Post-mealWalking vs. Pre-meal Vinegar Ingestion: Strategies to Reduce Postprandial Hyperglycemia

BRADY[1]

[1]University of Florida

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Abstract

Postprandial hyperglycemia is a risk factor for cardiovascular events. Independent of fasting blood glucose, impaired glucose tolerance predicts mortality. Lifestyle interventions that blunt the postprandial glucose spike are healthy overall and may reduce diabetic and CVD risk in at-risk populations. Apple cider vinegar has been shown to attenuate the rise in glucose following a meal. Similarly, aerobic exercise (walking) reduces blood glucose levels when performed before or following a high-glycemic meal. This study aimed to compare these interventions in terms of their ability to reduce postprandial glucose (BG) in older adults. Furthermore, we investigated whether this population would self-select a walking speed sufficient to reduce their postprandial BG spike. All participants (n=12) reported for testing on 2 occasions. A subset (n=5) completed a third visit. Participants arrived following a 3 hour fast. Baseline glucose was measured upon arrival, after which participants completed on 1 of the following 2 conditions in a randomized, crossover order: (1) Consumption of standard meal with either (1) addition of apple cider vinegar (V) (.3g/kg BW) or (2) 15 minutes of self-paced walking following the meal (W). The subset engaged in a third condition (C) (3) Consumption of meal followed by 2 hours of little to no activity to highlight the efficacy of the meal to induce a spike in glucose. BG was taken by finger stick at 30, 60, 90, and 120 minutes following meal consumption. The meal was designed to be high glycemic-index (GI) and included a bagel, butter, and orange juice. Total energy content of the meal was 470kcal (79g CHO [28gsugar], 12g FAT, 1g PRO). The control trial confirmed the ability of the meal to spike BG as levels rose following the meal at 30 (167.8$\pm$6.1 vs. 91.8$\pm$2.4; p<.005) and 60 minutes (172.8$\pm$11.8 vs. 91.8$\pm$ 2.4; p<.05). There was no difference in BG area under the curve (AUC) at any time point between conditions. However, following both vinegar and walking, the absolute increase in BG at 30 minutes following the meal was significantly reduced compared to control ([?]30BG in C 76.1+-7.0 vs. V 46.8+-9.2 vs. W 44.3+-7.5; p<.05 for all). Speed was found to be correlated with glucose AUC, such that an increase in walking speed was associated with a greater reduction in 2-hour glucose AUC (R=.590, p<.05). Lifestyle interventions such as walking and vinegar ingestion may be effective in acutely lowering spikes in glucose following a meal. For older adults, these represent alternative therapies to aid in glucose management and improve metabolic health.

INTRODUCTION

The global burden of diabetes is on the rise. The World Health Organization (WHO) estimated that 422 million adults were living with the disease in 2014, a number that has nearly doubled since 1980 (22). Sustained hyperglycemia ultimately increases one's susceptibility to cardiovascular disease and other health complications. It seems pertinent to investigate therapies which may lessen the disease burden of diabetes at the individual and population level.

The earliest experimental studies of vinegar's health benefits demonstrated that acetic acid and vinegar have inhibitory effects on the rapid increase in blood glucose concentrations following sucrose ingestion (7).

Ebihara et al investigated blood glucose and insulin responses to a 300ml sucrose solution with and without the addition of 60ml strawberry vinegar (5% acetic acid). Notably, the time to attain maximal glycemic response was delayed in the vinegar condition. Furthermore, the area under the insulin response curve was 20% smaller in the vinegar-containing test meal. These early experimental studies provided evidence that vinegar may exert potent anti-glycemic effects when consumed with a glycemic load.

The antiglycemic benefits of vinegar have been demonstrated in healthy subjects with normal glucose control (3,8,18) and insulin-resistant subjects (11,21). Those with impaired glucose tolerance or insulin resistance have shown long-term supplementation with vinegar reduced HbA1c values by 0.16% (21) and improved insulin sensitivity by 34% via a mechanism proposed to work similar to the drug metformin (11). A dose-response relationship for blood glucose and serum insulin concentrations after a bread meal have been observed, noting that 28 mmol acetic acid significantly lowered blood glucose and insulin compared to lower doses (18). In fact, the ability of vinegar to lower postprandial glucose excursions may be its most potent quality, as isolated postprandial hyperglycemia has been demonstrated to increase CV mortality, even in the absence of impaired fasting glucose.

Aerobic exercise is well-known to benefit glucose control. (6,7,9) Research has shown duration and timing (pre-vs. post meal) of exercise to be factors in the extent to which glucose is controlled. Dipietro et al. observed that a single bout of 15 minutes of walking performed 30 minutes post-meal was effective in improving 24-hour glycemic control in insulin resistant subjects and reducing glucose levels 3 hours post-meal (6). This highlights the need to verify if pre-meal exercise can benefit postprandial glucose.

Currently, the efficacy of pre vs. postmeal walking has not been established. No studies to date have compared a bout of post-meal walking with other glucose control strategies such as pre-prandial vinegar ingestion. Therefore, the aim of the present study was to compare the efficacy of a mass-relative dose of pre-prandial vinegar to a 15-minute bout of self-paced treadmill walking in reducing postprandial response to high-glycemic meal in glucose-intolerant participants. We hypothesized that 15 minutes of postprandial walking and preprandial vinegar ingestion would both reduce postprandial glycemia. However, we expected that a larger reduction would be observed with postprandial walking.

METHODS

The study was approved by the institutional review boards. All procedures were followed in accordance with the ethical standards of the Declaration of Helsinki.

PARTICIPANTS

Participants were recruited using flyers and other materials placed at local senior centers and retirement communities. Interested participants were screened based on inclusion and exclusion criteria. Inclusion criteria included (a) 55 years of age or older, (b) prediabetic condition defined as fasting glucose levels between 100-125mg/dl OR diagnosed with type II diabetes, (c) controlled glucose between 70 and 130 mg/dl at the start of testing (baseline), (d) no history of diabetic coma, and (e) willing to participate in two trials of the study and dress appropriately for the exercise condition. Exclusion criteria included (a) diagnosed diabetic retinopathy, neuropathy, or nephropathy, (c) known foot ulcers, (d) rapid heartbeat (over 100 at rest), (e) noticeable sweating at rest, (f) high levels of reported anxiety, confusion following requested tasks, (g) use of an insulin pump or insulin secretagogues, or (h) had experienced falls that would prevent safe treadmill exercise. Eligible, interested participants were provided an informed consent and subsequently enrolled in the study.

PROTOCOL

Testing occurred at the Campbell County Senior Center (Highland Heights, KY) or the Abilene Christian University Human Performance Laboratory (Abilene, TX). Participants completed the testing visits in a randomized, crossover fashion. Participants were not given information as to which trial was being completed. At each respective location, the same researchers conducted all experimental visits, including meal preparation and measurements. A diagramatic representation of the protocol can be seen in Figure 1.

Participants were informed to report to each testing session having fasted for a minimum of 3 hours. Each testing session for a given participant was conducted at the same time throughout the study. A minimum of 48 hours separated each trial. All participants completed the testing visits within a two-week time span. A subset of participants completed a third, control arm, also within the two weeks.

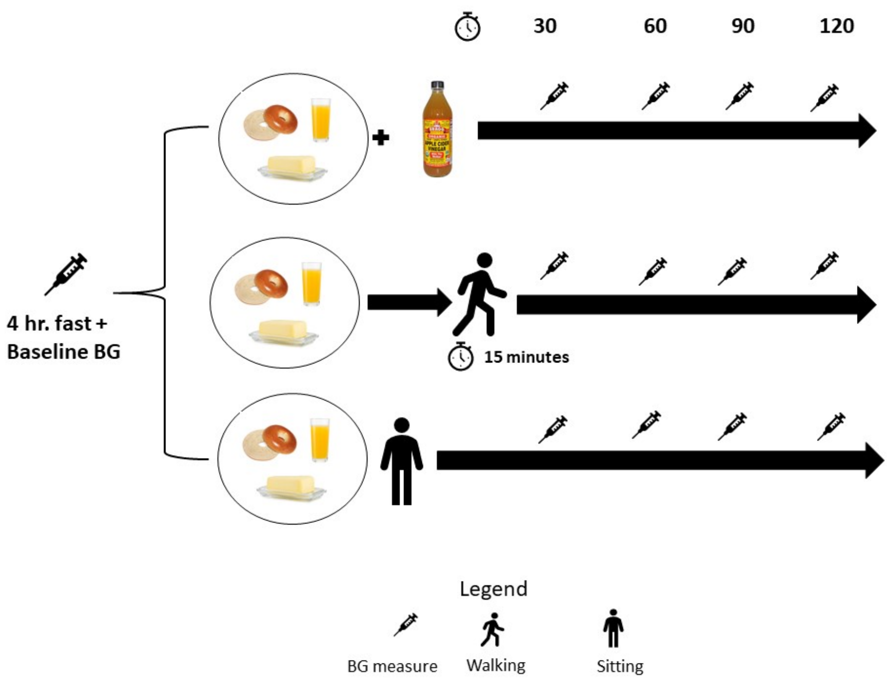

Figure 1: Study Protocol

Standard meal

The standard meal used in this study (replicated in each trial) was based on the protocol of Johnston et al (10) in order to elicit a prominent glycemic response. The meal contained an 85g bagel, 13g of butter and 237ml orange juice. Total energy content and macronutrient content of the of the meal was the following: 470 kcal, 79g carbohydrate (28g sugar), 12g fat (7g saturated), 1g protein.

Vinegar Trial

In the vinegar trial, participants consumed the standard meal described above with the addition of a dose of apple cider vinegar relative to their body weight (.3g/kg). The vinegar dose was mixed with the orange juice. Participants were instructed to consume the meal in under 10 minutes. After the meal, participants were restricted to sedentary activities (sitting, reading, playing games). Blood glucose readings were taken at baseline (pre-meal) and at 30, 60, 90, and 120 minutes after meal consumption using a commercial blood glucose meter and test strips. All measurements were taken, in duplicate by the same researcher.

Exercise Trial

In the exercise trial, participants consumed the standard meal described above and then waited for 15 minutes, during which time they sat quietly. Following this time period, participants completed a 15-minute session of treadmill walking at a self-selected pace. No instruction was given to participants regarding their walking pace or intensity. Although exercise was based on self-selected pace, intensity was monitored via heart rate and RPE. Intensity of exercise would be based upon subject's age predicted max HR using the equation 208-(.7*age) with moderate intensity exercise occurring at 64-75 percent of maximum HR according to the American College of Sports Medicine (1).

Each three minutes throughout the exercise session participants were asked to provide their rating of perceived exertion (Borg 6-20 scale) by verbally indicating their rating shown on the chart provided. Heart rate and blood pressure were recorded every five minutes during the exercise session. Blood glucose readings were taken at baseline (pre-meal) and at 30, 60, 90, and 120 minutes.

Control Trial

A subset of participants completed a control trial. For these participants the control trial was randomized with the vinegar and exercise trials within the two-week time span. The standard meal was consumed, per protocol, followed by a 2-hour period in which the participants sat or otherwise took part in leisure-time (non-physical) activities. Blood glucose readings were taken at baseline (pre-meal) and at 30, 60, 90, and 120 minutes.

Statistical Analyses

To verify that the standard meal provided a significant glycemic response in which to test the effect of vinegar and walking, a one-factor (time) repeated measures ANOVA was used to compare blood glucose at each time point within the control trial. Effect of vinegar and walking on blood glucose response following the standard meal was compared by calculating Area Under the Curve (AUC) for both trials and analyzing with a paired t-test. Blood glucose changes between time points (0 to 30, 30 to 60, 60 to 90, 90 to 120) were compared between trials (vinegar vs. walking, vinegar vs. control, control vs. walking) using an independent-samples t-test. Furthermore, correlations were run between independent variables "walking speed" and the dependent variable "blood glucose AUC."

Results

Participant Characteristics

Subjects (n=12)	Mean±SD
Age	71±7.8
Weight (kg)	84.9±20.5
Weight (lbs)	186.9±45.0
Height(cm)	167.3±10.5
BMI	30.1±5.3
Fasting BG	106±12.8

Participant characteristics are seen in Table 1. A total of 12 participants (8 females) completed the study, with an average age of 71±7.8 years. Weight of the participants was 186.9 ±45 lbs and BMI was 30.1±5.3. A total of 5 participants completed the control meal test condition, to verify that the test meal resulted in a significant blood glucose response.

Test Meal

To verify that our test meal resulted in a significant postprandial glycemic increase, 5 participants completed a trial in which they consumed the test meal and sat quietly for 2 hours. Results of the control condition can be seen in Figure 2. Fasting BG for the control trial was 91.8±2.4.Blood glucose was significantly elevated at 30 minutes (167.8±6.1 vs. 91.8±2.4, $p<.005$)), as well as 60 minutes (172.8±11.8 vs 91.8±2.4, $p=.024$) following the meal.

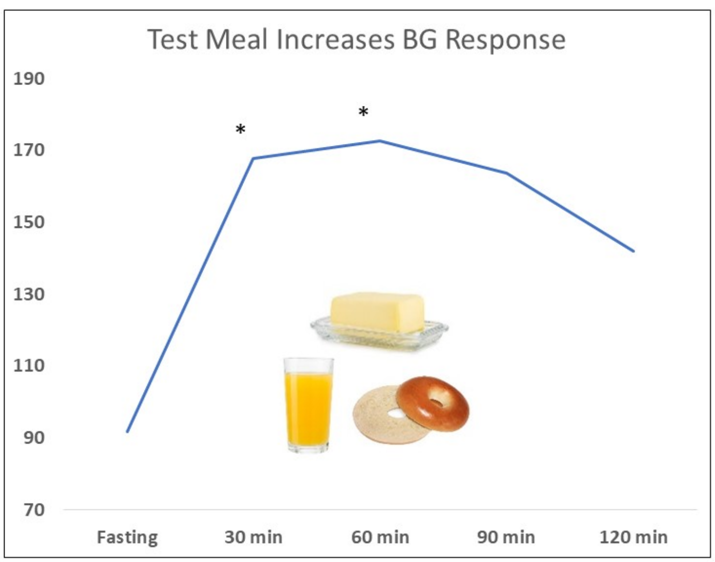

Figure 2: Blood glucose response to the test meal (control condition only)

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be seen in figure 2. Fasting BG for the control trial was 91.8±2.4.Blood glucose was significantly elevated at 30 minutes (167.8±6.1 vs. 91.8±2.4, p<.005), and 60 minutes (172.8±11.8 vs 91.8±2.4, p=.024) following the meal.

Blood glucose response following vinegar ingestion

Baseline fasting blood glucose during the vinegar ingestion trial was 110.1±4.2. There were no differences in total blood glucose AUC following vinegar ingestion when compared to control condition at any time point (Table 2). Furthermore, we found no significant differences in AUC between the vinegar condition and the postprandial walking condition (Table 2). However, when comparing the absolute change in blood glucose between each time point, it was revealed that vinegar ingestion significantly reduced the postprandial glucose spike from baseline to 30 minutes following the meal by 38% (vinegar 46.9±9.2 versus control, 76.0±7.0; p = .024. Figure 3).

Blood glucose response following postprandial walking

Values for blood glucose in the walking condition are shown in table 2. Baseline blood glucose was 103.5±3.6. When compared to the control trial, blood glucose AUC following postprandial

walking was not different at any time point following the meal (table). However, when comparing the absolute change in blood glucose among time points between all conditions, it was revelated that postprandial walking significantly attenuated the glucose spike from baseline to 30 minutes following the meal (walking 44.3±7.5 versus control 76.0±7.0, p = .023).

Exercise Intensity is Correlated with Blood Glucose Reductions

When exploring whether any exercise-related variables (heart rate, blood pressure, % maximum HR achieved) were associated with the postprandial response, it was revealed that preferred treadmill walking speed (reported as average speed throughout the 15-minute bout) was significantly and negatively correlated with blood glucose AUC (R=.590, figure 4).

		Baseline	**30**	**60**	**90**	**120**
	BG	91.8±2.4	167.8±6.1	172.8±11.9	163.8±21.8	142.0±20.1
Control	AUC		64.91.5	150.14.6	234.212.0	310.721.7
	BG change		76.07.0	81.011.8	72.021.7	50.219.8
	BG	110.1±4.1	156.8±8.6	169.2±10.8	173.9±12.5	161.5±12.3
Vinegar	AUC		66.7±2.5	148.3±6.9	234.0±12.3	317.9±17.7
	BGChange		46.8±9.2*	59.1±10.1	63.8±11.6	51.3±10.6
	BG	103.5±3.6	147.7±7.1	173.1±11.0	183.8±16.8	169.9±18.4
Walking	AUC		62.8±2.1	143.0±5.9	232.2±11.9	320.7±19.9
	BGChange		44.3±7.5*	69.7±9.9	80.4±14.9	66.5±16.2

Discussion

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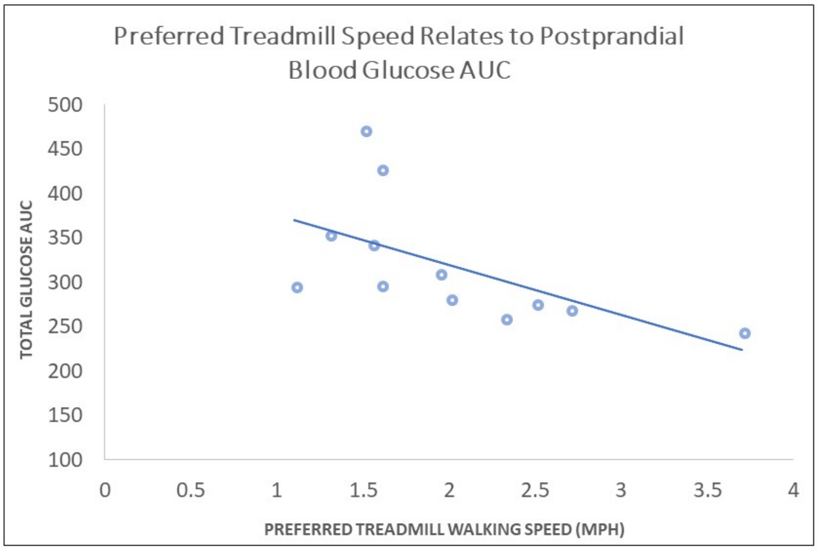

Figure 3: This is a caption

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