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Multiple short bouts of exercise over 12-h period reduce glucose excursions more than an energy-matched single bout of exercise

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ABSTRACT

Objective. Long, uninterrupted bouts of sedentary behavior are thought to negatively influence postprandial glucose and insulin concentrations. We examined the effects of a 1-h bout of morning exercise versus intermittent walking bouts of short duration on glucose excursions and insulin secretion over 12-h.

Materials/Methods. Eleven young, obese individuals (18–35 years, BMI > 30 kg/m^2) with impaired glucose tolerance were studied on three 12-h study days: 1) sedentary behavior (SED); 2) sedentary behavior with 1-h morning exercise (EX) at 60%–65% VO_{2peak}; and 3) sedentary behavior with 12-hourly, 5-min intervals of exercise (INT) at 60%–65% VO_{2peak}. Meals (1046 kJ/meal) were provided every 2-h. Blood samples were collected every 10 min and measured for glucose, insulin, and c-peptide concentrations.

Results. Glucose iAUC (12-h) was attenuated in the INT and SED conditions compared to the EX condition ($P < 0.05$). Glucose concentrations were higher in the EX compared to the SED condition for ~150 min (20% of the study day), and comparison of the EX-INT study days revealed that glucose concentrations were greater for ~ 240 min (~1/3 of the 12-h day). In the SED condition, the 12-h insulin iAUC was ~15% higher ($P < 0.05$) compared to the INT and EX conditions. Insulin production rate was found to increase ~20% with INT exercise vs. the SED and EX condition ($P < 0.05$).

Conclusions. Short, frequent periods of exercise attenuated glucose excursions and insulin concentrations in obese individuals to a greater degree than an equal amount of exercise performed continuously in the morning.

Abbreviations: BMI, body mass index; SED, sedentary behavior; EX, 1-h of morning exercise; INT, 12 hourly, 5 min intervals of exercise; VO2peak, measure of aerobic capacity-peak oxygen consumption; T2D, type 2 diabetes; iAUC, incremental area under the curve; HOMA, Homeostasis Model Assessment (**HOMA**) estimates steady state beta cell function (%B) and insulin sensitivity (%S); QUICKI, Quantitative Insulin Sensitivity Check Index; PRO, protein; CHO, carbohydrate; OGTT, oral glucose tolerance test.

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1. Introduction

Type 2 diabetes is characterized by repeated hyperglycemic periods throughout the day that can eventually result in numerous health complications. Increased physical activity has been shown to reduce these hyperglycemic excursions [1], and is known to reduce the risk of complications of type 2 diabetes. Muscle glucose transport and reduced insulin secretion are seen both acutely and chronically with physical activity in both lean and obese individuals with impaired fasting glucose concentrations [2,3]. The reduced insulin demand is closely associated with the contraction-mediated GLUT-4 translocation in skeletal muscle, resulting in increased glucose uptake during and following exercise. One study demonstrated a 51% reduction in insulin concentrations, which corresponded with a 48% reduction in the secretory rate of insulin following an hour-long bout of low-intensity (40% VO_{2peak}) exercise [4].

Recent investigations also point to the negative aspects of accumulating long periods of sedentary behavior regardless of adherence to physical activity guidelines, and recommend the use of short bouts of activity to break up sedentary periods throughout the day [5,6]. An increased number of breaks in sedentary behavior, corresponding with short active bursts, are associated with reduced 2-h plasma glucose concentrations in middle-aged, healthy individuals following an oral glucose tolerance test [7]. Dunstan and colleagues [8] recently reported lower glucose and insulin responses to a single test drink in obese adults with the addition of light- and moderate-intensity walking during the 5 h testing period. These findings [7,8] raised the question of whether short, frequent bouts of exercise would be more beneficial than 1-h of acute morning exercise in modulating insulin secretion and glucose excursions when multiple meals are consumed over the course of an entire day.

The purpose of this study was to determine the effect of exercise on glucose and insulin concentrations during a 12-h study period in obese individuals with impaired fasting glucose concentrations. It was hypothesized that 1-h of walking in the morning or accumulated through short, frequent bouts throughout the 12-h study period would attenuate glucose excursions and insulin secretion to multiple meals over the course of a day as compared to a sedentary condition. We also hypothesized that the short, frequent walking bouts would improve glucose control more so than the single 1-h exercise bout, and this would be independent of insulin concentrations. Further previous studies have only examined postprandial glucose or insulin responses to a single OGTT, and did not examine the hormone responses over the course of an entire day when multiple meals are consumed. Since the glucose and insulin responses to the first meal are not replicated in subsequent meals (known as the second-meal phenomenon) [9–11], and there is evidence that glucose tolerance [12,13] exhibits diurnal patterns, it is possible that postprandial glucose and insulin responses may also demonstrate altered responses with subsequent meals, and that this response may be altered through various patterns of physical activity. This study allowed us to examine the hormonal response across a 12 h day, and with frequent blood sampling identify how responses differ with different exercise patterns.

2. Methodology

2.1. Study subjects

All subjects completed a written informed consent document prior to participation in this study which was approved by the Syracuse University Institutional Review Board. Details of this study have been published previously [14]. Subjects were young (18–35 years old), obese (BMI >30 kg/m^2) individuals with impaired fasting glucose concentrations (>5.55 mmol/L following a 12-h fast). Inclusion criteria were non-hypertensive; total cholesterol <11.1 mmol/L and low-density lipoprotein cholesterol <8.88 mmol/L; with no known cardiovascular disease. Exclusion criteria included weight loss or gain in the prior 3 months, gastrointestinal problems, type 2 diabetes, or orthopedic limitations to normal walking activity. All subjects engaged in light to moderate walking no more than five times per week. Female subjects did not use oral contraceptive agents, and were consistently tested within the first eight days of their menstrual cycle.

2.2. Experimental Design

Each subject reported to the Human Performance Lab on three separate occasions for 12-h of meal testing, beginning at 0700 h. Each subject completed all three conditions, including sedentary (SED), exercise (EX; 60%–65% VO_2 peak; 1-h continuous bout from 0705–0805 h), and intermittent exercise protocols (INT; 12 bouts of 5 min duration, hourly). Subjects were randomly allocated to each intervention [14]. Exercise duration and intensity were matched between the EX and INT study days.

2.3. Protocols

After completing written informed consent, each subject's habitual dietary intake and meal frequency, general health, physical activity, and physical inactivity levels were obtained using questionnaires. Height and weight were obtained. Body composition was assessed using air-displacement plethysmography (BODPOD system, Life Measurement, Concorde, CA). Aerobic capacity was assessed using a continuous treadmill exercise stress test [15] in accordance with American College of Sports Medicine guidelines [16]. The results were used for assigning exercise intensity during the study days.

2.4. Study Day

Subjects reported to the Human Performance Laboratory at 0700, were fasted, abstained from caffeine consumption for the previous 12-h, and from alcohol and structured exercise for at least 24-h. Subjects recorded their dietary intake for 3 days prior to each testing day, and this was used as a guide to consume similar foods and amounts in the days leading up to the two remaining visits. Upon arrival to the lab, subjects