JAMDA 15 (2014) 261–266

JAMDA

journal homepage: www.jamda.com

Original Study

Exercise Effects on Postprandial Glycemia, Mood, and Sympathovagal Balance in Type 2 Diabetes

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Keywords:
Type 2 diabetes
physical activity
glycemia
sympathovagal balance
mood state

A B S T R A C T

Objectives: To compare the impact of walking with a recreational activity on postprandial glycemia, heart rate variability, and mood state following the dinner meal.
Design: Participants with type 2 diabetes (T2D) participated in 3 trials on different days in random order after ingestion of a standardized dinner meal (300 ± 6 kcals).
Setting: University clinical testing laboratory.
Participants: Twelve participants (9 female, 3 male; 58.7 ± 2.4 years) with uncomplicated T2D not taking insulin or beta-blocker medications.
Intervention: Thirty minutes of self-paced walking on a treadmill (TM), 30 minutes of table tennis played continuously against the iPong robot (TT), and 30 minutes of rest (CON) undertaken 30 minutes after the start of ingestion of the same dinner meal on three occasions within a week.
Measurements: Blood glucose was measured at 30-minute intervals through 180 minutes starting immediately prior to the dinner meal. Profile of Mood States was completed before and immediately following exercise or rest. Sympathovagal balance (heart rate variability) was measured prior to eating and 30 minutes after trial completion.
Results: Compared with TT or CON, TM resulted in significantly lower postprandial blood glucose ($P < .05$), as well as a greater quantity of physical activity than TT (+72%) or rest (+91%; $P < .01$). Mean heart rate during TM was significantly greater than during TT (+25.9 beats per minute; $P < .01$). However, neither mood state nor HRV were significantly different among trials.
Conclusions: Thirty minutes of self-paced walking following the dinner meal may be more effective at lowering postprandial glycemia in T2D than a similar duration of table tennis played continuously against a robot.

Type 2 diabetes (T2D) management involves optimal regulation of glycemic levels, and exercise is considered a cornerstone treatment and prevention strategy.[1] Physical activity (PA) undertaken regularly has been shown to improve glycemia and reduce both cardiovascular events and overall mortality in T2D.[2] Nevertheless, the majority of individuals with T2D are not regularly active.[3] In fact, almost one-third of US adults with T2D report being completely sedentary, while an additional 38% engage in less than the recommended levels of PA.[4]

The timing of both meals and exercise is of importance to overall glycemic balance in T2D. In fact, postprandial glycemia may be a more significant contributor to glycated hemoglobin A1c (HbA1c) levels than fasting glucose.[5] Exercise, however, can play an important role in mitigating postfeeding glucose excursions. For example, 1 hour of aerobic exercise significantly decreased plasma glucose in men with T2D following a breakfast meal, but had a minimal impact on glycemia when in a fasted state.[6] More recently, Colberg et al[7] demonstrated that 20 minutes of mild-to-moderate intensity walking significantly lowered postprandial glycemia to a greater extent in individuals with T2D when undertaken after the evening meal as compared to the same activity undertaken before eating (or no exercise).

Autonomic nervous system deterioration is a common complication of T2D and prevalence rates have been reported as high as 100%.[8] Damage to the autonomic nervous system manifests as a reduction in heart rate variability (HRV), which is commonly regarded as a reliable

This investigation was funded by the Old Dominion University Office of Research in Norfolk, Virginia.
The authors declare no conflicts of interest.
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http://dx.doi.org/10.1016/j.jamda.2013.11.026

measure of cardio-autonomic modulation. HRV reflects the inter-beat intervals between successive cardiac cycles and has been shown to be an early predictor of macrovascular disease and to correlate with carotid artery atherosclerosis in T2D.[9] Loss of HRV is associated with T2D and prediabetes and is inversely associated with plasma glucose levels.[10] In fact, Ziegler et al[8] determined that the primary factor predicting decreased HRV was presence of diabetes. However, exercise training can significantly improve HRV in individuals with T2D.[11–13]

Walking is the most commonly prescribed and undertaken form of PA in adults with T2D.[3] While walking has many health benefits, individuals with T2D are among the least likely to exercise on a regular basis; therefore, additional measures are necessary to encourage greater PA levels. A more recreational form of exercise (eg, table tennis) may be perceived as being more enjoyable and increase the volume of PA.[14] Affective responses to exercise may be important predictors of adoption and maintenance, and encouraging activity at intensities below the ventilatory threshold may be most beneficial.[14,15]

The activity most frequently studied in T2D has been walking; however, no studies to date have examined the glycemic impact of a recreational activity like table tennis compared with more common ones. Similarly, the differential effects of an acute bout of standard vs recreational PA on HRV or mood state in T2D have not been examined. Thus, the aim of this study was to compare the impact of a traditionally prescribed exercise (walking) with a more recreational activity (table tennis) on postprandial glycemia, HRV, and mood state following the dinner meal.

Methods

Participants

A total of 12 persons (9 female, 3 male) with uncomplicated T2D treated with diet and/or oral antidiabetic medications participated in this investigation. Eleven of the participants were currently taking oral glucose-lowering drugs, and one was controlled with lifestyle only; none were using exogenous insulin. Only persons who were not using beta-blockers were allowed to participate due to that class of medications' potential impact on HRV measures. The study was approved by the university Institutional Review Board, and participants provided signed informed consent prior to their participation.

Protocol

Each subject performed 1 control and 2 research trials in a randomized order on 3 different days within a 1-week period. Each trial was approximately 180 minutes in length (Table 1) and included the following: (1) 30 minutes of self-paced walking on a motorized treadmill, undertaken 30 minutes after the start of a standardized meal (TM); (2) 30 minutes of continuous table tennis (TT), played against an iPong automated table tennis robot (IPONG, Rockville, MD), begun 30 minutes after the start of a standardized meal; and (3) a control trial consisting of 30 minutes of rest following consumption of the same standardized meal (CON).

From the different options presented on the evening of the first trial, each subject selected a single microwavable, frozen meal (Lean Cuisine) of approximately 300 kcals with a carbohydrate/protein/fat ratio representative of a typical American dinner. All participants then consumed the same meal that they had selected for all 3 trials.

All participants remained in a seated, resting state throughout the trial, except when engaging in postprandial activity (TM or TT). Exercise heart rates were calculated as the mean heart rate over the intervention period. Intensity was calculated as a percentage of age-predicted maximal heart rate (220 minus age).

Table 1
Testing Procedures Timetable

Time (min)	5:00–6:00 PM			6:00–7:00 PM		7:00–8:00 PM	
	0	30	60	90	120	150	180
CON	HRV/POMS	Dinner	30 min Rest	POMS	HRV	Rest	Rest
TM	HRV/POMS	Dinner	30 min TM	POMS	HRV	Rest	Rest
TT	HRV/POMS	Dinner	30 min TT	POMS	HRV	Rest	Rest

CON, control trial (rest); HRV, heart rate variability; POMS, Profile of Mood States; TM, treadmill trial; TT, table tennis trial.

Blood Sampling

Baseline blood samples were collected at the beginning of the first trial using standard venipuncture technique. A full lipid panel, including total cholesterol, high-density lipoprotein, low-density lipoprotein, and triglycerides, as well as HbA1c, were analyzed using enzymatic assays (Cholestech Corporation, Hayward, CA and Siemens Healthcare Diagnostics, Tarrytown, NY, respectively). To measure changes in plasma glucose, finger-stick measures of whole blood glucose levels were obtained using a Lifescan OneTouch Ultra (Johnson and Johnson, Milpitas, CA). Measurements were taken at 30-minute intervals, beginning 30 minutes after arrival, for a total of 5 plasma glucose measurements.

Measurement of Heart Rate Variability

HRV measurements were taken at 2 time points during each trial: shortly after arrival to the laboratory and 30 minutes after the end of each exercise or rest intervention. Participants were placed in a supine position, instructed to relax, speak, and move as little as possible, and allowed to breathe spontaneously for a 10-minute period. Heart rate data were recorded using the Polar WearLink system (Polar, Finland), with a sampling rate of 1000 Hz. HRV measurements were calculated from the final 5 minutes of the 10-minute rest period. Data were visually inspected on a computer monitor to minimize presence of artifact.

Time and frequency domain measurements were analyzed using Kubios HRV analysis 2.0 software (University of Kuopio, Kuopio, Finland). Detrending of raw data was performed according to Tarvainen et al,[16] and power frequency analysis was performed using a fast Fourier transform with Welch's periodogram (256s window with 50% overlap). Time domain HRV measurements included mean RR interval (time between heart beats), standard deviation of the normal-to-normal consecutive heart beats (SDNN), and square root of the mean squared differences of successive normal heart beats (RMSSD). The SDNN is a global measure of variability, whereas the RMSSD reflects only the vagal influence. Frequency domain measurements included low (LF) and high frequency (HF) power measurements and total power, presented as absolute power (ms^2) and normalized units (n.u.). Normalized LF power was calculated as LF/(total power-VLF) × 100 and HF power as HF/(total power-VLF) × 100. LF and HF measurements represent the power of the heart period power spectrum between .04–0.15 Hz and 0.15–0.40 Hz, respectively. The interpretation of LF power is somewhat controversial, considered either a marker of only sympathetic input or a combination of both sympathetic and parasympathetic input. HF power, however, is known as a marker of vagal activity, whereas total power is considered a marker of total variance.[17] The LF/HF ratio, a quantification of sympathovagal balance, was calculated as LF (ms^2)/HF (ms^2).

Accelerometry Measures

As a quantification of PA, total motion was measured using the Bioharness BT (Zephyr Technology, Annapolis, MD). Each subject was