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Abstract

The purpose of this study is to investigate blood glucose changes, as measured by a continuous glucose monitoring system, that occur in women with gestational diabetes mellitus (GDM) following an acute bout of moderate-intensity walking after consuming a high carbohydrate/low fat meal. This study found that moderate-intensity walking induced greater postprandial glucose control compared to sedentary activity and it appears that moderate-intensity activity may be used to reduce postprandial glucose levels in women with GDM.

Key Words: Pregnancy, Physical Activity, Continuous Glucose Monitoring System, Moderate Intensity

Introduction

Approximately 5–10% of all pregnant women will develop GDM during their pregnancy (Chen et al., 2016, Public Health Agency of Canada, 2014). Treatment of GDM is critical to preventing complications for both the mother and the fetus. If satisfactory control of blood glucose cannot be achieved through dietary intervention, then insulin may be required. Physical activity is considered an adjunctive therapy, due to the insulin-like effect on glucose uptake in skeletal muscle (ACOG, 2015).

Physical activity interventions implemented during pregnancy have resulted in lower fasting glucose levels (Davenport et al., 2008; Jovanovic-Peterson et al., 1989). However, studies investigating blood glucose changes after an acute bout of activity have found only modest changes lasting 45 to 60 minutes post activity. This includes studies incorporating a variety of intensities (light to moderate), modes of activity (cycling, walking), and timing of activity (pre- and postprandial) (Avery & Walker, 2001; Garcia-Patterson et al., 2001; Lesser et al., 1996). Postprandial glucose levels often represent the highest peak in maternal blood glucose, and may have a greater impact on insulin response and fetal glucose uptake compared to fasting glucose levels (Heine et al., 2004).

Physical activity recommendations during pregnancy include up to 30 minutes of moderate intensity activity on most or all days of the week (ACOG, 2015; Wolfe & Davies, 2003, Colberg et al., 2016). Artal recommended a similar amount of moderate activity to take place approximately 30 minutes following a meal (2003). Observing the time course of changes in postprandial blood glucose levels following moderate-intensity walking may give greater insight into the physiological impact of postprandial physical activity in women with GDM.

Therefore, the purpose of this study was to investigate blood glucose changes, as measured by continuous glucose monitoring system (CGMS), that occurred following an acute bout of moderate-intensity walking after consuming a high carbohydrate (CHO)/low fat meal.

Materials and Methods

Participants

Eight women with GDM (29.2$\pm$5.1y, 1.7$\pm$0.6m, 92.2$\pm$23.0kg) were recruited by a nurse practitioner from a high risk obstetric clinic. Participants were either in their second or third trimester (24–35 weeks), free of any contraindications to physical activity, as outlined in the ACOG guidelines (ACOG, 2015), and not using insulin. The Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for pregnancy) (Canadian Society for Exercise Physiology, 2002) was completed by a physician for all participants. This study was approved by the Institutional Review Board.

Instruments

Medtronic iPro Recorder CGMS

The *i*Pro Recorder CGMS (Medtronic Inc.; Minneapolis, MN) has been validated and used in pregnant women with diabetes (Kerssen et al., 2004, 2005). The CGMS requires the subcutaneous insertion of small catheter containing a glucose sensor and a transmitter. The glucose sensor utilizes interstitial glucose to calculate blood glucose levels, and records and stores glucose measurements every five minutes for multiple days.

Omron HJ-720 ITC Pedometer

The Omron HJ-720 ITC pedometer (Omron, Lake Forest, IL) was worn in the pants pocket to document daily physical activity. This pedometer has been shown to be accurate when worn in this location in pregnant women (Connolly et al., 2011). Steps were averaged for days two and four since 24-hour data were available for each of these days.

Procedures

Each participant began the study on Day 1 and concluded on Day 5. Days 2 and 4 were the experimental days, when the women either walked or remained sedentary. Day 3 did not require women to report to the clinic. On Day 5, the CGMS was removed and the participant returned her glucose logs and pedometer.

On Day 1, the CGMS was placed above the hip on the lower back (Medtronic Inc., 2004). On Days 2 and 4, the participants reported to the clinic after fasting at least two hours and were provided a prepackaged meal (60 grams CHO, 10 grams protein, 7 grams fat; ~400 Kcal). After eating, the participants sat for 30 minutes and glucose was assessed using the participants' personal glucometers. The participants were then randomly assigned to either 30 minutes of treadmill walking or 30 minutes of sitting.

Walking Trial

The participants walked for 30 minutes at 80.4 m•min^{-1} (3.3 METs), following physical activity recommendations (ACOG, 2015, Wolfe & Davies, 2003). The speed of the treadmill was adjusted if the intensity of the activity was too high as determined by telemetry-measured heart rate (Davies et al., 2003) (out of recommended range for maternal age), RPE (≥14 Borg Scale), or if the participant was uncomfortable walking at that pace. Following the walking bout, blood glucose was assessed. Fetal heart rate was assessed by Doppler (Huntleigh Dopplex FD3; Wales UK) before and within five minutes of completing the walking bout. The recommended fetal heart range is 110–160 beats•min^{-1} (ACOG, 2009).

Sedentary Trial

During this trial, participants sat and talked with researchers for 30 minutes. Before and after the sedentary trial, blood glucose and fetal heart rates were assessed.

Statistical Analyses

The primary outcome variables evaluated were postprandial (i.e., immediately prior to the walking bout or sedentary bout) and post-treatment (i.e., immediately following the walking bout or sedentary bout) glucose levels obtained from glucometers and continuous, 24-h CGMS blood glucose measurements. Glucose and the area under the curve for glucose ($AUC_{Glucose}$) from one until six hours postprandial were calculated from CGMS output. Differences in glucose levels and $AUC_{Glucose}$ were analyzed over time using paired t-tests and a repeated-measures ANOVA. An alpha level of $p<0.05$ was used to determine significance. In order to obtain a power of 0.80, a sample size of eight participants was needed. Post-hoc power analysis indicated an effect size of 2.32, with a measured power of 0.999. All analyses were done using SPSS Statistics, Version 17.0.

Results

There was one brief incidence of hypoglycemia ($\leq$3.9mg/dL) in a single subject that was resolved in the following hour. All measured fetal heart rates were within the normal range. Thirty-minute postprandial glucose (pre-treatment) was not different between the walking and sedentary trials. Immediate post-treatment glucose ($p<0.01$) and two-hour postprandial glucose levels ($p<0.05$) were lower in the walking compared to the sedentary trial (Figure 1). When all glucose values for the 24-h periods following the trials were averaged, glucose measurements were not significantly different [5.1$\pm$0.2 mmol•L^{-1} (walking) vs. 5.2$\pm$0.5 mg•dL^{-1} (sedentary)].

$AUC_{Glucose}$ was lower for the walking bout compared to the sedentary trial, for three hours after the meal (Table 1). There was a trend towards differences in $AUC_{Glucose}$ between the walking and sedentary trials in hours 4-6 after the meal (Table 1).

Maternal heart rate averaged 134±12 beats•min^{-1} (walking) and 85±9 beats•min^{-1} (sedentary). Fetal heart rate averaged 147±7 beats•min^{-1} following the walking trial and 142±11 beats•min^{-1} after the sedentary trial. Pedometer step counts for the women averaged 7,111±1,221 steps on the walking day and 3,838±1,925 steps on the sedentary day. The women averaged approximately 3,300 steps during the 30-minute walking trial, which accounts for this step difference.

Discussion

This study utilized a bout of physical activity consistent with current guidelines and investigated blood glucose changes in women with GDM after an acute bout of moderate-intensity walking following a high CHO/low fat meal. The primary findings indicate that a 30-minute bout of moderate intensity walking resulted in lower postprandial glucose levels for two hours after activity and better glucose control ($AUC_{glucose}$) for up to three hours postprandial on the walking day compared to the sedentary day.

There is limited research regarding blood glucose changes after an acute bout of physical activity. Avery and Walker (2001) looked at glucose levels under three conditions: resting, cycling at a low intensity, and cycling at a moderate-intensity two hours after a meal. The authors found that the women had more favorable blood glucose levels for up to 45 minutes after exercise compared to the rest day only with the moderate intensity cycling (Avery & Walker, 2001). Garcia-Paterson and colleagues (2001) compared blood glucose levels of women with

GDM after the women completed a 60-minute walk (2.52 km•hr^{-1}) immediately following a meal. Results showed a decreased postprandial glucose excursion for one hour after the meal (Garcia-Patterson et al., 2001). The findings from these studies suggest that physical activity after a meal has a greater impact on postprandial glucose levels in women with GDM, compared to activity before a meal. In the current study, the women performed a bout of moderate intensity walking 30 minutes after a meal, and the results showed better glucose control for up to three hours postprandial.

The duration of glucose control in the current study is greater than what was previously reported. In addition to the timing of the activity, these results could also possibly be due to the use of weight-bearing, moderate-intensity activity. This type and intensity of activity may increase the magnitude of physical activity's effect on glucose control in women with GDM. Avery and Walker utilized cycling (non-weight-bearing activity) at low and moderate intensities and only found an effect with moderate intensity (2001). Garcia-Paterson et al. (2001) had their participants walk at a low intensity. Although they utilized low intensity activity, the weight-bearing nature may be responsible for the increased glucose control for a slightly longer duration compared to Avery and Walker (Garcia-Patterson et al., 2001). Moderate-intensity, weight bearing activity also leads to a greater caloric expenditure compared to non-weight-bearing, moderate-intensity activity, which may enhance glucose uptake by the muscles.

The current study found significant improvements in glucose control for up to three hours postprandial following an acute bout of activity. Heine et al. (2004) has suggested that researchers and clinicians focus on postprandial glucose levels instead of fasting blood glucose. Postprandial glucose levels may have a greater impact on disease-related complications and adverse effects on individuals with diabetes. Higher peak postprandial glucose levels can potentially induce a hyperglycemic state; increasing the amount of glucose supplied to the fetus. Although this has not been an area of focus in women with GDM, it is possible that higher postprandial glucose levels, which tend to exceed fasting glucose levels, may have a greater negative impact on the fetus compared to higher fasting glucose levels (Heine et al., 2004).

Study limitations include a small sample size and limited dietary control. However, there was sufficient power to find significant differences in postprandial glucose levels. Detailed dietary data were available for the meals provided on the study days, but no dietary data on the remainder of the study days are available. A significant strength of this study was the use of the CGMS, which allowed the researchers to monitor time-course changes in blood glucose values that result from food intake and activity. Additionally, the activity prescribed during this study aligned with current guidelines.

In conclusion, moderate-intensity walking had a positive impact on postprandial glucose levels for up to two hours and better glucose control ($AUC_{glucose}$) for up to three hours after the meal. These findings suggest that women who participate in postprandial activity consistent with the guidelines can reduce postprandial glucose levels and improve glucose profiles. Future studies should investigate the thresholds for duration, intensity, and timing of activity, and impact of chronic physical activity participation on postprandial glucose and glucose control in women with GDM.

Conflict of Interest Disclaimer

The authors have no conflicts of interest to disclose regarding this manuscript.

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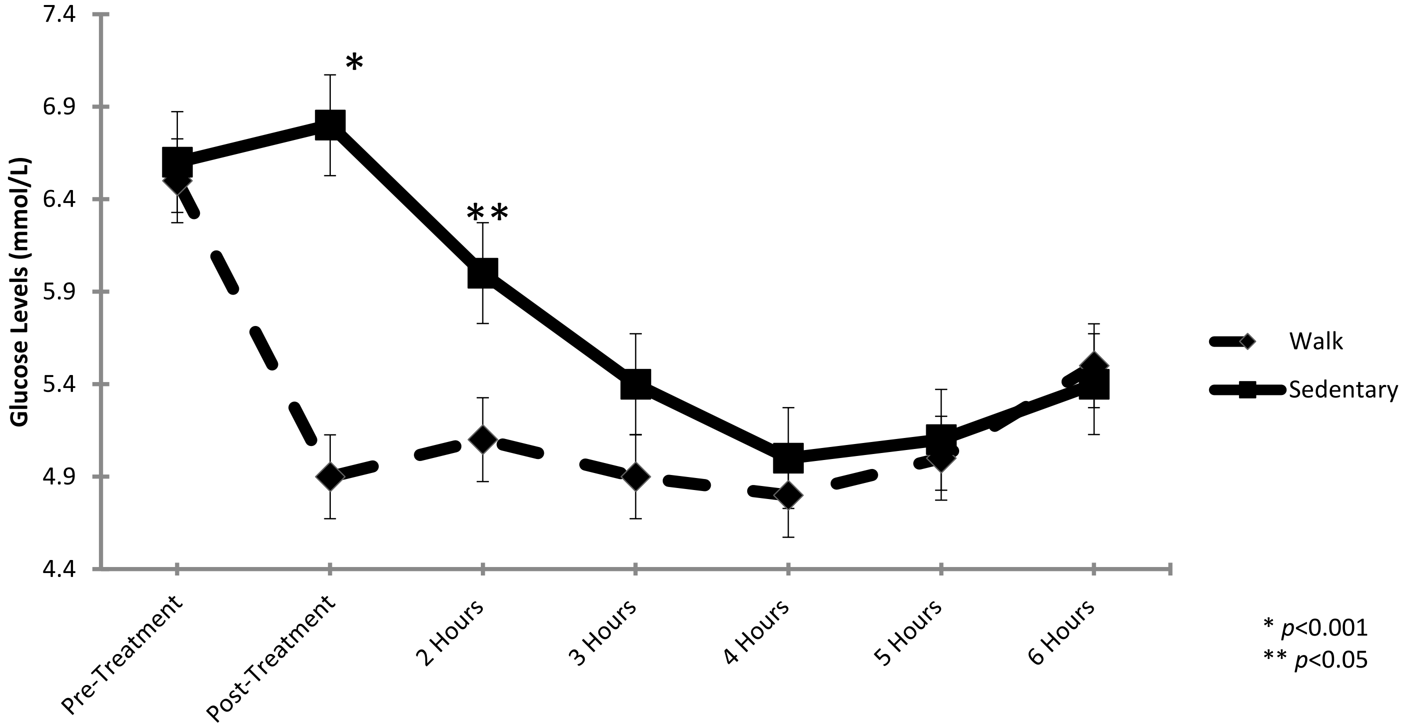
Table 1. $AUC_{Glucose}$ values for walking and sedentary trials following a meal

Time after meal	$AUC_{Glucose}$ Walking Trial	$AUC_{Glucose}$ Sedentary Trial	*p* value
One hour	5.3 $\pm$ 0.2	6.5 $\pm$ 0.7	0.001
Two hours	10.2 $\pm$ 0.5	12.0 $\pm$ 1.2	0.003
Three hours	15.3 $\pm$ 1.2	17.2 $\pm$ 1.7	0.018
Four hours	20.5 $\pm$ 1.9	22.7 $\pm$ 2.4	0.058
Five hours	25.5 $\pm$ 2.6	28.3 $\pm$ 3.2	0.057
Six hours	30.3 $\pm$ 3.3	33.8 $\pm$ 4.0	0.053

Figure Caption

Figure 1. Postprandial blood glucose levels following walking and sedentary trials. The solid line represents glucose levels during walking trial and the dashed line represents glucose levels during the sedentary trial.


7.4
6.9
6.4
5.9
5.4
4.9
4.4
Glucose Levels (mmol/L)
*
**
Walk
Sedentary
Pre-Treatment
Post-Treatment
2 Hours
3 Hours
4 Hours
5 Hours
6 Hours
* p<0.001
** p<0.05