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Cardiovascular benefits of combined interval training and post-exercise nutrition in type 2 diabetes

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ABSTRACT

Aim: The purpose of this study was to examine whether the combination of high-intensity interval training (HIIT) and post-exercise protein supplementation would improve cardiovascular outcomes in individuals with T2D.
Methods: In a double-blind controlled trial, fifty-three adults with T2D (free of CVD and not on exogenous insulin) were randomized to 12 weeks of cardio and resistance-based HIIT (4-10 × 1 min at 90% maximal heart rate) with post-exercise milk, milk-protein, or placebo supplementation, thrice weekly. Before and after, carotid and femoral artery intima media thickness (IMT) and femoral flow profiles were assessed using high-resolution ultrasound. Central and peripheral arterial stiffness were assessed by pulse wave velocity (PWV), and resting and maximal heart rate rates were measured.
Results: After 12 weeks of HIIT femoral IMT (Pre: 0.84 ± 0.21 mm vs. Post: 0.81 ± 0.16 mm, $p = 0.03$), carotid-femoral PWV (Pre: 10.1 ± 3.2 m/s vs. Post: 8.6 ± 1.8 m/s, $p < 0.01$) and resting heart rate (Pre: 70.4 ± 10.8 bpm vs. Post: 67.8 ± 8.6 bpm, $p = 0.01$) were all significantly lower. There were no differences between nutrition groups (all significant main effects of time) for all outcomes.
Conclusion: HIIT reduces femoral IMT, arterial stiffness and resting heart rate in individuals with T2D. The addition of post-exercise milk or protein to HIIT did not have additive effects for improving cardiovascular outcomes in the present study. Taken together, HIIT alone may be an effective means to reduce the burden of cardiovascular complications in T2D.

1. Introduction

Lifestyle interventions, including exercise and nutrition, remain the frontline treatment option to reduce the burden of cardiovascular disease (CVD) in patients with type 2 diabetes (T2D).[1,2] The high cardiovascular mortality in individuals with T2D is largely owing to the development of atherosclerosis, accelerated by arterial stiffening, vascular inflammation and reduced perfusion.[3–5] Importantly, improvements in vascular function may explain a large proportion of the cardioprotective effects of exercise training.[6] Interventions including both exercise and nutrition components appear to show stronger effects on cardiovascular risk factors, particularly those that encourage favorable changes in body composition.[7,8] Separately, high-intensity interval training[9] and milk-protein supplementation[10] have been shown to improve vascular function in individuals with hypertension. In this regard, consuming high-quality protein after high-intensity interval exercise (a time-effective and powerful exercise stimulus) may be a promising combination to improve cardiovascular health in T2D. However this novel combination has not yet been tested.

Exercise exerts directs effects on the vasculature, indeed, elevated blood flow (and associated shear stress and pressure) during and following exercise mediate favorable structural and functional vascular adaptations.[11] A growing body of literature has demonstrated the effectiveness of high-intensity interval training (HIIT) to improve several cardiovascular risk factors in individuals with T2D.[12] We have previously shown that HIIT with or without post-exercise nutrition improves endothelial function, glucose control and cardiorespiratory fitness in individuals with T2D.[13] Interestingly, the combination of high-intensity resistance and aerobic training appears to promote superior cardiometabolic health benefits.[14–16] We have previously shown that a single bout of cardio-based and resistance-based HIIT improves endothelial function in individuals with T2D.[17] Thus, incorporating both resistance and cardio-based HIIT may help to optimize health benefits.[2,18] The addition of high-quality protein supplementation in the post-exercise recovery period has been shown to enhance body composition changes.[19] Whether the combination of resistance and cardio-based HIIT with post-exercise protein supplementation can enhance cardioprotective effects is currently unknown.

Abbreviations: ASR, antegrade shear rate; HIIT, high-intensity interval training; IMT, intima-media thickness; PWV, pulse-wave velocity; RER, respiratory exchange ratio; RSR, retrograde shear rate; T2D, type 2 diabetes.

Authors have no conflicts of interest to declare.

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While our recently published trial[13] demonstrates that HIIT improves glycemic control (A1c by −0.2 ± 0.4%, 24-hour average glucose by 0.5 ± 1.1 mmol/l), blood pressure (mean arterial pressure by −6 ± 7 mm Hg) and cardiorespiratory fitness (by 2.5 ± 1.6 ml/kg/min), the effect of HIIT on arterial stiffness, intima-media thickness, and basal blood flow profiles in T2D remains to be determined. Accordingly, the present study represents secondary analyses of this trial[13] and reports on the impact of 12 weeks of combined cardio and resistance HIIT, with or without post-exercise protein, on measures of vascular structure and function in individuals with T2D. Resting and peak exercise heart rates, as global indices of cardiovascular function, were also assessed before and after each intervention.

2. Methods

2.1. Ethical approval

A double-blind clinical trial conducted between January 2015 and December 2016 randomized adults with T2D to 12 weeks of HIIT with a post-exercise skim-milk, milk-protein concentrate or water placebo beverage after exercise (Trial registration #NCT02251301 clinicaltrials.gov). Participants first provided written informed consent and all study protocols were approved by the University Clinical Research Ethics Board (CREB number H14-01636). The study conformed to the ethical principles and standards set by the Declaration of Helsinki.

2.2. Participants

Fifty-three individuals with physician-diagnosed T2D (>six months) not on exogenous insulin, and without diagnosed cardiovascular disease, neuropathy or nephropathy were recruited after a baseline screening visit that included a 12-lead cardiologist cleared exercise test. Characteristics and medications of participants are described in Table 1. Of the fifty-three participants who were randomized, two participants did not complete the trial; one due to personal reasons and one due to a non-fatal myocardial infarction occurring following an exercise training session in week eight of the intervention. Before each session participants were asked to report on any health events, injuries or illnesses.

Table 1
Baseline characteristics of participants.

	Milk (n = 18)	Macronutrient Control (n = 16)	Placebo (n = 19)
Sex	11 F	12 F	11 F
Age (y)	62 ± 8	56 ± 9	55 ± 9
BMI (kg/m^2)	36 ± 7	35 ± 6	33 ± 6
HbA_{1c} (%)	7.1 ± 0.8	6.9 ± 0.8	6.9 ± 0.8
$VO_{2\ peak}$ (mL/kg/min)	18 ± 3	19 ± 4	22 ± 5
Years of diagnosis	6 ± 6	7 ± 7	5 ± 6
Medications			
Lifestyle only	5	5	3
Metformin	10	11	13
Sulfonylureas	6	1	3
SGLT2 inhibitors	1	2	3
DPP4 inhibitors	1	2	3
GLP1 analogs	1	2	0
Lipid lowering	9	7	7
Ace inhibitor	3	3	4
Angiotensin II	2		1
Beta-blocker		1	2
Hydrochlorothiazide	2	2	1
Nutrition supplementation			
Energy (cal)	187	186	<10
Protein (g)	19	21	<1
Carbohydrate (g)	26	24	1
Fat (g)	<1	<1	1

F = Females, BMI = Body Mass Index, HbA1c = Glycated Hemoglobin, $VO_{2\ peak}$ = Cardiorespiratory fitness.

2.3. Intervention

All participants performed 12 weeks of supervised low-volume HIIT, thrice weekly (Fig. 1). Training sessions involved cardio-based (2 sessions/week; elliptical, treadmill, or cycle based on participant preference) and resistance-based (1 session/week; whole body resistance exercises performed in the same interval pattern) interval exercise. The low-volume HIIT progressed from 4 × 1 min intervals per session in week one to 10 × 1 min intervals through week six to twelve; such that 32–48 min of exercise was performed per week. Previous studies have shown that this low-volume HIIT protocol is effective for improving cardiometabolic health outcomes in T2D.[15,20] The intensity of the 1 min intervals was prescribed as 85–90% of maximal heart rate achieved at the end of each interval for cardio-HIIT and an RPE of ~5–7 ('hard') for resistance-HIIT, with 1 min of low intensity recovery between intervals.[17] For the resistance HIIT, each exercise was performed for one minute with participants aiming to complete as many repetitions as possible to elicit an RPE of 5 'hard' on the rating of perceived exertion scale [category ratio (CR)-10[21]] at the end of each interval, as previously published.[13,22] A three-minute warm-up and cool-down was performed with all sessions. Heart rate and RPE were monitored throughout exercise, and blood pressure was monitored before, during and after each exercise session. Within one hour after each session participants consumed 500 mL of either: (i) low-fat milk (skim milk powder; MedallionMilk Co., Canada); (ii) milk-protein macronutrient-matched control (milk protein concentrate; Vitalus Nutrition Inc., Canada with lactose; NOW® Foods, IL, US) matched protein without the micronutrients found in milk; or (iii) placebo (flavored water). Macronutrient composition is provided in Table 1. The macronutrient protein control was included to ascertain whether there was any additive effect of the added micronutrients and probiotics in milk, compared to milk-protein alone. The participants and lead investigator were blinded to the beverage condition, thus all beverages were masked with 1 tsp of cocoa powder and ¼ tsp of stevia (Stevia In The Raw®, Cumberland Packing Corp). Normal medication and dietary intake were maintained throughout the intervention, assessed with 3-day food and activity records collected before, and at six and twelve weeks of the intervention.

2.4. Experimental measures and analyses

Measurements were obtained before and 48–72 h after the last training session, at the same-time of day within participants (Fig. 1). Participants were tested four hours postprandial, with medication and the preceding meal standardized within participants. Measurements were made with participants having abstained from caffeine and alcohol (for 12 h) and exercise (>48 h) before data collection. All measures (described below) were performed after 20 min of supine rest, in a quiet and dimly lit room. To ensure the chronic, rather than acute, effects of HIIT were investigated fasting blood was obtained 48 h after the last training session, and measures of heart rate, vascular function and peak power were obtained 60–72 h after the intervention.

2.4.1. Resting heart rate and heart rate variability

Heart rate was monitored continuously by three-lead electrocardiography and detection of the R wave made using LabChart software (LabChart Pro v. 7.1, ADInstruments, Dunedin, New Zealand). The resting heart rate was calculated as the average of the last three min of a 5-min block where the participant rested silently and uninterrupted. Time and frequency domain indices of heart rate variability (HRV) were calculated as per the task force guidelines[23] from the last minute of a 2-min controlled breathing block (15 breaths/min), using the HRV macro in LabChart. From the time-domain analysis two measures were recorded: a) the SD of all RR intervals (SDNN), and b) the square root of the average of sum of squares of difference between adjacent filtered RR intervals (rMSSD). The two frequency domain variables, low frequency (LF) and high frequency (HF), were analyzed and calculated