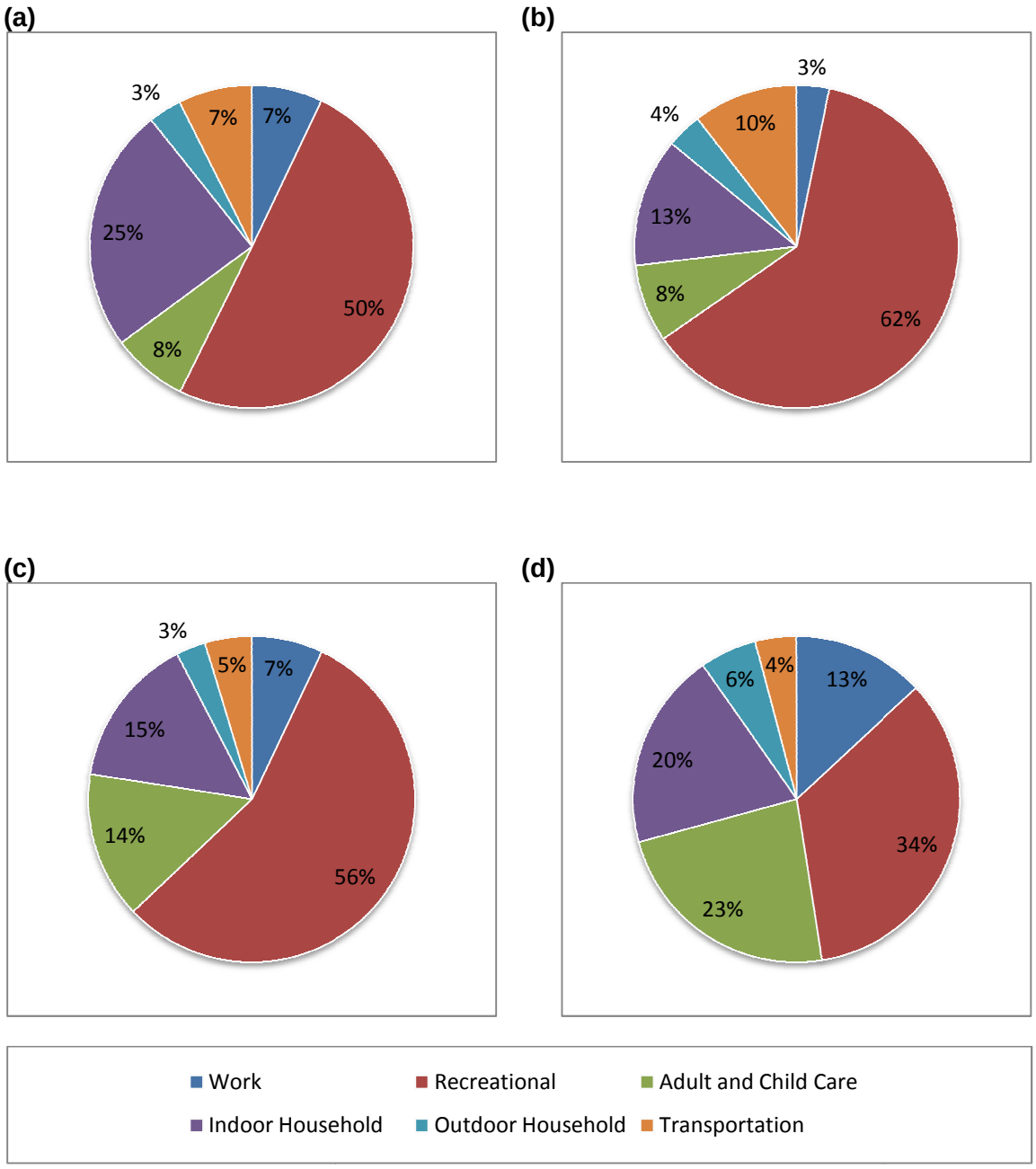

FIGURE 4.1. Percentages of domain-specific moderate-to-vigorous physical activity (MVPA) in hours/week at 17-22 weeks' gestation by quartile of total MVPA among women enrolled in the third phase of the Pregnancy, Infection, and Nutrition Study with any MVPA. (a) 1st quartile n=203, range 0.03-1.17 (b) 2nd quartile n=202, range 1.23-2.53 (c) 3rd quartile n=206, range 2.57-5 (d) 4th quartile n=200, range 5.07-63.

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CHAPTER V

MANUSCRIPT 2: PHYSICAL ACTIVITY DURING PREGNANCY AND POSTPARTUM DEPRESSIVE SYMPTOMS

A. Abstract

Mothers who are physically active during pregnancy may have lower levels of depressive symptoms during the postpartum period, but few studies have been conducted and none have looked at differences by domain of activity. We examined the associations between total and domain-specific (work, recreational, adult and child care, indoor and outdoor household, transportation) moderate-to-vigorous physical activity (MVPA) during pregnancy and postpartum depressive symptoms. Data were obtained from 652 women who participated in the Pregnancy, Infection, and Nutrition (PIN) Postpartum Study. MVPA measured at 17-22 and 27-30 weeks' gestation was investigated as a predictor of depressive symptoms assessed with the Edinburgh Postnatal Depression Scale at 3 months postpartum**.** Total MVPA was not associated with depressive symptoms when using either 17-22 or 27-30 weeks' gestation MVPA measures. In general, there were minimal associations for domain-specific MVPA. Differences across time were found for work, adult and child care, and outdoor household MVPAs. The association between physical activity and postpartum depressive symptoms may differ with the timing of assessment. Additional studies following women throughout pregnancy and postpartum are needed to explore differences in the influence of physical activity on depressive symptoms.

B. Introduction

Physical activity is a major component to living a healthy life, influencing mortality, disability, physical and mental health, and health behaviors. It is estimated that physical inactivity is responsible for 1.9 million deaths worldwide (World Health Organization [WHO], 2002). Being physically active reduces the risk of premature death (Warburton et al, 2006; WHO, 2003; United States Department of Health and Human Services [U.S. DHHS], 2008) and many chronic diseases (U.S. DHHS, 2008; WHO, 2003; Warburton et al, 2006; Chen and Millar, 1999) and promotes better psychological health (WHO, 2003; Warburton et al, 2006; Chen and Millar, 1999).

The US DHHS recommends that adults perform a minimum 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity a week (U.S. DHHS, 2008). It is recommended that pregnant women who are not regularly active or who engage in low intensity activity participate in at least 150 minutes/week of moderate-intensity activity while women who are highly active can continue at their pre-pregnancy activity levels (U.S. DHHS, 2008). Though there is consistent evidence that physical activity during pregnancy benefits the mental and physical health of the mother and fetus (U.S. DHHS, 2008; Pivarnik et al, 2006; Vladutiu et al, In Press), a national study found that pregnant women are less likely to meet physical activity recommendations than non-pregnant women (Evenson et al, 2004).

Studies have shown there is a positive benefit of physical activity on depression for both patient and non-patient populations, and the benefits may be long-lasting (Teychenne et al, 2008; Biddle, 1995; Craft and Perna, 2004). Women are at increased risk of developing depression during the childbearing years (Burke et al, 1991; Weissman et al, 1993), and the postpartum period is a particularly vulnerable time period (Vesga-Lopez et al, 2008; Dietz et al, 2007; Munk-Olsen et al, 2006; Eberhard-Gran et al, 2003; O'Hara et al, 1990). Postpartum depression negatively impacts the maternal health and behavior, child

outcomes, maternal-infant interactions, and the father's mental health (Marcus, 2009; Lusskin et al, 2007; Lee and Chung, 2007; Logsdon et al, 2006).

Only five studies have investigated the association between physical activity during pregnancy and postpartum depressive symptoms, and all but one suggested that physical activity during pregnancy individually is related to lower levels of postpartum depressive symptoms (Nordhagen and Sundgot-Borgen, 2002; Abraham et al, 2001; Symons Downs et al, 2008). Ersek and Brunner Huber (2009) did not find a significant association between physical activity during pregnancy and postpartum depressive symptoms. No studies have investigated the role of physical activity domain in the development of depressive symptoms among postpartum women. The objective of this investigation was to determine the association between total and domain-specific moderate-to-vigorous physical activity (MVPA) at two time points during pregnancy and postpartum depressive symptoms in a prospective cohort of women followed from pregnancy to postpartum.

C. Methods

1. Participants

This investigation reports on participants in the Pregnancy, Infection, and Nutrition (PIN) Postpartum Study, a prospective cohort of postpartum women originally enrolled in the third phase of the PIN (PIN3) Study while they were pregnant. Data from both the prenatal and postpartum components are used in this analysis. The PIN3 study recruited 2006 women from prenatal clinics at UNC Hospitals in Chapel Hill, NC if they were at less than or equal to 20 weeks' gestation between January 2001 and June 2005. To be eligible for PIN Postpartum recruitment, mothers had to have delivered live-born infants between October 2002 and December 2005 and lived in the study's catchment area (in order to conduct home visits). Out of the 2006 expectant mothers recruited into the PIN3 Study, 1169 women were eligible, 938 women were invited to participate in the study, and 688 women had usable

data from a 3-month home interview. Additional information regarding the PIN3 Study and attrition from PIN3 to the PIN Postpartum Study is available elsewhere (Siega-Riz et al, 2009).

Comparing the 688 women included at 3 months postpartum with the 481 (1169-688) women that were eligible for the PIN Postpartum Study but did not participate, participating women were older (29.4 vs. 28.7 years old, p=0.02), more educated (15.8 vs. 15.2 years, p=0.0002), more affluent (423.4% vs. 390.3% of the poverty level, p=0.02), more likely to be married (χ^2=21.2, p<0.0001), more likely to be of White race (χ^2=20.9, p<0.0001), had lower body mass index (25.4 vs. 26.4 kg/m^2, p=0.01), and had lower depressive symptoms at both <20 weeks (11.1 vs. 12.6 Center for Epidemiologic Studies- Depression [CES-D] score, p=0.02) and 24-29 weeks' gestation (11.2 vs. 12.6 CES-D score, p=0.03). The overall distributions of total MVPA at 17-22 and 27-30 weeks' gestation did not differ between the groups of women. The same comparisons were made between the 688 participating women and the 250 (938-688) women who were invited to participate but declined; there were no differences for any of the above-reported measures.

2. Procedures

Potential participants for PIN3 were identified through medical chart reviews of new prenatal patients at the UNC Hospitals and written consent was obtained from each woman. Women were asked to participate in two research clinic visits (at <20 and 24-29 weeks' gestation), two telephone interviews (at 17-22 and 27-30 weeks' gestation), and two self-administered questionnaires which were given at each of the clinic visits and mailed back to study staff. Most psychosocial factors were assessed on the self-administered questionnaires. During the telephone interviews, general health, additional psychosocial measures, sociodemographic information, occupational information, physical activity, reproductive history, and health behaviors were assessed. Delivery logs and medical charts

were abstracted after delivery to obtain information on pregnancy complications and outcomes. Those eligible for PIN Postpartum who agreed to be contacted after delivery where phoned for recruitment purposes and written consent was obtained from those that participated in the 3-month home interview. Women were asked about demographics, occupation, physical activity, and other measures and anthropometrics were collected. The Institutional Review Board of the UNC School of Medicine reviewed and approved the study protocols.

3. Physical activity assessment

Women were asked to recall past week physical activity during the two telephone interviews at 17-22 and 27-30 weeks' gestation utilizing a structured instrument with documented validity and reliability (Evenson and Wen, 2010). Assessments of occupational, recreational, household, child and adult care, and transportation activity were performed at each time point. Frequency, duration, and intensity of each activity type were determined. For each type of activity, women were asked if they participated in activity that resulted in at least some increase in breathing and heart rate. If so, women were asked to list all the domain-specific activities they performed. Subsequently, they were asked to report the number of sessions, average duration per session, and perceived intensity level of each activity type. Perceived intensity was assessed based on the Borg scale- fairly light, somewhat hard, and hard or very hard (Borg and Linderholm, 1974). Self-reported activities that were "fairly light" corresponded with light activity, "somewhat hard" corresponded to moderate activity, and "hard or very hard" corresponded to vigorous activity (Pollock et al, 1998).

Physical activity for this analysis was characterized in hours/week, calculated by multiplying the number of times a participant reported an activity by the number of hours she reported, focusing only on activities reported as "somewhat hard" or "hard or very hard."

Hours per week of activity was then aggregated by intensity and domain. The exposures of interest for this analysis are total and all domain-specific MVPA of perceived intensity at 17-22 and 27-30 weeks' gestation.

4. Depression assessment at 3 months postpartum

The Edinburgh Postnatal Depression Scale (EPDS) (Cox et al, 1987) was used to assess postpartum depressive symptoms. The EPDS is a 10-item postpartum depression screening questionnaire that has been used extensively in research. The scale assesses the woman's mood during the past week using 4-point response categories. A composite score was calculated by summing across items, some of which required reverse-coding. A threshold score of 12 has been shown to indicate depression of various severities and persons needing further assessment (Cox et al, 1987). Therefore, a score of 13+ was considered as having significant depressive symptoms.

5. Covariates

Factors found to be associated with both physical activity and depression in previous research and factors adjusted for in previous analyses were considered potential confounders. This includes sociodemographic variables such as age at pregnancy (< 25, 25-29, 30-34, and 35+ years), race (White, Black, or other), marital status during pregnancy (married or unmarried), education (≤12, 13-16, and 17+), employment status at either 17-22 weeks or 27-30 weeks' gestation (yes, no), and poverty status during pregnancy (≤185% or >185% of the poverty line). The cutpoint of 185% is the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) income guideline cutpoint (U.S. Department of Agriculture, 2009). Health indicators included were: parity before this birth (0, 1, or 2+), pre-pregnancy body mass index (Institute of Medicine, 1990 categories: <19.8, 19.8-26, >26-29, >29) based on height and weight reported at recruitment, general health

status at 17-22 weeks' gestation (poor/fair, good, and very good/excellent), vaginal bleeding (any or none), gestational diabetes (indicated in medical chart or not), and smoking status for the first six months of pregnancy (any smoker or nonsmoker). Sleep quality at 24-29 weeks' gestation (fair/poor, good/excellent) was also investigated as a potential confounder when investigating physical activity at 27-30 weeks' gestation.

Psychosocial factors include number of negative life events and social support. Life events were assessed at 17-22 and 24-29 weeks' gestation with the Life Experiences Survey (LES) which examines both acute and chronic life stresses (Sarason et al, 1978). It provides a composite score of life events and the impact of those events. Women are asked if events occurred since the start of pregnancy and, if so, they are asked to report the impact of each item as having a positive (+1 to +3), negative (-1 to -3), or no impact (0). The LES was modified by eliminating the item asking whether the respondent experienced a pregnancy, and combining husband and boyfriend (details of marital status, cohabitation, and relation with the father of the baby are obtained elsewhere), resulting in 39 items from the original 57 in the LES. The composite score of the impact of negative events was examined as a covariate and was categorized as 0- <1, 1-<4, and 4+. Social support was assessed at <20 weeks' gestation with the Medical Outcomes Study Social Support Scale which assesses the availability of perceived social support in four categories (Sherbourne and Stewart, 1991). It uses a five-category Likert response for 19 items. The overall score was used as a covariate and was categorized as 0- <78, 78- <89, and 89+. Partner support (a lot, some, not much/none) was assessed at 27-30 weeks' gestation with a single item about the amount of emotional support the woman receives from the man acting as the child's father was considered a covariate with physical activity at 27-30 weeks' gestation.

It was determined *a priori* that recent depressive symptoms would be included as a covariate in the final models as antepartum depression is a strong risk factor for postpartum depression (Lusskin et al, 2007) and depressed individuals are less likely to be active

(Egede et al, 2009). The Center for Epidemiological Studies-Depression (CES-D) Scale (Radloff 1977) was used to assess depression during pregnancy at <20 and 24-29 weeks' gestation. The scale measures depressive symptoms, particularly depressed mood in the general population. The CES-D is a 20-item, structured self-administered questionnaire. Each response was given a score of 0 to 3. A composite score is calculated summing responses and the score ranges from 0 to 60. A variety of cutoff scores have shown associations with a clinical diagnosis of depression, with a score of 16+ suggested as an appropriate positive screen for depression (Gaynes et al. 2005; Radloff 1977). In this analysis, a cutoff of 17 was used as CES-D scores for pregnant women may be higher due to overlap between depressive and pregnancy symptoms (Hoffman and Hatch 2000; Orr and Miller 1995; Klein and Essex 1994/1995). Depressive symptoms at <20 weeks was included as a covariate with 17-22 weeks' gestation physical activity and depressive symptoms at 24-29 was included as a covariate with 27-30 weeks' gestation physical activity.

6. Data analysis

Analyses were performed using version 9.1 of the SAS statistical software (SAS Institute Inc, Cary, NC) and STATA 11 (StataCorp, College Station, TX). Univariate analysis was conducted to describe sample characteristics of potential covariates and physical activity. A factor was considered a confounder if it was associated with both physical activity and depressive symptoms at 3-month interview (using Chi-square analysis) and changed the estimate of the association by ≥10% in the modeling stage using a backwards approach (Rothman and Greenland, 1998). Fisher's exact test p-values were reported for Chi-square analysis when appropriate. Chi-square analysis and the Fisher's exact test were also used to compare MVPA by depressive symptoms. Exact logistic regression modeling was utilized to calculate odds ratios (ORs) and 95% confidence intervals (CIs). Regression models were

calculated using 529 women who had complete data for exposures, outcome, and covariates (36 women were missing pregnancy physical activity data and 123 women were missing covariate data). MVPA was dichotomously coded (none, any) for analysis.

D. Results

1. Sample characteristics

Among the 652 mothers participating in the PIN Postpartum Study at 3 months postpartum in this sample, only 43 (7%) reported having elevated depressive symptoms. Scores ranged from 0 to 25 and the median score was 5. Among these women, the majority (78%) were White, 14% were Black, and 9% were of another race. Almost two-thirds (63%) of the women were at least 30 years of age; only 15% were less than 25 years of age. The majority of the women enrolled in this study were highly educated (86% attended college) and married (83%). Approximately half of the women were working at 3 months postpartum (52%), had given birth to their first child (49%), and were of normal BMI at 3 months postpartum (50%). A quarter of the women had incomes that met the WIC eligibility criteria. Only 8% of the women had smoked at least once since giving birth. Overall statistics and differences in postpartum characteristics by depressive symptoms status are found in Table 5.1. Those with high depressive symptoms were more likely to be younger, Black or of other race, unmarried, less educated, of lower income, and smokers.

About one-third (31%) of the mothers in this sample did not participate in any MVPA at 17-22 weeks' gestation according to their perceived intensities. The median of total MVPA in hours/week was 1 (with an interquartile range [IQR] of 0-1). The median value for all domain-specific values of MVPA was 0. Women were most likely to participate in recreational activity, which represented 53% of their activity on average, and least likely to participate in outdoor household activity (3%). At 27-30 weeks' gestation, 37% of the mothers did not participate in any MVPA and the median and IQR values were the same. At

this time, women were still spending most of their MVPA time doing recreational activities (43%) and were spending the least amount of time in transportation (6%).

Physical activity levels during pregnancy differed by postpartum depressive symptoms status. At 17-22 weeks' gestation, women with high depressive symptoms spent a lower mean proportion of their total MVPA at work (8% vs. 1%, $p<0.001$) and in transportation (1% vs. 7%) and greater mean proportions of time in the indoor household (30% vs. 15%, $p=0.01$) and outdoor household (1% vs. 3%, $p=0.01$) domains than women with low levels of depressive symptoms. At 27-30 weeks' gestation, women with high depressive symptoms spent less time doing recreational (25% vs. 44%, $p=0.03$) and outdoor household (2% vs. 6%) activities than women with low levels of depressive symptoms. A full graphical comparison of mean proportions of time spent in each domain by depressive symptoms status is presented in Figure 5.1 for both time points. Results of Chi-square analysis of dichotomous MVPA by depressive symptoms status is presented in Table 5.2. There were differences by depressive symptoms in indoor household MVPA at 17-22 weeks' gestation and adult and child care MVPA at 27-30 weeks' gestation.

2. Physical activity associations with depressive symptoms

Results from crude and adjusted regression models of the associations between MVPA, measured in hours/week, at 17-22 weeks' gestation and depressive symptoms at 3 months postpartum are presented in Table 5.3. Most of the associations produced estimates close to the null: total, adult and child care, indoor household, and transportation MVPAs. Women participating in recreational MVPA had a small decrease in the odds of having depressive symptoms at 3 months postpartum and women participating in outdoor household MVPA had a small increase in the odds of being depressed at 3 months postpartum. The strongest association with 3-month depressive symptoms was work MVPA which conferred an 86% reduction in the odds (OR=0.14, 95% CI=0.01, 1.17).

Results from crude and adjusted regression models of the associations between MVPA, measured in hours/week, at 27-30 weeks' gestation and depressive symptoms at 3 months postpartum are presented in Table 5.4. Most of the associations were similar to those found for 17-22 weeks' gestation MVPA. However, reverse directions of associations were found for work, adult and child care, and outdoor household MVPAs. Participation in work and adult and child care MVPA was associated with an increase in the odds of having high depressive symptoms at 3 months postpartum. Women participating in outdoor household MVPA had lower odds of having elevated 3-month postpartum symptoms. The biggest variation between the two assessments was for work MVPA which, at 27-30 weeks' gestation, was associated with a 1.47 (95% CI= 0.50, 4.33) increase in the odds of postpartum depressive symptoms.

The interpretation of the results from both time points did not differ substantially upon adjusting additionally for all other domains of physical activity. The OR for outdoor household MVPA at 17-22 weeks' gestation did change by more than 20%, but was at the null (OR=1.00, 95% CI=0.24, 4.10).

E. Discussion

In this sample of 529 women followed prospectively from pregnancy to postpartum, no significant associations were found between total or domain-specific MVPA at either 17-22 or 27-30 weeks' gestation and postpartum depressive symptoms. Most estimates of the associations were similar across the two physical activity assessments, but differences across time existed for work, adult and child care, and outdoor household MVPA.

We found no significant associations between physical activity and depressive symptoms while the four previously conducted cohort studies have each suggested that physical activity during pregnancy may have some benefit for depressive symptoms (Nordhagen and Sundgot-Borgen, 2002; Abraham et al, 2001; Symons Downs et al, 2008;

Ersek and Brunner Huber, 2009). All the studies looked at the association between third trimester physical activity and postpartum depressive symptoms and only Nordhagen and Sundgot-Borgen (2002) found significant associations with either exercise or total physical activity. Abraham et al (2001) found less depressive symptoms among women who exercised during months 3-4 of pregnancy, but not during months 6-7. Symons Downs et al (2008) found that a cumulative index of pregnancy exercise (combining behavior from all three trimesters) indicated that women participating in more activity experienced lower depressive symptoms at 6 weeks postpartum than less active women, but no association with third trimester activity alone. Ersek and Brunner Huber (2009) did not find a significant association between physical activity during the last trimester of pregnancy and postpartum depressive symptoms among women who had given birth in the last 2 to 6 months, but found that being active both before and during pregnancy was associated with reduced odds of feeling depressed. The latter three studies correspond with our findings of no association between MVPA at 27-30 weeks' gestation and 3-month depressive symptoms.

The variation in physical activity and depression assessments makes it somewhat difficult to compare results across studies. Abraham et al (2001) assessed if participants participated in low-intensity exercise as a means of controlling weight or shape. They included exercise measurements at pre-pregnancy, 3-4 months in pregnancy, and 6-7 months in pregnancy simultaneously in a model predicting postpartum depressive symptoms at 1 week postpartum; only the 3-4 month measure was associated with symptoms. Ersek and Brunner Huber (2009) found a benefit of physical activity performed pre-pregnancy and during last 3 months of pregnancy on depressive symptoms over 2-6 months postpartum. Both Nordhagen and Sundgot-Borgen (2002) and Symons Downs et al (2008) looked at the association between third trimester physical activity and depressive symptoms at 6 weeks postpartum. The former found an association with total physical activity, while the latter did not with exercise. Perhaps why we found no association between physical activity and

postpartum depressive symptoms is because we assessed depressive symptoms at 3 months postpartum or because it is important to assess physical activity over the entire length of the pregnancy and perhaps even obtain pre-pregnancy levels.

Limitations and Strengths

The results of this study must be considered along with its limitations. First, the EPDS is a self-report scale that assesses depressed mood and symptoms, not a diagnosis of depression; depression can only be diagnosed through clinical assessment. However, performing clinical assessments on participants in population studies is costly and timely; therefore, depression screening tools are frequently used in research studies. The EPDS has been determined to have satisfactory sensitivity, specificity, and positive predictive value (PPV) (Cox et al, 1987; Gaynes et al, 2005). The EPDS was designed with the purpose of identifying women who are depressed after childbirth and it is a widely utilized screening tool for assessing postpartum depressive symptoms (Cox et al, 1987; Gaynes et al, 2005; Pogany and Petersen 2007).

Physical activity measurement also relied on a self-report tool which can result in recall issues. However, since the assessment asked about the past week, recall issues may be limited. The questionnaire asked women to consider the frequency, duration, and intensity of all forms of physical activity by domain. This framework may contribute to better recall. Self-report methods are frequently used to assess physical activity and have been determined to be an acceptable method to assess physical activity with a number of advantages (Dale et al, 2002). Another concern is that physical activity was only assessed during the past week. Physical activity behavior can change from week to week and the reported values may not be representative of usual behavior. This may be an important consideration for the early postpartum since women are likely developing new daily routines.

Precision was of concern in this study. The reporting of elevated depressive symptoms was low in this sample (7%). Many women also reported no MVPA overall (31% at 17-22 weeks and 37% at 27-30 weeks' gestation) and by the different domains, and the variation in levels of activity was low. This resulted in wide confidence intervals for the regression analysis. The confidence limit ratios for the adjusted odds ratios ranged from 4.72 (recreational MVPA at 17-22 weeks' gestation) to 83 (outdoor household MVPA at 27-30 weeks' gestation).

Generalizability of the results may be an issue as this sample was comprised of mostly White, educated, married, and financially stable women. One possible mechanism of physical activity's effect on depression is that it serves as a distraction from life stressors (North et al, 1990; Craft and Perna, 2004). It is possible that the contribution of physical activity to the development of depressive symptoms may differ among women of different profiles, such as disadvantaged women with different or elevated amount of stressors. The association may also differ for women from different cultures, as the benefits and burdens of physical activity may be perceived differently. When comparing the women who participated in the PIN Postpartum Study to the women considered eligible and invited to participate in the study, the women did not differ in regards to any socio-demographic variables or MVPA levels at either 17-22 or 27-30 weeks' gestation. Heckman modeling (Heckman, 1978; Heckman, 1979) was used to determine if there was selection bias in our final model sample as compared to the women eligible for the PIN Postpartum Study. No substantial bias was found.

Despite the limitations discussed, there are also several strengths to this investigation. The prospective cohort design of the PIN Postpartum Study provided us with the opportunity to examine if the association with physical activity during pregnancy and postpartum depressive symptoms differed by the timing of the physical activity assessment, which were found in this investigation. The length of time between exposure and outcome is

over 3 months. This is beneficial for an investigation of depression since it is a chronic condition and length of exposure might need to be considerable to have an impact. Data collection was extensive; a variety of factors related to the health of new mothers were assessed. This enabled us to control for a number of potential confounders, however, there is still the possibility of residual confounding. Another strength is that both physical activity and depressive symptoms were assessed using reliable and valid assessment tools (Evenson & Wen, 2010; Cox et al, 1987; Gaynes et al, 2005). The physical activity assessment was comprehensive- collecting data on duration, frequency, intensity, and domain. Previous studies of the association between physical activity during pregnancy and postpartum depressive symptoms have either only assessed total activity or exercise.

F. Conclusion

We investigated the associations between total and domain-specific MVPA at two times during pregnancy and 3-month postpartum depressive symptoms. No significant associations were found for either time point, but a substantial decrease in the odds was found for work MVPA at 17-22 weeks' gestation and postpartum depressive symptoms. Most of the associations were similar across time, but reverse direction of associations were found for work, adult and child care, and outdoor household MVPAs. Previous research has produced mixed results of the association between pregnancy physical activity and postpartum depressive symptoms depending on both the physical activity and depressive symptom assessment used. The research on this area is still in its infancy. More research is needed to examine the impact of physical activity before and throughout pregnancy on depressive symptoms at different times in the postpartum period so that results can be better compared and contrasted. Future studies examining associations between physical activity and postpartum depression should not only report on total and recreational physical activity, but explore the impact of being active in other domains.

Table 5.1. Postpartum characteristics of women enrolled in the postpartum phase of the Pregnancy, Infection, and Nutrition Study with physical activity data from pregnancy and the 3-month home interview depressive symptoms status (<13 score on the Edinburgh Postnatal Depression Scale [EPDS] scale versus ≥ 13 score on the EPDS) (n=652).

		EPDS		
	Total	**< 13 (n=609)**	**≥ 13 (n=43)**	
	n (%)	**n (%)**	**n (%)**	**χ^2 (p-value)**
Age (years)				17.26 (.0006)
< 25	95 (15)	80 (13)	15 (35)	
25-29	149 (23)	138 (23)	11 (26)	
30-34	240 (37)	229 (38)	11 (26)	
35+	168 (26)	162 (27)	6 (7)	
Race				11.04 (.0040)
White	507 (78)	480 (79)	27 (63)	
Black	88 (14)	75 (12)	13 (30)	
Other	57 (9)	54 (9)	3 (7)	
Marital status				8.30 (.0040)
Married	543 (83)	514 (84)	29 (67)	
Unmarried	109 (17)	95 (16)	14 (33)	
Education (years)				
≤12	95 (15)	78 (13)	17 (40)	23.78 (<.0001)
13-16	311 (48)	294 (48)	17 (40)	
17+	246 (38)	237 (39)	9 (21)	
Working*				0.24 (.6390)
Yes	342 (52)	321 (53)	21 (49)	
No	310 (48)	288 (47)	22 (51)	
Income (percent of the poverty line)*[a]				9.37 (.0052)
≤ 185	160 (25)	141 (23)	19 (44)	
>185	487 (75)	463 (77)	24 (56)	
Parity				0.85 (.6530)
1	321 (49)	301 (49)	20 (47)	
2	227 (35)	213 (35)	14 (33)	
3+	104 (16)	95 (16)	9 (21)	
Body mass index (kg/m^2)[b]				3.49 (.3220)
<19.8	28 (4)	28 (5)	0 (0)	
19.8-26	328 (50)	307 (51)	21 (49)	
>26-29	110 (17)	104 (17)	6 (14)	
>29	185 (28)	169 (28)	16 (37)	
Smoking*				14.11 (.0013)
Yes	53 (8)	43 (7)	10 (23)	
No	599 (92)	566 (93)	33 (77)	

* Fisher's Exact Test p-value reported
[a] Missing data on 5 women
[b] Missing data on 1 woman

Table 5.2. Frequencies and Chi-square statistics (with Fisher's Exact p-values) of moderate-to-vigorous physical activity (MVPA) during pregnancy by depressive symptoms status (<13 score on the Edinburgh Postnatal Depression Scale [EPDS] scale versus ≥ 13 score on the EPDS) among women enrolled in the postpartum phase of the Pregnancy, Infection, and Nutrition Study (n=652).

		EPDS		
	Total	**< 13 (n=609)**	**≥ 13 (n=43)**	
	n (%)	**n (%)**	**n (%)**	**χ^2 (p-value)**
17-22 weeks' gestation				
Total MVPA				0.25 (.6197)
None	220 (34)	204 (34)	16 (37)	
Any	432 (66)	405 (67)	27 (63)	
Work MVPA				3.48 (.0734)
None	581 (89)	539 (89)	42 (98)	
Any	71 (11)	70 (11)	1 (2)	
Recreational MVPA				1.41 (.2674)
None	368 (56)	340 (56)	28 (65)	
Any	284 (44)	269 (44)	15 (35)	
Adult and Child Care MVPA				1.57 (.2049)
None	545 (84)	512 (84)	33 (77)	
Any	107 (16)	97 (16)	10 (23)	
Indoor Household MVPA				4.86 (.0443)
None	524 (80)	495 (81)	29 (67)	
Any	128 (20)	114 (19)	14 (33)	
Outdoor Household MVPA				1.13 (.2958)
None	615 (94)	576 (95)	39 (91)	
Any	37 (6)	33 (5)	4 (9)	
Transportation MVPA				0.06 (1.0000)
None	600 (92)	560 (92)	40 (93)	
Any	52 (8)	49 (8)	3 (7)	
27-30 weeks' gestation				
Total MVPA				0.11 (.8706)
None	243 (37)	228 (37)	15 (35)	
Any	409 (63)	381 (63)	28 (65)	
Work MVPA				0.55 (.4412)
None	583 (89)	546 (90)	37 (86)	
Any	69 (11)	63 (10)	6 (14)	
Recreational MVPA				1.37 (.3244)
None	416 (64)	385 (63)	31 (72)	
Any	236 (36)	224 (37)	12 (28)	
Adult and Child Care MVPA				4.48 (.0434)
None	557 (85)	525 (86)	32 (74)	
Any	95 (15)	84 (14)	11 (26)	

Table 5.2. Concluded.

	Total	EPDS		
		< 13 (n=609)	≥ 13 (n=43)	
	n (%)	n (%)	n (%)	χ^2 (p-value)
Indoor Household MVPA				3.45 (.0907)
None	500 (77)	472 (78)	28 (65)	
Any	152 (23)	137 (23)	15 (35)	
Outdoor Household MVPA				1.64 (.3540)
None	605 (93)	563 (92)	42 (98)	
Any	47 (7)	46 (8)	1 (2)	
Transportation MVPA				0.14 (.7661)
None	601 (92)	562 (92)	39 (91)	
Any	51 (8)	47 (8)	4 (9)	

Table 5.3. Odds ratios (OR) and 95% confidence intervals (CI) from logistic regression analysis of the association between total and domain-specific physical activity of somewhat hard and hard/very hard perceived intensity (hours/week) at 17 to 22 weeks' gestation and depressive symptoms at 3 months postpartum among women enrolled in the PIN Postpartum Study (n=529).

		Crude Model		Final Adjusted Model	
	n	**OR**	**95% CI**	**OR**	**95% CI**
Total Activity (hrs/wk)[a]					
None	164	1.00	--	1.00	--
Any	365	1.46	0.50, 2.90	1.07	0.46, 2.46
Work Activity (hrs/wk)[b]					
None	478	1.00	--	1.00	--
Any	51	0.29	0.01, 1.82	0.14	0.02, 1.17
Recreational Activity (hrs/wk)[a]					
None	280	1.00	--	1.00	--
Any	249	0.66	0.30, 1.46	0.84	0.39,1.84
Adult and Child Care Activity (hrs/wk)[c]					
None	437	1.00	--	1.00	--
Any	92	2.32	0.95, 5.85	0.90	0.36, 2.26
Indoor Household Activity (hrs/wk)[d]					
None	428	1.00	--	1.00	--
Any	101	2.35	0.99, 5.81	1.19	0.49, 2.88
Outdoor Household Activity (hrs/wk)[e]					
None	494	1.00	--	1.00	--
Any	35	2.12	0.52, 7.05	1.25	0.34, 4.58
Transportation Activity (hrs/wk)[f]					
None	483	1.00	--	1.00	--
Any	46	1.09	0.21, 4.07	0.95	0.26, 3.51

[a]Adjusted for depressive symptoms at <20 weeks' gestation.
[b]Adjusted for depressive symptoms at <20 weeks' gestation, smoking.
[c]Adjusted for depressive symptoms at <20 weeks' gestation, education, life events at 17-22 weeks' gestation.
[d]Adjusted for depressive symptoms at <20 weeks' gestation, education, marital status, health status at 17-22 weeks' gestation.
[e]Adjusted for depressive symptoms at <20 weeks' gestation, education, poverty.
[f]Adjusted for depressive symptoms at <20 weeks' gestation, life events at 17-22 weeks' gestation.

Table 5.4. Odds ratios (OR) and 95% confidence intervals (CI) from logistic regression analysis of the association between total and domain-specific physical activity of somewhat hard and hard/very hard perceived intensity (hours/week) at 27 to 30 weeks' gestation and depressive symptoms at 3 months postpartum among women enrolled in the PIN Postpartum Study (n=529).

		Crude Model		Final Adjusted Model	
	n	OR	95% CI	OR	95% CI
Total Activity (hrs/wk)[a]					
None	195	1.00	--	1.00	--
Any	334	1.31	0.58, 3.31	1.02	0.45, 2.32
Work Activity (hrs/wk)[b]					
None	475	1.00	--	1.00	--
Any	54	1.67	0.48, 4.52	1.47	0.50, 4.33
Recreational Activity (hrs/wk)[b]					
None	326	1.00	--	1.00	--
Any	203	0.72	0.29, 1.62	0.91	0.40,2.07
Adult and Child Care Activity (hrs/wk)[b]					
None	452	1.00	--	1.00	--
Any	77	2.18	0.77, 6.49	1.33	0.53, 3.34
Indoor Household Activity (hrs/wk)[c]					
None	411	1.00	--	1.00	--
Any	118	1.91	1.91, 4.55	0.93	0.39, 2.25
Outdoor Household Activity (hrs/wk)[d]					
None	488	1.00	--	1.00	--
Any	41	0.38	0.01, 2.34	0.44	0.05, 4.15
Transportation Activity (hrs/wk)[e]					
None	487	1.00	--	1.00	--
Any	42	1.22	0.23, 4.75	0.94	0.26, 3.43

[a]Adjusted for depressive symptoms at 24-29 weeks' gestation, smoking.
[b]Adjusted for depressive symptoms at 24-29 weeks' gestation, education.
[c]Adjusted for depressive symptoms at 24-29 weeks' gestation, education, health status at 17-22 weeks' gestation.
[d]Adjusted for depressive symptoms at 24-29 weeks' gestation, health status.
[e]Adjusted for depressive symptoms at 24-29 weeks' gestation.

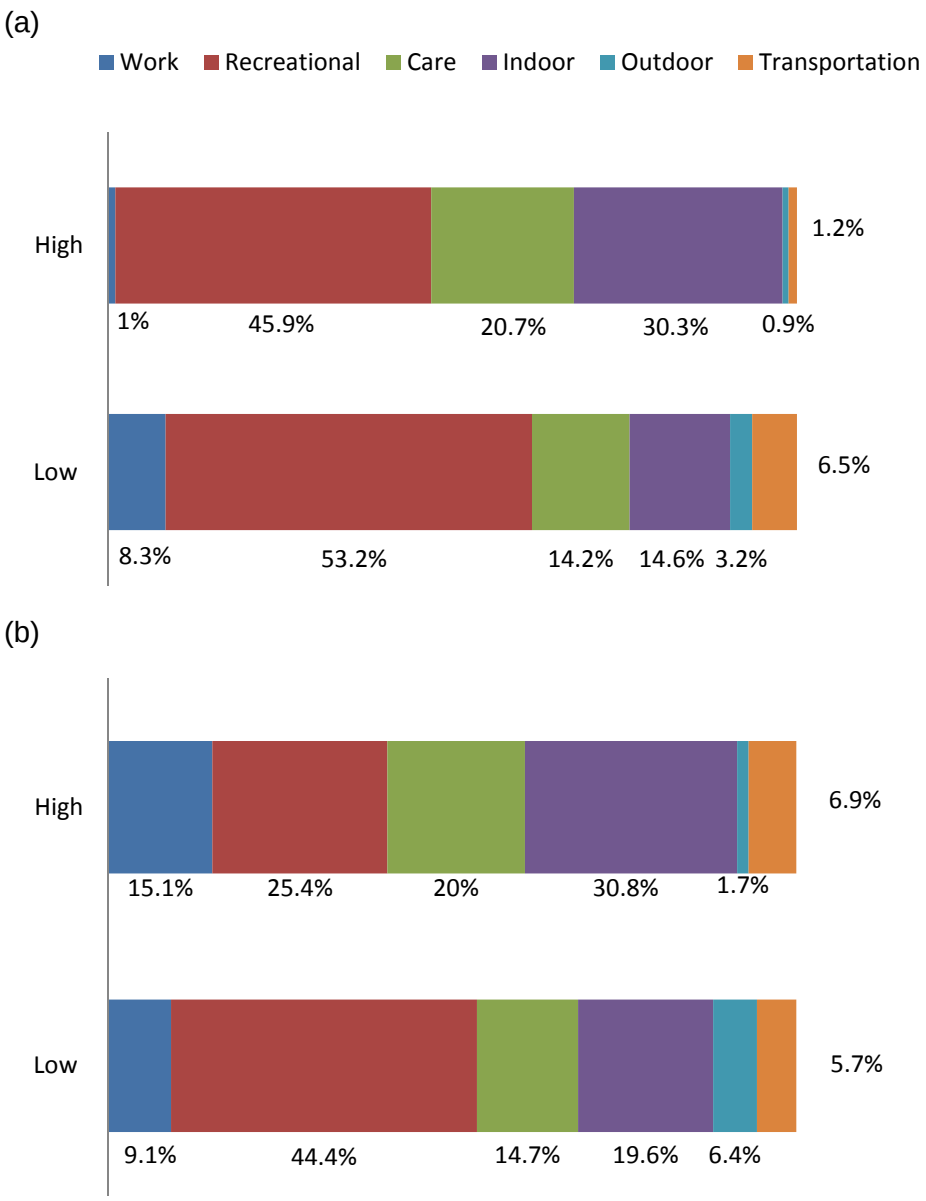

FIGURE 5.1. The mean proportions of total moderate-to-vigorous physical activity (MVPA) in hours/week spent in each domain by Edinburgh Postnatal Depression Scale (EPDS) symptoms status (low= EPDS < 13, high= ≥13) among women enrolled in the postpartum phase of the Pregnancy, Infection, and Nutrition Study with complete data on physical activity and depressive symptoms at 3 months postpartum (n=652): (a) 17-22 weeks' gestation and (b) 27-30 weeks' gestation.

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CHAPTER VI

MANUSCRIPT 3: ASSOCIATIONS BETWEEN TOTAL AND DOMAIN-SPECIFIC PHYSICAL ACTIVITY AND POSTPARTUM DEPRESSIVE SYMPTOMS: PIN POSTPARTUM STUDY

A. Abstract

Postpartum women are at increased risk for developing depression which can contribute to the ill health of the mother and her family. Previous research indicates that physically active mothers experience lower levels of postpartum depressive symptoms than inactive mothers. The objective of this investigation was to examine the associations between total and domain-specific moderate-to-vigorous physical activity (MVPA) during postpartum and subsequent postpartum depressive symptoms. Data were obtained from 550 women who participated in the Pregnancy, Infection, and Nutrition (PIN) Postpartum Study, a prospective cohort of mothers who delivered live-born infants from October 2002 to December 2005 in North Carolina. Three-month postpartum MVPA was investigated as a predictor of 12-month postpartum depressive symptoms. Those who participated in MVPA had two times the odds of developing elevated depressive symptoms at 12 months postpartum than those with no MVPA (odds ratio [OR]=2.00, 95% confidence interval [CI]= 0.71, 6.75). Different associations were suggested when examining domain-specific MVPA. Those participating in adult and child care and indoor household MVPA at 3 months postpartum had more than double the odds of having elevated depressive symptoms at 12 months postpartum (OR=2.66, 95% CI=1.03, 8.11 and OR=2.72, 95% CI=0.96, 10.18, respectively). Work MVPA also conferred a doubling of the odds (OR=1.95, 95% CI=0.46, 7.13) for depressive symptoms. Recreational and outdoor household MVPA showed no associations with depressive symptoms. Associations between MVPA and depressive

symptoms differ by domain. Future studies of postpartum depressive symptoms should explore potential differences in physical activity by domain.

B. Introduction

Depression is a serious mental health condition, affecting more than 340 million people worldwide and serving as the leading cause of disability in high-income countries (Greden, 2001; Lopez et al, 2006). The risk of developing depression is increased for females during the childbearing years as compared to earlier periods (Burke et al, 1991). There is evidence that postpartum women are more likely to be depressed or report more symptoms than non-postpartum women (Vesga-Lopez et al, 2008; Eberhard-Gran et al, 2003; O'Hara et al, 1990). More than 50% of postpartum women report elevated depressive symptoms at some point in the first 12 months after birth (Gaynes et al, 2005).

Depressive symptoms typically include sad mood, loss of interest in activities, feelings of helplessness and hopelessness, decreased energy, decision-making difficulties, sleep problems, restlessness, irritability, changes in eating patterns, suicidal ideations or attempts, and persistent physical symptoms that do not respond to treatment (U.S. Department of Health and Human Services [U.S. DHHS], 2007). Depression has serious consequences at any point in life, however, when it occurs postpartum, the disease can negatively impact the mother's health and the well-being of her newborn and family (Lusskin et al, 2007; Lee and Chung, 2007). Mothers with postpartum depression (PPD) tend to provide less adequate care to their child, exhibit negative parenting behaviors (intrusiveness, withdrawal/disengagement, lowered sensitivity, and lowered responsiveness), and have poorer mother-infant bonding (Lee and Chung, 2007; Marcus, 2009; Logsdon et al, 2006). Women with PPD are also significantly more likely to experience depression later in life (Phillips and O'Hara, 1991). Children of depressed mothers have poorer sleep patterns and are more likely to experience behavioral and

development (cognitive, socio-emotional, language) problems (Lusskin et al, 2007; Lee and Chung, 2007; Marcus, 2009; Logsdon et al, 2006). Maternal depression can also have consequences for fathers. Depressed mothers report poorer partner satisfaction and if she has depression, there is a 40-50% risk that the child's father will also develop depression (Appolonio and Fingerhut, 2008; Lee and Chung, 2007).

Several reports in the literature have examined the association between physical activity and depression or depressive symptoms in non-pregnant populations, most finding that physical activity is associated with better mental health (Teychenne et al, 2008b). Research investigating the association between physical activity and depressive symptoms among postpartum women is much more limited. Most previous studies of this population have been exercise intervention trials that have been limited by the small sample size and representativeness (Heh et al, 2008; Armstrong and Edwards, 2004; Armstrong and Edwards, 2003; Koltyn and Schultes, 1997; Daley et al, 2008; May, 1995; Da Costa et al, 2009) while observational studies have examined either walking or recreational physical activity only and have not focused on other types or domains of physical activity (Craike et al, 2010; Herring et al, 2008; Haas et al, 2004). Overall, results indicate that physical activity promotes lower depressive symptoms. The objective of this investigation was to determine the association between total and domain-specific moderate-to-vigorous physical activity (MVPA) and depressive symptoms in a prospective cohort of postpartum women.

C. Materials and Methods

1. Participants

This investigation used data from Pregnancy, Infection, and Nutrition (PIN) Postpartum Study, a prospective cohort of postpartum women originally enrolled during pregnancy in the third phase of the PIN Study. Eligible women delivered live-born infants between October 2002 and December 2005 and lived in the study's catchment area. Out of

the 2006 expectant mothers recruited in the prenatal study, 1169 women were eligible, 938 were invited to participate, and 688 (73.3%) agreed to participate and had data for the 3-month home interview. More detailed information on the PIN Study methods and attrition from the prenatal to postpartum study is available elsewhere (Siega-Riz et al, 2009).

Comparing the 688 women who participated at 3 months postpartum with the 481 (1169-688) women who were eligible but did not participate in the PIN Postpartum Study, participating women were older (29.4 vs. 28.7 years, p=0.02), more educated (15.8 vs. 15.2 years, p=0.0002), more affluent (423.4% vs. 390.3% of the poverty level, p=0.02), more likely to be married (80.4% vs. 68.6% p<0.0001), more likely to be of White race (76.5% vs. 68.2%, p<0.0001), had lower body mass index (25.4 vs. 26.4 kg/m^2, p=0.01) at 3 months postpartum, and had lower depressive symptoms at both <20 weeks (11.1 vs. 12.6 Center for Epidemiologic Studies- Depression [CES-D] score, p=0.02) and 24-29 weeks' gestation (11.2 vs. 12.6 CES-D score, p=0.03). The overall distribution of total MVPA at 27-30 weeks' gestation did not differ between the groups of women (p=0.26). The same comparisons were made between the 688 participating versus the 250 (938-688) women that were invited to participate but declined; there were no differences for any of the above-reported measures.

2. Procedures

Women eligible for the PIN Postpartum Study who agreed to be contacted after delivery where phoned for recruitment purposes and written consent was obtained from those who participated in the 3-month home interview. At the 3-month home interview, women were asked about infant health and feeding, tobacco and drug use, psychosocial measures, sociodemographics, occupation, and physical activity. Anthropometrics were also measured at this visit. Women were interviewed again at 12 months postpartum and asked questions similar to the 3-month interview. The Institutional Review Board of the

University of North Carolina at Chapel Hill School of Medicine reviewed and approved the study protocols.

3. Physical activity assessment

Women were asked to recall physical activity performed during the past week at the 3-month home interview utilizing a structured instrument with documented validity and reliability (Evenson and Wen, 2010). Assessments included occupational, recreational, child and adult care, and indoor and outdoor household activity. Frequency, duration, and intensity of each activity type were determined. For each type of activity, women were first asked if they participated in activity that resulted in at least some increase in breathing and heart rate. If so, women were asked to list all of the domain-specific activities they performed. Subsequently, they were asked to report the number of sessions, average duration per session, and perceived intensity level of each activity type. Perceived intensity was assessed based on the Borg scale: fairly light, somewhat hard, and hard or very hard (Borg and Linderholm, 1974). Self-reported activities that were "somewhat hard" corresponded to moderate activity, and "hard or very hard" corresponded to vigorous activity (Pollock et al, 1998).

Physical activity for this analysis was characterized in two ways: hours/week and metabolic equivalent (MET)-hours per week, based on perceived and absolute intensity, respectively. Hours per week was calculated by multiplying the number of times a participant reported an activity by the number of hours she reported, focusing only on activities reported as "somewhat hard" or "hard or very hard." Hours per week of activity was then aggregated by intensity and domain. We also created an aggregate, non-elective MVPA variable that combined the MVPA of all non-recreational activities. MET-hours per week was calculated by multiplying the number of times the participant reported the activity by the number of hours it is reported and then multiplying by the MET value for the activity.

The activities were coded based on compendium-established intensities (Ainsworth et al, 2000; Ainsworth et al, 1993). The standards for adults aged 20-39 years were used: MET values of 4.8-7.1 were classified as moderate intensity and values of 7.2+ were classified as vigorous activity (Pollock et al, 1998). Documentation of the MET values and categories assigned to activities in our study is available elsewhere (Pregnancy, Infection, and Nutrition Study, 2007). The MET-hour values were summed across activity type to establish total physical activity in MET-hours/week. The exposures of interest for this analysis are total and all domain-specific MVPA of perceived intensity and total MVPA of absolute intensity at three months postpartum.

4. Depression assessment

The Edinburgh Postnatal Depression Scale (EPDS) was used to assess postpartum depressive symptoms (Cox et al, 1987). The EPDS is a 10-item postpartum depression screening questionnaire that assesses mood during the past week using 4-point response categories. A composite score was calculated by summing across items, some of which required reverse-coding. A threshold score of 12 has been shown to indicate depression of various severities and persons needing further assessment (Cox et al, 1987). Therefore, a score of 13+ was considered as having significant depressive symptoms. Depressive symptoms at 12 months postpartum was the outcome variable and symptoms at 3 months postpartum was included as a covariate.

5. Covariates

Factors found to be associated with both physical activity and depressive symptoms in previous research and factors adjusted for in previous analyses were considered potential confounders. This included sociodemographic measures such as maternal age at the 3-month interview (≤ 24, 25-29, 30-34, or 35+ years), race (White, Black, other), marital status

at the 3-month interview (married, unmarried), years of education (≤12, 13-16, or 17+), employment status at the 3-month interview (yes or no), and poverty status at the 3-month interview (≤185% or >185% of the poverty line). A cutpoint of 185% was used as it is the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) income guideline cutpoint (U.S. Department of Agriculture, 2009). Health indicators included parity at the 3-month interview (1, 2, or 3+), smoking since birth (any smoker, nonsmoker), and current body mass index based on height and weight measured at the 3-month interview categorized using National Heart, Lung and Blood Institute guidelines (U.S. DHHS, 1998; <18.5, 18.5-24.9, 25-29.9, or 30+ kg/m^2). Three-month interview responses for any breastfeeding practice (current, stopped, or never), sleep quality (fair/poor or good/excellent), and partner support (a lot, some, or not much/none) were also investigated as potential confounders. Partner support was assessed with a single item about the amount of emotional support the woman receives from the man acting as the child's father.

6. Data analysis

Analyses were performed using version 9.1 of the SAS statistical software (SAS Institute Inc, Cary, NC) and STATA 11 (StataCorp, College Station, TX). Univariate analysis was conducted to describe sample characteristics of potential covariates and physical activity. A factor was considered a confounder if it was associated with both physical activity at 3-month interview and depressive symptoms at 12-month interview (using Chi-square analysis) and changed the estimate of the association by ≥10% in the modeling stage using backwards deletion (Rothman and Greenland, 1998). Fisher's exact test p-values were reported for Chi-square analysis when available. It was determined *a priori* that depressive symptoms at 3 months postpartum would be included as a covariate in all models, as previous history of depression is a major risk factor for postpartum depression (Marcus, 2009) and is expected to be associated with previous activity given previous literature.

Exact logistic regression modeling with the Monte Carlo option was utilized to calculate odds ratios (ORs) and 95% confidence intervals (CIs). Regression models were calculated using 528 women who had complete data for exposures, outcome, and covariates (22 women were missing covariate data). MVPA, total and domain-specific, was dichotomously coded (none, any) for analysis. Heckman modeling (Heckman, 1978; Heckman, 1979) was used to determine if there was selection bias in our final model sample as compared to the women eligible for the PIN Postpartum Study. After considering pregnancy sociodemographics and depressive symptoms as potential selection factors, marital status and depressive symptoms at 24-29 weeks' gestation were determined to be selection factors, measures that predict selection into the final sample. As some women were missing data on depressive symptoms during pregnancy, the Heckman modeling used 470 uncensored observations. Due to precision of the MET-hours/week analysis, domain-specific MVPA is not reported.

D. Results

1. Sample characteristics

Of the 550 mothers participating in the PIN Postpartum Study at 12 months postpartum, only 35 (6%) reported having elevated depressive symptoms. Scores ranged from 0 to 23 and the median score was 4. Among these women, the majority (79%) were Whites, 13% were Black, and 9% were of another race. Almost two-thirds (63%) of the participants were at least 30 years of age; 13% were less than 25 years of age, the majority of the women were college educated (63% attended college) and married (85%). A low proportion of women (24%) had incomes that met the WIC eligibility criteria. Many women had given birth to their first child (48%) and the majority were breastfeeding at 3 months postpartum (68%). Differences in these variables and the other potential confounders by depressive symptoms status is found in Table 6.1. Those with high depressive symptoms

were more likely to be younger, Black or other race, unmarried, less educated, of lower income, and smokers. These women were also more likely to have fair or poor sleep quality, have less partner support, and not breastfeed at 3 months.

Almost one-third (32%) of the mothers did not participate in any MVPA at 3 months postpartum. The median of total MVPA in hours/week was 1.3 (with an interquartile range [IQR] of 0- 4.25).Women were most likely to participate in recreational activity (48%) and least likely to participate in outdoor household activity (7%). There were few differences in physical activity levels by depressive symptoms. The median for total MVPA for women with low depressive symptoms was 1.3 (0-4) hours/week; for those with elevated depressive symptoms, the median was 1.6 (0-7.3). The median value for all domain-specific values of MVPA was 0 for both groups. Women with high depressive symptoms spent a lower proportion of their total MVPA in the recreational domain (36% vs. 54%, p=0.04) and a somewhat greater proportion in the adult and child care domain (31% vs. 19%, p=0.09) than women with low levels of depressive symptoms. Figure 6.1 shows the mean proportion of total MVPA hours spent in each domain by depressive symptoms status. Results of Chi-square analysis of dichotomous MVPA by depressive symptoms status is presented in Table 6.2. There were differences by depressive symptoms in indoor household MVPA and adult and child care MVPA.

2. Physical activity associations with depressive symptoms

Results from crude and adjusted regression models of the associations between MVPA, measured in hours/week, at 3 months postpartum and depressive symptoms at 12 months postpartum are presented in Table 6.3. In general, similar associations were found with the crude and adjusted models. There was a tendency toward increased odds of high depressive symptoms with participation in work, adult and child care, and indoor household MVPA. Women participating in work MVPA had two times the odds of developing high

levels of depressive symptoms. For care and indoor household MVPA, the adjusted ORs (95% CIs) were 2.66 (1.03, 8.11) and 2.72 (0.96, 10.18), respectively. There was not a relationship between either recreational or outdoor household MVPA with depressive symptoms at 12 months postpartum. Though the adjusted model for total MVPA suggested a stronger association than the crude model, both failed to reach statistical significance. We also examined the role of aggregate, non-elective MVPA (all non-recreational activities) in hours/week and found that women with any participation at 3 months postpartum had more than two times the odds of having depressive symptoms at 12 months postpartum (OR= 2.61, 95% CI=1.12, 6.11). When examining the association between total MVPA in absolute intensity (MET-hours/week) and depressive symptoms, null results were found when adjusted depressive symptoms at 3 months postpartum, maternal age, and partner social support (OR=1.01, 95% CI=0.38, 2.65).

The domain-specific MVPA final adjusted models shown in Table 6.3 were re-calculated adjusting additionally for MVPA in all the other domains. For example, the model for work MVPA was adjusted for a variable that subtracted the work MVPA from the total MVPA. The conclusions did not change after adjusting for other physical activity domains.

Assessment of Selection Bias

Heckman regression models are presented in Table 6.3. Once potential selection bias was taken into account, most of the estimates regressed to the null. The estimates for recreational MVPA and outdoor household MVPA became slightly stronger, but the rest became weaker. The estimates for adult and child care MVPA and indoor household MVPA changed the most as a result of considering the selection factors of marital status and depressive symptoms at 24-29 weeks' gestation; both OR estimates were nearly halved. The estimate for work MVPA was slightly weaker and became significant (OR=1.73, 95% CI= 1.01, 2.97).

E. Discussion

In this prospective study of mothers followed through 12 months postpartum, we examined the associations between MVPA and postpartum depressive symptoms among 528 women. We found that the association between MVPA and postpartum depressive symptoms varied according to the domain/type of physical activity. There was some evidence of increased odds in depressive symptoms due to participation in any MVPA. Women who participated in adult and child care, indoor household, and work MVPA at 3 months postpartum were more likely to report elevated depressive symptoms at 12 months postpartum. There was no association between recreational and outdoor household MVPA and depressive symptoms.

Our results contradict previously published research as none of the domains investigated were associated with a decrease in the odds of depressive symptoms. All but one (Daley et al, 2008) of the previous studies of physical activity and depressive symptoms in postpartum found that physical activity participation improves depressive symptoms. Nine previous studies have investigated the impact of postpartum physical activity on postpartum depressive symptoms; seven of these nine studies were intervention trials (Heh et al, 2008; Armstrong and Edwards, 2004; Armstrong and Edwards, 2003; Koltyn and Schultes, 1997; Daley et al, 2008; May, 1995; Da Costa et al, 2009). Though most of the studies examined the effects of physical activity on depression over time, one study examined the acute impact of physical activity on depressive symptoms (Koltyn and Schultes, 1997). Interventions were varied, including walking with a stroller, regular supervised exercise sessions, and home-based exercise training and support. Both intervention and observational studies focused on walking or recreational activity and did not address differences by physical activity domain. Two of the non-intervention studies were cohorts of pregnant women that were followed into postpartum. Herring and colleagues (2008) found

that women with postpartum depression walked significantly less than women without antenatal or postpartum depression in a prospective cohort of 850 women in Massachusetts. Data from a cohort of 1,809 pregnant women in San Francisco found that women who were inactive post-delivery were 1.62 (1.04-2.54) times more likely to have elevated depressive symptoms in comparison to women participating in more than 2 hours/week of activity (Haas et al, 2004). Craike et al (2010) found a significant inverse association between leisure-time MVPA and depressive symptoms in a prospective cohort of Australian women with infants aged 3-19 months. Daley et al (2008) reported the only study to find no effect of an exercise trial on depressive symptoms; but the study was not powered to determine such an effect.

Few studies have addressed the association between physical activity domain and depression. We found no studies using postpartum samples that have done so, but there has been some research among non-pregnant women. McKercher et al (2009) compared the association between physical activity and depression among young men and women and found that leisure activity was associated with decreased prevalence of major depression and work activity was associated with increased prevalence among women only. No associations were found among men. Teychenne and co-authors (2008a) investigated how the association between physical activity and depressive symptoms differed by domain among 1,501 women in Australia. They found that women participating in more than 3.5 hours of leisure-time physical activity per week had lower odds of depressive symptoms, but no significant association in any other domain (work, transportation, or domestic). These studies demonstrate that domain can influence physical activity-depression associations.

Thus far there has been little explanation as to why the association between physical activity and depression may differ by domain. It has been suggested that it may be due to adverse, unfavorable, or unhealthy conditions in which the activity is typically performed (Abu-Omar and Rütten, 2008). For example, those with high levels of work activity may be

conducting a lot of strenuous activity over long hours on the job (Abu-Omar and Rütten, 2008). The benefits of activity may be countered by these adverse conditions. Another possible explanation is that different types of activity may serve as stressors or burdens which may contribute to the development of depressive symptoms. We suspect that performing "involuntary" physical activity (i.e., to perform housework or as part of their job) may be stressful, therefore contributing towards elevated depressive symptoms rather than alleviating them.

There is evidence supporting that specific activity domains may be stressful or burdensome, which may explain why we saw such large increases in odds of depressive symptoms related to adult and child care and indoor household MVPA and overall non-elective MVPA. Performing housework and being a housewife have both been identified as risk factors for depression (Glass and Fujimoto, 1994; Marchesi et al, 2009). Performing housework has been found to be associated with increased perceived stress (Asztalos et al, 2009). A study of postpartum women found that women who took care of handicapped or ill relatives were 4 times more likely to have major depressive symptoms (Garcia-Esteve et al, 2008). A study of Swedish adults found that though the number of hours spent doing domestic work was not associated with anxiety or depression, participation in burdensome domestic work was associated with significantly increased odds of anxiety/depression (Molarius et al, 2009). This study's findings of increased odds of depressive symptoms with indoor household, adult and child care, and non-elective MVPA is supported by these other studies.

Limitations and Strengths

The results of this study must be considered within the context of its limitations. First, a diagnosis of depression can only be done through clinical assessment. The EPDS is a self-report scale that assesses depressed mood and symptoms. However, performing

clinical assessments on participants in population studies is costly and timely; therefore, depression screening tools are frequently used. The EPDS has been found to have satisfactory sensitivity, specificity, and positive predictive value (Cox et al, 1987, Gaynes et al, 2005). The EPDS was designed with the purpose of identifying women who are depressed after childbirth and it is a widely used screening tool available for postpartum depression (Cox et al, 1987; Gaynes et al, 2005; Pogany and Petersen, 2007).

Physical activity measurement also relied on a self-report tool which can result in recall issues. However, since the assessment asked about the past week, problems with recall may be limited. The questionnaire asked women to consider the frequency, duration, and intensity of all forms of physical activity by domain which may contribute to better recall. Self-report methods are frequently used to assess physical activity and have been determined to be an acceptable method to assess physical activity with a number of advantages (Dale et al, 2002). Another concern is that physical activity was only assessed during the past week. Physical activity behavior can change from week to week and the reported values may not be representative of usual behavior. This may be an important consideration for the early postpartum since women are likely developing new daily routines.

Precision was of concern in this study. The reporting of elevated depressive symptoms was low in this sample (6%). Many women also reported no MVPA overall and by the different domains, and the variation in levels of activity was low. This resulted in wide confidence intervals for the regression analysis.

There may be a concern of selection bias in our sample. Though the rho for selection bias, the correlation between the error terms of the selection model and final adjusted model, in the Heckman modeling was only significant for work MVPA; the estimates once taking into account marital status and pregnancy depressive symptoms changed by up to 63%. Therefore, we presented both the exact logistic regression and Heckman logistic

regression estimates. Most conclusions made did not differ, but there was large attenuation of the estimates of adult and child care and indoor household MVPA.

Generalizability of the results may be an issue. Analysis using data from previous PIN cohorts also found that less educated, younger, African American, and more parous women and women with higher pregnancy risk profiles were more likely to be underrepresented in the study (Savitz et al, 1999; Savitz et al, 2005). However, when comparing the women who participated in the PIN Postpartum Study to the women considered eligible and invited to participate in the study, the women did not differ in regards to any socio-demographic variables or MVPA levels at 27-30 weeks' gestation.

Despite these limitations, there are several strengths of this study. The prospective cohort design of the PIN Postpartum Study provided us with the opportunity to examine the association with physical activity early in the postpartum period with later depressive symptoms. There was a nine month gap between assessments. This is beneficial for an investigation of depression since it is a chronic condition and length of exposure might need to be considerable to have an impact. Data collection was extensive; a variety of factors related to the health of new mothers were assessed. This enabled us to control for a number of potential confounders. However, there is still the possibility of residual confounding. Though we examined many factors to determine if they confounded the association between physical activity and depressive symptoms, there are known (i.e. life events) and unknown factors that were not examined. Another strength is that both physical activity and depressive symptoms were assessed using reliable and valid assessment tools (Evenson and Wen, 2010; Cox et al, 1987; Gaynes et al, 2005). The physical activity assessment was comprehensive- collecting data on duration, frequency, intensity, and domain. Previous studies of the association between physical activity and depressive symptoms among postpartum women have either been intervention trials or only investigated walking or recreational activity.

F. Conclusions

We investigated if the association between MVPA and depressive symptoms differed by domain of activity in a cohort of postpartum women. Participation in adult and child care and indoor household MVPA was associated with a significant increase in the odds of developing elevated depressive symptoms. Increased, but non-significant odds of elevated depressive symptoms were also found with total and work MVPA. No associations were found with recreational and outdoor household MVPA. Though previous work has indicated that physical activity may be a useful tool for preventing and controlling depression, our study does not support those findings. Multiple studies are needed assessing depressive symptoms at a given time point as previous studies vary with their assessments and etiology may differ during different periods. Future studies examining associations between postpartum physical activity and depressive symptoms should explore differences by physical activity domain. There is also a need for investigations of models and mechanisms that could explain why the physical activity-depression association may differ by domain.

Table 6.1. Characteristics of women enrolled in the postpartum phase of the Pregnancy, Infection, and Nutrition Study with data from the 12-month home interview by depressive symptoms status (<13 score on the Edinburgh Postnatal Depression Scale [EPDS] scale versus ≥ 13 score on the EPDS) (n=550).

	Total	EPDS		
		< 13 (n=515)	≥ 13 (n=35)	
	n (%)	n (%)	n (%)	χ^2 (p-value)
Age at 3-month interview (years)				28.91 (<.0001)
≤ 24	72 (13)	58 (11)	14 (40)	
25-29	132 (24)	121 (24)	11 (31)	
30-34	195 (35)	188 (37)	7 (20)	
35+	151 (27)	148 (29)	3 (9)	
Race				17.20 (.0002)
White	433 (79)	415 (81)	18 (51)	
Black	69 (13)	58 (11)	11 (31)	
Other	48 (9)	42 (8)	6 (17)	
Marital status at 3-month interview*				22.49 (<.0001)
Married	467 (85)	447 (87)	20 (57)	
Unmarried	83 (15)	68 (13)	15 (43)	
Education at 3-month interview (years)				24.94 (<.0001)
≤12	202 (37)	197 (38)	5 (14)	
13-16	266 (48)	251 (49)	15 (43)	
17+	82 (15)	67 (13)	15 (43)	
Working at 3-month interview*				0.002 (1.0000)
Yes	265 (48)	248 (48)	17 (49)	
No	285 (52)	267 (52)	18 (51)	
Income at 3-month interview (percent of the poverty line)*[a]				11.10 (.0025)
≤ 185	133 (24)	117 (23)	16 (52)	
>185	413 (76)	396 (77)	17 (48)	
Parity at 3-month interview				0.62 (.7325)
1	265 (48)	248 (48)	17 (49)	
2	198 (36)	184 (36)	14 (40)	
3+	87 (16)	83 (16)	4 (11)	
Body mass index at 3-month interview (kg/m^2)[b]				5.68 (.1280)
<18.5	3 (1)	3 (1)	0 (0)	
18.5-24.9	267 (49)	253 (49)	14 (40)	
25-29.9	149 (27)	142 (28)	7 (20)	
30+	130 (24)	116 (23)	14 (40)	

Table 6.1. Concluded.

	Total	EPDS		
		< 13 (n=515)	≥ 13 (n=35)	
	n (%)	n (%)	n (%)	χ^2 (p-value)
Breastfeeding at 3-month interview				9.21 (.0100)
Still breastfeeding	372 (68)	356 (69)	16 (46)	
Stopped breastfeeding	137 (25)	121 (24)	16 (46)	
Never breastfed	41 (7)	38 (7)	3 (9)	
Smoking at 3-month interview*				18.48 (.0003)
Yes	48 (9)	38 (7)	10 (29)	
No	502 (91)	477 (93)	25 (71)	
Sleep quality at 3-month interview*				21.22 (<.0001)
Fair/Poor	235 (43)	207 (40)	28 (80)	
Good/Excellent	315 (57)	308 (60)	7 (20)	
Partner support at 3-month interview[c]				18.65 (<.0001)
A lot	373 (70)	361 (72)	12 (38)	
Some	130 (24)	115 (23)	15 (47)	
Not much/None	29 (5)	24 (5)	5 (16)	

* Fisher's Exact Test p-value reported

[a] Missing data on 4 women

[b] Missing data on 1 woman

[c] Missing data on 18 women

Table 6.2. Frequencies and Chi-square statistics (with Fisher's Exact p-values) of 3-month postpartum moderate-to-vigorous physical activity (MVPA) by 12-month postpartum depressive symptoms status (<13 score on the Edinburgh Postnatal Depression Scale [EPDS] scale versus ≥ 13 score on the EPDS) among women enrolled in the postpartum phase of the Pregnancy, Infection, and Nutrition Study (n=550).

		EPDS		
	Total	**< 13 (n=609)**	**≥ 13 (n=43)**	
	n (%)	**n (%)**	**n (%)**	**χ^2 (p-value)**
Total MVPA				0.65 (.7122)
None	176 (32)	166 (32)	10 (29)	
Any	374 (68)	349 (68)	25 (71)	
Work MVPA				3.54 (.0809)
None	492 (89)	464 (90)	28 (80)	
Any	58 (11)	51 (10)	7 (20)	
Recreational MVPA				0.08 (.8619)
None	286 (52)	267 (52)	19 (54)	
Any	264 (48)	248 (48)	16 (46)	
Adult and Child Care MVPA				4.17 (.0466)
None	410 (75)	389 (76)	21 (60)	
Any	140 (25)	126 (24)	14 (40)	
Indoor Household MVPA				8.34 (.0069)
None	447 (81)	425 (83)	22 (63)	
Any	103 (19)	90 (17)	13 (37)	
Outdoor Household MVPA				0.04 (1.0000)
None	514 (93)	481 (93)	33 (94)	
Any	36 (7)	34 (7)	2 (6)	

Table 6.3. Odds ratios (OR) and 95% confidence intervals (CI) from exact logistic regression analysis of the association between total and domain-specific physical activity (hours/week) at 3 months postpartum and depressive symptoms at 12 months postpartum among women enrolled in the PIN Postpartum Study (n=528).

		Crude Model		Final Adjusted Model		Heckman Selection Model[a]	
	n	OR	95% CI	OR	95% CI	OR	95% CI
Total Activity (hrs/wk)[b]							
None	168	1.00	--	1.00	--	1.00	--
Any	360	1.15	0.50, 2.89	2.00	0.71, 6.75	1.39	0.86, 2.28
Work Activity (hrs/wk)[c]							
None	476	1.00	--	1.00	--	1.00	--
Any	52	1.87	0.52, 5.47	1.95	0.46, 7.13	1.73	1.01, 2.97
Recreational Activity (hrs/wk)[d]							
None	272	1.00	--	1.00	--	1.00	--
Any	256	0.76	0.33, 1.67	1.19	0.44,3.14	1.39	0.89, 2.17
Adult and Child Care Activity (hrs/wk)[e]							
None	392	1.00	--	1.00	--	1.00	--
Any	136	2.18	0.94, 5.64	2.66	1.03, 8.11	1.42	0.91, 2.22
Indoor Household Activity (hrs/wk)[f]							
None	430	1.00	--	1.00	--	1.00	--
Any	98	2.18	0.89, 5.77	2.72	0.96, 10.18	1.36	0.86, 8.04

Table 6.2. Concluded.

		Crude Model		Final Adjusted Model		Heckman Selection Model[a]	
	n	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Outdoor Household Activity (hrs/wk)[g]							
None	494	1.00	--	1.00	--	1.00	--
Any	34	1.01	0.11, 4.57	0.91	0.08, 4.66	0.89	0.32, 2.45

[a] Heckman selection model includes data on 470 total observations due to missing data on pregnancy depressive symptoms.
[b] Adjusted for depressive symptoms at 3 months postpartum, smoking, age, partner support.
[c]Adjusted for depressive symptoms at 3 months postpartum marital status, sleep quality.
[d]Adjusted for depressive symptoms at 3 months postpartum, age, partner support, sleep quality.
[e]Adjusted for depressive symptoms at 3 months postpartum, sleep quality.
[f]Adjusted for depressive symptoms at 3 months, sleep quality.
[g]Adjusted for depressive symptoms at 3 months postpartum, smoking.

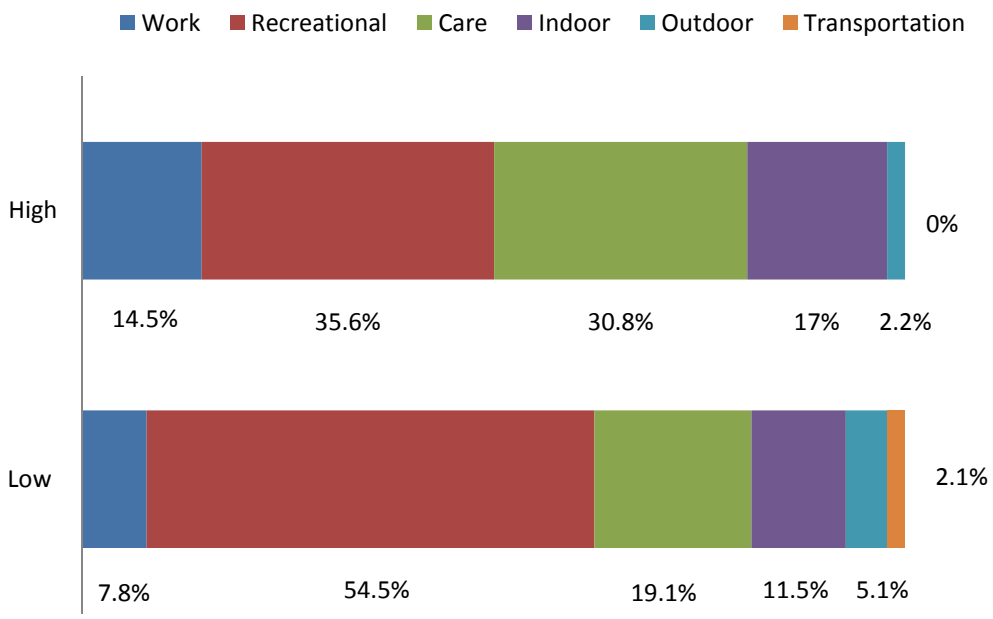

FIGURE 6.1. The mean proportions of total moderate-to-vigorous physical activity (MVPA in hours/week) at 3 months postpartum spent in each domain by 12-month Edinburgh Postnatal Depression Scale (EPDS) symptoms status (low= EPDS < 13, high= ≥13) among women enrolled in the postpartum phase of the Pregnancy, Infection, and Nutrition Study (n=550).

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CHAPTER VII

CONCLUSIONS

A. Summary of Results

Our study found that the association between MVPA and depressive symptoms varies by physical activity domain. Total perceived MVPA at 17-22 weeks' gestation was associated with reduced odds of elevated depressive symptoms at 24-29 weeks' gestation. However, we found few domain-specific associations. There were null results for recreational MVPA and depressive symptoms. Women participating in perceived adult and child care MVPA and high amounts of indoor household MVPA had increased odds of having high depressive symptoms. Increased odds of elevated depressive symptoms were found with participation in more than median levels of non-elective MVPA (all non-recreational activities) for both perceived and absolute intensities.

In postpartum, mothers who participated in any domain of MVPA at 3 months were two times more likely to have elevated depressive symptoms at 12 months than those did not participated in any MVPA, but the association was not significant. Women who participated in adult and child care and indoor household MVPA were almost three times as likely to later report elevated depressive symptoms. Women with work activity were also two times more likely to develop elevated depressive symptoms. Participation in recreational and outdoor household MVPA conferred a minimal increase and decrease in the odds of elevated depressive symptoms, respectively. Non-elective MVPA was associated with more than two times the odds of having depressive symptoms at 12 months postpartum.

There were no significant associations in the odds of developing high depressive symptoms when examining the association between MVPA in pregnancy (17-22 weeks and 27-30 weeks' gestation) and 3-month postpartum depressive symptoms. Most of the associations were similar across time points, but the directions were opposite for work, adult and child care, and outdoor household MVPA.

Our results contradict most of the previously published research as the only significant reduction of the odds in developing elevated depressive symptoms was found for total MVPA at 17-22 weeks' gestation and symptoms at 24-29 weeks' gestation. Furthermore, over all our analyses, participation in recreational physical activity showed no benefit on depressive symptoms.

B. Strengths and Limitations

Despite going beyond previous research conducted on physical activity and depression in pregnant and postpartum women, there are some limitations in this investigation. Self-report depression scales such as the CES-D and EPDS used in this study measure depressive symptoms. Clinical assessment is needed to diagnose depression. However, clinical assessments in population studies are costly and timely. Depression screening tools are frequently used in depression research involving large samples. Both the CES-D and EPDS are commonly used, reliable, and valid measurements of depressive symptoms that correlated well with clinical ratings (Pogany and Petersen, 2007; Gaynes et al, 2005; Beck and Gable, 2001; Radloff, 1997; Harris, 1989; Cox et al, 1987; Weissman et al, 1977).

Overall, investigating depression during pregnancy is difficult. No screening tool has been developed particularly for use in pregnancy (Ryan et al, 2005). Symptoms of pregnancy and depression overlap (Ryan et al, 2005; Brown and Solchany, 2004; Misri,

2007; Klein and Essex, 1994). Self-reported screening tools tend to focus on somatic symptoms, such as the symptoms that overlap, which makes determining depression status difficult; this is especially true for the CES-D (Ryan, et al 2005; Misri, 2007). To address this, we used a slightly higher cutpoint for CES-D than typically used in the general population. This cutpoint of 17 was compared to a method suggested by Hoffman and Hatch (2000) where the four scale items related to pregnancy are removed and the remaining items inflated so the scale range remains 0-60 and the 16 cutpoint is still used. The scores calculated by each method were highly correlated with each other and the women were largely categorized into the same binary category of depressive symptoms. When these re-categorized depressive symptoms scores were used in modeling, they performed similarly to our original scoring method.

Temporality is an issue when investigating physical activity and depression overall and in this study as depression can influence physical activity just as physical activity can influence depression levels. We did not have information regarding pre-pregnancy depressive symptoms status. Therefore, it is unknown if the women experiencing elevated depressive symptoms are new or prevalent cases. In analysis, we did, however, control for the previous measurement of depressive symptoms.

There are concerns for recall issues when using self-report methods of measurement. However, self-report methods are most commonly used to assess physical activity and have been determined to be an acceptable method to assess physical activity with a number of advantages (Dale et al, 2002). Physical activity investigations during pregnancy and postpartum are somewhat limiting since physical activity levels decline during pregnancy and are still below pre-pregnancy levels during the postpartum period. This results in distribution of physical activity levels that are shifted and it makes it more

difficult to examine more extreme levels of activity and dose responses. More than 30% of the women reported no total MVPA in each of our investigations.

Generalizability of the results to other populations may be of concern in this investigation as this sample was mostly White, well-educated, married, and financially stable. Selection bias may also be a factor. Analysis using data from previous PIN cohorts also found that less educated, younger, African American, and more parous women and women with higher pregnancy risk profiles were more likely to be underrepresented in the study when compared to the source population (Savitz et al, 2005; Savitz et al, 1999). One possible mechanism of physical activity's effect on depression is that it serves as a distraction from life stressors (North et al, 1990; Craft and Perna, 2004). It is possible that the contribution of physical activity to the development of depressive symptoms may differ among women of different profiles, such as disadvantaged women with different or elevated amount of stressors. The association may also differ for women from different cultures, as the benefits and burdens of physical activity may be perceived differently.

Statistical power was of concern in this investigation even though this study recruited a large number of pregnant women. Confidence interval ratios for the PIN Postpartum Study were particularly large. Also, the power for examining differences in the associations between physical activity and depressive symptoms by factors (i.e. effect modification by race, BMI, socioeconomic status, or education) was limited.

This study has a number of strengths. It is a large, prospective cohort study. Data collection was extensive which allowed for good control for confounders, however, as in any observational study, there may still be residual confounding. Physical activity and depression were both assessed multiple times over the pregnancy in a longitudinal manner. Reliable and valid assessment tools were used to measure physical activity, depression, and a number of the covariates. The physical activity assessment was comprehensive-

collecting data on duration, frequency, intensity, and domain. Previous research on the association between physical activity and depressive symptoms in pregnancy or postpartum has only investigated total or leisure-time activity or walking. The results of this investigation add to previous research by examining associations throughout pregnancy and postpartum and how these associations differ by domain.

C. Public Health Implications

Depression is a disease of great public health concern with millions of Americans affected in any given year. Pregnancy is a risky time period to be depressed as it the depression can affect mother, child, and family. Research has indicated that physical activity has beneficial effects on depression. However, the studies on pregnant and postpartum samples are limited. Studies are focusing on the utility of physical activity as an alternative to antidepressant medication and psychotherapy for the management and treatment of depression during pregnancy and postpartum due to concerns over cost, side effects, and stigma related to these established treatments (Daley et al, 2007; Hammond and Crozier, 2007; Bowen and Muhajarine, 2006; Manber et al, 2002). A study of the efficacy and dose-response effect of physical activity and depression found that those reaching the public health dose of physical activity had response and remission rates comparable to medication and cognitive behavioral therapy (Dunn et al, 2005). However, this investigation found few favorable associations between MVPA and depressive symptoms. There is some evidence that moderate-to-vigorous adult and child care and indoor household activities, in particular, may actually increase the odds of developing elevated depressive symptoms. As there is relatively little research of the association between physical activity and depressive symptoms among pregnant and postpartum women as compared to general population studies, it is important for future research to

clarify this association in order to make educated recommendations to women becoming mothers.

Pregnant and postpartum women are recommended to participate in at least 150 minutes of moderate-intensity physical activity per week while highly active women can participate in 75 minutes of vigorous-intensity physical activity per week (U.S. DHHS, 2008). However, these guidelines regard all types or domains of physical activity as equivalent and indicate that adults may meet these recommendations from various arenas. Our findings indicate that the association with depressive symptoms differs by domain. Other studies in the general population have found differences in associations with other conditions by physical activity domain, as well (Asztalos et al 2009; Autenrieth et al, 2009; Abu-Omar and Rütten, 2008; Oppert et al, 2005; Greendale et al, 2003). If results are replicated, future recommendations for pregnant and postpartum women should consider the domains in which women obtain their physical activity and how health effects may differ by these domains.

D. Future Research

Though research has been mixed, most of the previous research on the association between physical activity and depressive symptoms in pregnant and postpartum samples has found some benefit from physical activity. In contrast, our study only found a significant reduction of the odds in developing elevated depressive symptoms from total MVPA at 17-22 weeks' gestation and symptoms at 24-29 weeks' gestation.

There has been variation in both physical activity and depressive symptoms measurements in the literature. Studies have examined total physical activity, recreational activity/exercise, and walking at various time points during pregnancy and postpartum. One study assessed low-intensity exercise specific to controlling weight and shape (Abraham et

al, 2001). Depressive symptoms were measured using various tools at various times during pregnancy and postpartum. Repeated research using similar assessments are needed in order to compare results effectively. In addition, studies examining physical activity over time are needed to determine the most etiological relevant time points for the development of depression. Objective measures of physical activity (i.e., accelerometers or physical activity diaries) may serve as a good compliment to self-reported measures in order to assess physical activity prospectively in order to obtain values that are less subject to recall issues.

Physical activity levels are lower during the pregnancy and postpartum periods as compared to pre-pregnancy. In our study, at least 30% of the women had no MVPA at a given assessment time point. As a result, it was necessary to dichotomize physical activity levels in two sets of our analyses. Previous research on this topic also typically dichotomizes physical activity levels. Future studies should examine the potential dose-response of physical activity on depressive symptoms.

The focus of our study was to investigate the role of MVPA in the development of depressive symptoms. Previous studies have focused on overall physical activity, regardless of intensity. One study examined only low intensity exercise. We also examined both perceived and absolute measured physical activity during pregnancy, and found some differences. Studies should explore differences in association by intensity of activity (perceived vs. absolute and including light vs. moderate vs. vigorous activities).

In this study, we found differences in the association between physical activity and depressive symptoms by physical activity domain. However, previous research conducted among pregnant and postpartum women have not looked at these differences. Future research should explore differences in the associations by physical activity domains such as work, household, caregiving, and transportation. We found that adult and child care and

indoor household activities were particularly likely to result in increased odds of developing depressive symptoms. Studies investigating the reasons why the association between physical activity and depressive symptoms may differ by domain are needed. This research could potentially impact physical activity recommendations and how health care practitioners counsel their patients.

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