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# Towards an Understanding of Change in Physical Activity from Pregnancy Through Postpartum

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## Abstract

**Objective—**The purpose of this paper was to describe the rationale, data collection, and proposed analyses for examination of mediators of change in physical activity from pregnancy to postpartum among a cohort of pregnant women.

**Method—**The Pregnancy Infection and Nutrition 3 (PIN3) Study enrolled 2006 pregnant women into the cohort from 2001 to 2005. All women lived in central North Carolina upon enrollment. Physical activity was assessed using a self-reported one week recall, measured twice during pregnancy and once each at 3- and 12-months postpartum. On a subset of women, one-week accelerometer measures were also collected during the two postpartum time periods. Potential mediators (intrapersonal, interpersonal, community) were collected during pregnancy and postpartum through interviews and take home questionnaires.

**Results—**To assess mediation of physical activity among our cohort, we will first describe change in physical activity and the mediators, as well as their associations, through pregnancy into the postpartum period. Following this, the product of coefficients approach will be applied to examine whether each measure had indirect effects on change in physical activity. Each individual level mediator will be examined one at a time and across the time points in which it was available. The Sobel standard error approximation formula will be used to test for significance of the mediation effect.

**Conclusions—**This study will provide evidence to develop appropriate interventions targeted at physical activity and will help focus efforts on the appropriate time periods between pregnancy and postpartum.

## Introduction

Physical activity is recommended for pregnant and postpartum women. In 2002, the American Congress of Obstetricians and Gynecologists (ACOG) updated their exercise recommendations for pregnant women, stating that in the absence of medical or obstetric complications, 30 minutes or more of moderate exercise a day on most or all days of the week is advised (ACOG, 2002). According to the ACOG recommendations, many of the morphologic and physiologic changes of pregnancy persist at least one month postpartum. Thus, they recommend that prepregnancy exercise routines be resumed gradually, based on a woman's physical capability. In 2008, the US government released physical activity

guidelines for Americans, including recommending specifically for pregnant and postpartum women that they attain at least 150 minutes of moderate intensity aerobic activity spread over a week if not already highly active or doing vigorous intensity activity (U.S. Department of Health and Human Services, 2008). Healthy pregnant women who engaged in vigorous aerobic activity or were highly active prior to pregnancy are encouraged to continue physical activity.

Despite these recommendations, the prevalence of physical activity in the United States among pregnant and postpartum women remains suboptimal. Only about one in five pregnant women met ACOG recommendations for physical activity in the United States (Evenson & Wen, 2010a). The decline in physical activity may persist into postpartum for some women, although definitive studies are lacking (Pereira, et al., 2007). The postpartum period represents a time period for establishing a behavioral pattern contributing to the health of the mother (Peterson, et al., 2002). Childrearing demands coupled with fatigue, depression, and social isolation may exacerbate unhealthy activity patterns (Peterson, et al., 2002).

The lack of physical activity contributes to excess weight gain during pregnancy and weight retention during postpartum. Gestational weight gain is the strongest predictor of postpartum weight retention (Gunderson & Abrams, 2000). A consensus panel on physical activity in the prevention and treatment of obesity concluded that the development of physical activity interventions for pregnant women represented a potentially fruitful avenue for the prevention of overweight and obesity (Grundy, et al., 1999). However, to date few studies have addressed the reasons why women reduce their physical activity during pregnancy and how it changes into the postpartum period (Clarke & Gross, 2004; Rutkowska & Lepecka-Klusek, 2002). Exploration into the correlates of physical activity during pregnancy is one of the first steps to understanding where to focus interventions, building upon existing qualitative work (Devine, Bove, & Olson, 2000; Evenson, Moos, Carrier, & Siega-Riz, 2008; Kieffer, Willis, Arellano, & Guzman, 2002).

## Correlates of Physical Activity During Pregnancy and Postpartum

Cross-sectional studies have indicated that lower participation in leisure activity or exercise during pregnancy was associated with older age (Evenson, et al., 2004; Owe, Nystad, & Bo, 2009; Zhang & Savitz, 1996), lower English language acculturation (Chasan-Taber, et al., 2007; Gollenberg, Pekow, Markenson, Tucker, & Chasan-Taber, 2008), fair or poor general health (Evenson, et al., 2004), overweight or higher body mass index (Owe, et al., 2009; Zhang & Savitz, 1996), smoking (Owe, et al., 2009), higher parity or number of live births (Domingues & Barros, 2007; Owe, et al., 2009; Schmidt, Pekow, Freedson, Markenson, & Chasan-Taber, 2006), pelvic or musculoskeletal pain (Owe, et al., 2009), nausea (Owe, et al., 2009; Pereira, et al., 2007), and an unfavorable reproductive history (Zhang & Savitz, 1996). Leisure activity or meeting recommendations for physical activity was associated with younger age (Petersen, Leet, & Brownson, 2005), higher education (Domingues & Barros, 2007; Evenson, et al., 2004; Mottola & Campbell, 2003; Ning, et al., 2003; Owe, et al., 2009; Petersen, et al., 2005), health insurance (Evenson & Wen, 2010a), employment (Domingues & Barros, 2007), higher income (Domingues & Barros, 2007; Ning, et al., 2003; Petersen, et al., 2005), being married (Domingues & Barros, 2007; Petersen, et al., 2005), non-Hispanic White race/ethnicity (Ning, et al., 2003; Petersen, et al., 2005; Evenson & Wen, 2010a), having no children (Mottola & Campbell, 2003; Ning, et al., 2003; Pereira, et al., 2007; Rutkowska & Lepecka-Klusek, 2002), not smoking (Mottola & Campbell, 2003; Ning, et al., 2003; Petersen, et al., 2005), living in an urban area (Rutkowska & Lepecka-Klusek, 2002), and in the first trimester of pregnancy (Evenson & Wen, 2010a). In contrast, other studies found that meeting recommendations for physical activity or reporting

higher levels leisure activity was more common among Hispanic or African American pregnant women (Schmidt, et al., 2006), those with lower education (Schmidt, et al., 2006), those with a history of adverse pregnancy outcomes (Gollenberg, et al., 2008), and those with self-report of illicit drug use (Gollenberg, et al., 2008). Leisure activity during pregnancy was also associated with exercise prior to pregnancy (Chasan-Taber, et al., 2007; Hinton & Olson, 2001; Ning, et al., 2003; Pereira, et al., 2007), exercise intention (Hausenblas, Symons Downs, Giacobbi, Tuccitto, & Cook, 2008), and physical activity advice during pregnancy (Domingues & Barros, 2007).

Fewer studies have explored correlates of physical activity during postpartum (Albright, Maddock, & Nigg, 2005; Blum, Beaudoin, & Caton-Lemos, 2004; Larson-Meyer, 2002; Pereira, et al., 2007; Smith, Cheung, Bauman, Zehle, & McLean, 2005). In one prospective cohort study, insufficient leisure activity between prepregnancy to 6 months postpartum was associated with prepregnancy exercise, weight retention, employment (45 or more hours/ week) in early pregnancy, and reporting lack of child care as a barrier to physical activity (Pereira, et al., 2007). Exploration into correlates of other types of physical activity, beyond leisure activities, is needed (Chasan-Taber, et al., 2007) and no studies have examined correlates of objectively measured physical activity. Furthermore, few studies have prospectively explored factors influencing physical activity from pregnancy through the postpartum period.

## Intervention Studies on Physical Activity During Pregnancy and Postpartum

To date, a few but growing number of behavioral interventions have been developed and rigorously tested with a primary focus on physical activity or exercise, either during pregnancy or postpartum (for example: Aittasalo, et al., 2008; Albright, Maddock, & Nigg, 2009; Cramp & Brawley, 2009; Ebbeling, et al., 2007; Hausenblas, Brewer, et al., 2008; Ostbye, et al., 2008; Mottola et al., 2010; Peterson, et al., 2002; Santos, et al., 2005; Symons Downs, et al., 2009; van Zutphen, Milder, & Bemelmans, 2008; Wen, et al., 2007; Yeo, 2009). Exploration of mediators of change in physical activity during or after pregnancy is needed to identify factors to focus intervention efforts, where interventions have shown success. Other studies focus on weight gain or weight retention, incorporating components of physical activity into the intervention (for example: Claesson, et al., 2008; Kinnunen, et al., 2007; Leermakers, Anglin, & Wing, 1998; O'Toole, Sawicki, & Artal, 2003; Olson, Strawderman, & Reed, 2004; Ostbye, et al., 2009). An assessment of the mediators that influenced physical activity is often not reported in intervention studies. Evaluating an existing cohort of pregnant and postpartum women to identify mediators of physical activity change would be an efficient and meaningful contribution to inform interventions in this population.

## Theoretical Framework of Current Project

Scientists have urged investigators to focus on quantifying and reporting the causal pathways and mechanisms of physical activity behavior change from a multilevel perspective, in order to further our knowledge of this behavior (Baranowski, Anderson, & Carmack, 1998; Bauman, Sallis, Dzewaltowski, & Owen, 2002; Masse, Dassa, Gauvin, Giles-Corti, & Motl, 2002; Pellmar, Brandt, & Baird, 2002). Traditionally, physical activity interventions have not been successful, in part because (1) current theoretical formulations to predict physical activity behavior were quite limited and (2) interventions were not substantially affecting mediator variables (Baranowski, et al., 1998). With the lack of evidence from the literature on mediation variables to focus on in an intervention of physical activity from pregnancy through postpartum, we proposed a study to fill this gap. Very few

studies among pregnant and postpartum women include intrapersonal, interpersonal, and community measures; we propose to gather all of these in one study.

The current study will examine the intrapersonal, interpersonal, and community level mediators of change in physical activity (i) during pregnancy and during pregnancy to 3-months postpartum using self-reported physical activity and (ii) from 3- to 12-months postpartum using self-reported and objectively measured physical activity. The socioecologic framework or perspective guides this process; the framework emphasizes the multidimensionality of health behaviors, as well as the interaction between and interdependence of factors within and across the levels (intrapersonal, interpersonal, and community (neighborhood/environment, organizational, or public policy factors) levels) (McLeroy, Bibeau, Steckler, & Glanz, 1988; National Cancer Institute, National Institutes of Health, & US Department of Health and Human Services, 2005; Sallis & Owen, 1997). We propose that physical activity behavior for women during this time period of rapid change through pregnancy to postpartum period is influenced by these multiple levels of influence. The socioecologic framework incorporates reciprocal causation; that people both influence and are influenced by those around them (National Cancer Institute, et al., 2005). Our study focuses on the mediators of change in physical activity during this critical time period among a prospective cohort study of pregnant women. We include measures of potential mediators that address the various levels of the socioecologic framework. The usefulness of the socioecologic framework is that intervention strategies can be developed to target identified mediators of change in physical activity, accommodating the various levels of influence.

Moreover, a large body of literature supports social cognition theories applied to physical activity behavior. In support of this, we will collect measures associated with the Theory of Planned Behavior (Ajzen, 2002) to determine whether these measures mediate changes in physical activity over time among pregnant to postpartum women, considering the broader socioecologic framework.

The socioecologic framework postulates that physical activity is both directly and indirectly influences by environmental factors. The Theory of Planned Behavior hypothesizes how environmental factors may indirectly influence behaviors, through attitudes, perceived behavioral control, social norms, and intention. The association between external factors, such as the environment, and physical activity could be mediated by the social cognitive factors (e.g., attitudes, perceived behavioral control, social norms, intention). In addition, environmental factors could be considered as moderators in the relationship between the social cognitive factors and physical activity behavior. Several authors have begun to integrate the Theory of Planned Behavior within the larger socioecologic framework to try to better explain physical activity behavior (examples include (de Bruijn, et al., 2006; Kamphuis, et al., 2009; Maddison, et al., 2009; Rhodes, et al., 2006; Rhodes, Courneya, Blanchard, & Plotnikoff, 2007)), but none include pregnant or postpartum women. The integration of these concepts can be further explored among our cohort of pregnant and postpartum women.

## Description of Study

To explore our research questions, we will use the third phase of the Pregnancy, Infection, and Nutrition Study (PIN3), a prospective study that examined whether physical activity or stress were associated with preterm birth. The participants were pregnant women seeking services from prenatal clinics at the University of North Carolina Hospitals (Chapel Hill, NC) and were identified by study staff through a review of all medical charts of new prenatal patients. Women were recruited at their second prenatal visit before 20 weeks of

gestation and those who consented to participate in this study had study-specific data collected on them through pregnancy. Women who were less than 16 years of age, non-English speaking, not planning to continue care or deliver at the study site, or carrying multiple gestations were excluded. Recruitment began in January 2001 and ended in June 2005, with 2006 women recruited into the study. Women were asked to attend two research clinic visits (<20 and 24–29 weeks' gestation) and complete two telephone interviews (17–22 and 27–30 weeks' gestation) and several self-administered questionnaires (distributed at each clinic visit) during pregnancy. Following delivery, women were asked to complete a brief interview in the hospital and medical records were abstracted.

The PIN3 Postpartum Study builds on the PIN3 Study to explore postpartum weight retention with an examination of diet, physical activity, infant feeding, psychosocial factors, and other health behaviors. This study extended data collection for a subset of study participants into the postpartum period starting in 2003. At 3- and 12-months postpartum, home visits were conducted, which included and interview and measurement of height, weight, and percent body fat using bioelectric impedance. The interview included assessment of diet, physical activity, breastfeeding, body image, psychosocial measures, sociodemographics, and other health behaviors. The study website (http://www.cpc.unc.edu/pin) provides greater detail on the protocols and measures. All data collection described herein was approved by the University of North Carolina - Chapel Hill Institutional Review Board and each participant provided her informed consent prior to participation in the studies.

## Self-reported Physical Activity Measurement

At the time PIN3 Study began enrollment in 2001, there lacked a physical activity questionnaire tailored to pregnant women. Thus, a one-week interviewer administered recall questionnaire was developed, designed to capture moderate and vigorous activity in the past week (Evenson & Wen, 2010b). The questionnaire assessed frequency and duration of all moderate and vigorous physical activities the woman participated in, including activity done at work, leisure, for transportation, childcare, adult care, and both indoor and outdoor household activities. Intensity of activity was assessed (i) using a modified Borg scale (Borg & Linderholm, 1974) to capture the participant's perception of intensity, and (ii) classified using published metabolic (MET) tables (Ainsworth, Haskell, Leon, & et al, 1993; Ainsworth, et al., 2000). This physical activity questionnaire provided an estimate of (i) the total number of minutes in the past week of moderate and vigorous physical activity, based on their perceived intensity of the activity or classified based on established MET intensities; and (ii) the total number of MET minutes per week spent in activity, based on established MET intensities. The questionnaire also provided this information by mode (e.g., leisure, work, outdoor/indoor household, child/adult care, and transportation activity) or by intensity (e.g., moderate, vigorous). The questionnaire was collected at both telephone interviews during pregnancy (17–22 and 27–30 weeks' gestation) and at both in-home visits at 3- and 12-months postpartum. Intra- and inter-interviewer quality control measures, such as expert review of taped interviews, were established to ensure that interviewers were asking questions reliably and systematically.

Evidence for validity and reliability of the questionnaire were later assessed among pregnant women (Evenson & Wen, 2010b). To assess concurrent-related validity, 177 pregnant women kept a structured diary and wore an accelerometer (Actigraph) for one week. At the conclusion of the week, they completed the physical activity questionnaire over the telephone. Comparison of the questionnaire to the structured diary was moderate to substantial (Spearman correlation coefficient 0.47 to 0.69) for several measures of moderate or vigorous physical activity using either perceived or absolute intensity. Comparison of moderate to vigorous physical activity from the questionnaire (absolute intensity using

MET-hours/week) to the accelerometer ranged from 0.12 to 0.23 using Spearman correlation coefficients for absolute intensity (MET-hours/week) and 0.28 to 0.34 using relative intensity (hours/week). To assess evidence for test-retest reliability, 109 pregnant women completed the questionnaire twice over the telephone, within 48 hours apart, recalling the same time period. Test-retest reliability was moderate to near perfect for moderate to vigorous physical activity, with the intraclass correlation coefficients ranging from 0.56 to 0.82 for both perceived and absolute intensities.

## Objective Physical Activity Measurement

In addition to self-report measures, a subset of women was asked to wear an accelerometer for one-week at 3- and 12-months postpartum. This provided an objective assessment of physical activity. We used the Manufacturing Technology Inc. (MTI) Actigraph accelerometer model #7164, a small, light-weight uniaxial accelerometer that worn at the hip. The data are recorded as counts and directly downloaded into a computer as an electronic data file. Accelerometer data were collected with 1-minute epochs, and the monitors were regularly calibrated throughout the study. Spurious counts were flagged, assessed, and set to missing if determined to be invalid. We defined non-wear time as a period of 20 minutes or more of zeros, based on our prior work (Evenson & Terry Jr, 2009). We defined a standard measurement day as the length of time in which >=70% of the sample was wearing the accelerometer, separately for weekdays and weekends similar to others (Catellier, et al., 2005). We classified participants as having complete accelerometry data if they had nonmissing counts over at least 70% of a standard measurement day.

Ignoring missing values in the accelerometer file can cause a biased estimate of the true level of physical activity (Catellier, et al., 2005). Therefore, missing data were filled by using multiple imputation inference strategy (using SAS proc MI) through expectation-maximization algorithm and a Markov Chain Monte Carlo method. Others have shown this method to be valid, even when data were not missing at random (Catellier, et al., 2005). Considering the wearing time of our participants, non-missing accelerometer data falling into the daily time window of 5am to midnight was selected as reference data for the imputation. Indicators on ten blocks of the time period (5am to midnight) and week day versus weekend were used for the imputation procedure. In order to represent a random sample of the missing values, ten multiple imputed data sets were created by the multiple imputation procedure and each imputation contained minute-by-minute daily activity count data from 5am to midnight. For our analyses, we will be able to compare results using the full sample, the imputed sample, and the smaller sample defined by complete accelerometry data.

From the accelerometer, we will use the data several ways. First, using total counts per week we evaluated the raw data provided by the accelerometer without imposing cutpoint decisions. Mean counts per week was calculated by dividing the sum of activity counts over 7 days by the number of minutes of wear time across the 7 days. Second, activity was calculated as hours per week (using count thresholds) and counts per week spent in differing intensities (e.g., light, moderate, vigorous). A number of calibration studies of adults provide count thresholds (e.g., cutpoints) for moderate and vigorous activity. We calculated cutpoints using three of these studies: Freedson et al (Freedson, Melanson, & Sirard, 1998), Swartz et al (Swartz, et al., 2000), and summary cutpoints from National Heath and Nutrition Examination Survey (NHANES) data (Troiano, et al., 2008).

## Potential Mediator Measures

A mediator is a variable that explains how or why another variable or intervention changes physical activity. In our case, we will focus on whether a hypothesized mediator or changes

in a hypothesized mediator account for changes in physical activity. Hypothesized mediators were collected during pregnancy and postpartum and are summarized in Table 1, along with a description of the timing of their measurement. Consistent with the socioecologic framework, we consider intrapersonal, interpersonal, and community measures as potential mediators.

**Intrapersonal Level Measures—**Measures focused on the woman include individual characteristics that may influence physical activity behavior. In this study, this includes behavioral measures, such as weight gain, loss, and retention, percent body fat, sleep quality, and breastfeeding during postpartum. We also will explore psychosocial measures, such as self-esteem, self-efficacy, enjoyment of physical activity, anxiety, perceived stress, depressive symptoms, body image, and time for activity. In addition, we developed intrapersonal measures, to be administered twice in postpartum, specific to the Theory of Planned Behavior (Hales et al., 2010). This theory proposes that intention is the central determinant of a given behavior, such as physical activity (Ajzen, 2002). If an individual evaluates physical activity positively (positive attitude), believes that important others think they should engage in physical activity (positive subjective norms), and perceive physical activity to be under their control (positive perceived behavioral control), their intention to perform physical activity will be higher. Constructs included in the Theory of Planned Behavior have been shown to correlate or mediate physical activity behavior (Symons Downs & Hausenblas, 2005), including during pregnancy and postpartum (Symons Downs & Hausenblas, 2004).

**Interpersonal Level Measures—**These measures include interpersonal processes, such as with family, friends, and peers. Measures we are considering as potential mediators include advice about physical activity, advice about weight gain, talking with her partner, emotional support, social support, and social support to be physically active.

**Community Level Measures—**These measures consider the neighborhood and broader community environment, including perceived measures of the safety in the neighborhood and of availability and use of physical activity facilities. This study also collected objective measures of the neighborhood environment, such as from neighborhood audits and other geographic data (Evenson, et al., 2009), but these measures were not hypothesized as mediators of change in physical activity. While institutional and public policy measures are also included in this level of the socioecologic framework, we did not collect them as part of the PIN3 Study.

## Statistical Analyses

First, we will descriptively describe change in physical activity through pregnancy into the postpartum period. With our questionnaire, we will explore changes by intensity (both perceived and absolute), duration, and mode. Next, we will assess whether each potential mediator and changes in the mediator are associated with change in physical activity during pregnancy and postpartum using cross-tabulations and correlations.

With this understanding of the data, the product of coefficients approach (MacKinnon, 2000) will be applied to examine whether any mediators had indirect effects on change in physical activity from the first phone interview (17–22 weeks' gestation) to the second phone interview (27–30 weeks' gestation), from pregnancy to 3-months postpartum, and from 3-months to 12-months postpartum. Each individual level mediator will be examined one at a time and across the time points in which it was available. The total effect, mediated effect, and the proportion of the total mediated effect will be reported. All single-mediator models showing significance will be reexamined with further control for potential

confounders. The Sobel (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002; Sobel, 1982)) standard error approximation formula will be used to test for significance of the mediation effect. In addition to these proposed analyses, we could use structural equation modeling to understand the complexity of these data.

These rich data will also allow us to explore other research questions, such as whether the mediation of physical activity is moderated by factors such as parity or race/ethnicity among women progressing from pregnancy to postpartum. Considering the integration of the Theory of Planned Behavior within the socioecologic framework, we can examine questions such as (i) whether the association between the environment and physical activity is mediated by social cognitive factors (e.g., attitudes, perceived behavioral control, social norms, intention) or (ii) whether environmental factors are moderators in the relationship between the social cognitive factors and physical activity behavior.

## Limitations and Strengths of the Study

There are several limitations of this research. First, mismeasurement due to recall bias of physical activity may occur. Using the PIN3 physical activity questionnaire, women were asked to report their activities. We tried to minimize this bias by asking the questions during a short recall time frame (one week). Furthermore, we have objective measures of physical activity during the postpartum period on a sample of women.

Second, we cannot exclude the possibility that important mediators might be neglected in the data collection and analysis or that adjustment for potential confounders will be incomplete. The diversity and quality with which the existing PIN3 Study measures many variables, however, is remarkable.

Third, because we are using observational data, we are evaluating the natural changes in mediators rather than trying to change them, as in an intervention. This allows us to examine if naturally occurring changes in potential mediators result in changes in physical activity during pregnancy and the postpartum period. The next step in this line of research would then be to take the mediators that we found to affect change in physical activity, and test them in an intervention setting. These tests would involve assessing if the intervention resulted in a change in the mediator and whether the change in the mediator resulted in a change in physical activity (Baranowski, Lin, Wetter, Resnicow, & Hearn, 1997).

Fourth, as with most US cohort studies of pregnant and postpartum women, refusal to participate and subsequent attrition is a challenge. In an earlier PIN cohort study, those women who were eligible for the study but not recruited were more often White compared to African American and of lower education (Savitz, et al., 1999). Thus, it is important to recognize the potential for selection bias. In general, while women may be interested in research about pregnancy given their state, they may also lack the time as they prepare for the child's arrival. Based on a survey from a subset of the PIN3 cohort, once women were enrolled in the study, they were often willing to complete most components of an intensive study, suggesting that initial efforts for recruitment are most important (Daniels, et al., 2006). At recruitment, maintaining a positive rapport between study staff and participants was key. During the study, the participants received an ultrasound and small monetary incentives for completing different components of the study. However, the participant survey indicated that more women were motivated by the fact that they were contributing to science, rather than the monetary rewards (Daniels, et al., 2006).

Finally, we have only crude measures of physical activity prior to pregnancy. These include indicators of regular vigorous leisure activity only. It would be useful for other studies to

consider mediators of the change in physical activity behaviors starting prior to pregnancy. It may be that women change their behavior when they consider becoming pregnant.

This study will provide evidence to better develop an appropriate intervention and to focus efforts on the appropriate time periods (e.g., during and/or after pregnancy). Some other advantages of the cohort include the longitudinal nature of the data, allowing us to explore mediators that might be important at different time periods from pregnancy to postpartum.

## Conclusion

This study addresses an issue of substantial importance and widespread implications: what are the important factors mediating change in physical activity during the pregnancy through the postpartum period? We focus on pregnancy and the postpartum period as a window of opportunity (Peterson, et al., 2002). The health benefits of physical activity or exercise during pregnancy include the possible prevention of gestational diabetes, preeclampsia, and chronic musculoskeletal conditions, support of healthy weight, and improved mental health (ACOG, 2002; Davies, Wolfe, Mottola, & MacKinnon, 2003; McMurray, et al., 1993; Royal College of Obstetricians and Gynaecologists, 2006). Moreover, regular exercise helps maintain cardiovascular fitness level throughout pregnancy and thus improves postpartum recovery (Davies, et al., 2003; McMurray, et al., 1993). Given the substantial rise in obesity, especially among women of reproductive age, the development of novel, successful physical activity interventions for pregnant and postpartum women are critical.

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**Table 1**

Potential mediators of change in physical activity, collected during pregnancy and postpartum

| | | Measures Collected During Pregnancy | | | | | Postpartum Measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | | **17–22 weeks' gestation phone interview** | **27–30 weeks' gestation phone interview** | **<20 weeks' gestation SAQ** | **24–29 weeks' gestation SAQ** | **Medical record abstraction** | **3 month interview** | **3 month SAQ** | **12 month interview** | **12 month SAQ** |
| **Intrapersonal** | | | | | | | | | | |
| Weight gain | Weight at each prenatal visit was abstracted from the medical record after delivery. Recalled pregravid weight was reported at the time of the first prenatal clinic visit and documented in the medical record. The total weight gain during pregnancy was calculated by subtracting the last reported weight in the medical record from the pregravid weight. | | | | | X | | | | |
| Weight loss or retention | Maternal weight was collected using a digital scale (Tanita) by trained personnel according to guidelines established by the National Center for Health Statistics (Lohman, Roche, & Martorell, 1988). The estimated weight at delivery was computed by adding total weight gain to the pregravid weight. The postpartum weight was then subtracted from the estimated weight at delivery or at 3-months postpartum to compute the amount of weight retained at each point in the postpartum period. | | | | | | X | | X | |
| Percent body fat | An estimate of body fat was obtained through a leg-to-leg bioelectrical impedance analysis using a Tanita scale. | | | | | | X | | X | |
| Sleep quality | A question by Jenkins et al (Jenkins, Stanton, Niemcryk, & Rose, 1988) asked about the quality of sleep on most nights (poor, fair, good, or excellent). | | | | X | | X | | X | |
| Breastfeeding | Women were asked about total duration of breastfeeding, period of exclusive breastfeeding, and the timing of the introduction of solids at postpartum. From this we derived a variable defining whether the mother breastfed at each postpartum time period. | | | | | | X | | X | |
| Self-esteem scale | A 10-item self-esteem scale (Rosenberg, 1965) assessed a positive or negative orientation toward oneself. | | | X | | | | | | |
| Physical activity self-efficacy | A single item question, derived from a 20-item measure of self-efficacy (DeClemente, Prochaska, & Gibertini, 1985), asked women how confident they were that they could exercise more. Response options included very confident, somewhat confident, or not at all confident. | | X | | | | X | | X | |
| Enjoyment of physical activity | Enjoyment of physical activity was assessed with a single item that asked how enjoyable physical activity or exercise was at this time. Response options included very enjoyable, somewhat enjoyable, a little enjoyable, or not enjoyable (Stucky-Ropp & DiLorenzo, 1993). | | X | | | | X | | X | |
| | Enjoyment of physical activity was assessed during postpartum using a 5-item version from the physical activity enjoyment scale [Kendzierski, 1991 #2144]. | | | | | | | X | | X |
| Anxiety | The Spielberger State-Anxiety scale asked women to react to 20 short statements with how they feel "right now" and provided a measure of the current emotional state including subjective feelings of tension, apprehension, nervousness, and worry (Spielberger, 1983). | | | X | X | | X | | X | |
| Perceived stress | The 10-item perceived stress scale (Cohen, Kamarck, & Mermelstein, 1983) is a measure of the degree to which situations in one's life are appraised as stressful (Cohen & Williamson, 1988) and provided an index of chronic stress or strain, and effectiveness in coping with these stresses. | X | X | | | | X | | X | |

| | | Measures Collected During Pregnancy | | | | | Postpartum Measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | | **17–22 weeks' gestation phone interview** | **27–30 weeks' gestation phone interview** | **<20 weeks' gestation SAQ** | **24–29 weeks' gestation SAQ** | **Medical record abstraction** | **3 month interview** | **3 month SAQ** | **12 month interview** | **12 month SAQ** |
| Depressive symptoms | Women answered the 20-item Center for Epidemiological Studies – Depression Scale (CES-D) (Radloff, 1977) to indicate depressive symptoms during pregnancy. The scale was also categoried into 3 levels (0–16, 17–24, and 25+) and two levels (0–25, 26+). | | | X | X | | | | | |
| | Women answered the 10-item Edinburgh Postnatal Depression Scale (EPDS) during postpartum (Cox, Holden, & Sagovsky, 1987; Kennedy & Suttenfield, 2001). The scale was also categorized into 2 levels (<10 or 11+). | | | | | | X | | X | |
| Body image | Body size satisfaction using body image assessment is the discrepancy between current (self) and ideal body size (Williamson, Gleaves, Watkins, & Schlundt, 1993; Williamson, et al., 2000). Women were given a series of 18 cards in a random order with black and white line-drawn silhouettes. The women were asked to indicate which drawing most resembled her pregravid figure or body size. The cards were then shuffled and the women were asked which figure they wished most to resemble. A high score indicated a larger body size and a greater difference between the pregravid and ideal body scores. The difference was used in the analysis (−2 or less=prefer heavier weight; −1 to 1=no discrepancy; 2 to 4 prefer slightly lighter; 5 to 10 prefer much lighter). | | | | | | X | | X | |
| Able to take time for exercise | Women were asked if they were able to take time to do recreational physical activities if they wanted to all of the time, some of the time, or none of the time. | | X | | | | | | | |
| Theory of planned behavior measures | The following measures were developed using the theory of planned behavior (Ajzen, 1991; Courneya & Friedenreich, 1999) and tested for factor validity and longitudinal invariance within the PIN Study (Hales, Evenson, Wen, & Wilcox, 2009). | | | | | | | | | |
| Perceived behavioral control | This scale indicates perceived difficulty of engaging in physical activity. Scores from three questions were added together and a mean was calculated. A higher score indicated more perceived behavioral control. | | | | | | | X | | X |
| Attitude (instrumental and affective) | Two scales were derived to indicate overall feelings towards physical activity, both instrumental and affective. Each scale was comprised of three items. The scores of corresponding items were added together and a mean was calculated. A higher score indicated a more positive attitude. | | | | | | | X | | X |
| Subjective norm | A single item indicated perceived social pressure to perform physical activity. A higher score indicated more perceived social pressure. | | | | | | | X | | X |
| Behavioral beliefs | This scale indicated perceived advantages and disadvantages of performing physical activity. Scores from five items were added together and a mean was calculated. A higher score indicated more advantage from physical activity. | | | | | | | X | | X |
| Normative beliefs | This scale indicated approval of physical activity by their spouse, family, friends, and physician. Scores from four items were added together and a mean was calculated. A higher score indicated more approval for physical activity. | | | | | | | X | | X |
| Control beliefs (ability and resource) | Two scales were derived to indicate ability and resources available for performing physical activity. Each scale was comprised of three items. The scores of corresponding items were added together and a mean was calculated. A higher score indicated more ability and resources available. | | | | | | | X | | X |
| Intention | Women were asked if they intended to engage in regular physical activity during the next 9 months. Response options varied on a 7-point scale from strongly disagree to strongly agree. | | | | | | | X | | X |
| **Interpersonal** | | | | | | | | | | |
| Advice about physical activity | Women are asked whether or not they received any advice from a doctor, nurse, or other health professional about physical activity during pregnancy (yes or no). | | X | | | | | | | |

| | | Measures Collected During Pregnancy | | | | | Postpartum Measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | | **17–22 weeks' gestation phone interview** | **27–30 weeks' gestation phone interview** | **<20 weeks' gestation SAQ** | **24–29 weeks' gestation SAQ** | **Medical record abstraction** | **3 month interview** | **3 month SAQ** | **12 month interview** | **12 month SAQ** |
| | Women were asked at 3-months postpartum, "At any time since delivery, has a doctor, nurse, or other health professional, or have family members or friends, given you advice about physical activity or exercise?" A similar question was asked at 12-months postpartum, recalling back 9 months. | | | | | | X | | X | |
| Advice about weight gain | Women are asked whether or not they received any advice from a doctor, nurse, or other health professional about weight gain during pregnancy. | | X | | | | | | | |
| | Women were asked at 3-months postpartum, "At any time since delivery, has a doctor, nurse, or other health professional, or have family members or friends, given you advice about weight loss after pregnancy?" A similar question was asked at 12-months postpartum, recalling back 9 months. | | | | | | X | | X | |
| Partner talk regarding concerns | A question was developed for the PIN Study to assess how often the women talked with her partner regarding concerns. Response options included almost every day, a few times a week, a few times a month, once or twice, or never. | | X | | | | X | | X | |
| Emotional support | A question was developed for the PIN Study to assess how much emotional support she received. Response options included a lot of emotional support, some emotional support, not much emotional support, or none. | | X | | | | X | | X | |
| Partner support to be physically active | Women were asked if their husband or partner was supportive of them being active all of the time, some of the time, or none of the time. | | X | | | | | | | |
| Social support to be physical active | The physical activity social support questions were derived from Sallis et al (Sallis, Grossman, Pinski, Patterson, & Nader, 1987). The scale consisted of 5 questions with 4 response choices ranging from "strongly agree" to "strongly disagree". An overall scale (5 items) and two subscales are derived: social support from friends (2 items) and relatives (2 items). The scales was calulated by adding scores from appropriate items together and taking the mean. | | | | | | | X | | X |
| Social support | The 19-item Medical Outcomes Study (MOS) social support scale assesses dimensions of social support (Sherborne & Stewart, 1991). We used the total social support scale and several subscales including tangible/instrumental support subscale, affectionate support subscale, positive social interaction subscale, and a combination of emotional/ informational support subscale. | | | X | | | | | | |
| **Community** | | | | | | | | | | |
| Perceived neighborhood safety score | Seven questions to assess the woman's perception of safety in and stress from living in her neighborhood provide a subjective assessment of their contextual environment (Stancil, Hertz-Picciotto, Schramm, & Watt-Morse, 2000). A higher score indicated less perceived safety. | | X | | | | X | | X | |
| Perceived measure of availability and use of physical activity facilities | Eleven questions are asked on the availability, quality, and use of private and public recreational facilities and schools as places to be active (Evenson & McGinn, 2005). Three questions were scored on availability, with a higher score indicating more availability. Three questions were asked on how often of those facilities being used. The use score was added to the availability score to account for both availability and use, with a higher score indicating more availability and use. | | | | | | X | | X | |

SAQ=self-administered questionnaire, the dates correspond to when the questionnaire was given to the women