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

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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$_{2\text{peak:}}$ 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}) ($\beta = 0.03$ g, 95% CI: -0.03, 0.08 g) and CRF (ml O$_2$·kg^{-1}·min^{-1}) ($\beta = -8.8$ g, 95%CI: -42.2, 24.5 g) were neither independently nor jointly ($\beta = 0.006$ 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

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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 $\leq$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 missing. Given the difficulty of women to accurately report their pre-pregnancy weight (Russell et al., 2013) and the assumption that minimal weight is gained in the first trimester (Hytten and Leitch, 1964), we created an additional GWG variable using the objectively-measured weight at 17 weeks and weight at delivery ($\text{Weight}_{\text{delivery}} - \text{Weight}_{17\ \text{weeks}}$). For the significant missing data for 'weight at delivery', we performed multiple imputation. We compared the results between both expressions of GWG (data not shown) and found a similar impact on the regression coefficients and standard errors. As such, we elected to use the objectively-measured GWG measure. Group allocation was also considered a potential covariate given the exposure of this intervention trial was exercise, which may influence the independent and outcome variable of interest.

2.7. Statistical analysis

Differences in demographic, pregnancy-related and behavioral characteristics between the walking and control groups were determined using Student's *t*-tests and Pearson's Chi-Square test. For our analytical approach, we carried out three separate analyses using multiple linear regression. In this study, we attempted to determine the following: 1) the independent association of PA and CRF and infant birthweight and, 2) the joint associations of PA and CRF and infant birthweight.

We first assessed the assumptions of linear regression and all were reasonably satisfied. Bivariate associations between all the independent (primary and covariates) and dependent variable were performed. To assess the independent associations of PA and CRF on infant birthweight, the main effects were first added to the model. Next, covariates were sequentially added. To examine the joint association of PA and CRF, we used an interaction term between PA and CRF. We first evaluated the joint association in an unadjusted model. Following this, covariates were sequentially added to the model. The following variables were expressed continuously: CRF ($\text{ml O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), PA (steps per day), GWG (kg), age (y), and gestational age (weeks). Group allocation was treated as a categorical variable. For all analyses, the significance level was set at 0.05 and were conducted in SAS 9.4 (Cary, North Carolina).

2.8. Missing data

For the purposes of this study, only women with complete data on infant birthweight were included in the analyses. As a result, only 89 of the 124 women participating in the study were available for the final analyses. To determine the potential effects of selection bias, we tested the differences of select maternal characteristics (age, gestational age, BMI, and GWG) between women with complete and missing infant birthweight data. We found there to be no significant differences. The final sample size was 89 pregnant women.

3. Results

The sample characteristics, inclusive of maternal, pregnancy and behavior-related factors are provided in Table 1. At 17 weeks of gestation, the average pregnant woman was 32 years old and with a BMI classified as overweight/obese (BMI: 29.97 ± 7.14 kg/m^2). In addition, these women, on average, delivered full-term, NW infants (gestational age: 38.64 ± 1.88 weeks; birthweight: 3477.48 ± 577.48 g) and gained approximately 6.5 kg in mid-pregnancy (17 to 28 weeks). The prevalence of macrosomia in this sample was 14%, nearly double the current prevalence estimate of macrosomia the United States (~8%). Only 4% of infants delivered were low-birthweight (< 2500 g). The CRF levels of the pregnant women were low ($\text{VO}_{2\text{peak:}}$ 19.85 ± 3.35 ml $\text{O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), and considered "unfit" ($\text{VO}_{2\text{peak:}} \leq 21.0$ ml $\text{O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) compared to CRF levels of similar pregnant women established by Mottola et al. Similarly, on average, this sample accumulated 6600 steps per day, suggesting a "low active" level of daily physical activity (Tudor-Locke and Bassett, 2004). Nearly all characteristics between intervention conditions were similar with the exception of daily PA, where the walking condition accrued more steps per day compared to the stretching condition (7718.19 ± 2223.78 vs 5185.53 ± 1750.39 steps/day; $p < 0.0001$).

The adjusted linear regression coefficients for the independent associations between CRF, PA and infant birthweight are presented in Tables 2 and 3, respectively. The independent association between CRF at 17 weeks gestation and infant birthweight did not reach statistical significance ($\beta = -8.83$ g, 95%CI: −42.2, 24.5 g), after adjusting for gestational age and weight gain, and group allocation. Similarly, the relationship between daily PA, expressed in steps per day, and infant birthweight (Table 3), was not statistically significant ($\beta = 0.03$ g, 95%CI: −0.03, 0.08 g), after controlling gestational age, weight gain, and group allocation.

The adjusted linear regression coefficients for the joint relationship between CRF and PA, and infant birthweight are depicted in Table 4. The joint association was assessed via an interaction between CRF and PA, and was found to not be significantly associated with infant birthweight ($\beta = 0.006$ g, 95%CI: -0.01, 0.02 g), after adjusting for gestational age and weight gain, and group allocation.

4. Discussion

Considerable evidence indicates that maternal PA during pregnancy exerts a protective effect on infant birthweight (Wiebe et al., 2015). However, null associations are found among OW/OB women and because nearly 50% of women of reproductive age are OW/OB (Fisher et al., 2013), we thought it important to determine if a protective effect existed in OW/OB pregnant women. Thus, in the present study, we examined the association between maternal PA in pregnancy and infant birthweight in a sample of OW/OB pregnant women. The major finding of this study was that, in overweight and obese pregnant women, PA was not associated with infant birthweight.

Our observation that maternal PA was not associated with infant birthweight in OW/OB pregnant women is consistent with the limited number of previous studies assessing this relationship in this group (Nascimento et al., 2011; Oostdam et al., 2012; Ruiz et al., 2013). For example, Nascimento et al. (2011) examined the effects of a weekly supervised, light-to-moderate intensity exercise program on several maternal-infant outcomes including infant birthweight. Similarly, Oostdam et al. (2012) assessed the effects of a bi-weekly moderate intensity aerobic and strength-training exercise program on maternal metabolic health (i.e. blood glucose and insulin sensitivity) and infant birthweight. Lastly, Ruiz et al. (2013) examined the effects of a light-to-moderate intensity exercise program consisting of aerobic and strength exercises, performed three times per week. Collectively, these studies found that maternal PA was not associated with infant birthweight. These findings conflict with the established inverse relationship found in NW pregnant women. A possible explanation for the conflicting evidence between these subpopulations is that the dose of PA was insufficient to influence infant birthweight (McDonald et al., 2016). An obvious difference in these studies is the fact that OW/OB women possess more fat mass. Consequently, increased adiposity and elevated blood lipids are posited to be one of the mechanisms leading to greater energy supply to the fetus, resulting in higher birthweights (Archer, 2015; Archer and McDonald, 2017; Herrera, 2002; Long et al., 2012). Strong evidence indicates that PA inversely associates with blood lipid levels (Aas et al., 2005; Kiens, 2006). As such, the amount of PA necessary to affect these levels in OW/OB pregnant women, and thereby significantly impact infant birthweight, may be considerably higher than the levels of PA exhibited in our sample and those in previous studies.

Currently, the U.S. PA Guidelines, with concurrence from the American Congress of Obstetricians and Gynecologists (Artal and

Table 1
Maternal and infant sample characteristics, by total and intervention group.

Sample characteristics	Total (n = 90)			Exercise (n = 49)			Stretching (n = 41)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Maternal[a]									
Age (y)	90	32.28	4.65	49	32.47	21.45	41	32.05	4.93
Weight (kg)	90	80.37	18.69	49	79.85	19.12	41	80.99	18.37
Height (m)	90	1.64	0.08	49	1.64	0.07	41	1.64	0.08
Body mass index (kg/m^2)	90	29.97	7.14	49	29.72	7.48	41	30.28	6.79
CRF (ml O_2 kg^{-1} min^{-1})[b]	90	19.85	3.35	49	20.01	3.11	41	19.65	3.64
Physical Activity (steps/day)	89	6579.91	2379.17	49	7718.19**	2223.78	40	5185.53	1750.39
No. days monitored	89	114.15	32.60	49	114.57	32.63	40	113.63	32.96
Infant									
Gestational age (weeks)	90	38.64	1.88	49	38.51	2.04	41	38.80	1.68
Gestational weight gain*	90	6.45	3.55	49	6.03	2.90	41	6.96	4.18
Birthweight (g)	90	3477.48	577.48	49	3475.49	613.36	41	3479.85	538.55
Macrosomia (%)	90	14.44	–	49	14.29	–	41	14.63	–

Note: Between-group comparisons were performed using Student's *t*-test and Pearson's Chi-Square for continuous and categorical characteristics, respectively. [a]Demographic characteristics (age, weight, height, and body mass index) are reported at 17 weeks gestation. *Gestational weight gain represents weight gain during 17 weeks and 28 weeks of gestation (corresponding to participant laboratory visits). **denotes significant between-group differences ($p < 0.0001$). **For all behavioral characteristics (cardiorespiratory fitness [CRF], physical activity and number of days monitored) average values were calculated using all available time points throughout pregnancy: CRF (17 weeks), PA steps/day and days monitored (17 weeks until delivery).

Table 2
Adjusted linear regression coefficients assessing the independent association between CRF and birthweight (g).

Predictors	Parameter estimates		
	β	SE	p-value
Primary exposures			
CRF (ml O_2·kg^{-1}·min^{-1}) at 17 weeks	−8.83	16.77	0.6000
Covariates			
Maternal age (y)	7.56	12.13	0.5347
Gestational age (weeks)	144.98	30.14	< 0.0001
Gestational weight gain*	10.64	7.30	0.1485
Group allocation			
Exercise	60.54	112.38	0.5915
Stretching (referent)	–	–	–

* Gestational weight gain represents weight gained during 17 weeks and 28 weeks of gestation (corresponding to participant laboratory visits).

Table 3
Adjusted linear regression coefficients assessing the independent association between average PA (steps/day) in pregnancy and birthweight (g).

Predictors	Parameter estimates		
	β	SE	p-Value
Primary exposures			
Average PA (steps/day)	0.03	0.03	0.3037
Covariates			
Maternal age (y)	7.53	12.06	0.5342
Gestational age (weeks)	144.28	29.97	< 0.0001
Gestational weight gain (17 to 28 wks)	10.76	7.24	0.1408
Group allocation			
Exercise	−16.06	131.98	0.9034
Stretching (referent)	–	–	–

*Gestational weight gain represents weight gain during 17 weeks and 28 weeks of gestation. (corresponding to participant laboratory visits). Note: No. of PA days represents the number of days the pedometer was worn during pregnancy.

Table 4
Adjusted linear regression coefficients assessing the joint association between average PA (steps/day) and CRF in pregnancy and birthweight (g).

Predictors	Parameter estimates		
	β	SE	p-Value
Primary exposures			
Average PA (steps/day)	−0.09	0.12	0.4441
CRF (ml O_2·kg^{-1} min^{-1}) at 17 weeks	−52.23	41.45	0.2111
Average PA*CRF	0.006	0.006	0.2929
Covariates			
Maternal age (y)	7.38	12.11	0.5439
Gestational age (weeks)	143.64	30.17	< 0.0001
Gestational weight gain (17 to 28 weeks)	11.30	7.31	0.1268
Group allocation			
Exercise	−9.30	132.75	0.9443
Stretching (referent)	–	–	–

*Gestational weight gain represents weight gain during 17 weeks and 28 weeks of gestation (corresponding to participant laboratory visits).

O'Toole, 2003; USDHHS, 2008), recommend that pregnant women engage in 150 min per week of moderate-intensity aerobic and strength-training activities throughout pregnancy. Given the low amount of PA achieved by the pregnant women in this sample, it is likely they did not meet the current recommendations. However, the PA prescribed in the aforementioned studies appears to exceed this recommendation yet, infant birthweight remained unaffected across all studies. From these findings, two important observations can be made. First, the PA levels in the current and other studies may have been insufficient to impact birthweight, suggesting that a higher dose of PA may be required. Second, given that the dose of PA prescribed in these studies exceeded the current PA guidelines, revised recommendations specific to OW/OB pregnant women may be necessary. However, given the paucity of studies conducted in this population, more research assessing the effect of various doses of PA on infant size are essential to ascertain the existence of an effect.

Another possible explanation for the null association found in this present study is low variability in PA levels. In this study, the average daily steps accumulated was 6579 steps with a SD of 2379 steps. While the variability in daily PA in this study is higher compared to previous studies (Huberty et al., 2016), this amount of variability may have been insufficient to detect an effect. Limited variability in the independent variable may result in a loss of power, thus reducing the likelihood of finding a statistically significant association (Rosenthal and Rosenthal, 2011). The reduced variability in PA found in this sample may be result of strict eligibility criteria imposed during participant recruitment. Specifically, these women had a history of preeclampsia, which affects between 3 and 10% of all pregnancies (Wallis et al., 2008). Common characteristics of women with preeclampsia are overweight or obesity and sedentarism (O'Brien et al., 2003; Leibel et al., 1995). Given the selective population from which these women were drawn, it is not surprising that their daily PA patterns were similar, consequently reducing variability in this behavior. In addition, the small sample size in this study likely reduced our statistical power, potentially explaining our null findings.

This study was novel in that it was the first to examine the association between maternal CRF and birthweight in a sample of OW/OB pregnant women. Previous studies limited their samples to NW pregnant women; therefore, we lack scientific knowledge about this relationship in OW/OB pregnant women. Based on the strong metabolic effects of PA and posited influence on fetal nutrient supply (Archer, 2015; Archer and McDonald, 2017), we hypothesized that maternal CRF, an indicator of habitual PA, would inversely associate with birthweight. However, the findings of this study suggest that maternal CRF does not influence infant birthweight. A potential explanation for the lack of an association demonstrated in this study may be limited variability in the levels of CRF in the study sample. Few studies have assessed CRF in OW/OB pregnant women. Collectively, these studies have indicated reduced variability in the levels of CRF in this group. For example, Mottola et al. (2006) found that the average CRF among a diverse sample of pregnant women was 23.7 ml $O_2{\cdot}kg^{-1}{\cdot}min^{-1}$ with a standard error (SE) of 5.0 ml $O_2{\cdot}kg^{-1}{\cdot}min^{-1}$ (Mottola et al., 2006). In a similar study, Davenport et al. (2008), assessed the CRF of overweight and obese pregnant women and found lower levels of CRF (21.6 ml $O_2{\cdot}kg^{-1}{\cdot}min^{-1}$) and reduced variability (SE: 3.8 ml $O_2{\cdot}kg^{-1}{\cdot}min^{-1}$) (Davenport et al., 2008). The lower levels of CRF found in the latter study are similar to those found in our study with an average CRF of 19.85 ml $O_2{\cdot}kg^{-1}{\cdot}min^{-1}$ and SE of 3.35 ml $O_2{\cdot}kg^{-1}{\cdot}min^{-1}$. While low variability may be inherent in this specific subpopulation (i.e. history of preeclampsia, sedentarism), the additional requirement of a low fitness level ($<$ 50th percentile) likely further reduced the variability in CRF levels. Consequently, the limited variability potentially precluded our ability to ascertain an effect through a loss in statistical power.

This study has strengths and limitations. First, to our knowledge, this is the first study to address the independent and joint associations between maternal PA and CRF and infant birthweight in a sample of OW/OB pregnant women. Given the well-documented health benefits of CRF and PA, the investigation of its potential influence on maternal-fetal health was warranted. Second, objective measures of PA and CRF were used in this study, thus reducing biases associated with subjective assessments (e.g. self-report) (Archer et al., 2013). In addition to these significant strengths and the aforementioned limitations (i.e. limited variability), this study has other limitations. First, while our sample is one of the largest available that includes measures of PA, CRF and birthweight (i.e., $n = 89$), it may have been too small to detect an association. The recruitment and retention of pregnant women, especially the OW/OB subpopulation, is a considerable challenge in this field; poor study adherence are common. Second, the use of birthweight as a measure of fetal growth may have resulted in our inability to capture important changes in tissue composition and future health risks (Archer, 2015; Archer and McDonald, 2017). Evidence indicated that PA and exercise may yield significant differences in tissue composition with no differences found in birthweight (Sewell et al., 2006).

In conclusion, the scientific evidence regarding the relationships between PA, CRF and birthweight is limited, especially among overweight and obese pregnant women. This study is the first to examine these relationships and contributes to this rapidly advancing area of research. Nonetheless, to address the aforementioned limitations of this study, future investigators should consider employing sampling strategies (e.g. purposive sampling) that may increase variability in the levels of maternal PA and CRF. Additionally, the development of novel strategies to enhance recruitment and retention should be encouraged given the established issues with the overweight and especially the obese subpopulations. Lastly, the underlying mechanisms that are posited to explain the relationships between PA and CRF and birthweight, such as maternal metabolic control, are often neglected in these studies. Accordingly, we strongly recommend that future researchers assess metabolic profiles of their study population. In closing, our study provides evidence that neither maternal PA nor CRF in the prenatal period are associated with birthweight.

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Conflict of interest

The authors have no conflicts to disclose.

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