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Maternal physical activity mode and fetal heart outcome

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ABSTRACT

Background: Maternal leisure-time physical activity (LTPA) improves cardiac autonomic function in the fetus. The specific physical activity attributes (e.g., mode) that produce this benefit are not well understood.
Aim: To determine if more time spent performing non-continuous LTPA during pregnancy is significantly associated with lower fetal heart rate (HR) and increased heart rate variability (HRV).
Study design: This paper presents a retrospective analysis of previously reported data. Fetal magnetocardiograms (MCG) were recorded from 40 pregnant women at 36-wk gestational age.
Outcome measures: Metrics of fetal HR and HRV, self-reported min of continuous and non-continuous LTPA performed during the 3-months preceding the 36-wk assessment point and covariates (maternal weight change pre to 36-wk, age, and resting HR and fetal activity state during MCG recordings.
Results: Positive correlations were significant ($p < 0.05$) between min of continuous LTPA, the time domain metrics that describe fetal overall HRV, short-term HRV and a frequency domain metric that reflects vagal activity. Time spent in non-continuous LTPA was positively correlated ($p < 0.05$) with two HRV metrics that reflect fetal overall HRV. In the multiple regression analyses, minutes of non-continuous LTPA remained associated with fetal vagal activity ($p < 0.05$) and the relationships between minutes of non-continuous LTPA and fetal overall HRV ($p < 0.005$) persisted.
Conclusion: These data suggest non-continuous physical activity provides unique benefits to the fetal autonomic nervous system that may give the fetus an adaptive advantage. Further studies are needed to understand the physiological mechanisms and long-term health effects of physical activity (both non-continuous and continuous) performed during pregnancy to both women and their offspring.

1. Introduction

It is commonplace for women with a routine physical activity regimen to stop when they become pregnant [1]. In addition, relatively few start engaging in physical activity during pregnancy due to barriers such as excessive fatigue, lack of time, or physical limitations [2]. Pregnant women inquiring about physical activity are sometimes unsure what types are safe and whether it will benefit or harm the developing fetus. Obstetricians tend to prescribe overly conservative physical activity regimens to pregnant mothers [3], while nearly half counsel physically active patients to reduce activity during pregnancy [4].

According to the American College of Obstetricians and Gynecologists (ACOG), in the absence of either medical or obstetric complications, pregnant women can adopt the current Centers for Disease Control and Prevention and The American College of Sports Medicine recommendation of 30 minutes or more of moderate physical activity on most, if not all days of the week [5]. Physical activity has been reported to have numerous positive maternal effects related to pregnancy and delivery. These benefits include shorter labor and delivery time, decreased pregnancy-related complications, decreased pregnancy discomfort, improved mental status, and faster recovery after delivery [6,7]. Routine physical activity has been shown to reduce the incidence of maternal and childhood obesity, hypertension, gestational diabetes, dyspnea, and pre-eclampsia [1,6,8,9].

The fetal cardiovascular system is responsive to maternal physical activity [10–14]. Regular maternal physical activity throughout gestation results in lower fetal heart rate (HR) and increased heart rate variability (HRV) [15]. Heart rate variability is the physiological phenomenon of variation in the time interval between heartbeats (i.e., beat-to-beat interval). The measures of HR and HRV are used during pregnancy to determine overall health and appropriate nervous system development of the fetus. A detailed examination of the associations between intensity and duration of maternal physical activity and fetal HR and HRV suggests a dose-response relationship exists [16].

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Higher intensity physical activities were associated with lower HR and greater overall HRV of the developing fetus. Many benefits of maternal physical activity persist at birth and some studies have shown that these benefits continue to manifest after birth. For instance, lower HR and increased HRV in the fetus are associated with significantly higher motor development indices, positive expressions of body composition, and better language development at two years of age [8,17].

Although ACOG provides physical activity guidelines regarding exercise during pregnancy, the guidelines are not specific regarding the modes of physical activity, i.e., continuous vs. non-continuous physical activity. Non-continuous physical activity combines moderate aerobic and/or anaerobic intervals of physical activity with either passive or active rest periods. Resistance training is an example of a non-continuous activity that requires active, weight lifting tasks interspersed with periods of rest. The physiological responses, e.g., HR, are elevated more so during the active verse rest periods. The perception that non-continuous physical activity is unsafe for less fit populations has been discredited [18]. It can stimulate similar, if not superior, changes in both work performance and cardiovascular regulation and appears to be a greater stimulus for improvements in arterial function relative to continuous aerobic exercise [19,20]. In the only study on non-continuous physical activity and pregnancy, Satyapriya et al. observed increased power in maternal HRV metrics linked to parasympathetic activity and lower power in those metrics that represent sympathetic activity [21]. Therefore, it is plausible that non-continuous maternal physical activity has independent effects on fetal autonomic development; however, scientific evaluations of this contention have not been described in the literature.

We previously reported that pregnant women who engaged in continuous physical activity on a regular basis (i.e., >30 min of moderate intensity aerobic activity, three times per week throughout the pregnancy) resulted in a trend towards lower fetal HR and increased HRV at 32 weeks gestational age (GA) that reached significance at 36 weeks GA [15,16]. Given evidence that non-continuous and continuous physical activities both evoke beneficial physiological adaptations and the lack of information on responses of pregnant mothers and their fetuses to non-continuous physical activity, we conducted a post-hoc analysis of existing data to determine the effects of non-continuous maternal physical activity performed during pregnancy on fetal cardiac autonomic control. We hypothesized that more time spent performing non-continuous physical activity during pregnancy is significantly associated with lower fetal HR and increased HRV.

2. Methods

2.1. Study participants

This was a retrospective analysis of data from a cohort of 40 pregnant women living within the Kansas City metropolitan area who participated in a cross-sectional study of the associations between self-reported leisure-time physical activity (LTPA) and fetal cardiac autonomic nervous system development. All women had singleton pregnancies, were healthy, non-smokers with no history of alcohol or illicit drug use and free from pregnancy related complications. Height was self-reported and weight was measured at each study visit utilizing a calibrated digital scale. Written informed consent was obtained from women prior to participation. All study protocols were approved by the Kansas City University of Medicine and Biosciences and University of Kansas Medical Center Institutional Review Boards and Human Subjects Committees.

2.2. Physical activity assessment

In order to assess all LTPA performed during the three months prior to the 36 wk assessment, women completed the Modifiable Physical Activity Questionnaire (MPAQ) at 36 wk GA. Physical activities were classified as continuous (e.g., walking, jogging) and non-continuous (e.g., weight lifting, yoga) as detailed in Table 1. Both classifications had a range of intensities. This study did not assess occupational and daily living (e.g., getting dressed) activities. The MPAQ was selected due to its reliability and validity for assessing the duration of physical activity in various populations including pregnant women [2,22,23]. Duration (min/wk) was derived by multiplying the number of sessions by session length (min) for all physical activities performed during the period of interest.

2.3. Magnetocardiogram (MCG) recording

An investigational 83 channel dedicated fetal biomagnetometer (CTF Systems, Inc.), housed in a magnetically shielded room, was utilized to record maternal-fetal biomagnetic signals [15]. In order to minimize the influence of external factors, all recordings were done at least two hours after caffeine consumption and/or exercise; all women were free from medications as well. Women were tested between 10:00 and 17:00 hours. Pregnant subjects were comfortably seated, slightly reclined and in contact with the surface of the biomagnetometer interface without applying pressure to the gravid maternal abdomen. The data were acquired in a continuous 18 minute recording using 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).

2.4. Processing magnetocardiogram (MCG) signals

All MCG recordings were presented to an Infomax independent component analysis algorithm implemented in EEGLAB toolbox [24]. This process separates maternal MCG, fetal MCG and various fetal movements with distinct and previously characterized biomagnetic signatures [25–27]. The fetal MCG was identified and fiducial R-peaks were automatically detected using a template-matching algorithm to generate the interbeat-interval time-series [15,16,25–27]. All MCG traces were manually checked (LEM, KMG) for incorrectly marked or missed beats.

2.4.1. HR and HRV measures

The metrics applied to the fetal interbeat-interval time-series include rate [HR in beats per minute (bpm)]; metrics of variability in the time domain (msec); the square root of the mean squared differences between adjacent normal R-R intervals (RMSSD) (hereafter; short-term HRV) and the standard deviation of all normal R-R intervals (SDNN) (hereafter; overall HRV). Frequency domain metrics (msec^2) were derived from the interbeat-interval time-series by Fast Fourier Transform. From this we derived power in the following frequency bands: very low frequency (VLF [0.02–0.08 Hz], low frequency (LF) [0.08–0.2 Hz], and high frequency (HF) [0.4–1.7 Hz] [28]. Fetal activity state was determined by visual inspection of the HR pattern generated from the interbeat-interval-time series by two independent investigators (LEM/KMG) [29–31]. If state determination differed between

Table 1
Continuous and intermittent leisure-time physical activities.

Continuous	Intermittent
Jogging, swimming, bicycling	Baseball/softball
Football/soccer	Volleyball
Basketball	Bowling
Aerobic dance	Calisthenics/toning
Water aerobics	Hunt/fish
Dancing	Gardening/yardwork
Stairmaster	Strength training
Walking/Hiking	Tennis
Jump rope	Golf
Cross country snow skiing	Yoga