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Associations between maternal physical activity and fitness during pregnancy and infant birthweight

Samantha M. McDonald[a,*], SeonAe Yeo[b], Jihong Liu[c], Sara Wilcox[d], Xuemei Sui[d], Russell R. Pate[d]

[a] Department of Physical Education, Sport and Human Performance, Winthrop University, Rock Hill, SC, United States
[b] School of Nursing, University of North Carolina, Chapel Hill, NC, United States
[c] Department of Epidemiology and Biostatistics, University of South Carolina, Columbia, SC, United States
[d] Department of Exercise Science, University of South Carolina, Columbia, SC, United States

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ABSTRACT

Prenatal physical activity (PA) reduces the risk of delivering infants with a birthweight ≥4000 g among normal-weight pregnant women, but evidence on the impact of maternal cardiorespiratory fitness (CRF) on birthweight remains equivocal among overweight or obese (OW/OB) pregnant women. The purpose of this study was to evaluate the relationship between maternal prenatal PA and CRF and birthweight in OW/OB pregnant women.

Data from a randomized controlled exercise intervention trial in sedentary, OW/OB pregnant women were used. Women with complete data (n = 89) on birthweight, peak oxygen consumption (at 17 weeks), and daily PA were selected for analyses. Multiple linear regression models were performed to determine the independent and joint associations of maternal PA and CRF with birthweight while adjusting for gestational age, weight gain, and group allocation.

On average, participants were 32 years old, OW/OB (BMI 29.97 ± 7.14 kg/m^2), unfit ($VO_{2peak:}$ 19.85 ± 3.35 ml O_2 kg^{-1} min^{-1}), and led low active lifestyles (6579.91 ± 2379.17 steps/day). Analyses showed that maternal PA (steps·day^{-1}·month^{-1}) (β = 0.03 g, 95% CI: -0.03, 0.08 g) and CRF (ml O_2·kg^{-1}·min^{-1}) (β = −8.8 g, 95%CI: −42.2, 24.5 g) were neither independently nor jointly (β = 0.006 g, 95%CI: −0.005, 0.02 g) associated with birthweight.

Maternal PA and CRF during pregnancy were not related to birthweight in OW/OB pregnant women. The limited variability in maternal PA and CRF and low dose of PA may explain the null findings of this study. Given the paucity of studies examining these relationships in OW/OB pregnant women, more research is warranted.

1. Introduction

The average birthweight of US-born infants increased in the U.S. over the past 20 years (Martin et al., 2015). Higher birthweight (≥4000 g) is associated with altered growth trajectories that predispose neonates to obesity and the associated cardio-metabolic morbidities throughout their lives (Evagelidou et al., 2006). Intrauterine energy supply is considered the strongest predictor of fetal growth, and in excess, leads to higher infant birthweights and macrosomia (Pedersen, 1971). Maternal metabolic control, defined as control of circulating levels of blood sugars and lipids, is a major determinant of the energy supplied to the fetus. Any loss in metabolic control results in the delivery of increased energy supply and fetal overgrowth (Herrera, 2000). Importantly, it is also well established that maternal body mass is strongly and positively related to offspring birth weight and adiposity (Walton and Hammond, 1938). Specifically, overweight or obese mothers (OW/OB) are more likely to deliver larger infants. This relationship is posited to be a function of reduced maternal metabolic control leading to augmented fetal energy supply and subsequent higher birthweight infants. Currently, nearly 50% of women of reproductive age are OW/OB (Fisher et al., 2013) as such, the exploration of factors that may enable these women to control the amount of nutrient-energy supplied to the fetus is critical to the health of her offspring.

Among non-pregnant populations, considerable scientific evidence demonstrates that physical activity (PA) and cardiorespiratory fitness (CRF) exhibit protective effects on several cardio-metabolic health outcomes (Blair et al., 1996). This is consequent to the improvements in metabolic health (e.g., insulin sensitivity, glucose and lipid disposal) via adaptations to habitual PA (Shojaee-Moradie et al., 2007). Notably, these strong effects persist in the presence of excess adiposity. This

* Corresponding author at: Department of Physical Education, Sport and Human Performance, College of Education, Winthrop University, 216 West Center, Rock Hill, SC 29733, United States.
E-mail address: mcdonaldsm@winthrop.edu (S.M. McDonald).

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finding suggests that the increased prevalence of adverse cardio-metabolic health outcomes among OW/OB persons (Lee et al., 2011) may not be a result of their excess adiposity per se, but rather their lower levels of CRF and PA. We previously posited that this same phenomenon operates in pregnancy, whereby the lower levels of maternal PA and CRF in pregnancy, especially among the OW/OB women, reduce metabolic health, augment energy supply, and result in a larger neonate (Archer, 2015; Archer and McDonald, 2017; Archer et al., 2013). Collectively, this suggests that adequate levels of maternal PA and CRF may have the potential to "normalize" the amount of nutrient-energy available to the fetus thereby promoting optimal fetal growth.

Many studies assessed maternal PA and CRF in the prenatal period on various maternal-infant health outcomes (da Silva et al., 2017). Several studies examined the effects of PA on fetal growth (Badon et al., 2016; Bisson et al., 2017), with a recent review of exercise intervention trials concluding a significant protective effect of PA on birthweight (Wiebe et al., 2015). Yet, this conclusion applied only to NW pregnant women, with null effects found among their OW/OB counterparts. The latter conclusion may be largely due to a small number of rigorous intervention studies implemented among this subpopulation. Conversely, fewer studies have assessed the effects of maternal CRF on offspring growth during infancy. The focus of the existing studies was on changes in maternal CRF with advancing gestation (Dibblee and Graham, 1983) and in response to exercise training (Pivarnik et al., 1993). As such, the scientific evidence regarding the impact of CRF on birthweight is rather limited and equivocal, with previous studies yielding reports of positive, negative or null findings (Kardel and Kase, 1998; Wong and McKenzie, 1987; Price et al., 2012). Importantly, no studies examining this relationship were conducted among OW/OB pregnant women. Taken together, knowledge of the impact of CRF and PA on birthweight in overweight and obese pregnant women is extremely limited, warranting further exploration.

Thus, the overall purpose of this study was to investigate the relationships between maternal PA and CRF in the prenatal period and birthweight. We addressed the purpose of this study by evaluating the independent and joint associations of PA and CRF on birthweight. We conducted a secondary data analysis using the data from a randomized exercise intervention trial implemented in a sample of OW/OB pregnant women.

2. Methods

2.1. Study design

The present study employed a prospective design using data from a randomized exercise comparative trial conducted between November 2001 and July 2006. Briefly, the primary purpose of the trial was to examine the effects of moderate-intensity exercise during pregnancy on the incidence of preeclampsia and the pathophysiological progress of preeclampsia. Secondary outcomes included maternal weight gain and birth outcomes (Yeo, 2009).

2.2. Participant eligibility & recruitment

Pregnant women were recruited from nine prenatal clinics under two medical care systems in Michigan. Women were eligible to participate in the exercise trial if they were: 1) > 14 weeks gestation, 2) diagnosed with preeclampsia in a previous pregnancy, 3) low-fit (oxygen consumption ≤50th percentile), 4) self-reported participation in a sedentary lifestyle or PA energy expenditure of < 840 kcals per day. Exclusion criteria for the exercise trial were: 1) chronic hypertension or pre-gestational diabetes, 2) medical or physical limitations preventing participation in exercise, 3) physician instructions prohibiting prenatal exercise or 4) low mental acuity or language barrier preventing effective communication with research staff.

2.3. Randomization and intervention groups

Of the 210 women who agreed to participate in the study, 41% (n = 86) did not meet the eligibility criteria. The remaining 124 eligible participants were randomly allocated to the intervention group (n = 64) or comparative group (n = 60). The intervention group consisted of a walking program. Participants in this group were instructed to walk for 40 min, five times per week at a moderate intensity (55–69% maximum heart rate). In the comparative group, participants engaged in a stretching program of equivalent frequency and duration as compared to the walking group, however the women were instructed not to exceed a 10% increase in resting heart rate. Women also performed stretching movements via videotape. All participants wore Polar S810 heart rate monitors and wristwatch devices to validate their adherence to the walking or stretching programs. Further details on the intervention and comparative groups can be found elsewhere (Yeo, 2006). For the purposes of this study, the data were collapsed across both groups and group allocation was controlled for in the analyses.

2.4. Outcome variable: infant weight

Infant birthweight was defined as the weight of the neonate at the time of delivery and measured in grams. Data on birthweight were extracted from the mothers' medical records.

2.5. Exposure variables: PA and CRF

Daily PA was measured using a pedometer (Digiwalker SW200) attached to an elastic belt and worn on the participants' waist. The participants were instructed to wear the pedometer during waking hours and to remove them during sleep and any water-based activities (e.g., showering). Additionally, the participants were asked to keep a log of their total daily step counts. The pedometers were distributed to the participants at 18 weeks of gestation and were retrieved at the end of pregnancy (prior to delivery). For the purposes of this study, total daily steps counts were averaged across all the available days for each participant to provide an estimate of the average daily PA (steps per day) during pregnancy.

CRF was defined as peak oxygen consumption ($\dot{V}O_{2peak}$) and estimated via a submaximal treadmill test at 17 and 28 weeks of gestation. The exercise testing followed the Cornell Exercise Protocol. This protocol consisted of walking on a treadmill for eight, two-minute stages with progressive increments in speed and grade. The metabolic and respiratory markers (e.g. oxygen consumption) were assessed using a portable indirect calorimeter (VO2000, Medical Graphics Corporation, Minneapolis, MN), that was previously validated in a sample of sedentary pregnant women (Yeo et al., 2005). $\dot{V}O_{2peak}$ was determined by the highest amount of oxygen consumed during the exercise test and expressed relative to participants' body weight as (mL $O_2 \cdot kg^{-1} \cdot min^{-1}$). Several dramatic physiological changes occur throughout pregnancy, thus, any apparent change in CRF between 17 and 28 weeks may not be reflective of a true change in CRF but merely a pregnancy-related change in physiology. As such, for the purposes of this study, CRF at 17 weeks gestation was used to provide an estimate of the average level of CRF in early pregnancy.

2.6. Covariate variables: maternal and infant characteristics

Maternal and infant characteristics considered potential covariates included: maternal age, gestational weight gain (GWG), gestational age and group allocation. Maternal age and gestational age were extracted from medical records. GWG was calculated using the objectively-measured weight at weeks 17 and 28 weeks of gestation ($Weight_{28\ weeks} - Weight_{17\ weeks}$). This non-traditional expression of GWG was used because nearly 40% of the data necessary to provide the standard expression of GWG (weight at delivery - pre-pregnancy weight) was

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