Management of Prolonged Aerobic Exercise in People With Type 1 Diabetes on Automated Insulin Delivery Systems: A Randomized Controlled Study

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Regular exercise brings extensive benefits to individuals with type 1 diabetes (1). However, even for individuals who use automated insulin delivery (AID) systems, managing glycemia around exercise can be challenging due to individual variability and depending on the type and intensity of exercise (2). While AID allows for adjustment of glucose targets to reduce hypoglycemia, strategies like carbohydrate intake before and during exercise may trigger unintended automated delivery of insulin and, therefore, need efficacy assessment (3). Current guidelines, often based on short-duration studies or observations of highly active individuals, do not fully address the needs of less active individuals with type 1 diabetes who engage in prolonged leisure activities, which pose a higher risk of glycemic instability (2,4).

In a randomized controlled trial, we compared three different strategies for managing prolonged aerobic exercise in individuals with type 1 diabetes who use AID. The study was approved by the institutional ethics committee of Federico II University and registered at ClinicalTrials.gov (NCT05936203). Fifteen participants, aged 51.5 ± 14.0 years (mean ± SD), BMI 25.9 ± 3.7 kg/m^2, HbA_{1c} 6.9 ± 0.5% (52.4 ± 5.4 mmol/mol), diabetes duration 29 ± 13 years, and moderately active on average (32.2 ± 18.0 MET [metabolic equivalent of task] h/week, based on the International Physical Activity Questionnaire), completed the study. The AID systems were MiniMed 780G (n = 8), Tandem t:slim X2 with Control-IQ (n = 6), and an open-source artificial pancreas system with Omnipod (n = 1), with Guardian, Dexcom G6, or Freestyle Libre, respectively, being used for continuous glucose monitoring (CGM) systems.

On three occasions, 1 month apart, participants engaged in a 4-h morning group hike (10-km circular route, 200- to 300-m elevation gain) supervised by health care professionals. According to a randomized crossover design, three strategies were compared: *1*) target, in which a higher temporary glucose target was set from 1 h before until the end of exercise; *2*) snack, in which 15 g of complex carbohydrates (25 g wholegrain crackers) were consumed every 30 min during exercise, unless sensor glucose was >180 mg/dL and rising rapidly; and *3*) target plus snack, in which the two interventions were combined. On the three experimental days, participants consumed the same breakfast without reduction of insulin bolus. Participants could start hiking if glycemia was between 100 and 200 mg/dL. During exercise, 25 g crackers and 15 g sucrose were supplemented if glycemia <120 mg/dL and dropping rapidly. CGM-derived metrics (time in range 70–180 mg/dL [TIR70–180], time above range 180–250 mg/dL [TAR180–250] and TAR>250, and time below range 70–54 mg/dL [TBR70-54] and TBR<54), mean glycemia, and coefficient of variation during exercise were calculated.

Interstitial glucose profiles significantly differed across the three interventions ($P < 0.001$ for time by group interaction), with target showing a notably lower and more stable profile than snack (P = 0.038) or target plus snack ($P < 0.001$) (repeated-measures general linear model with Bonferroni post hoc test) (Fig. 1). TIR70–180 was substantially higher during target (97.7 ± 4.7%) than snack (83.7 ± 12.1%, P = 0.006) or target plus snack (73.2 ± 14.4%, $P < 0.001$) (univariate general linear model) (Fig. 1). TAR180–250 was lower during target (0.9 ± 3.6%) than snack (13.2 ± 11.2%, P = 0.002) or target plus snack (19.2 ± 10.1%, $P < 0.001$). TAR>250, TBR70–54, and TBR<54 did not significantly differ across the interventions (P = 0.127, P = 0.663, and P = 0.632, respectively). Mean glycemia and coefficient of variation were lower during target (113.2 ± 16.9 mg/dL; 16.6 ± 5.9%) than snack (135.7 ± 17.6 mg/dL, P = 0.020; 25.5 ± 8.9%, P = 0.012) or target plus snack (149.1 ± 26.2 mg/dL, $P < 0.001$; 28.4 ± 8.1%, $P < 0.001$). Number of hypoglycemia events (<70 mg/dL) were 3, 4, and 4 during target, snack, and target plus snack, respectively (P = 0.803). Automated insulin delivery by AID was lower during target (1.6 ± 0.8 IU) than snack (4.2 ± 1.4 IU, $P < 0.001$) or target plus snack (4.6 ± 2.2 IU, $P < 0.001$). The glucose and insulin results were unmodified after adjusting

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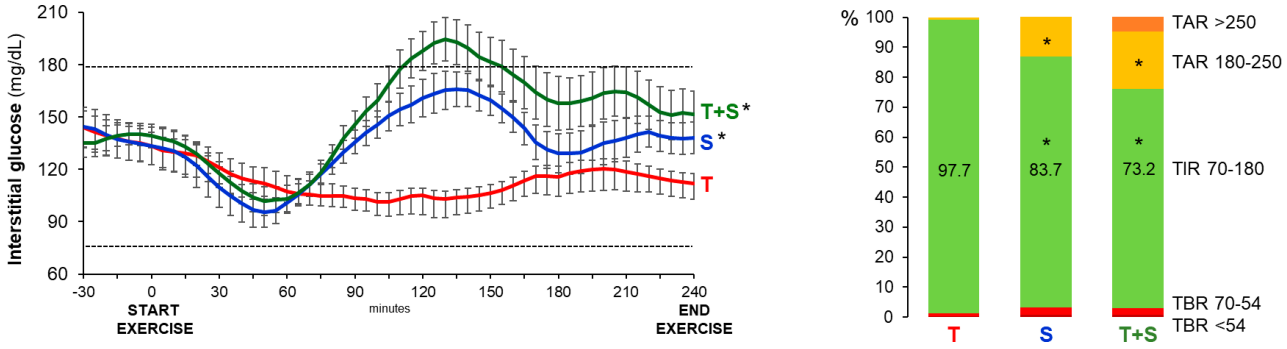

Figure 1—Interstitial glucose profile and CGM metrics evaluated by CGM during the 4 h of exercise with target (T), snack (S), or target plus snack (T + S). *$P < 0.05$ vs. target. Analyses used repeated-measures (profile) and univariate (metrics) general linear models with Bonferroni post hoc test.

for age, sex, BMI, HbA_{1c}, AID system, allocation sequence, glucose trend 30 min before exercise, and carbohydrate consumed for impending hypoglycemia.

Across all interventions, overall glycemia during exercise was stable with low hypoglycemia, confirming the safety and efficacy of AID for prolonged moderate-intensity exercise that, in addition to hiking, corresponds to common activities such as bicycle tour, city walking, strenuous garden work, and house cleaning. Setting a higher glucose target alone (i.e., 1 h before exercise, after breakfast) was the most effective strategy to maintain glycemia during exercise compared with carbohydrate snacks or a combination of a higher level of target and snack. It is worth noting that the optimal glycemic outcomes with target were obtained with considerably lower doses of automatically delivered insulin. The study's strengths include the randomized crossover design and supervised setting of a common real-life physical activity in individuals with type 1 diabetes using AID. This is relevant because existing literature focuses on shorter periods of exercise, leaving a gap in controlled experimental data for longer-duration activities.

In conclusion, this study suggests that low-to-moderately active individuals with type 1 diabetes with tight glycemic control using AID can safely engage in prolonged aerobic activities. In particular, setting a higher glucose target without additional carbohydrate intake could benefit those concerned with body weight management (5), encouraging a shift toward a more active lifestyle.

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