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Research Article

Influence of Maternal BMI and Exercise on Fetal Heart Outcomes

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Abstract

We previously reported decreased fetal heart rate (FHR) and increased heart rate variability (HRV) in fetuses exposed to exercise during gestation. However, sympathetic over activity is seen in overweight and obese individuals. Further, overweight and obese women have increased likelihood of negative pregnancy outcomes and congenital anomalies. The purpose of this retrospective analysis was to determine if maternal BMI status has an effect on fetal cardiac outcomes. We hypothesized that higher maternal BMI would be related to less changes on fetal heart rate and heart rate variability measures.

Women were classified as healthy weight (HW) or over weight/obase based on pre-pregnancy BMI. Women were classified as Exercisers if they continued moderate-vigorous activity throughout pregnancy for at least 30 minutes, 3 times a week or Controls if their activity was below this minimum. We performed a secondary analysis using ANOVA, ANCOVA, and Spearman's correlations. Subjects per BMI- activity category: HW Exercise (n=16), HW Control (n=17), OW/OB Exercise (n=12), OW/OB Control (n=16). We found women and their fetuses with lower BMI have lower HR, though this was not significant. Regardless of BMI, women in exercise group had fetuses with higher HRV. Overall, maternal pre-pregnancy BMI was not related to fetal cardiac autonomic development. There were no significant differences or correlations with sympathovagal balance. These findings suggest that maternal physical activity and not maternal fitness or fatness influences fetal cardiac autonomic control.

Keywords: BMI; Physical Activity; Fetal Heart Rate; Heart Rate Variability; Pregnancy

Introduction

In the United States, 64% of women of reproductive age are overweight (OW) or Obese (OB) [1,2]. When women who are OW or OB conceive, they are already at increased risk of pregnancy and childbirth complications [3-6]. Overweightedness during pregnancy is associated with abnormal autonomic control [7]. Furthermore, the offspring of overweight and obese women are at increased risk of macrosomia, infant death, and heart congenital anomalies [3, 8-10]. Studies have demonstrated that exercise throughout gestation is associated with decreased risk of childbirth complications, as well as improved fetal cardiac autonomic development [11-16]. Furthermore, research shows that childbirth complications decrease in overweight and obese women in response to an exercise regime while pregnant [17]. However, it is not known if fetal adaptations to maternal exercise occur in normal weight, overweight, and obese women. The purpose of this retrospective analysis was to determine if maternal BMI status has an effect on fetal cardiac outcomes. We hypothesized that higher maternal BMI would be related to less changes on fetal heart rate and heart rate variability measures.

Methods

This is a secondary analysis from a larger study looking at the effects of exercise during pregnancy and fetal/neonatal heart outcomes.

Study participants: The women in this study (n=66) were part of a longitudinal, non-blinded study designed to determine the effects of self-reported exercise on fetal cardiac autonomic nervous system development. The study was approved by the Kansas City University of Medicine and Biosciences and the University of Kansas Medical Center Institutional Review Boards and Human Subjects Committees. Written informed consent was obtained from each participant. All women had healthy singleton pregnancies, were 23-39 years of age, non-smokers with no history of alcohol or drug use. Previously we found lower HR and increased HRV in fetuses exposed to maternal exercise at 32 and 36 weeks gestational age [13], therefore we limited this retrospective analysis to these time points. One subject did not complete the questionnaire properly and was excluded from the analysis leaving a sample size of 65. Pre-pregnancy BMI was calculated using the formula [weight (kg) ÷ height (m) squared]. The pre-pregnancy height and weight were self-reported. The pre-pregnancy BMI was utilized to categorize women as healthy weight (normal BMI= 18.5 to 24.9), overweight (BMI between 25.0 to 29.00), and obese (BMI ≥ 30).

Physical activity questionnaire: The Modifiable Physical Activity Questionnaire was used to assess physical activities performed during the past twelve months; we focused on third trimester (months 10 through 12) activity. This questionnaire is a reliable and valid instrument for assessing the duration and intensity of physical activity during pregnancy [18,19]. Physical activities were aerobic (e.g., walking, jogging), anaerobic (e.g., weight lifting, yoga), and lifestyle (e.g., gardening, cleaning house) activities. Occupational and daily living (e.g., getting dressed) activities were not assessed. Women who met the minimum guidelines for sedentary women from the American Congress of Obstetrics and Gynecology (ACOG) for exercise [20] were classified as exercisers. Those women who reported less than 30 minutes of aerobic activity 3 times per week throughout pregnancy were classified as controls.

Magnetocardiogram (MCG) recording: Women were tested between 10:00 and 17:00 hours and were instructed to eat a snack 1.5 hours prior to their visit. At each visit, participants were comfortably seated, slightly reclined immediately in front of the bio magnetometer interface (CTF Systems, Inc) in a magnetically shielded room as previously described [13]. The 83 axial gradiometer sensors are spatially distributed to cover the gravid maternal abdomen. Biomagnetic signals were recorded for 18 minutes with a 300 Hz sampling rate and recording filter of 0-75 Hz. Data were digitally filtered between 1 and 40 Hz offline (bidirectional fourth-order Butterworth filter).

Processing magnetocardiogram signals: Each 18 minute recording was presented to an independent component analysis algorithm via EEGLAB toolbox [21] to separate maternal MCG, fetal MCG and fetal movements into distinct components [22-24]. A template-matching algorithm was used to mark fetal R peaks and hence generate the interbeat-interval time-series [13,22-24]. All fetal MCG traces were manually checked (LEM, KMG) for incorrectly marked or missed beats. Once fetal R peaks were marked, then the marked componenet was submitted to HRV analysis via MatLab.

HR and HRV measures: From the fetal interbeat-interval-time series, we measured fetal heart rate (HR; bpm), root mean square of successive differences (RMSSD), and standard deviation of interbeat-interval series (SDNN) (Table 1). Fast Fourier Transform was used to convert the interbeat-interval time-series to frequency bands (Table 1): very low frequency (VLF), low frequency (LF), and high frequency (HF) [25]. Ratios of VLF/LF, VLF/HF and LF/HF were used to assess sympatho-vagal balance. Fetal activity state was determined by visual inspection of the HR pattern [26-28] by two independent investigators (LEM/KMG). If state determination differed between investigators, a third opinion was obtained and consensus reached. Each recording was classified as either an active (2F, 4F) or quiet (1F, 3F) activity state.

Table 1. Description of HRV measures

Fetal HRV Measure (units)	Autonomic Association	Description
HR (bpm)	Sympathetic and Parasympathetic	--
RMSSD (ms)	Parasympathetic (Short-term HRV)	Root mean square of successive differences between normal-to-normal (NN) intervals
SDNN (ms)	Sympathetic and Parasympathetic (Overall HRV)	SD of all NN intervals
VLF (ms^2)	Primarily sympathetic	Power between 0.02 – 0.08 Hz
LF (ms^2)	Sympathetic and Parasympathetic	Power between 0.08 – 0.2 Hz
HF (ms^2)	Primarily parasympathetic	Power between 0.4 – 1.7 Hz
VLF/LF	Sympathovagal balance	Ratio between VLF and LF
VLF/HF	Sympathovagal balance	Ratio between VLF and HF
LF/HF	Sympathovagal balance	Ratio between LF and HF

Statistical Analyses: The level of significance was set a priori at alpha < 0.05 and all statistical analyses were performed using SAS version 9.2(SPSS version 17.1, Chicago, 2009). Based on similar physiological and pregnancy outcomes, overweight and obese women were grouped together (OW/OB). Group differences were compared between healthy weight women (HW group) with normal BMI and those with overweight or obese BMI (OW/OB group). Maternal and fetal measures were summarized as means ± standard deviations (SD) if their distributions were approximately normal. We performed a secondary analysis using Spearman's correlations and ANCOVA to assess the relationships between maternal body fatness and fetal HR and HRV outcomes.

Results

Complete fetal measures and maternal weight and physical activity data were obtained from 61 maternal-fetal pairs at 36 weeks gestational age: if 36 week measures was not performed then 32 week measure was used for analysis. We analyzed data for 33 healthy weight women and 28 overweight/obese women.

Descriptive statistics: There are no differences between BMI groups in maternal weight gain, maternal resting HR, or fetal measures (data not shown). Further analysis between the 4 group classifications [HW Exercise (n=16), HW Control (n=17), OW/OB Exercise (n=12), OW/OB Control (n=16)] showed differences and trends. There are no differences in maternal age between groups (Table 2).

Table 2. Differences between Healthy Weight and Overweight/Obese Women Within Level of Exercise grouping.

	Exerciser		Control	
Maternal Variables	**HW (n=20)**	**OW/OB (n=12)**	**HW (n=18)**	**OW/OB (n=15)**
Age (years)	28.5 + 3.7	29.2 + 5.3	30.2 + 3.5	29.3 + 3.5
Resting HR (bpm)	67.3 + 10.5	71.9 + 7.6	67.5 + 12.4	72.1 + 7.4
BMI	22.6 + 1.7***	28.5 + 3.4	21.1 + 1.5***	29.5 + 4.7
Exercise (min/3rd trimester)	3951 + 1365§	3975 + 1411§	370 + 481	503 + 582
Fetal Variables	**HW**	**OW/OB**	**HW**	**OW/OB**
HR (bpm)	138.4 + 10.0	136.7 + 8.4	143.5 + 9.0	141.1 + 10.2
SDNN (msec)	26.5 + 9.3	31.0 + 11.4⌘	20.5 + 6.5	23.2 + 5.8
RMSSD (msec)	7.5 + 2.9	8.6 + 4.2 ⌘	5.2 + 1.5	7.2 + 4.2
VLF (msec^2)	116.8 + 77.5	122.9 + 90.1	68.2 + 46.1	77.8 + 49.9
LF (msec^2)	51.4 + 41.1	62.2 + 50.1⌘	21.1 + 12.0	32.3 + 26.9
HF (msec^2)	13.5 + 9.3	20.6 + 21.8	7.1 + 3.5	16.9 + 26.1

***p<0.001 lower than OW/OB exercise and control; § p<0.001 higher than HW and OB/OB control groups; ⌘significantly higher than Non-exercise HW, p<0.05

In resting maternal HR, HW pregnant women tended to have lower HR than OW/OB of the same group (exercise or control), and within same BMI classification there were only slightly lower HR in HW to OW/OB categories (Table 2). For fetal HR, there is a trend for HW groups to have lower HR than OW/OB groups, but this was not significant (Table 2). Exercise groups tended to have higher HRV measures (SDNN, RMSSD, LF) than control groups, this is significantly different between Exercise OW/OB relative to Control HW (Table 2).

Spearman correlations: As expected, there is a significant and positive association between maternal resting HR and fetal HR. Although there is no significant association between level of maternal BMI and fetal HR or HRV (Table 3), there are significant and positive associations between maternal time in exercise and all fetal HRV measures (SDNN, RMSSD, VLF, LF, HF).

Table 3. Bivariate Spearman Correlations between maternal BMI, aerobic activity, and fetal heart measures.

Maternal Variables	**Fetal MCG Outcome Variables**						
	HR	SDNN	RMSSD	VLF	LF	logHF	LF/HF
Aerobic Exercise (total min)	-.22	.35**	.26*	.32*	.32*	.30*	
Mom age	.25	.12	-.09	.02	-.01	-.15	
BMIpre	-.01	.16	.20	.05	.15	.24	
Mom rest HR	.37**	-.08	-.05	-.17	-.07	-.06	
FAS (A vs. Q)	.12	.34**	.04	.15	.13	.10	

*p<0.05;**p<0.005;values in table are Spearman correlation coefficients r values.

In the ANCOVA interaction model, the interaction between maternal BMI and Group is not significant (p = 0.82). In fact, the correlation between maternal BMI and fetal HR is not significant (r = 0.21, p = 0.14), either. However, fetal HR is significantly different between the exercise and the control groups (p = 0.005).

There was no significant correlation between maternal physical activity measures and fetal cardiac sympatho-vagal balance (VLF/LF, VLF/HF, or LF/HF).

Discussion

We hypothesized that higher maternal BMI would be related to less changes on fetal heart rate and heart rate variability measures. We found women and their fetuses with lower BMI have lower HR, though this was not significant. Regardless of BMI, women in exercise group had fetuses with higher HRV. Overall, maternal pre-pregnancy BMI was not related to fetal cardiac autonomic development. These findings are important regarding pregnant women, exercise, and fetal development.

We found women with lower BMI have fetuses with lower HR, though this was not significant. There are 2 possible explanations for this finding. The first is that there is a possible maternal-fetal synchrony between their heart rhythms or this is an indicator of maternal fitness and fetal exercise exposure. Data from maternal:fetal pairs suggests occasional coupling does occur between maternal and fetal heart rates [29]. However, applying these same techniques to maternal:fetal pairs who have exercised or not during pregnancy finds the HR coupling overall weak [30]. Possibly this trend is related to maternal fitness and exercise exposure. Possibly the exercise women with lower BMIs are also those who train more, since previous findings demonstrated a maternal exercise dose response with fetal cardiac autonomic outcomes [14]. This suggests further controlled studies need to be done assessing maternal pre-pregnancy fitness effects on fetal cardiac autonomic development.

Regardless of BMI, women in the exercise group had fetuses with higher HRV. Physicians often do not recommend physical activity for pregnant women who are overweight, obese, and/or sedentary [31]. Research demonstrates overweight women engaging in physical activity during pregnancy have positive behavioral as well as metabolic adaptations as a result of their activity [32]. Further, these findings suggest that the fetus can benefit from the activity regardless of maternal fitness prior to conception. These findings support current American Congress of Obstetrics and Gynecology (ACOG) recommendations encouraging pregnant women to engage in physical activity for 30 minutes, 3 times a week or more if they were previously active [33]. Considering increased pre-pregnancy BMI is associated with future chronic disease in offspring, such as heart disease, [34] these findings are exciting and suggest the potential positive effects physical activity during pregnancy can have for offspring outcomes, especially for women who are sedentary and overweight.

Overall, maternal pre-pregnancy BMI was not related to fetal cardiac autonomic development. These findings are different than what we would expect based on higher BMI during pregnancy being associated with poor fetal and pregnancy outcomes [3, 8-10]. Furthermore, a study by Ojala et al. 2009 found increased fetal sympathetic measures during labor associated with increased maternal BMI [35]. Our findings may be different since the measures were done at rest and not during the stress of labor and delivery. Other studies have found pre-pregnancy BMI to be associated with changes in infant birth weight [36-40]. However, other data suggests that maternal energy intake is more predictive than pre-pregnancy BMI, but only if pre-pregnancy BMI was associated with weight gain and energy intake [41]. This is supported by other work that demonstrates overweight women engaging in physical activity during pregnancy will have positive behavioral and metabolic changes as a result of their activity [32]. Therefore, if pregnant women focus on positive behaviors of exercise and healthy diets, then pre-pregnancy BMI does not predict outcomes for their child. These findings are important for obstetric providers and pregnant women to realize.

The results of this study should be interpreted with regards to its limitations. First, physical activity was calculated utilizing the modifiable physical activity questionnaire, a reliable and valid instrument for assessing physical activity in pregnant women [18,19,42]. Since this questionnaire is an instrument that relies on self-report from the participant it may be vulnerable to recall bias that could lead to inflated estimations of physical activity levels [43]. Second, this was a secondary analysis and the initial study was not intended to answer this question. Therefore, increased numbers of women, for all four categories are necessary to answer the question of the relationship between maternal fatness, exercise, and the effects on the fetal cardiac development.

Summary

There is strong support that maternal pre-pregnancy BMI is not associated with fetal heart outcomes. Regardless of maternal BMI, improvements in fetal cardiac autonomic development appear to be due to chronic maternal physical activity. Furthermore, these findings support ACOG recommendations for women to maintain current exercise routine of moderate physical activity most days of the week. More importantly, this data supports the recommendation for sedentary, overweight and obese pregnant women to initiate physical activity during pregnancy to achieve at least 30 minutes three times per week in order to improve fetal autonomic heart development. For women who are not necessarily "in shape" when they conceive, this study suggests that the main influence on fetal cardiac autonomic development is participating in exercise during the pregnancy; therefore, pregnant women should not feel as though they must "get in shape" quickly during the pregnancy, but should work to reach the ACOG guidelines of 30 minutes of moderate activity most days of the week. For obstetric providers, this guideline should be mentioned to all women who are pregnant with low risk pregnancy regardless of BMI or sedentary lifestyle.

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