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Title: 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, $p = .03$) suggesting that both HIIT and MICT replaced time spent previously being sedentary.

Keywords: sedentary behaviour, accelerometer, exercise, high-intensity interval training, HIIT

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Introduction

Physical inactivity is a significant independent risk factor for cardiovascular disease (CVD), 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 characterised 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, 2013). 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 to more

traditional MICT. However, the impact of HIIT on sedentary behaviour, in comparison to 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 compensatory increase in sedentary behaviour when compared to 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 ten sessions of HIIT or MICT, which occurred over a two-week period. Prior to engaging in this structured exercise program all participants wore an accelerometer for seven days to assess baseline PA and sedentary behaviour. During the second week of the supervised intervention, participants wore an accelerometer for three 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: 1. physician-diagnosed, 2. HbA1c of 5.7-6.4% (American Diabetes Association 2015) (HbA1c Now, Bayer Inc., Ontario, Canada), 3. fasting blood glucose of 5.6–6.9 mmol/L (American Diabetes Association 2015), and/or 4. 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-minute bouts of moderate-intensity PA per week and <150 minutes of moderate-to-vigorous PA assessed during baseline accelerometry. Exclusion criteria included diagnosed diabetes, glucose lowering medications, uncontrolled hypertension (>160/90 mmHg), 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 (VO_{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 individualised exercise training sessions, as described previously (Jung et al. 2015). The study consisted of a two-week exercise and counselling intervention, with eligible participants being randomly assigned to perform HIIT or MICT five 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-minute intervals that elicited ~90% peak heart rate (HR_{peak}), with 1-minute rest intervals at an easy recovery pace with a three-minute warm-up and two-minute cool-down incorporated. The intervention started with four intervals and progressed to ten intervals throughout the ten days of training. MICT consisted of continuous exercise at ~65% HR_{peak} starting with 20 minutes and progressing to 50 minutes 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 ten minutes of behaviour change

counselling during each in-lab training day (for a total of 70-minutes). The behavioural counselling was identical in content for both conditions, as described by Jung et al. (2015).

Measures

Participants wore Actigraph GT1M accelerometers (Actigraph, LCC, Fort Walton Beach, FL, USA) on an elastic band around their waists for seven days pre-intervention, and three 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 one 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 to the supervised exercise intervention because it was prescribed on weekdays only. Data were recorded in five-second epochs, and analysed 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 minutes with 0-99 cpm, with less than one minute allowed outside of this range. Non-wear time was calculated using Choi et al.'s methodology (2012). Valid days were defined as having ≥ 10 hours of wear time. Participants with at least two valid days at both pre-intervention and during-intervention were included in the analyses. Two valid days was chosen as we only analysed the five weekdays and guidelines indicate that two weekdays and one weekend day are required for seven-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 analysed accelerometer data with a 2 (group: HIIT vs. MICT) X 2 (time: pre-intervention vs. during intervention) repeated measures ANOVA. $P < .05$ 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, NY, USA).

Results

A total of 29 participants (14 HIIT, 15 MICT) from the original 32 were included for the pre vs. 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 (HIIT Pre = 837.5 +/- 87.5 min; HIIT Post = 854 +/- 74.3 min; MICT Pre = 839.6 +/- 89.9 min ; MICT Post = 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 analysed accelerometer data from weekdays pre-intervention and compared it to 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, $p = .03$, $d = -.34$), as well as significant increases in the percentage of wear time and minutes per day spent in MVPA (main effect of time, $p = .01$, $d = 1.33$; $p = .01$, $d = 1.03$; respectively), with no differences between conditions (group x 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 to 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 of, 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, whether 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 two-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.

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References

- Alahmadi, M.A., Hills, A.P., King, N.A., and Byrne, N.M. 2011. Exercise intensity influences nonexercise activity thermogenesis in overweight and obese adults. *Med. Sci. Sports Exerc.* **43**(4): 624-631. doi:10.1249/MSS.0b013e3181f7a0cb [doi]
- American Diabetes Association. 2015. Classification and diagnosis of diabetes. *Diabetes Care*, **38** Suppl: S8-S16. doi:10.2337/dc15-S005 [doi]
- Biswas, A., Oh, P.I., Faulkner, G.E., Bajaj, R.R., Silver, M.A., Mitchell, M.S., and Alter, D.A. 2015. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: A systematic review and meta-analysis. *Ann. Intern. Med.* **162**(2): 123-132. doi:10.7326/M14-1651 [doi]
- Choi, L., Ward, S.C., Schnelle, J.F., and Buchowski, M.S. 2012. Assessment of wear/nonwear time classification algorithms for triaxial accelerometer. *Med. Sci. Sports Exerc.* **44**(10): 2009-2016. doi:10.1249/MSS.0b013e318258cb36 [doi]
- Cooper, A.R., Page, A., Fox, K.R., and Misson, J. 2000. Physical activity patterns in normal, overweight and obese individuals using minute-by-minute accelerometry. *Eur. J. Clin. Nutr.* **54**(12): 887-894.
- Freedson, P.S., Melanson, E., and Sirard, J. 1998. Calibration of the computer science and applications, inc. accelerometer. *Med. Sci. Sports Exerc.* **30**(5): 777-781.
- Goran, M.I., and Poehlman, E.T. 1992. Endurance training does not enhance total energy expenditure in healthy elderly persons. *Am. J. Physiol.* **263**(5 Pt 1): E950-7.
- Gillen, J.B., and Gibala, M.J. 2013. Is high-intensity interval training a time-efficient exercise strategy to improve health and fitness? *Appl. Physiol. Nutr. Metab.* **39**(3): 409-412.

- Jung, M.E., Bourne, J.E., Beauchamp, M.R., Robinson, E., and Little, J.P. 2015. High-intensity interval training as an efficacious alternative to moderate-intensity continuous training for adults with prediabetes. *J. Diabetes Res.* **2015**: 191595. doi:10.1155/2015/191595 [doi]
- Katzmarzyk, P.T., Church, T.S., Craig, C.L., and Bouchard, C. 2009. Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Med. Sci. Sports Exerc.* **41**(5): 998-1005. doi:10.1249/MSS.0b013e3181930355 [doi]
- Knowler, W.C., Barrett-Connor, E., Fowler, S.E., Hamman, R.F., Lachin, J.M., Walker, E.A., et al. Diabetes Prevention Program Research Group. 2002. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N. Engl. J. Med.* **346**(6): 393-403. doi:10.1056/NEJMoa012512 [doi]
- Kriemler, S., Hebestreit, H., Mikami, S., Bar-Or, T., Ayub, B.V., and Bar-Or, O. 1999. Impact of a single exercise bout on energy expenditure and spontaneous physical activity of obese boys. *Pediatr. Res.* **46**(1): 40-44.
- Lee, I.M., Shiroma, E.J., Lobelo, F., Puska, P., Blair, S.N., Katzmarzyk, P.T., and Lancet Physical Activity Series Working Group. 2012. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet*, **380**(9838): 219-229. doi:10.1016/S0140-6736(12)61031-9 [doi]
- Meijer, E.P., Westerterp, K.R., and Verstappen, F.T. 1999. Effect of exercise training on total daily physical activity in elderly humans. *Eur. J. Appl. Physiol. Occup. Physiol.* **80**(1): 16-21. doi:10.1007/s004210050552 [doi]
- Public Health Agency of Canada. CANRISK: The canadian diabetes risk questionnaire user guide for pharmacists [online]. Available from: <http://www.healthycanadians.gc.ca/health-sante/disease-maladie/diabetes-diabete/canrisk/index-eng.php>. [Accessed 20 June 2016]

- Sallis, J.F., Haskell, W.L., Wood, P.D., Fortmann, S.P., Rogers, T., Blair, S.N., and Paffenbarger, R.S., Jr. 1985. Physical activity assessment methodology in the five-city project. *Am. J. Epidemiol.* **121**(1): 91-106.
- Sedentary Behaviour Research Network. 2012. Letter to the editor: Standardized use of the terms "sedentary" and "sedentary behaviours". *Appl. Physiol. Nutr. Metab.* **37**(3): 540-542.
doi:10.1139/h2012-024 [doi]
- Shephard, R.J., and Balady, G.J. 1999. Exercise as cardiovascular therapy. *Circulation*, **99**(7): 963-972.
- Trost, S.G., McIver, K.L., Pate, R.R. 2004 Conducting accelerometer-based activity assessments in field-based research. *Med. Sci. Sports Exerc.* **37**(11 Suppl):S531-43.
- Tudor-Locke, C., Ham, S.A., Macera, C.A., Ainsworth, B.E., Kirtland, K.A., Reis, J.P., and Kimsey, C.D., Jr. 2004. Descriptive epidemiology of pedometer-determined physical activity. *Med. Sci. Sports Exerc.* **36**(9): 1567-1573. doi:00005768-200409000-00016 [pii]
- Weston, K.S., Wisloff, U., and Coombes, J.S. 2014. High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: A systematic review and meta-analysis. *Br. J. Sports Med.* **48**(16): 1227-1234. doi:10.1136/bjsports-2013-092576 [doi]

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 (years)	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/m ²)	34.2 (8.3)	35.2 (11.1)	33.3 (4.6)
VO _{2peak}	20.0 (4.4)	20.0 (5.4)	20.0 (3.1)
Baseline MVPA (min/day)	39.0 (19.5)	37.4 (19.7)	40.1 (19.6)
Baseline sedentary time (min/day)	636.8 (98.8)	634.9 (103.0)	638.5 (98.3)

All data presented as mean (SD), unless indicated as n (%). HIIT, high intensity interval training; MICT, moderate intensity continuous training; MVPA, moderate-to-vigorous physical activity.

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.

Variable	HIIT (n=14)		MICT (n=15)		P-value		
	Pre	During	Pre	During	Time	Group	Interaction
<u>Percentage of wear time in type of activity (%)</u>							
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
<u>Time per day in type of activity (min/day)</u>							
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
<u>Sedentary analyses</u>							
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

All data are presented as mean (SD). HIIT, high intensity interval training; MICT, moderate intensity continuous training; MVPA, moderate-to-vigorous physical activity.

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