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Brief Report

Acute glycemic responses along 10-week high-intensity training protocols in type 1 diabetes patients

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ABSTRACT

Glycemic fluctuations were compared throughout 10-week high-intensity training protocols in T1DM patients. Differences were compared using the rate of change in glycaemia during exercise (RoC_E). HIIT sessions led to lower RoC_E in most weeks than other training protocols. The occurrence of level 1 hypoglycemia along sessions were similar among interventions.

1. Introduction

Inadequate knowledge around hypoglycemia management during exercise contributes to the low physical activity levels observed in type 1 diabetes (T1DM) patients [1–3]. T1DM individuals may present inadequate glucose production, abnormal counterregulatory hormone and attenuated lipolysis rate in response to constant-load workout such as the continuous moderate-intensity aerobic exercise, despite its regular practice provides several health benefits [4]. So, anaerobic and mixed (anaerobic+aerobic) exercises have been recommended for reducing the risk of hypoglycemia [1,2,5]. Most studies with strength or high-intensity interval exercises have been performed in strictly controlled conditions such as clamp techniques or insulin deprivation [6–9], however, more real-life studies are needed to mimic reality in T1DM. The long-term effect of glycemic fluctuations during strength and/or high-intensity sessions in T1DM have been much less studied than in type 2 diabetes [10–13]. Indeed, studying the impact of different exercise types on glycaemia is crucial in order to ensure the safety and quality of the interventions. Moreover, chronic glycemic benefits are considered as the sum of the effects of each successive exercise session [11,13]. Thus, this study aimed to compare the glycemic fluctuations throughout 10-week high-intensity protocols in T1DM patients.

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2. Material and methods

2.1. Participants

This is a secondary analysis of a randomized clinical trial (NCT02939768) approved by the local Ethics Committee [14]. The following inclusion criteria were adopted: T1DM for ≥4 years, HbA1c < 10%, no exercise programs in the previous three months [14] and, aged 18–40 years.

2.2. Training protocols

Interventions were conducted 3x/week. As previously described for these volunteers [14], HIIT (n = 9) sessions were characterized by 10x60-s cycling intervals at ~90% maximal heart rate (HR_{max}), interspersed with 60-s active recovery [15]. Strength training (ST) (n = 9) sessions comprised 3x8 rep on bench press, leg press, lat pulldown, leg extension, shoulder press and leg curl [6], besides 3x15 rep of abdominal crunches. It was respected 1-min rest between series. ST +HIIT (n = 10) encompassed ST and HIIT protocols. In order to closely keep track training protocols, exercise sessions were performed individually or in pairs.

2.3. Acute changes in capillary glucose levels

Capillary glucose levels (CGL) were measured with a hand-held glucose meter (Optium Xceed, Abbott Laboratories, USA). Maltodextrin flavored diluted in water, gels containing maltodextrin, fructose and waxy maize, cookies and fruits were utilized to reverse CGL ≤5.5 mmol/L [16], according to the glycaemia and volunteers' preference. Hyperglycemia (13.9–16.7 mmol/L) was not set as a reason for postponing exercise if patient felt well and ketones were negative [16]. In order to reflect a real-world setting, researchers did not advise about decreasing fast-acting insulin dosage or increasing carbohydrate consumption prior to each exercise session. Volunteers were only asked to arrive with glycaemia 5.7–13.9 mmol/L [17].

Since HIIT (25 min) and ST (~40 min) included three CGL measurements per session (before, at mid, and right after) and ST+HIIT (65–70 min) comprised five measurements per session (before and at mid ST, before, at mid and right after HIIT), comparisons were performed using the rate of change in glycaemia during exercise (RoC_E), calculated through post minus pre-exercise CGL divided by the duration of the exercise (h) [7,18]. Adherence to exercise sessions was 96.7 ± 3.8% for HIIT, 92.6 ± 8.3% for ST, and 94.7 ± 4.3% for ST+HIIT. The amount of training sessions with at least one glucose reading ≤3.9 mmol/L (level 1 hypoglycemia) [3] was also registered.

2.4. Statistical analysis

Chi-square test was used to compare the frequency of CGL ≤3.9 mmol/L. Data from each exercise session were pooled into weekly average values over each of the 10 weeks for statistical comparisons. RoC_E values were compared using a two-way ANOVA and subsequent Bonferroni analysis when necessary. Statistical Package for Social Sciences (v 19.0 Inc, USA) was utilized and $P < 0.05$ considered significant.

3. Results

There were no differences regarding volunteers' body weight ($P = 0.44$), cardiorespiratory fitness ($P = 0.915$), sex ($P = 1$), age ($P = 0.538$), time of day to exercise ($P = 0.466$), diabetes duration ($P = 0.964$) or basal insulin type among groups ($P = 0.716$) (data not shown). As previously reported [14], the 10-week interventions decreased similarly HbA1 levels (HIIT: 7.5 ± 1.5 *vs.* 7.2 ± 1.1, ST: 8.1 ± 1.3 *vs.* 8 ± 0.8, ST+HIIT: 7.5 ± 1 *vs.* 7.2 ± 0.7%; $P = 0.013$), although only participants from ST+HIIT decreased their self-reported daily insulin dosage after intervention (61.6 ± 11.6 *vs.* 53.8 ± 14.3 IU/day, $P = 0.047$). Regarding glycaemia ≤ 3.9 mmol/L, there were 41 registers from 261 sessions in HIIT (15.7%), 32 registers from 250 sessions in ST (12.8%), and 27 registers from 284 session in ST+HIIT (9.5%) group. However, no differences were found among the groups ($P = 0.094$).

Two-way ANOVA revealed a main effect of group ($P < 0.001$), but not regarding time ($P = 0.307$) or interaction ($P = 0.141$) for RoC_E. More specifically, HIIT sessions induced: (i) lower values than ST on weeks 1 ($P < 0.05$), 3 ($P < 0.001$), 5 ($P < 0.01$), 8 ($P < 0.05$) and 9 ($P < 0.05$) and; (ii) lower values than ST+HIIT on weeks 1 ($P < 0.01$), 2 ($P < 0.01$), 8 ($P < 0.05$) and 10 ($P < 0.05$) (Fig. 1).

4. Discussion

HIIT sessions induced lower RoC_E values than ST and ST+HIIT on most weeks. RoC_E converts the impact of exercise types on glucose dynamics into information that supports patient self-management and clinicians, improving safety and quality of life in T1DM patients [18]. Considering all HIIT sessions along 10 weeks, an average RoC_E −6.83 mmol/L/h is found, similar to previous findings involving one session of sprint interval exercise (RoC_E −5.25 mmol/L/h) [18] or a very similar HIIT protocol (RoC_E −7.36 mmol/L/h) in which participants injected their insulin as they usually would do before exercising [19], as in the present study.

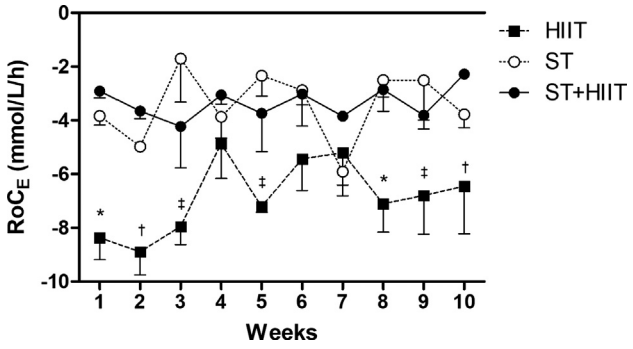

Fig. 1 – Rate of change in glycaemia during exercise (RoC_E) along weeks in HIIT, ST and ST+HIIT groups. Data represented as mean ± standard error. ‡ $P < 0.05$ when compared with ST. † $P < 0.05$ when compared with ST+HIIT. * $P < 0.05$ when compared with ST and ST+HIIT.

The applied HIIT involved 60-s workouts at ~90% HR_{max} (contribution of phosphagen, anaerobic and aerobic glycolytic pathways) interspersed with 60-s recoveries (predominance of aerobic metabolism) [14]. Indeed, aerobic exercises raise skeletal muscle glucose consumption and may acutely increase insulin 'on board' in T1DM individuals at a higher rate than strength-based workouts, due to elevated blood flow to working tissues, vasodilation around subcutaneous depots, releasing of residual insulin from active muscles and partial hepatic glucose inhibition [20,21]. We hypothesize that HIIT sessions induced lower RoC_E values probably due to a less contribution of anaerobic pathways (linked to gluconeogensis and transient inhibition of insulin-mediated glucose uptake) than ST and ST+HIIT sessions [1].

In conclusion, HIIT sessions decreased glycaemia at a higher degree than ST or ST+HIIT sessions along 10 weeks under real-life conditions. T1DM patients who tend to develop severe exercise-associated hypoglycemia and/or present pre-exercise CGL close to 5.5 mmol/L may perform (preferably) ST or HIIT after ST. We did not measure food intake or insulin dosage prior each exercise session, which may have interfered CGL. However, we averaged many CGL (around 3000 tests) determinations at different days and time points for reducing the biological variability regarding exercise sessions, besides for increasing the power and novelty of study concerning T1DM.

Declaration of Competing Interest

The authors declare no conflicts of interest.

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