Postprandial Walking is Better for Lowering the Glycemic Effect of Dinner than Pre-Dinner Exercise in Type 2 Diabetic Individuals

Sheri R. Colberg, PhD, Lida Zarrabi, MPH, Linda Bennington, RN, MSN, CSN, Abhijeet Nakave, MD, C. Thomas Somma, EdD, David P. Swain, PhD, and Scott R. Sechrist, EdD

Objectives: In prior studies of exercise done before or after breakfast and lunch, postprandial activity generally reduces glycemia more than pre-meal. This study sought to examine the effects of exercise before or after an evening meal.

Design: Examined the differing effects of a single bout of pre- or postprandial moderate exercise or no exercise on the glycemic response to an evening (dinner) meal in individuals with type 2 diabetes.

Setting: Community-dwelling participants tested at a research university in Virginia.

Participants: Twelve men and women subjects (mean age of 61.4 ± 2.7 years) with type 2 diabetes treated with diet and/or oral medications.

Intervention: Three trials conducted on separate days consisting of a rest day when subjects consumed a standardized dinner with a moderate glycemic effect and 2 exercise days when they undertook 20 minutes of self-paced treadmill walking immediately before or 15 to 20 minutes after eating.

Measurements: Blood samples taken every 30 minutes over a 4-hour period and later assayed for plasma glucose; from these data both absolute and relative changes in glucose levels were determined, as well as the total glucose area under the curve (AUC) of the 4-hour testing period. Initial samples were additionally assayed for glycated hemoglobin and lipid levels.

Results: Twenty minutes of self-paced walking done shortly after meal consumption resulted in lower plasma glucose levels at the end of exercise compared to values at the same time point when subjects had walked pre-dinner. Total glucose AUC over 4 hours was not significantly different among trials.

Conclusion: Postprandial walking may be more effective at lowering the glycemic impact of the evening meal in individuals with type 2 diabetes compared with pre-meal or no exercise and may be an effective means to blunt postprandial glycemic excursions. **(J Am Med Dir Assoc 2009; 10: 394–397)**

Keywords: Physical activity; walking; exercise; type 2 diabetes; postprandial glucose; blood glucose

The timing of moderate aerobic exercise around a meal can affect the glycemic effect of this activity when done by individuals with type 2 diabetes. For instance, postprandial exercise of moderate intensity decreases glycemia after breakfast in type 2 diabetic patients, but this effect does not persist during and after the following lunch meal.[1] Moreover, 1 hour of aerobic exercise has a minimal impact on plasma glucose level when performed in fasted moderately hyperglycemic type 2 diabetic men, but induces an important decrease in plasma glucose level when performed 2 hours after breakfast.[2]

To our knowledge, the effects of undertaking physical activity before or after the evening meal in individuals with type 2 diabetes have not been reported, but would have practical implications for the prescription of physical activity aimed at providing the greatest benefit to glycemic control at that time of day. Thus, the purpose of this study was to examine the differing effects of a single bout of pre- or postprandial

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Address correspondence to Sheri Colberg, PhD, ESPER Department, Old Dominion University, Norfolk, VA 23529. E-mail: scolberg@odu.edu

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Table 1. *Resting Subject Characteristics*

	Females	Males	Total
Subjects	6	6	12
Age, y	60.3 ± 4.5	62.5 ± 3.2	61.4 ± 2.7
Diabetes, # years	8.7 ± 3.3	14.0 ± 2.6	11.3 ± 2.1
HbA1c, %	7.0 ± 0.4	6.9 ± 0.6	7.0 ± 0.3
Height, cm	164.4 ± 2.0	178.6 ± 2.0	171.5 ± 2.5
Weight, kg	104.0 ± 10.4	98.1 ± 10.0	101.0 ± 6.9
Body mass index	38.5 ± 3.6	30.5 ± 2.5 *	34.5 ± 2.4
SBP, mm Hg	129.5 ± 6.1	128.2 ± 3.1	128.9 ± 3.4
DBP, mm Hg	67.3 ± 4.6	77.0 ± 4.3	71.7 ± 3.4
Cholesterol, mmol/L	5.3 ± 0.5	5.7 ± 0.8	5.5 ± 0.4
LDL-C, mmol/L	3.5 ± 0.3	3.4 ± 0.6	3.5 ± 0.3
HDL-C, mmol/L	1.2 ± 0.2	1.1 ± 0.1	1.1 ± 0.1

SBP, systolic blood pressure; DBP, diastolic blood pressure; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.

* $P < .05$ females versus males. All results are mean ± SEM.

exercise done at a moderate pace on the glycemic response to a standardized evening (dinner) meal in older individuals with type 2 diabetes.

METHODS

A total of 12 older subjects (6 female, 6 male) with uncomplicated type 2 diabetes treated with diet and/or a variety of oral diabetic medications participated in this study. Before their participation, each subject signed an informed consent form approved by the Institutional Review Board at Old Dominion University. Medical personnel involved with the study initially screened subjects for the presence of diabetic complications (ie, any neuropathy-related changes, diagnosed kidney disease, unstable proliferative retinopathy, signs or symptoms of cardiovascular disease, smoking habits, and blood pressure) via questionnaire and recorded all diabetes and other prescribed medications. Subjects were also asked to describe their usual exercise participation.

Subjects were requested not to eat within 3 hours of reporting to the laboratory for testing (and nothing more than a small snack, if anything, after lunch). They were also to refrain from participating in moderate or heavy exercise on testing days although they were allowed to do normal amounts of walking and other unstructured exercise as long as they did the same amount and type on each of the 3 study days. On each testing day, subjects were then asked if they had taken their usual medications, when they had last participated in any structured exercise, and how much time had elapsed since they had eaten, and their answers were recorded.

Each subject performed trials on 3 different occasions in a randomized order: (1) control day (NO EX), when only a standardized dinner was consumed; (2) exercise day, when a single bout (20 minutes) of moderate aerobic exercise (ie, walking on a treadmill) was undertaken immediately before dinner (PRE); and (3) a second exercise day with a similar bout of walking done 15 to 20 minutes after dinner (POST). Subjects walked at a self-selected, comfortable pace on the first exercise day and at the same speed for the second one. Heart rates during the final 5 minutes of each exercise session were recorded, and exercise intensity was calculated using the heart rate reserve (HRR) method, which takes into account resting heart rate (HR) and estimated maximal HR (calculated as 220 minus the subject's age), where the HRR is a percentage of the difference between the 2 above resting values.

To measure changes in glycemia in response to the meal and each testing condition, each subject had an intravenous catheter placed in a forearm or hand vein for blood sampling at 30-minute intervals throughout a 4-hour period before and following dinner and exercise. On exercise testing days, walking was begun 5 minutes after the first blood draw for pre-meal exercise or 5 minutes after the third draw (at 60 minutes) for post-meal measures. Subjects began eating their meals 30 minutes into the testing protocol, immediately after the second blood draw. Dinners consisted of a Marie Callendar brand microwaveable meal with 400 to 450 kilocalories and mixed macronutrients with a moderate glycemic effect. Blood samples were allowed to clot for several minutes before being centrifuged, and plasma glucose levels were later assayed. In addition, glycated hemoglobin and blood lipids were measured in the first sample taken each day. During testing, a Lifescan One Touch Ultra 2 meter was used to obtain fingerstick measures of whole blood glucose levels at the time of each draw to ensure the participants' safety.

The data were analyzed using repeated measures analysis of variance (ANOVA) to compare the mean glucose responses at each time point (reported as mean ± SEM). In addition, the total glucose area under the curve was compared between trials using 1-factor ANOVA. Subjects grouped by sex were compared using *t* tests. Significance for all analyses was set at *P* less than .05.

RESULTS

The subjects averaged 61.4 ± 2.7 years of age, with no significant difference in age between males and females, as shown in Table 1 along with their other resting characteristics. Males had a lower mean body mass index than females ($P < .05$). The mean duration of type 2 diabetes was 11.3 ± 2.1 years, and overall blood glucose control as measured by glycated hemoglobin was considered marginally adequate (7.0% ± 0.3%), as the target goal of the American Diabetes Association is a value of 7% or lower,[3] and it was similar between the sexes. Total cholesterol, high-density lipoprotein (HDL)-cholesterol, and low-density lipoprotein (LDL)-cholesterol were similar between groups, and only 1 (female) subject was taking a prescribed lipid-lowering medication.

Participants reported having eaten their last food an average of 3.6 and 3.8 hours (for females and males, respectively) before their arrival at the testing site, which did not vary significantly from one testing day to the next. For the study, they were allowed to choose from a selection of 4 different frozen dinners with similar caloric contents (grilled chicken, turkey, stuffed pasta, or breaded fish) during their first trial and consumed the same dinner on their subsequent 2 visits. The dinners averaged 420.9 ± 4.8 kilocalories per meal (range of 400 to 450), with a content of 43 to 54 grams of carbohydrate, 4 to 10 grams of fiber, 9 to 16 grams of fat, and 19 to 32 grams of protein. A typical meal (eaten by half of the subjects) consisted of grilled chicken with penne pasta and green beans containing 430 kilocalories, 43 grams of carbohydrate, 9 grams of fiber, 16 grams of fat (9 grams saturated), and 28 grams of protein.

Subjects had an average resting heart rate of 76.2 ± 3.3 beats per minute (Table 2). After a short warm-up, participants self-selected a walking pace that averaged 40.3% ± 2.7% of their calculated heart rate reserve (HRR), indicating that their pace was low- to moderate-intensity (range 24.8% to 53.3% HRR). Walking speed ranged from 0.7 to 3.5 miles per hour, with a mean pace of 2.2 ± 0.3. On average, males walked at a faster self-selected pace than females ($P < .05$).

Figure 1 shows mean plasma glucose values over time, which were only significantly different between groups at 90 minutes into testing, which was immediately following after-dinner exercise (or an additional 30 minutes of sitting during the other 2 trials). The POST group values (6.1 ± 0.4 mmol/L) were significantly lower than PRE (8.8 ± 1.0; $P = .048$), but not compared to NO EX (7.8 ± 0.7). These data were also analyzed as a change in glucose values from baseline, and the results were that POST values at 90 minutes were similarly lowered in the POST group (–0.41 ± 0.34 mmol/L), which was significantly lower than both PRE (1.83 ± 0.66) and NO EX (0.73 ± 0.56) conditions ($P = .003$). However, the glucose area under the curve (AUC) was not significantly different among testing conditions. Glucose AUC values averaged 13.7 ± 2.2 mmol/L for PRE, 11.3 ± 3.7 for POST, and 11.7 ± 2.0 for NO EX trials.

DISCUSSION

The current study examined the glycemic effects of 20 minutes of self-paced, mild to moderate walking done either immediately before or shortly after eating the same dinner. Walking after meal consumption resulted in lower plasma glucose levels at the end of exercise compared to values at the same time point when subjects had walked pre-dinner.

Table 2. *Exercise Subject Characteristics*

	Females	Males	Total
Subjects	6	6	12
Resting HR, bpm	77.0 ± 5.2	75.3 ± 4.5	76.2 ± 3.3
Walking speed, mph	1.8 ± 0.3	2.7 ± 0.3 *	2.2 ± 0.3
Maximal HR, bpm	165.8 ± 3.2	164.3 ± 2.3	165.0 ± 1.9
PRE HR, bpm	110.3 ± 2.2	112.8 ± 4.9	111.6 ± 2.6
POST HR, bpm	116.5 ± 2.1	110.8 ± 4.8	113.7 ± 2.6
HRR, %	40.0 ± 3.9	40.6 ± 4.1	40.3 ± 2.7
No. regular exercisers	0	5 *	5

HR, heart rate; bpm, beats per minute; mph, miles per hour; PRE, pre-meal exercise; POST, post-meal exercise; HRR, heart rate reserve (exercise intensity).

* $P < .05$ females versus males. All results are mean ± SEM.

The blunting effect of postprandial exercise on blood glucose elevations has been well established.[1,2,4–6] Moderate intensity exercise done 2 hours after breakfast decreases glucose levels more than during fasting conditions in type 2 diabetic subjects,[1,2] but the effect does not persist after lunch without additional exercise.[1,4] For diabetic subjects in this study, none of whom were being treated with exogenous insulin, consumption of a meal with a moderate glycemic effect likely resulted in a greater release of endogenously released insulin that lowered their post-meal glycemic responses further with the addition of exercise.[1,2,5,6] The binding of insulin to its cellular receptors in muscle and adipose tissues recruits GLUT4 transport proteins to the cell surface that facilitate glucose transport.[7] Muscular contractions themselves are known to stimulate glucose transport into muscle cells without the need for insulin through an independent mechanism, but in an additive manner, thereby potentiating the effects of post-meal exercise.[8]

The findings in our study also concur with Poirier and colleagues,[9] who found that moderate cycle exercise after any meal (breakfast, lunch, or dinner) results in a significant decrease in glucose levels, again likely resulting from the natural release of insulin stimulated by food intake. Others have reported that both postprandial high-intensity exercise and longer bouts of walking (ie, 2 hours versus 1) reduce glucose levels and insulin secretion, suggesting that the effect of exercise is related more to total energy expenditure rather than to peak exercise intensity.[4,10] Thus, it is possible that the short duration of the exercise bout in this study (20 minutes) might have had a greater impact on absolute and relative glycemia and total glucose AUC if either its intensity or its duration had been increased.

Aerobic exercise releases glucose-raising hormones, such as epinephrine and norepinephrine, in response to exercise intensity, with large amounts generally only being elicited by intense activities (greater than 75% of maximal aerobic capacity).[11] Given the mild or moderate pace chosen by the subjects in this study (~40% of HRR), it is unlikely that excessive amounts of these catecholamines were released. Although differing amounts may have been released during exercise at opposing times around the evening meal, others have shown that postprandial exercise releases more of these hormones and increases fat use compared with preprandial,[12] making it unlikely that varying catecholamine release can explain the lower blood glucose values following post-meal exercising observed in the current study.

Exercise timing and intensity aside, individuals with diabetes will likely experience improved glycemic control from simply engaging in regular training at any time of day, although the acute glycemic impact of a single bout of moderate activity may vary with the timing, as was demonstrated in the present study. When moderate aerobic exercise is undertaken regularly, this type of training has a more chronic effect in that it increases whole-body insulin-mediated glucose disposal in obese type 2 diabetic patients, independently of alterations in the insulin-signaling cascade, likely as the result of a greater GLUT4 protein content.[13] The subjects in this study varied in their self-reported regular exercise participation;

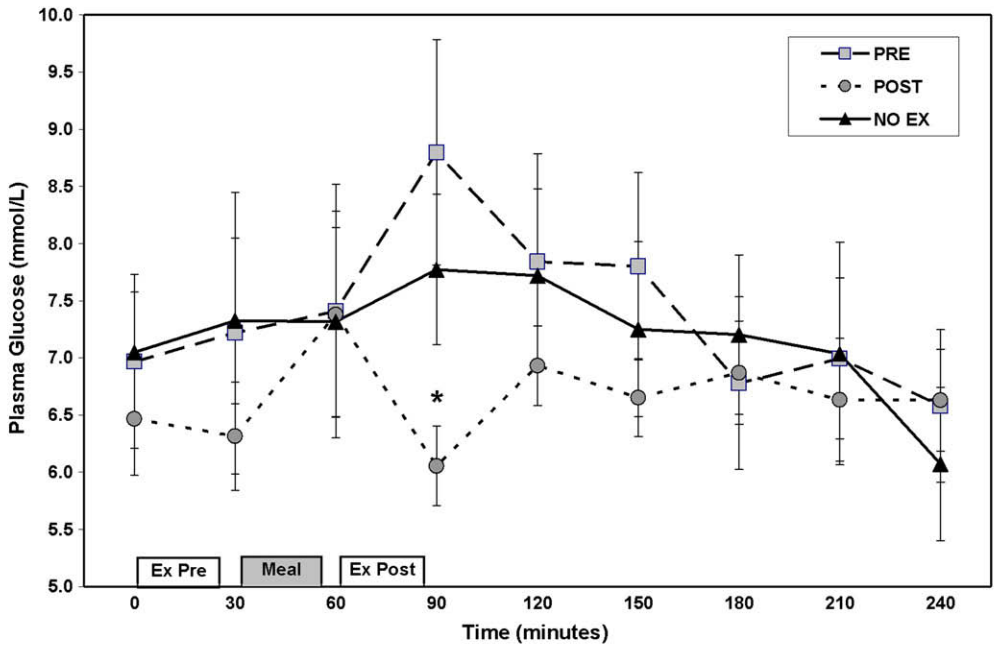

Fig. 1. *Plasma glucose in response to dinner with no exercise (NO EX), 20 minutes of walking before dinner (PRE), or similar exercise after dinner (POST). *P < .05 PRE versus POST trials.*

however, exercise done outside the study was limited on test days and was not a factor in the current findings.

CONCLUSION

In summary, it appears that 20 minutes of self-paced mild to moderate intensity walking may be more beneficial for controlling postprandial glycemia in type 2 diabetic individuals when undertaken shortly after an evening meal rather than immediately beforehand. Postprandial hyperglycemia is an established cardiovascular risk factor[14] and oxidative damage resulting from such glycemic excursions is a factor in the development of diabetic complications that may be moderated by exercise.[15] Accordingly, older diabetic individuals are advised to undertake aerobic exercise after meals, including the evening one, to blunt the glycemic response resulting from meal consumption and reduce the likelihood of negative health consequences associated with postprandial glucose excursions.

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