THESIS

ACCELEROMETER MEASUREMENTS OF PHYSICAL ACTIVITY IN PREGNANT ADOLESCENTS

Submitted by

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ABSTRACT

ACCELEROMETER MEASUREMENTS OF PHYSICAL ACTIVITY IN PREGNANT ADOLESCENTS

In adult women, physical activity during pregnancy, assessed objectively with accelerometry, has been related to less excess gestational weight gain and better health outcomes for mother and child. Objectively-measured physical activity has not been reported in pregnant adolescents, and it is unclear to what extent accelerometers are feasible in this group of young women who are at very high-risk for social-emotional challenges and excess gestational weight gain. The main purpose of the current thesis project was to investigate the feasibility of using accelerometers to objectively quantify physical activity in pregnant adolescents. The second aim was to explore the associations of physical activity with pregnant adolescent health characteristics including pre-pregnancy body mass index (BMI; kg/m^2), first-trimester weight (kg), depression symptoms, emotional eating, and loss-of-control eating. Participants were $N =$ 28 15-19 year old patients, 12-18 weeks gestation, obtaining prenatal care at a multidisciplinary adolescent pregnancy clinic. Physical activity was assessed with GT3-X wrist-worn accelerometers for 7 days to assess average moderate-vigorous physical activity (MVPA) per day, percentage of time spent in MVPA, daily average sedentary bouts, percent of time spent sedentary, average step counts, and maximum step counts. Feasibility was determined as median days of wear time equal to or exceeding 4 out of 7 days (of $\geq$10 hours of wear time per day). Adolescents reported pre-pregnancy weight/height to compute pre-pregnancy BMI; first-trimester weight was assessed from measured weight. Depression symptoms and emotional eating were assessed with validated self-report questionnaires. Presence of loss-of-control eating was evaluated by interview. In addition to reporting statistical significance ($p < .05$), strength of bivariate associations were described as moderate ($r \geq .40$) and large ($r \geq .60$), given the pilot nature of the study. Results indicated that the median days of valid wear was 5 days, and 59.3% of pregnant adolescents met criteria for valid wear. Adolescents who did not have valid accelerometer reported heavier pre-pregnancy BMI (28.63 ± 6.75 kg/m^2 vs. 23.55 ± 5.21 kg/m^2, $p = .04$), with no other significant differences. Among pregnant adolescents with valid data (N = 16), there was an inverse, moderate association of average MVPA per day with depression symptoms ($r = -.44$ $p = .09$). In conclusion, there were mixed results for the feasibility of accelerometry in pregnant adolescents. In order to increase wear time compliance in this population, particularly for heavier adolescents, more incentives are required. Finally, results from this study suggest that the connection between pregnant adolescents' physical activity and depression warrants exploration in future research.

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INTRODUCTION

Although adolescent (<20 years) birth rates have declined in the United States over the past 20 years, the 2017 national birth rate of 194,377 babies born remains much higher than in other industrialized countries (Centers for Disease Control and Prevention [CDC], 2019). Adolescents in the United States are two and a half times more likely to give birth than adolescents in Canada, and American adolescents are four times more likely to give birth than German adolescents (Kearney and Levine, 2012). Further, there are serious health disparities as adolescent pregnancy disproportionately affects racial/ethnic minority adolescents from disadvantaged socioeconomic contexts (Hodgkinson, Beers, Southammakosane, & Lewin, 2014). For instance, in 2017, there were 18.8 births for every 1,000 adolescent women ages 15-19 years overall, but up to 27.5 births for every 1,000 Black/African American teenagers and 28.9 births for every 1,000 Hispanic/Latino teenagers (CDC, 2019).

Excess gestational weight gain, and the strong, concomitant risk it carries for intergenerational transmission of obesity, is a major health concern in adolescent pregnancy (Zamora-Kapoor & Walker, 2015). The Institute of Medicine recommends that lean mothers (body mass index [BMI] 18.5-24.9 kg/m^2) gain 25-35 pounds during pregnancy, women with overweight (BMI 25-29.9 kg/m^2) gain 15-25 pounds, and women with obesity (BMI $\geq$30 kg/m^2) gain 11-20 pounds (American College of Obstetricians and Gynecologists, 2013). However, according to the CDC, an estimated 48% of pregnant females, gain more weight than recommended during pregnancy (Hamilton, Martin, Osterman, & Curtin, 2015). Consistent with data in adult women (Mamun et al., 2010), excess gestational weight gain appears to be deleterious for adolescent mothers' and their offspring's future well-being (Oken, Rifas-Shiman, Field, Frazier, & Gillman, 2008). Excess gestational weight gain promotes maternal postpartum weight retention and has been related to offspring's greater risk of health problems such as obesity and cardiometabolic disease (Shapiro et al., 2017).

Developmental Timing of Excess Gestational Weight Gain in Adolescent Pregnancy.

Excess gestational weight is particularly troubling when timed during the developmental period of adolescence for a number of reasons. Excess gestational weight gain is associated with increased medical complications in pregnancy, such as a pregnancy-induced hypertension, gestational diabetes mellitus, macrosomia, birth canal tear, and cesarean section (Oken et al. 2008; Monleón et al., 2015; Vivatkusol et al., 2017). Compared to adult mothers, adolescent mothers overall have an increased risk of preeclampsia and preterm labor, which may be further heightened with excess gestational gain (Vivatkusol et al., 2017). Also, adolescence is a sensitive developmental period for weight trajectories due to the increased psychosocial and behavioral risk factors of this age group and the likelihood that health behaviors established during adolescence influence lifetime pathways of obesity and cardiometabolic disease (Jasik & Lustig, 2008). In addition, the physiological and metabolic changes involved in puberty, including normative gains in adiposity and pubertal insulin resistance, may contribute to excess weight gain in non-pregnant adolescents (Jasik & Lustig, 2008). Consequently, the combination of becoming pregnant and experiencing excess gestational weight gain during adolescence has high potential to adversely influence adolescents' weight and metabolic health. Regardless of pre-pregnancy BMI, adolescent mothers whose gestational weight gain exceeds the recommendations of the Institute of Medicine are 4 to 5 times more likely to have obesity 10 years post-pregnancy than those whose weight gain is within the recommendations (Groth, 2008; Mamum et al., 2010). Whereas mothers, in general, retain weight during pregnancy to provide adequate nutrients for the developing child, adolescents also have higher fat acquisition than adults, with accompanying changes in metabolism and increased insulin resistance (Chu, Callaghan, Bish, & D'Angelo, 2009; Jasik & Lustig, 2008). Pregnancy in adolescents can therefore exacerbate increases in fat deposition that normally characterize puberty (Hediger, Scholl, & Schall, 1997). These developmental phenomena may increase pregnant adolescents' potential for excess gestational gain, propagating an intergenerational transmission of obesity and cardiometabolic disease (Monleón et al., 2015).

Context of Psychosocial and Behavioral Challenges in Adolescent Excess Gestational Weight Gain

There are frequent psychosocial and behavioral challenges that complicate adolescent pregnancy and have likely contributed to making pregnant adolescents an understudied group with respect to understanding gestational weight gain. Many pregnant adolescents have experienced trauma, with some estimates suggesting up to 50% (Leplatte, Rosenblum, Stanton, Miller, & Muzik, 2012). Major adverse life events such as abuse, domestic violence, poverty, homelessness, and loss are also common (Hodgkinson et al., 2014). Moreover, internalizing symptoms such as depression and anxiety as well as externalizing symptoms such as delinquency and aggression are common in adolescents who become pregnant and carry to term (Hodgkinson et al., 2014). A greater likelihood of cumulative, serious adverse life events is associated with increases in non-pregnant adolescents' depression symptoms (Ford, Elhai, Connor, & Frueh, 2010), and depression symptoms, in turn, have been related to more excess weight gain in non-pregnant adolescents, pregnant adolescents, and adult pregnant women (Blaine, 2008; Groth, Holland, Kitzman, & Meng, 2013).

Adolescence can be designated as an important transitional phase in development with periods of rapid physical development, relationship and role transitions, and identity discovery (Graber & Brooks-Gunn, 1996; Wise, 2015). Puberty, on average, lasts about 2 years in females from the age of pubertal onset to the advent of menarche, with earlier onset of puberty leading to a longer duration of puberty than in those with later pubertal onset (Martí-Henneberg & Vizmanos, 1997). Yet, current perspectives on adolescence suggest that this age period spans the initiation of puberty, through sexual maturation, and up to age 25 years, when self-regulatory capacities have neared maturity and social and economic independence have been achieved (Steinberg, 2014). Reproductive transitions, like puberty, are time periods in which a woman's physiological system can be more influenced by stressors (Graber & Brooks-Gunn, 1996). These transitions involve hormonal changes, which likely magnify the influence of social-environmental stressors on adolescent behavior and health (Graber & Brooks-Gunn, 1996). Moreover, when pregnancy occurs during adolescence, girls are frequently unprepared socially, emotionally, economically, and/or psychologically for being a parent (Vivatkusol et al., 2017). Thus, the cumulative stress of reproductive transitions at puberty combined with the reproductive transition of pregnancy may contribute to further increasing psychosocial challenges of pregnant adolescents (Graber & Brooks-Gunn, 1996). Understanding potentially modifiable health behaviors that relate to excess gestational weight gain in adolescent pregnancy is critical to the design of preventative interventions in this high-risk population. One such health behavior is physical activity.

Physical Activity and Gestational Weight Gain

Physical activity in adult pregnancy is increasingly recognized as an important contributor to healthy gestational weight gain (Streuling et al., 2011). Studies have demonstrated that walking, moderate-to-vigorous physical activity (MVPA), and total activity during adult pregnancy are associated in observational studies with a lower likelihood of mothers having excessive gestational weight gain (Stuebe, Oken, & Gilllman, 2008). Regular activity, such as at least 30 minutes per day of MVPA, in pregnancy has been associated with a host of mental and physical benefits such as improved mood, less excess weight gain during pregnancy, improved cardiovascular function, decreased risk of developing gestational diabetes, and less weight retention in the postpartum (Poyatos-León et al., 2016; Sanda et al., 2017). Indeed, physical activity is recommended for at least 150 minutes per week in pregnancy (Centers for Disease Control, 2015; Sanda et al., 2017). Unfortunately, in individuals who are insufficiently active prior to pregnancy, physical activity levels during pregnancy tend to decline further (Sanda et al., 2017).

Most studies of physical activity in pregnancy focus on adults rather than adolescents. In national, community samples of adolescents, studies show that more than 80% of adolescents do not meet the recommended daily physical activity guidelines for youth to achieve at least 60 minutes per day of MVPA intensity (Centers for Disease Control, 2015; Cradock, Kawachi, Colditz, Gortmaker, & Buka, 2009; U.S. Department of Health & Human Services & Council on Sports, 2017). Further, total physical activity actually declines during the adolescent years, particularly in females, and thus, this pattern presents a particular challenge when combined with pregnancy (Webber et al., 2008). The American College of Obstetricians and Gynecologists (2015) recommends that pregnant adolescents participate in a minimum of 30 minutes per day of daily moderate physical activity (i.e., equivalent to brisk walking). Although there have been previous studies that have used self-reported measures of physical activity (Whisner et al., 2014), there are virtually no published studies objectively quantifying physical activity patterns in pregnant adolescents measured with accelerometers, yet preliminary data from a couple of very small reports point to a majority having insufficient activity measured with pedometers (Behrens, Bradley, Kirby, & Nanney, 2012; Rockette-Wagner et al., 2017).

Physical activity in pregnancy and its relationship to offspring outcomes. Physical activity during pregnancy may affect metabolic outcomes for pregnant women and also affect the likelihood of obesity in their offspring (Hayes, Bell, Robson, & Poston, 2014). Studies have suggested that women who participate in routine exercise during pregnancy are more likely to give birth to infants within a healthy weight range than women who do not exercise (Hopkins, Baldi, Cutfield, McCowan, & Hofman, 2010). Furthermore, physical activity during pregnancy also affects the risk of gestational diabetes, which has important immediate and longer-term implications for the developing fetus. In particular, mothers who develop gestational diabetes can adversely impact their offspring's risk for experiencing excess fetal growth, developing childhood obesity, and even future type 2 diabetes (Shapiro et al., 2017). Activity characteristics in pregnancy such as time spent sedentary also have been positively associated with an offspring's increased risk of obesity at the 8 years of age (Mourtakos et al., 2015). These collective studies suggest that engaging in healthy physical activity before and during pregnancy, and limiting sedentary time, have the potential to improve mothers' glucose metabolism and fetal environment, which may in turn reduce the risk for offspring obesity and risk factors for cardiometabolic disease.

Measurement of Physical Activity

Instruments to objectively measure physical activity, such as accelerometers, are crucial for accurately quantifying and studying the role of physical activity in weight and associated health outcomes (Schuster, Kokic, & Sindik, 2016; Scott et al., 2017). In contrast, questionnaires are an alternate method frequently used to assess physical activity. Questionnaires are an easy and low-burden method to obtain information from pregnant women about physical activity; however, they may not provide the most comprehensive and valid assessment of physical activity during pregnancy (Schuster et al., 2016). There have not been studies comparing self-report versus accelerometery in this pregnant adolescents, yet unfortunately, it is highly likely that surveys of physical activity in this population would carry similar biases. In contrast, accelerometers have the potential to be used as a method to reduce self-report biases, and they are also highly supported with validation of their accuracy of physical activity measurements in both non-pregnant adolescents and in pregnant women (Schuster et al., 2016). Accelerometers have been determined to be suitable for pregnancy in adults due to their relatively non-invasive nature (van Hees et al., 2011).

Despite previous studies concerning pregnant adults and separately, non-pregnant adolescents, to our knowledge, physical activity has not yet been objectively measured with accelerometers in pregnant adolescents (Poyatos-León et al., 2016). Measurements of physical activity using accelerometry may or may not be feasible for pregnant adolescents and should be determined. The increased psychosocial challenges that pregnant adolescents face are likely to influence their compliance, wear time practices, and investment in research, requiring an assessment of the feasibility of accelerometry in pregnant teenagers. Therefore, the first aim of the current study was to explore the feasibility of using accelerometry to objectively measure pregnant adolescent physical activity.

Exploring Associations with BMI and Other Health Behaviors

Pregnant adolescents typically have many psychosocial issues that contribute to considerable difficulty in studying this at-risk group of young women (Leplatte et al., 2012).

Moreover, it is critical that we test methods to accurately characterize the health behaviors of pregnant adolescents, as no prior studies have researched objective measures of physical activity nor its associations with physical and mental health indices in this group. Therefore, the second aim of the study was to investigate the associations of pregnant adolescent physical activity with clinical characteristics important for gestational weight gain including pre-pregnancy BMI, first-trimester weight, depression symptoms, emotional eating, and loss-of-control eating.

Pre-pregnancy BMI and first-trimester weight. Past literature suggests that accelerometry-measured physical activity characteristics in pregnant women have been associated with pre-pregnancy BMI and first-trimester weight (Herring et al., 2012). Therefore, similar associations were expected to be observed in pregnant adolescents.

Depression symptoms. Depression is highly common in non-pregnant adolescents and even more prevalent in pregnant adolescents (Center for Behavioral Health Statistics and Quality, 2017; Hodgkinson et al., 2014). For example, in 2016, approximately 2.2 million adolescents in the United States exhibited at least one major depressive episode (Center for Behavioral Health Statistics and Quality, 2017). In the pregnant adolescent literature, estimates of depression prevalence range from 16-44%; however, these estimates are limited due to small samples (Szigethy, 2001). Past studies in adult pregnancy have suggested that women's higher self-reported depression and stress are associated with less physical activity engagement (Mouchacca, Abbott, & Ball, 2013). Thus, we anticipated a similar association of depression and physical activity in adolescent pregnancy. Exploring the association of depression symptoms to physical activity in pregnant adolescents is important because depression may influence gestational weight gain, through physical activity as well as through overeating patterns, including emotional eating and loss-of-control eating.

Overeating behaviors. One common overeating behavior in adolescents is emotional eating, which refers to eating in response to negative emotions (Faith, Allison, & Geliebter, 1997). Emotional eating is relatively common in adolescents and predicts excess weight gain in non-pregnant adolescents, particularly in combination with a propensity for uncontrolled eating (Stojek et al., 2018). In theory, emotional eating may be particularly important in this population because pregnant adolescents frequently face social-emotional adversities and many experience depression symptoms during pregnancy that could be anticipated to trigger emotional eating in an effort to cope (Vandewalle, Moens, & Braet, 2014).

Another related, but distinct, overeating construct is loss-of-control eating, which refers to a subjective sense of lack of control while eating any amount of food (American Psychiatric Association, 2013). Loss-of-control eating is common in adolescents who have overweight or obesity, affecting up to 50% of teenagers seeking intervention for weight management (Tanofsky-Kraff et al., 2014). In pregnant women, 28% report loss-of-control eating before or during early pregnancy (Kolko, Emery, Marcus & Levine, 2017). Loss-of-control eating patterns have not been articulated in adolescent pregnancy, in spite of the potential importance of this construct for excess gestational weight gain. For instance, compared to those who do not report loss-of-control eating, non-pregnant adolescents who experience of loss-of-control eating have a greater risk of having excess weight/adiposity and of excessive weight gain over time (Shomaker et al., 2010; Tanofsky-Kraff et al., 2007). There has been increasing, recent interest in understanding the overlap among health behaviors, such as eating behavior and physical activity together, rather than studying health behaviors in isolation (Thivel et al., 2019). Therefore, we sought to explore the relations of physical activity characteristics to emotional eating and loss-of-control eating and anticipated that there would be inverse associations with activity and positive associations with sedentary time.

Current Study

The primary purpose of this master's thesis project was to investigate the feasibility of using accelerometers to objectively quantify physical activity in adolescents who are pregnant. Feasibility was determined through adolescents' wear time, with the primary criterion being that median days of wear would equal or exceed 4 out of 7 days of at least 10 hours per day of wear. Further, we predicted that a minimum of 70% of pregnant teenagers would have valid data, using this wear criterion (i.e.,_at least 4 out of 7 days with ≥10 hours/day). These thresholds were based upon Van Coevering and colleagues' (2005) and Hesketh and colleagues' (2018) studies on using accelerometers to measure physical with adolescents and pregnant women, respectively. It was hypothesized that accelerometers would be feasible according to these criteria. The second purpose of this project was to explore the associations of physical activity, measured via accelerometry, with core characteristics relevant to gestational weight gain. Specifically, we characterized the associations of pregnant adolescents' physical activity patterns with pre-pregnancy BMI, first-trimester weight, depression symptoms, emotional eating, and loss-of-control eating. It was hypothesized that physical activity characteristics, including average MVPA per day, percentage time spent in MVPA, average step counts, and maximum steps would be inversely associated with pre-pregnancy BMI, first-trimester weight, depression symptoms, and overeating behaviors, and whereas daily average sedentary bouts and percentage time spent sedentary would be positively related to each of these characteristics.

METHODS

Participants

Recruitment and sampling procedures. Purposive sampling was utilized to recruit expectant adolescent mothers receiving prenatal care at the Colorado Adolescent Maternity Program (CAMP) clinic at Children's Hospital Colorado. For the purposes of this project, baseline data from $N = 28$ pregnant adolescents recruited to take part in a pilot study for prevention of excess gestational weight gain were examined. Research staff approached all potentially eligible pregnant adolescents enrolled in the CAMP clinic at their first obstetrics appointment to determine if they would be interested in volunteering in a research study designed to help expectant adolescent mothers gain a healthy weight for themselves as well as their baby. If adolescents were interested in participating, they were scheduled for a screening visit at the CAMP clinic to determine sustained interest and study eligibility that included measures of age, location of prenatal care, gestational weeks, BMI, and physical and mental health.

Eligibility and characteristics. Participants were eligible if they were (i) expectant mothers 13-19 years of age, (ii) enrolled as patients in the CAMP clinic, (iii) estimated to be 12-18 gestational weeks at the time of enrollment, and (iv) had a pre-pregnancy BMI >5th percentile for age and sex. Exclusion criteria included (i) current psychiatric concerns that necessitated more intensive treatment and would interfere with compliance (e.g., active suicidal ideation, bipolar disorder, panic disorder, obsessive-compulsive disorder, alcohol or substance abuse or dependence, conduct disorder, psychosis, anorexia nervosa, and bulimia nervosa), (ii) medical and high-risk pregnancy conditions (e.g., gestational diabetes, bariatric surgery, cancer, refractory hypertension, and preeclampsia), and (iii) use of medication that affects insulin sensitivity, weight gain, or mood (e.g., insulin sensitizers, anti-depressants, or mood stabilizers).

Procedures

All procedures were approved by the Colorado Multiple Institutional Review Board, the University of Colorado's Scientific Advisory Research Council, and the Research Institute of Children's Hospital Colorado. A screening visit was scheduled with interested volunteers at the CAMP clinic at a time that was convenient for the participant, often adjacent to an obstetrics prenatal appointment. At this visit, the study was described in detail and interested adolescents provide consent. As adolescents are emancipated minors in Colorado State Law, adolescents under 18 years were permitted to consent for themselves without a parent/guardian. At this visit, surveys and interviews were administered, height and weight were collected to compute BMI metrics, and adolescents reported on pre-pregnancy height and weight using a standard protocol to estimate pre-pregnancy BMI (Kabir, Sheeder, & Stevens-Simon, 2008). They were fitted with an accelerometer on a non-dominant wrist and were directed to wear the device for 7 days during the day and while sleeping. The device was then collected after at least 7 days of wear at a return visit. Adolescents were compensated for completing the clinic screening visit. However, due to the pilot nature of this study, they were not given additional incentives for accelerometry wear, and they were paid for their effort to complete the clinic screening appointment regardless of whether they subsequently wore the accelerometer.

Measures

Physical activity by accelerometer. Physical activity was measured through ActiGraph's GT3-X accelerometer worn on the non-dominant wrist, which has been validated in non-pregnant adolescents, non-pregnant adults, and pregnant adults (Crouter, Flynn, & Bassett, 2015;

Jaeschke, Steinbrecher, Jeran, Konigorski, & Pischon, 2018; Rousham, Clarke & Gross, 2006). Although physical activity may vary weekly, this measurement has demonstrated good week-to-week reliability for habitual physical activity when measured over a one to two-week period (Jaeschke et al., 2018). After raw data were downloaded, the ActiLife software package was used to convert raw data into a specific epoch necessary for analysis. Wear-time compliance was obtained through the ActiLife software (Crouter et al., 2015). In order to have valid, usable data, wear-time compliance must have been at least 4 days within a 7-day period of time. In individuals with valid data, physical activity was expressed as average MVPA minutes per day, percentage time in minutes spent in MVPA (of total valid days), average length of sedentary bouts in minutes per day (indicating the length of time spent in sedentary sessions), percentage of time in minutes spent sedentary (of total valid days), average step counts (average number of steps performed per minute), and maximum step counts (maximum number of steps performed per minute) using Freedson cutpoints (Freedson, Melanson, & Sirard, 1998). Maximum step counts from waist worn monitors are typically used as a proxy of physical function (Tudor-Locke et al., 2019). Participants did not complete a log for sleep time.

Body measurements. Height was measured three times to the nearest millimeter by trained research staff using a stadiometer. Weight was measured to the nearest 0.1 kg by a calibrated electronic scale. BMI was calculated with the participant's weight (kg) divided by the height (m) squared. The following formula was used: weight (kg)/ [height (m)]^2 (CDC, 2014). We also calculated BMI *z*-score and percentile based upon CDC 2000 growth charts. Participants also were asked to recall their height and weight prior to pregnancy, and self-reported height and weight were used to compute pre-pregnancy BMI (raw, *z*-score, and percentile) (Kabir et al., 2008).

Depression symptoms. The Center for Epidemiologic Studies Depression Scale (CES-D) is a well-validated continuous measure of depression symptoms (Radloff, 1977). This survey has been validated in pregnant adolescents (Kabir et al., 2008). This survey has a total of 20 questions that are each scored on a Likert scale from "0" (*rarely or none of the time; less than 1 day*) to "3" (*all of the time; 5-7 days*), with items such as "I was bothered by things that usually don't bother me." The total score is calculated as the sum of all items. Higher total score values indicate greater depression symptomatology.

Overeating patterns. Two measures of overeating were administered. First, the Emotional Eating Scale adapted for Children and Adolescents (EES-C) is a reliable and valid self-report survey for adolescents that was used to measure eating in response to three subcategories of feelings: depression, anxiety/anger/frustration, and fatigue/boredom (Tanofsky-Kraff et al., 2007). The EES-C has a total of 25 self-report items scored on Likert scale from "0" (*I have no desire to eat*) to "5" (*I have a very strong desire to eat*). Participants read the prompt, "We all react to different feelings in different ways. Some types of feelings make us want to eat. Please let us know how much the following feelings make you want to eat by selecting the appropriate box." An example feeling is "resentful." The total score is calculated from the average of items for the respective scales. Higher scores indicate a greater desire to eat in response to these negative feelings (Tanofsky-Kraff et al., 2007). Second, trained research staff administered the Eating Disorder Examination (EDE) – Overeating Section version 12.0 (Bryant-Waugh, Cooper, Taylor, & Lask, 1996; Fairburn & Cooper, 1993). This semi-structured interview assesses episodes of overeating. Consistent with past literature (Rizvi, Peterson, Crow, & Agras, 2000), responses were used to categorize adolescents as having a presence or absence of loss-of-control eating in the past month.

Pregnancy information. Gestational age of pregnancy and other pertinent medical and psychiatric complications were obtained from the patient's medical chart. These characteristics were necessary in order to determine the initial eligibility of the participant as well as to develop a baseline understanding of pregnancy stage and current mental and physical health status in order to rule out exclusionary criteria.

Data Analysis

Analyses were performed using IBM SPSS Statistics 25. To address the main aim of feasibility of accelerometers in pregnant adolescents, descriptive information was generated to describe the median number of valid days and the percentage of adolescents who met validity criteria for wear-time. In addition, for descriptive purposes, average MVPA per day, percentage of time spent in MVPA, daily average sedentary bouts, percentage time spent sedentary, average step counts, and maximum step counts were calculated to explore the variations physical activity. Independent samples t-tests and chi-squared tests were used to compare adolescents who did and did not have valid accelerometry data on other study characteristics in order to explore whether any differences existed between these two categories.

To address the secondary aim regarding exploratory associations of physical activity with health characteristics, bivariate correlations were used to evaluate the associations of physical activity indices (average MVPA per day, percentage time spent in MVPA, daily average sedentary bouts, percentage time spent sedentary, average step counts, and maximum step counts) with pre-pregnancy BMI indices, first-trimester weight, depression symptoms, and emotional eating. The correlations with adolescent age, gestational age, and race/ethnicity (0 = Hispanic/Latino or Black/African American race/ethnicity, 1 = other) also were described. Independent samples t-tests were used to explore differences in physical activity dimensions between pregnant adolescents with and without reported loss-of-control eating. Statistical significance was determined as $p < .05$. In addition, large correlations, determined as $r \geq .40$ also were discussed, regardless of statistical significance, given that this study was pilot in nature.

RESULTS

Preliminary Analyses

Twenty-eight pregnant adolescents 15 to 19 years of age, *M* = 17.68 years, *SD* = 1.02, participated in this study. The majority of participants (75.0%) were of Hispanic/Latino or Black/African American race/ethnicity. Baseline demographic and anthropometric characteristics of the sample are provided in **Table 1**.

Primary Aim: Feasibility of Accelerometry in Pregnant Adolescents

Median number of wear time days for the total sample was 5 out of 7 days, with a range of 0 to 7. Of the 28 participants, 16 (59.3%) had valid accelerometry data, referring to at least 4 out of 7 days of ≥10 hours/day of wear time. Of note, all participants who wore the device (*N* = 16) wore it for a minimum of 5 days; whereas the participants who did not have valid data (*N* = 12), all had 0 days of valid wear. One participant had 0 days of wear time because the device was not returned; all other adolescents returned their device.

Compared to adolescents with valid accelerometry data, those without valid data reported higher pre-pregnancy BMI ($M = 28.63$, $SD = 6.75$ kg/m^2 vs. $M = 23.55$, $SD = 5.21$ kg/m^2, $p = .04$). There were no significant differences in baseline wear compliance versus non-compliance by race/ethnicity, adolescent age, gestational age, first-trimester weight, depression symptoms, emotional eating, or loss-of-control status.

Among pregnant adolescents who had valid wear time data, descriptive information for average MVPA per day, percentage time spent in MVPA, daily average sedentary bouts, percentage time spent sedentary, average step counts, and maximum step counts are presented in **Table 2**. On average, pregnant adolescents exceeded the recommended guidelines of 30 minutes of MVPA per day in pregnancy and 60 minutes of MVPA per day in non-pregnant adolescents without outliers (*M* = 103.53, *SD* = 59.71 minutes). Of the participants with valid data, 81.3% met or exceeded the recommended guidelines for physical activity, and 18.8% did not meet these activity guidelines.

Associations of Physical Activity with BMI, Depression, and Overeating

Table 3 summarizes the results from the Pearson correlations that examine cross-sectional associations of adolescent age (years), race/ethnicity (Hispanic/Latino or Black/African American race/ethnicity versus other; dummy coded 0 = Hispanic/Latino or Black/African American race/ethnicity, 1 = other), gestational age (weeks), pre-pregnancy BMI (kg/m^2), first-trimester weight (kg), depression symptoms, emotional eating, average MVPA per day, percentage time spent in MVPA, daily average of sedentary bouts, percentage time spent sedentary, average step counts, and maximum step counts.

There were no statistically significant associations between physical activity and key health characteristics of interest. There was a trend-level, inverse moderate-size association between pregnant adolescents' average MVPA per day and depressive symptoms ($r = -.44$; $p = .09$), meaning that higher MVPA tended to be related to lower depressive symptoms.

In terms of other demographic/pregnancy characteristics, adolescent age showed moderate bivariate associations with a number of dimensions of physical activity. Specifically, there was a significant negative association between average MVPA per day and pregnant adolescents' age, such that older adolescents engaged in less MVPA ($r = -.49$; $p = .05$). Likewise, percentage time spent in MVPA was inversely associated with adolescent age ($r = -.55$; $p = .03$). In addition, there was a significant positive and moderate association between percentage time spent sedentary and adolescent age such that older adolescents spent more time sedentary (*r* = .51; *p* = .04). Last, there was a trend-level moderate association between average step counts and adolescent age (*r* = -.46; *p* = .07), indicating that older adolescents tended to have lower average step counts.

The results also indicated a negative association of daily average sedentary bouts and race/ethnicity, such that adolescents of Hispanic/Latino or Black/African American race/ethnicity had fewer sedentary bouts per day than adolescents of Other race/ethnicities (*r* = -.55; *p* = .03). Furthermore, there was a positive, trend-level and moderate association of average step counts and baseline gestational age (*r* = .47; *p* = .06), such that the further along in gestational age, the greater adolescents' average step counts.

Table 4 shows the differences in study characteristics by loss-of-control eating status. Forty percent of adolescents endorsed loss-of-control eating. Adolescents who had loss-of-control eating were older than those who did not endorse loss-of-control eating (*M* = 18.38, *SD* = 0.52 years versus *M* = 17.40, *SD* = 1.05 years, *p* = .02). There were no other significant or trend-level differences by loss-of-control eating status.

Table 1. *Descriptive Information for Study Participants*

Characteristic	Mean (SD) or % (*n*)	Range
Age, years	17.68 (1.02)	15.00 – 19.00
Race/ Ethnicity		
Hispanic	39.3% (*n* = 11)	
Non-Hispanic Black	35.7% (*n* = 10)	
Non-Hispanic White	10.7% (*n* = 3)	
Asian	3.6% (*n* = 1)	
Multiple Races	10.7% (*n* = 3)	
Gestational Age at Screening, weeks	14.41 (2.59)	9.00 – 18.86
Pre-Pregnancy BMI, kg/m^2	25.72 (6.20)	17.19 – 41.81
Pre-Pregnancy BMI, percentile	68.71 (29.76)	6.73 – 99.23
Pre-Pregnancy Weight Status		
Lean, BMI 5-84^{th} percentile	60.7% (*n* = 17)	
Overweight, BMI 85-94^{th} percentile	21.4% (*n* = 6)	
Obesity, BMI $\geq 95^{th}$ percentile	17.9% (*n* = 5)	
First-Trimester Weight, kg	73.34 (27.95)	48.10 – 152.40

Note: N = 28.

Table 2. *Physical Activity Indices of Pregnant Adolescents with Valid Data*

Variable	M (SD)	Range
Average MVPA in Minutes Per Day	103.53 (59.71)	2.90 – 188.20
% Time in MVPA Minutes Per Week	10.12 (5.90)	0.24 – 19.08
Average Sedentary Bouts in Minutes Per Day	425.75 (211.83)	148.30 – 740.80
% Time in Sedentary Minutes Per Week	51.63 (15.14)	31.66 – 81.31
Average Step Counts Per Minute	7.04 (2.68)	0.60 – 11.60
Maximum Step Counts Per Minute	101.06 (26.01)	21.00 – 127.00

Note. MVPA = Moderate vigorous physical activity. *N* = 16.

Table 3. *Bivariate Correlations among Key Variables*

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. Age, years	--														
2. Hispanic/Black (vs. Other)	-.06	--													
3. Gestational Age, weeks	-.27	.38*	--												
4. Pre-Pregnancy BMI, kg/m^2	-.09	.22	-.33	--											
5. First-Trimester Weight, kg	-.17	.12	-.06	.71***	--										
6. EE, Anger/Anx/Frustration	-.23	.14	.08	-.11	-.07	--									
7. EE, Depression	-.17	.11	.08	-.16	-.12	.91***	--								
8. EE, Unsettled	-.16	.02	.17	-.30	-.23	.94***	.88***	--							
9. Depression Symptoms	-.00	.07	.23	.16	.28	-.28	-.16	-.28	--						
10. Average MVPA	-.49*	.25	.27	-.14	-.30	.36	.25	.26	-.44+	--					
11. % in MVPA	-.55*	.36	.32	-.09	-.26	.41	.30	.35	-.40	.91***	--				
12. Average of Sedentary Bouts	.37	-.55*	-.26	-.10	.03	-.23	-.14	-.17	.09	-.35	-.64**	--			
13. % in Sedentary	.51*	-.58*	-.43	.01	.15	-.35	-.24	-.27	.16	-.65**	-.82***	.90***	--		
14. Average Step counts	-.46+	.37	.47+	-.21	-.28	.26	.16	.23	-.18	.74***	.88***	-.72**	-.89***	--	
15. Maximum Step counts	-.20	-.08	.25	-.22	-.15	.18	.11	.10	.13	.34	.35	-.16	-.30	.55*	--

Note. BMI = Body mass index. MVPA = moderate-to-vigorous physical activity. EE = emotional eating.
***$p \le .001$. **$p \le .01$. *$p \le .05$. + $\le .10$. $N = 16\text{-}28$.

Table 4. *Physical Activity/Sedentary Time Characteristics of Pregnant Adolescents with and without Loss-of-Control Eating*

Variable	Loss-of-Control M (SD)	No Loss-of-Control M (SD)	*p* value
Average MVPA in Minutes Per Day	83.12 (66.95)	112.81 (57.03)	.38
% Time in MVPA Minutes Per Week	8.14 (6.71)	11.01 (5.60)	.39
Average Sedentary Bouts in Minutes Per Day	476.02 (223.76)	402.90 (213.18)	.54
% Time in Sedentary Minutes Per Week	55.98 (13.28)	49.65 (16.11)	.46
Average Step Counts Per Minute	6.36 (1.56)	7.35 (3.08)	.51
Maximum Step Counts Per Minute	106.80 (15.53)	98.45 (29.91)	.57

Note. BMI = Body mass index. MVPA = EE = emotional eating. Loss-of-Control group $N = 5$. No Loss-of-Control group $N = 11$.

DISCUSSION

The primary aim of the current study was to evaluate the feasibility of accelerometer use for objectively measuring physical activity characteristics in pregnant adolescents. The secondary aim of the study was to explore associations of adolescent physical activity characteristics with other core features relevant for gestational weight gain, including BMI, depression, and eating behavior.

Accelerometry Feasibility

With respect to this first aim, feasibility of accelerometer use in pregnant adolescents showed mixed results. In support of feasibility, median days of wear time in the total sample was 5 days, which exceeded the criterion of 4 out of 7 days of valid wear. However, only 57%, as opposed to the target of ≥70%, of pregnant adolescents in this sample had valid data, indicating challenges to feasibility. One adolescent lost the device; the other adolescents with non-valid data did not wear the accelerometer at all. To our knowledge, this is the first study to pilot the use of accelerometers in pregnant adolescents. Our results for feasibility in pregnant adolescents are inconsistent with previous studies using wrist-worn accelerometers to measure physical activity in non-pregnant adolescents and pregnant women. In community samples of non-pregnant adolescents, approximately 79%-86% have acceptable compliance, even without specific monetary incentives for wear time (Scott et al., 2017; Van Coevering et al., 2005). Comparatively, a study involving pregnant adult women had 74% compliance for wrist-worn accelerometers in the second trimester without specific or additional incentives for wear time (Hesketh et al., 2018). Thus, in studies with non-pregnant adolescents and pregnant adults, accelerometers have been demonstrated to be a feasible means of measuring physical activity.

Adolescents who are pregnant represent a very high-risk group of teenagers, often facing major social-emotional and behavior challenges (Vandewalle et al., 2014). While those pregnant adolescents who did comply with accelerometry wear did it quite well, additional incentives are likely necessary to support better feasibility in a larger percentage of young, pregnant women. While compliance was not related to adolescents' age, gestational age, first-trimester weight, depression, or eating behavior, adolescents who reported a heavier pre-pregnancy BMI were less likely to wear the device. This finding has a number of possible explanations and warrants consideration in future research using accelerometers with this group of adolescents. One possibility is that heavier adolescents may experience increased body image disturbances and potentially feel less comfortable wearing the accelerometry device on their wrist. It is also important to consider the implications that pre-pregnancy BMI was as a self-reported measure; therefore, it is possible that the adolescents who did not wear the device may have perceived themselves as being heavier prior to pregnancy. Of note, in prior studies that included non-pregnant adolescents, adolescents with a higher BMI had lower accelerometer compliance compared to adolescents with a lower BMI (Jalo et al., 2019; Toftager et al., 2013), which is in line with our findings. In addition, we were not able to offer incentives specific to wear time. Previous literature shows that monetary incentives clearly increase participant compliance, including in adolescents with overweight/obesity, which would likely offer a beneficial approach for pregnant adolescents as well (Audrey, Bell, Hughes, & Campbell, 2012; Sirard & Slater, 2009). In addition, providing participants with the opportunity to re-wear the device and incorporating reminders could also potentially increase participant compliance. Taken together, our results suggest that accelerometer measurements may be suitable if additional measures are taken to increase compliance.

Exploratory Associations of Physical Activity with Health Characteristics

In the small sample of pregnant adolescents with valid data, physical activity and sedentary time were not significantly associated with pre-pregnancy BMI, first-trimester weight, depression, or overeating behaviors, as hypothesized. Unfortunately, it is not possible to determine whether these null findings are due to inadequate power to detect associations or to the notion that these factors are not related to physical activity/sedentary behavior patterns in pregnant adolescents. Previous studies of non-pregnant adolescents (Kuzik et al., 2017) and pregnant women (Fazzi, Saunders, Linton, Norman, & Reynolds, 2017) would suggest that physical activity and/or sedentary time measured via accelerometry are related to metabolic health, weight status, and for pregnant women, pregnancy outcomes. Thus, it will be important to evaluate these associations in future studies of pregnant adolescents.

We did observe a moderate trend-level association of depression symptoms with less average MVPA per day. Depression in non-pregnant adolescents has been related to increased risk of excess weight gain (Blaine, 2008) and to greater gestational weight gain in pregnant adolescents (Cunningham et al., 2018). In pregnant women, depression symptoms have been associated with less exercise (Pottinger, Troutman-Edwards, & Younger, 2009) and weight gain (Bodnar, Wisner, Moses-Kolko, Sit, & Hanusa, 2009); yet not all studies have consistently observed these association in adult pregnancy (Poudevigne & O'Connor, 2005). Depression is more common in adolescent pregnancy than in adult pregnancy and also more common in comparison to non-pregnant adolescents (Hodgkinson, Colantuoni, Roberts, Berg-Cross, & Belcher, 2010). Thus, if the association of depression symptoms and MVPA is supported in future studies with pregnant adolescents, there may be a number of possible implications. For instance, interventions to address depression in adolescent pregnancy may offer potential to increase adolescents' physical activity in pregnancy with implications for gestational weight gain. Alternatively, physical activity-based interventions in pregnancy could be a potential avenue for reducing depression symptoms in pregnant adolescents, which may then have salutary effects on gestational weight gain and a host of other pregnancy-related maternal and child health outcomes. For instance, Koniak-Griffin (1994) found that pregnant adolescents' participation in a 6-week exercise program was associated with significant decreases in depressive symptoms at post-treatment.

Although not an explicit aim or hypothesis, we observed a number of moderate associations of physical activity characteristics with adolescent age, race/ethnicity, and gestational age. Specifically, MVPA was lower among older adolescents, whereas sedentary behavior was higher the older adolescents were. Steinl and colleagues (2019) found the opposite; pregnant adolescents' MVPA as measured with physical activity 3-day recalls was weakly, positively correlated with maternal age. In contrast, our findings are consistent with national trends of non-pregnant adolescents showing a decrease in physical activity with age (Kann et al., 2016). We also found that Hispanic/Latino and Black/African American adolescents had significantly lower sedentary behavior compared to the other races/ethnicities in the sample. The lower sedentary behavior for this group, however, was inconsistent with other studies that suggested there were no overall differences in sedentary time among races/ethnicities (Whitt-Glover et al., 2009). One possible reason that pregnant adolescents in our study exhibited less sedentary time could be due to the physical demands of their jobs when they were not in school. In addition, some of the young women in our study did not have cell phones, which could have decreased their amount of screen time and time spent sedentary.

In a study that addressed the rate of adolescent compliance with physical activity guidelines in the United States, a majority of the female adolescents did not meet the daily recommendations at least 60 minutes of moderate physical activity (Butcher, Sallis, Mayer, & Woodruff, 2008). In another study that investigated objective measures of physical activity in pregnant women, the majority of these pregnant did not meet the daily pregnancy recommendation of 30 minutes of moderate physical activity (Evenson & Wen, 2011). Furthermore, in a study about pregnant adolescents' self-reported physical activity, slightly less than half of the pregnant adolescents in their study met the recommendations of at least 30 minutes per day of physical activity (Steinl et al., 2019); however in our study 81.3% of our participants with valid accelerometry data met or exceeded the activity recommendations for pregnant adolescents. One possibility is that this group of pregnant adolescents in our study may also have utilized more public transportation compared to their non-pregnant counterparts. In addition, some of these young women were in school and may have moved more in their daily routine. Moreover, the wrist-worn accelerometer could have increased physical activity measurements as extraneous arm movements may have constituted as increased physical activity while the wearer remained sedentary. Overall, potential explanations that warrant a mixed-method, comprehensive evaluation in future studies.

Limitations

Foremost, the small sample size of this pilot study raises a significant limitation that we were under-powered to detect effects. Another important shortcoming is that this study was a pilot in nature with limited resources; therefore, participants could not be financially compensated for their days of accelerometer wear, and there were no systematic reminders, after the initial instructions, given to participants regarding the devices. Currently, no self-report of qualitative data has been collected on the reasons behind participant wear and non-wear of the devices. In addition, the sample was primarily Hispanic/Latino and Black/African American adolescents seeking prenatal care from a multi-disciplinary adolescent pregnancy clinic and willing to participate in a study about gestational weight gain prevention. These characteristics limit generalizability of the results, and feasibility/associations with BMI, weight, depression, and eating behavior might be different among pregnant adolescents in other geographic locations or of other racial/ethnic identities (e.g., American Indian/Native American). Another limitation is that the accelerometer worn on the wrist could be less accurate than those worn on the waist. Previous studies have demonstrated psychometric support of GT3X accelerometers worn on the waist during pregnancy in adults, and other studies have shown adolescents are more likely to wear the device on the wrist due to its increased comfort and less embarrassing location (Poyatos-León et al., 2016). Our impressions were that the adolescents in our sample would have had even less compliance with hip-worn devices and a few were hesitant about wrist-wear. Non-pregnant adolescent accelerometer wear-time compliance is generally higher with wrist placement than waist placement; however, accelerometers worn on the waist may be more accurate in determining sedentary and activity levels without added arm movements that may be done while sitting (Poyatos-León et al., 2016). Another study consideration is that the cut-points we chose to analyze MVPA intensity accounted for the influence of age with regards to activity. Therefore, these cut-points may affect the accuracy of age-specific physical activity measurements in pregnant adolescents as the optimal cut-point for this group has not yet been established compared to non-pregnant adolescents and compared to pregnant adults. Finally, this study relied on self-reported pre-pregnancy BMI versus measured BMI. Therefore, this method of self-report could be less accurate than if objectively measured.

Strengths of the Study

Strengths of this study include the assessment of objective measurements of physical activity via accelerometry, compared to physical activity self-report which may be over or underrepresented (Prince et al., 2008), in a diverse population at very high-risk for obesity and cardiometabolic disease (Jasik & Lustig, 2008). Pregnant adolescents are at high-risk for experiencing psychosocial and behavioral challenges (Vandewalle et al., 2014), and have been understudied with respect to physical activity or to the development of interventions to address excess gestational weight gain. Thus, this study contributes to the literature about methods to objectively characterize physical activity/sedentary behavior.

Conclusions and Future Directions

Physical activity may be a potentially modifiable factor in a pregnant adolescent's life that offers the potential to increase perinatal emotional wellbeing as well as to affect perinatal maternal and offspring weight and metabolic health outcomes. The combination of psychosocial challenges, physical and physiological changes of puberty, and gestational weight gain may render pregnant adolescents particularly vulnerable to excess weight gain and to its adverse health outcomes (Graber & Brooks-Gunn, 1996). Findings from the current pilot study suggest that many (i.e., over half) adolescents who are pregnant can be recruited to wear a wrist-worn accelerometer for sufficient days to comprehensively characterize physical activity patterns. However, other pregnant adolescents, particularly those who report being heavier prior to starting pregnancy, may require additional measures to incentivize wear. Adolescents who wore the devices, on average, were quite active, exceeding recommended guidelines for MVPA for in adolescence and in pregnancy. Further, MVPA tended to be inversely related to depression symptoms, offering a potential avenue for future research in this age group. In future studies, it will likely be necessary to offer monetary incentives to maximize wear compliance, for staff to perform more frequent checks, to offer an opportunity for re-wear, or to even request wear over a slightly longer period to gather enough valid days of wear (Aadland et al., 2017). Ultimately, developing strategies and guidelines around accelerometer use specific to this particular at high-risk, high-need population is necessary for the characterization of physical activity patterns that will be required to carry out quality interventions with measured physical activity outcomes in this group. Given the limitations of self-reports of physical activity (Prince et al., 2008), more research on using accelerometers in pregnant adolescents in the future is important. Physical activity is an important area of research in pregnancy overall, and more research is needed in pregnant adolescents.

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