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BRIEF COMMUNICATION

The influence of high-intensity interval training and moderate-intensity continuous training on sedentary time in overweight and obese adults

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Abstract: High-intensity interval training (HIIT) elicits health benefits but it is unclear how HIIT impacts sedentary behaviour. In this preliminary study, we compared the effects of supervised HIIT or moderate-intensity continuous training (MICT) on sedentary time in overweight/obese adults. In both groups, percentage of time spent in sedentary activities was significantly reduced during the supervised exercise intervention (time main effect, $P = 0.03$), suggesting that both HIIT and MICT replaced time spent previously being sedentary.

Key words: sedentary behaviour, accelerometer, exercise, high-intensity interval training, HIIT.

Résumé : L'entraînement par intervalle d'intensité élevée (« HIIT ») engendre des bénéfices sanitaires, mais on ne connait pas nettement son impact sur le comportement sédentaire. Dans cette étude préliminaire, on compare les effets d'un HIIT supervisé ou d'un entraînement d'intensité modérée en continu (« MICT ») sur le temps de sédentarité chez des adultes en surpoids/obèses. On observe dans les deux groupes une diminution significative du pourcentage de temps de sédentarité au cours de l'intervention kinésique supervisée (effet principal du temps, $P = 0{,}03$); d'après ce résultat, HIIT et MICT ont occupé le temps consacré antérieurement à des activités sédentaires. [Traduit par la Rédaction]

Mots-clés : comportement sédentaire, accéléromètre, exercice physique, entraînement par intervalle d'intensité élevée, HIIT.

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Introduction

Physical inactivity is a significant independent risk factor for cardiovascular disease, type 2 diabetes (T2D), breast and colon cancer, and premature death (Lee et al. 2012). Increasing physical activity (PA) through structured exercise and/or lifestyle change is associated with improvements in cardiovascular and metabolic health (Knowler et al. 2002; Shephard and Balady 1999). In addition to physical inactivity, there is accumulating evidence that sedentary behaviour, which consists of any awake behaviour that is characterized by an energy expenditure <1.5 metabolic equivalents, while in a sitting or reclining posture (Sedentary Behaviour Research Network 2012), is an independent risk factor for cardiometabolic disease and all-cause mortality, even when controlling for total activity levels (Biswas et al. 2015). Thus, there is increasing recognition that interventions should aim to both increase PA and decrease sedentary time to maximize health benefits (Katzmarzyk et al. 2009).

Despite the well-established benefits of structured exercise there is some evidence and conjecture that individuals may compensate for engaging in exercise by lowering incidental PA and/or increasing sedentary time on days they perform exercise (Alahmadi et al. 2011; Goran and Poehlman 1992; Meijer et al. 1999), and this compensation may be positively related to exercise intensity (Goran and Poehlman 1992; Kriemler et al. 1999). One type of structured exercise is high-intensity interval training (HIIT), which involves short bursts of vigorous exercise separated by periods of rest or recovery. HIIT has gained popularity in the scientific community and general public as a time-efficient exercise option (Gillen and Gibala 2014). Several studies show health benefits that are equal, or superior, to moderate-intensity continuous training (MICT) in a variety of populations (Weston et al. 2014). HIIT is particularly effective at improving cardiorespiratory fitness (Weston et al. 2014), which is a major mechanism through which exercise is believed to elicit cardioprotective effects (Shephard and Balady 1999). Based on findings that vigorous exercise may lead to compensatory changes in total energy expenditure and/or activity levels (Goran and Poehlman 1992; Kriemler et al. 1999), it is possible that individuals may compensate their behaviour differently following HIIT compared with more traditional MICT. However, the impact of HIIT on sedentary behaviour, in comparison with less intense forms of activity such as traditional MICT, is currently unknown.

The purpose of this study was to examine, in inactive overweight/obese adults at elevated risk of T2D, whether participating in a supervised HIIT intervention influenced accelerometer-measured sedentary behaviour and to compare these responses to individuals participating in supervised MICT. We tested the hypothesis that engaging in purposeful bouts of HIIT would lead to a com-

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pensatory increase in sedentary behaviour when compared with MICT.

Materials and methods

Study design

This study represents a secondary analysis to address a separate research aim from our previously published study examining adherence and fitness responses to HIIT versus MICT, as described in Jung et al. (2015). Inactive individuals at elevated risk of developing T2D were recruited from the local community and were randomly assigned to participate in 10 sessions of HIIT or MICT, which occurred over a 2-week period. Prior to engaging in this structured exercise program all participants wore an accelerometer for 7 days to assess baseline PA and sedentary behaviour. During the second week of the supervised intervention, participants wore an accelerometer for 3 consecutive exercise days to assess PA and sedentary behaviour while they were engaging in structured exercise training. The purpose of the investigation described herein was to compare pre-intervention accelerometer data to during intervention accelerometer data to determine the impact of supervised HIIT and MICT on sedentary time.

Participants

The study protocol was approved by the University Clinical Research Ethics Board. Inclusion criteria were 30–60-year-old males and females with prediabetes (defined as having one of the following: (*i*) physician-diagnosed, (*ii*) HbA1c of 5.7–6.4% (American Diabetes Association 2015) (HbA1c Now; Bayer Inc., Ont., Canada), (*iii*) fasting blood glucose of 5.6–6.9 mmol/L (American Diabetes Association 2015), and/or (*iv*) CANRISK questionnaire score of moderate/high (>21) (Public Health Agency of Canada 2011). Participants were also inactive, assessed via 7-day PA recall interview (Sallis et al. 1985), based on completion of less than two 30-min bouts of moderate-intensity PA per week, and <150 min of moderate-to-vigorous PA assessed during baseline accelerometry. Exclusion criteria included diagnosed diabetes, glucose lowering medications, uncontrolled hypertension (>160/90 mm Hg), history of heart disease, myocardial infarction or stroke, and any contraindications to exercise. Sixty-four individuals attended an initial eligibility visit to the laboratory. Thirty-two participants met the eligibility criteria and were enrolled in the study after providing written informed consent, and were randomly assigned to HIIT (n = 15) or MICT (n = 17).

Intervention

Eligible participants completed a baseline peak oxygen uptake ($\dot{V}O_{2peak}$) test on a cycle ergometer (Lode Excalibur, Netherlands), using a metabolic cart (Parvomedics TrueOne 2400, Salt Lake City, Utah, USA), which was used to prescribe individualized exercise training sessions, as described previously (Jung et al. 2015). The study consisted of a 2-week exercise and counselling intervention, with eligible participants being randomly assigned to perform HIIT or MICT 5 times per week (Monday–Friday), for a total of 10 training days. Three of these days (days 4, 7, and 9) were performed outside of the laboratory to decrease reliance on staff and to encourage the practice of independent exercise. The short duration was chosen to avoid the confounding influence of weight loss/body composition changes and to ensure that compliance to the exercise intervention was high.

HIIT consisted of 1-min intervals that elicited ~90% peak heart rate (HR_{peak}), with 1-min rest intervals at an easy recovery pace with a 3-min warm-up and 2-min cool-down incorporated. The intervention started with 4 intervals and progressed to 10 intervals throughout the 10 days of training. MICT comprised continuous exercise at ~65% HR_{peak}, starting with 20 min and progressing to 50 min per session by day 10. Participants wore heart rate monitors (Polar FT7, Finland) to ensure compliance with prescribed exercise intensity. Participants self-selected exercise modality for each session, which included walking outdoors, elliptical machine, treadmill walking, or stationary cycling. Training volume progression (% estimated external work) was matched between HIIT and MICT. Participants in both groups received 10 min of behaviour change counselling during each in-lab training day (for a total of 70 min). The behavioural counselling was identical in content for both conditions, as described by Jung et al. (2015).

Table 1. Baseline characteristics of study participants included in the pre-intervention–during intervention analysis and comparisons between conditions.

Variable	All, n = 29	HIIT, n = 14	MICT, n = 15
Age, y	51.3 (10.2)	51.3 (10.9)	51.3 (10.0)
Sex, n (%)			
Male	4 (13.8%)	0 (0%)	4 (26.7%)
Female	25 (86.2%)	14 (100%)	11 (73.3%)
Height, cm	165.3 (6.2)	162.9 (4.7)	167.6 (6.7)
Weight, kg	93.5 (21.8)	93.2 (28.7)	93.7 (13.7)
BMI, kg/m²	34.2 (8.3)	35.2 (11.1)	33.3 (4.6)
$\dot{V}O_{2peak}$	20.0 (4.4)	20.0 (5.4)	20.0 (3.1)
Baseline MVPA, min/d	39.0 (19.5)	37.4 (19.7)	40.1 (19.6)
Baseline sedentary time, min/d	636.8 (98.8)	634.9 (103.0)	638.5 (98.3)

Note: All data presented as means (SD), unless indicated as n (%). BMI, body mass index; HIIT, high intensity interval training; MICT, moderate intensity continuous training; MVPA, moderate-to-vigorous physical activity; $\dot{V}O_{2peak}$, peak oxygen uptake.

Measures

Participants wore Actigraph GT1M accelerometers (Actigraph LCC, Fort Walton Beach, Fla., USA) on an elastic band around their waists for 7 days pre-intervention, and 3 days (days 7, 8, and 9) during the exercise intervention. Participants were instructed to wear the accelerometer for all waking hours of the day and to only remove it for sleeping or water-based activities. Although accelerometer data were collected pre-intervention for 1 week, to minimize any potential differences in activity patterns on weekdays and weekends (Cooper et al. 2000; Tudor-Locke et al. 2004), only the weekdays were used for comparison with the supervised exercise intervention because it was prescribed on weekdays only. Data were recorded in 5-s epochs, and analyzed using ActiLife software v6.11.8. Freedson et al. (1998) cut points were used to differentiate sedentary, light, moderate, and vigorous intensities of physical activity. Sedentary bouts were defined as having more than 5 min with 0–99 cpm, with less than 1 min allowed outside of this range. Nonwear time was calculated using Choi et al.'s methodology (Choi et al. 2012). Valid days were defined as having ≥10 h of wear time. Participants with at least 2 valid days at both pre-intervention and during-intervention were included in the analyses. Two valid days was chosen as we only analyzed the 5 weekdays and guidelines indicate that 2 weekdays and 1 weekend day are required for 7-day accelerometer analyses (Trost et al. 2005). Percentage accelerometer wear time in sedentary activity, light activity, and moderate-to-vigorous physical activity (MVPA) as well as minutes per day in sedentary activity, light activity, and MVPA were calculated for each participant from the accelerometer data.

Statistical analyses

To address our primary purpose, we analyzed accelerometer data with a 2 (group: HIIT vs. MICT) × 2 (time: pre-intervention vs. during intervention) repeated-measures ANOVA. $P < 0.05$ was considered statistically significant. All data were assessed for normality prior to analyses using the Shapiro–Wilk test, and non-normal data were log transformed. Effect sizes are reported as Cohen's d. Sample size was not calculated a priori as this was a secondary analysis. All statistics were performed using SPSS version 22 (IBM Corp, Armonk, N.Y., USA).

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Table 2. Percentage of wear time in type of activity, time per day in type of activity, and sedentary analysis for comparing pre-intervention to during intervention accelerometer data.

	HIIT (n = 14)		MICT (n = 15)		P		
Variable	Pre	During	Pre	During	Time	Group	Interaction
Percentage of wear time in type of activity (%)							
Sedentary	75.7 (6.2)	74.8 (4.6)*	76.4 (9.0)	73.5 (5.6)*	0.03	0.88	0.27
Light	19.5 (5.4)	18.3 (4.3)	19.2 (7.2)	19.1 (4.4)	0.42	0.88	0.51
MVPA	4.8 (2.1)	6.9 (1.9)*	4.4 (2.1)	7.4 (2.1)*	0.01	0.93	0.13
Time per day in type of activity (min/d)							
Sedentary	635 (103)	638 (87)	639 (98)	599 (96)	0.22	0.60	0.15
Light	162 (44)	156 (43)	164 (72)	154 (35)	0.43	0.99	0.82
MVPA	41 (20)	60 (20)*	37 (20)	60 (18)*	0.01	0.84	0.52
Sedentary analyses							
Average length per sedentary bout	13.4 (3.0)	13.4 (2.5)	14.3 (4.0)	13.8 (3.0)	0.61	0.52	0.60
Sedentary bouts per day	41.8 (9.2)	42.0 (11.1)	40.6 (7.9)	40.3 (9.8)	0.96	0.66	0.88

Note: All data are presented as means (SD). HIIT, high intensity interval training; MICT, moderate intensity continuous training; MVPA, moderate-to-vigorous physical activity; Pre, before intervention.

*Significant main effect of time, $P < 0.05$.

Results

A total of 29 participants (14 HIIT, 15 MICT) from the original 32 were included for the pre versus during intervention analysis. Three participants did not meet wear-time criteria and were excluded. Total accelerometer wear time was not different between groups or across time (pre-HIIT = 837.5 ± 87.5 min; post-HIIT = 854 ± 74.3 min; pre-MICT = 839.6 ± 89.9 min; post-MICT = 813.5 ± 78.9 min, $P > 0.30$ for time, group, and interaction effects). Descriptive characteristics of participants included in the analyses are presented in Table 1. To examine whether participating in supervised HIIT or MICT differentially impacts sedentary behaviour, we analyzed accelerometer data from weekdays pre-intervention and compared it with accelerometer data collected during the exercise intervention (Table 2). In both HIIT and MICT conditions, there was a significant reduction in the percentage of valid wear time spent in sedentary activities during the intervention (main effect of time, $P = 0.03$, $d = -0.34$), as well as significant increases in the percentage of wear time and minutes per day spent in MVPA (main effect of time, $P = 0.01$, $d = 1.33$; $P = 0.01$, $d = 1.03$; respectively), with no differences between conditions (group × time interaction, all $P \geq 0.13$). There were no differences in minutes per day spent in sedentary or light activities between conditions (all $P \geq 0.15$).

Discussion

In this study involving previously inactive adults at elevated risk of developing T2D, the results rejected the hypothesis that structured, supervised HIIT leads to compensatory increases in sedentary behaviour compared with MICT. In fact, there was a decrease in the percentage of wear time spent in sedentary activity, coupled with an increase in percentage of wear time and minutes per day spent in MVPA during the exercise intervention in both HIIT and MICT, with no differences between conditions. We interpret this finding to indicate that the time spent exercising during the intervention essentially replaced the time previously spent in sedentary activities, regardless of exercise intensity. This exchange of sedentary behaviour for physical activity may result in additive cardiometabolic benefits, as both a reduction in sedentary behaviour and an increase in physical activity are shown to be beneficial for cardiometabolic health (Knowler et al. 2002; Lee et al. 2012).

Although there was no evidence of compensatory sedentary behaviour when previously inactive adults participated in supervised HIIT or MICT, it must be acknowledged that the study design was of short duration, which is a limitation. We also included both men and women, which given the small sample size precluded testing for sex differences. This lack of homogeneity, however, simultaneously increased the external validity of our findings. Future studies involving larger sample sizes allowing for testing of potential moderators (e.g., sex, age), with longer intervention periods, are needed to conclusively determine from our preliminary findings that varying exercise intensities differentially impact sedentary behaviour.

Conclusions

This study tested the effects of HIIT and MICT on sedentary time and PA in a structured laboratory intervention. The findings indicate that a short-term supervised exercise intervention, performed as either HIIT or MICT, has no compensatory impact on sedentary behaviour. Participating in HIIT or MICT led to decreases in time spent in sedentary behaviour during the 2-week intervention period in previously inactive adults. Further studies are warranted to examine whether participating in HIIT or MICT influences sedentary behaviour over the longer term.

Conflict of interest statement

The authors declare they have no competing interest.

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