# Morning (Fasting) Vs. Afternoon Resistance Exercise in Individuals with Type 1 Diabetes: A Randomized Cross-Over Study

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RUNNING TITLE: Fasting resistance exercise in type 1 diabetes

KEY WORDS: weight lifting, circadian rhythm, blood glucose, continuous glucose monitoring

Word Count: abstract (250 words), main text 3742 words

Figures & Tables: 2 figures, 2 tables

DISCLOSURES

JEY has received speaker’s fees from Dexcom Canada, and in kind research support from Medtronic Canada, Dexcom Canada, LifeScan Canada, Abbott Nutrition Canada, and Ascensia Diabetes Canada. SRT has no conflict of interest to declare.

ABSTRACT

*Objective* **–** To determine the effect of morning exercise in fasting condition, versus afternoon exercise on blood glucose responses to resistance exercise (RE).

*Research Design and Methods* – Using a randomized crossover design, 12 participants with type 1 diabetes [9 females, aged 31 ± 8.9 years, diabetes duration 19.1 ± 8.3 years, HbA1c = 7.4 ± 0.8% (57.4 ± 8.5 mmol/mol)] performed ~40 minutes of RE (three sets of eight repetitions, seven exercises, at the individual's pre-determined eight repetition maximum) either at 7 am (fasting) or 5 pm. Sessions were performed at least 48 hours apart. Venous blood samples were collected immediately pre-, immediately post-, and 60-minutes post-exercise. Interstitial glucose was monitored overnight post-exercise by continuous glucose monitoring (CGM).

*Results* **–** Data are presented as mean ± SD. Blood glucose rose during fasting morning exercise (9.5 ± 3.0 to 10.4 ± 3.0 mmol/L) while it declined with afternoon exercise (8.2 ± 2.5 to 7.4 ± 2.6 mmol/L; p=0.031 for time by treatment interaction). Sixty minutes post-exercise, blood glucose concentration was significantly higher after fasting morning exercise compared to afternoon exercise (10.9 ± 3.2 vs. 7.9 ± 2.9; p=0.019). CGM data indicated more glucose variability (2.7 ± 1.1 vs. 2.0 ± 0.7 mmol/L; p=0.019) and more frequent hyperglycemia (12 events vs. 5 events; p=0.025) after morning RE compared to afternoon RE. There were two hypoglycemic events after morning RE compared to four after afternoon RE (NS).

*Conclusions* – Morning (fasting) RE is associated with distinctly different blood glucose responses and post-exercise profiles from afternoon RE.

## PRECIS

Morning resistance exercise performed while fasting increases blood glucose while resistance exercise performed later in the day decreases blood glucose in individuals with type 1 diabetes.

# INTRODUCTION

Resistance exercise provides the human body with a multitude of benefits including maintaining and/or building muscle mass, strength and metabolism (1), increasing resting energy expenditure (2), improving bone mineral density (3), decreasing the risk of type 2 diabetes by increasing insulin sensitivity (4) and improving cardiovascular health (5,6). In individuals with type 1 diabetes, resistance exercise is also associated with smaller changes in blood glucose during activity than aerobic exercise (7), seems to provide more stable blood glucose levels in the hour post-exercise (7), and may offer a protective effect on blood glucose levels when performed immediately prior to aerobic exercise (8).

While they are few and have small sample sizes, some studies examining the acute effects of resistance exercise on blood glucose have had divergent outcomes. Studies of afternoon resistance exercise by Yardley et al. [consisting of three sets of eight repetitions, at the participants' eight repetition maximum (8RM) of seven different exercises] have been associated with average declines in blood glucose of approximately 1.5 mmol/L (7,8) during exercise and an increased risk of nocturnal hypoglycemia (7). Conversely, studies performed by Turner et al., (9) where participants performed a very similar protocol while in a fasting state in the morning, have resulted in either a mean increase in blood glucose levels of 1.5 mmol/L when two sets of 10 repetitions were performed at 60% of the participants' 1RM (a similar intensity to the Yardley et al. studies) (7,8), or no significant change in blood glucose in either direction when three sets of eight repetitions (also at 60% of the 1 RM) were performed (10). As CGM data were not reported for the morning exercise studies, the risk of post-exercise nocturnal hypoglycemia remains unquantified. Whether the divergent responses are due to differences in participant characteristics, or differences in metabolism in the fasted versus fed state is uncertain.

The present study sought to determine whether or not individuals with type 1 diabetes would have different blood glucose responses to a standardized resistance exercise protocol if exercise was performed in the morning while fasting, or in the afternoon. By using a randomized, cross-over design, participant characteristics are removed as a potential confounder. We hypothesized that fasting exercise would be associated with smaller declines (if any) in blood glucose and a lower risk of post-exercise nocturnal hypoglycemia, than when the same resistance exercise protocol is performed in the late afternoon.

## METHODS

The study was approved with the University of Alberta research ethics board and all participants provided informed consent prior to their participation. Twelve non-smoking, non-obese, complication-free, recreationally active individuals with type 1 diabetes were recruited for the study. The study was carried out in accordance with the principles of the Declaration of Helsinki. Participants were required to be between the ages of 18 and 50, to have been diagnosed with type 1 diabetes for at least one year, to have HbA1c levels below 9.9% (84.7 mmol/mol) and to be habitually active, performing both aerobic and resistance exercise. Potential participants were excluded if they had any condition that would render exercise or physical activity contraindicated (e.g. severe hypoglycemia unawareness, autonomic neuropathy, severe proliferative, retinopathy, joint or limb injuries preventing weight-bearing activity/requiring limb immobilization, etc.), if they were performing shift work, or if they were using any medication (other than insulin) that would impact blood glucose levels. There were no exclusions based on insulin regimen or mode of insulin administration.

*Experimental Design*

Research took place in the Physical Activity and Diabetes Laboratory at the Alberta Diabetes Institute. Participants attended a baseline session where written consent was obtained. During the same session the participants' aerobic fitness was estimated using a modified Austrand-Rhyming Submaximal Cycle Ergometer test (11) on an electronically braked cycle ergometer (Monark Ergomedic 894E; Monark, Varberg, Sweden). A test of muscular strength (8RM) was performed in order to determine the maximum weight that participants could lift eight times with good form for the exercises included in the protocol (chest press, leg press, seated row, leg curl, shoulder press and lat pulldown) all of which were performed on weight-lifting machines to ensure consistent form and participant safety. At the end of the baseline sessions the order of exercise sessions was determined by flipping a fair coin before sessions were scheduled.

The study involved a randomized, open-label, cross-over design with two rounds of testing. One testing session took place at 7 am (as per Turner et al.) (10) with participants in the fasting state, and the other took place at 5 pm (as per Yardley et al.) (7), with at least 48 hours between sessions. At least 24 hours prior to the first session participants came to the lab for the insertion of an Enlite™ sensor with an iPro2® (Medtronic, Northridge, CA) blinded continuous glucose monitoring (CGM) system. Participants were provided with a log and asked to record their food intake and insulin dosage over the six days of CGM wear. While wearing the CGM, participants were asked to match their day to day food intake and insulin dosage (including adjustments for exercise) as closely as possible, while avoiding alcohol and strenuous exercise. The study also provided participants with a pedometer (Yamax DigiWalker 200, Yamax Corporation, Tokyo, Japan) to determine their background physical activity (daily step count), and a OneTouch® Ultra®2 glucose meter and test strips (LifeScan Milpitas, CA, USA) to record four daily capillary glucose tests for the purpose of calibrating the CGM. For female participants, both tests occurred in the same phase of the menstrual cycle.

*Experimental Sessions*

Participants arrived at the laboratory at 6 am in a fasting state for the morning exercise session (as per Turner et al.) (10) and at 4 pm for the afternoon session. Upon arriving at the lab for the afternoon session participants consumed a standardized snack (Glucerna Snack Bar, Abbott Laboratories, Abbott Park, IL), as per Yardley et al. (7). Exercise started at 7 am and 5 pm respectively for the morning and afternoon exercise conditions. As in previous studies, resistance exercise was performed with a 2-second count for both the eccentric and concentric phases of the lift. Participants performed three sets of eight repetitions (8RM) of all exercises with 90 seconds rest in between. The exercises ensured that all major muscles groups were targeted, and included leg press, bench press, leg curl, lat pulldown, abdominal crunches, shoulder press and seated row. Exercise lasted approximately 43 minutes, and was followed by a 60-minute period of seated recovery in the lab. In line with exercise guidelines of both Diabetes Canada (12) and the American Diabetes Association (13), participants using insulin pumps were asked to decrease their basal rate by 50% starting one hour before exercise and maintained until the end of exercise. Individuals using multiple daily injections were asked to reduce their long-acting insulin dose by 10% the day prior to exercise. The importance of repeating the same adjustments for both sessions was emphasized.

Prior to exercise, intravenous catheters were inserted in the antecubital vein for the purpose of blood sampling. Blood samples were drawn into 10-mL EDTA vacutainer tubes immediately before exercise, at the end of exercise and 60 minutes post-exercise. Tubes were immediately centrifuged at 1500 x g for 10 minutes at 4ºC to extract plasma. Samples were then stored in a -80ºC freezer until batch analysis could be completed. Plasma glucose values were determined using the hexokinase timed end point method on a Siemens ADVIA 1800 system with Siemens ADVIA chemistry glucose hexokinase_3 (GLUH-c) concentrated reagent.

Participants were asked to continue wearing their CGM for a full 24 hours after the lab testing sessions. CGM units were collected from participants and uploaded to the Medtronic Carelink web-based platform. Data were exported as Excel spreadsheets. EasyGV© Version 9.0.R2 (www.easygv.co.uk) was used to assess interstitial glucose means, and glucose variability expressed as mean absolute glucose change (MAG). Percentage of time spent in hypoglycemia (≤3.9 mmol/L) and hyperglycemia (≥10 mmol/L) were calculated (7) as well as the frequency of hypoglycemic and hyperglycemic excursions.

*Statistical Analysis*

Plasma glucose data were analysed using a repeated measures ANOVA in order to examine the whether there were significant changes in blood glucose, and if these differed depending on the timing of the exercise. CGM data that were normally distributed (mean, standard deviation, MAG) were compared using paired t-tests and are expressed as mean ± SD. Non-normally distributed data (percent of time in hypo/hyperglycemia, frequency of hypoglycemic events were assessed using Wilcoxon Signed Rank tests, and are expressed as median ± IQR. Statistical analyses were performed using SPSS 25.0 software (IBM, Amonk, New York, USA). We chose to examine the 6-hour window immediately post-exercise, as this is when the impact of exercise on blood glucose in individuals with type 1 diabetes is most clearly seen (7,14). We also chose to assess the overnight period (between 11 pm and 6 am) as nocturnal hypoglycemia is one of the greatest post-exercise risks for individuals with type 1 diabetes.

RESULTS

Participant characteristics can be found in Table 1. Participants were habitually physically active and were not taking any medications (other than insulin) that would alter glucose metabolism. Eight of the 12 participants were using insulin pumps, while four were using multiple daily insulin injections. Of the participants using multiple daily injections, three were using glargine as basal insulin (administering their dose at bedtime), and one was using levemir (late morning administration). These basal insulins were combined with either insulin lispro (n=2) or insulin aspart (n=2). Participant food logs indicate that all participants had consumed their evening meal at least 8 hours prior to the morning exercise session. Similarly, on afternoon exercise days, lunch was consumed at least three (n=4) or four (n=8) hours before the exercise session.

Eleven of the 12 participants had identical insulin adjustments prior to both morning and afternoon exercise, and one participant decreased the basal rate on their insulin pump by 50% for the afternoon exercise, but made no adjustment for morning exercise. Background physical activity, measured as pedometer step counts, was not significantly different between conditions on either the testing day, or the day after testing. None of the participants experienced dangerous declines in blood glucose, and it was not necessary to provide glucose supplements to participants at any point during the testing.

There was no difference in blood glucose levels at the start of exercise between the morning ($9.5 \pm 3.0$ mmol/l) and afternoon ($8.2 \pm 2.5$ mmol/l; $p = 0.289$) conditions. Changes in blood glucose were not significant during either the morning or the afternoon exercise sessions (effect of time $p = 0.405$). Blood glucose levels were higher throughout exercise and recovery after morning exercise (effect of treatment p = 0.041). A significant time by treatment interaction (p = 0.031) indicated that blood glucose levels were following different trajectories throughout the testing session, with morning exercise producing a consistent increase (from 9.5 ± 3.0 to 10.4 ± 3.0 mmol/L) in blood glucose (Figure 1), while afternoon exercise caused an initial decline in blood glucose (from 8.2 ± 2.5 to 7.4 ± 2.6 mmol/L) during exercise, with a return almost to baseline during the 60-minute recovery. At the end of 60 minutes of recovery, blood glucose levels were significantly higher after morning exercise (10.9 ± 3.2 vs. 7.9 ± 2.9; p=0.019).

*Continuous Glucose Monitoring*

Complete CGM data sets were available from 10 participants. Mean CGM glucose in the 6 hours post-exercise (Figure 2a) was not significantly different between the morning and afternoon exercise sessions (am: 11.5 ± 3.3, pm: 9.0 ± 3.9 mmol/L; p = 0.473). Mean absolute glucose change (MAG) for 6 hours post-exercise was greater (p = 0.019) after morning exercise (2.7 ± 1.1 mmol/L) compared to afternoon exercise (2.0 ± 0.7) indicating more glycemic variability after the fasting exercise session. Where the nocturnal period (midnight until 6 am) was concerned (Figure 2b), there were no significant differences between morning and afternoon exercise with respect to mean CGM glucose (p = 0.635) or glucose variability as expressed by MAG (p = 0.280).

There were no differences between morning and afternoon resistance exercise with respect to the frequency of hypoglycemia in the 6 hours post-exercise or in the nocturnal period after exercise (Table 2). Hyperglycemia was more common following morning exercise (p = 0.011). The percentage of time spent in hypoglycemia, according to CGM, was similar (p = 0.109) in both groups in the 6 hours immediately post-exercise, as well as during the nocturnal (p = 0.345) post-exercise period (Table 2). Time spent in hyperglycemia, on the other hand, was higher in the first six hours after morning exercise [62.0% (36.0-82.6%)] compared to the first six hours post-afternoon exercise [11.6% (0-36.0%); p = 0.037]. The difference between the amount of time spent in range following morning exercise compared to afternoon exercise approached statistical significance (p = 0.064) with afternoon exercise showing more favourable blood glucose profiles (less hyperglycemia) in the six hours following exercise. There were no differences between morning and afternoon exercise with respect to the percent of time spent in range during the overnight period.

## DISCUSSION

As hypothesized, fasting resistance exercise in the morning and afternoon resistance exercise have distinctly different effects on blood glucose levels with the former favouring an increase in blood glucose, and the latter a decrease. Due to a large amount of variability in the responses, the overall changes in blood glucose for both of these sessions were not statistically significant themselves. The time-by-treatment interaction, however, indicates that blood glucose trajectories over time were in fact significantly different between the morning (an increasing trend) and afternoon (a decreasing trend) exercise sessions.

These outcomes are consistent with what has been observed in previous exercise studies in type 1 diabetes. While they are not numerous, studies where resistance exercise was performed in the afternoon resulted in a decline in blood glucose levels (7,8), while studies where exercise was performed while fasting in the morning (after evening administration of glargine) either showed no change (10) or a mean increase (9) in blood glucose in response to resistance exercise. Aerobic exercise studies examining the impact of time of day have found similar results with repeated measures designs. A study by Ruegemer et al., (15) found distinctly different patterns of blood glucose response to 30 minutes of stationary cycling at 60% of the participant's aerobic capacity performed while fasting in the morning, or fed in the late afternoon. Morning exercise produced an increase in blood glucose from 6.7 ± 0.4 mmol/L to 9.1 ± 0.4 mmol/L ($p<0.01$), while a small non-significant decline was found in the afternoon. More importantly, the inclusion of a non-exercise control day showed that blood glucose levels in these participants were otherwise stable at this time of day. Meals, snacks and insulin injections (including basal ultralente in the evening) were also kept consistent across sessions by the research team. Recently, a study observing both moderate aerobic exercise (65% $VO_{2peak}$ for 30 minutes) and high intensity interval exercise (6 X 1 minute at 100% $VO_{2peak}$, with 1 minute of recovery in between, for a total of 17 minutes of exercise), performed while fasting did not find any declines in blood glucose for either type of exercise (16). These results are in contrast to several studies of aerobic (7,14,17-22) and high intensity interval (17-20,22) exercise in fed participants where declines in blood glucose were observed, in spite of starting blood glucose levels being similar to those seen in the fasted exercise studies.

A strong potential cause of the divergent blood glucose trends in the present study would be a difference in circulating insulin. While similar adjustments for exercise were made by all but one participant, if exercise is taking place 8 to 10 hours after the last meal, it is likely that only basal insulin will be present. Conversely, when afternoon exercise is performed, it is generally taking place within 4 to 5 hours of a meal, at which point there may still be some of the previous meal's bolus remaining in circulation. Unfortunately we were unable to measure insulin levels as part of this study, as this would have provided more concrete evidence as to insulin's involvement. It should be noted, however, that when performing afternoon exercise the participants were provided with a standardized pre-exercise snack (Glucerna snack bar – 19g of carbohydrate) one hour before exercise similar to previous studies by Yardley et al. (7,8), and consistent with current guidelines for exercise in individuals with type 1 diabetes (13,23). Eight out of twelve participants did not bolus for this snack, while the final four opted for a reduced (50%) bolus in order to prevent hyperglycemia. This snack should have, to some extent, attenuated the impact of potentially higher insulin levels during the afternoon exercise session.

Individuals with type 1 diabetes often experience a period of high blood glucose in the early morning, which is generally referred to as the “dawn phenomenon” (24). This early morning rise in blood glucose has often been attributed to an increase in growth hormone (25-27). While starting blood glucose levels in the present study were not significantly higher during the fasting session compared to the afternoon session, the presence of a higher level of growth hormone could play a role in the divergent blood glucose outcomes observed in this study. Previous studies of exercise in type 1 diabetes have suggested that higher growth hormone levels may have a glucose sparing (8,28) effect by stimulating lipolysis (29). As we did not have the means to measure growth hormone for the present study, this possibility remains speculative.

In addition to higher levels of growth hormone, there is also evidence to suggest that insulin sensitivity is lower in the morning compared to the afternoon in individuals with type 1 diabetes (30,31) and that there is less suppression of endogenous glucose production (30). A recent meta-analysis of metabolic responses to fed and fasted exercise also found that fasting exercise is associated with a higher level of circulating free fatty acids post-exercise than fed exercise (32). As elevated free fatty acids could lead to an even greater degree of insulin resistance (33), this may explain not only the change in glucose during exercise, but also the resulting post-exercise hyperglycemia.

Besides the fasting versus non-fasting state being a potential driver for the divergent blood glucose outcomes, it is also possible that, in previous resistance exercise studies, small samples sizes (varying from n=8 (9,10) to n=12 (7,8)), and differences in the sample composition had an effect on blood glucose outcomes. Participants in the studies of afternoon exercise by Yardley et al. had lower mean HbA1c [7.1±1.1% (54±10 mmol/mol) (7,8) versus 8.7±1.1% (72±10 mmol/mol) (9,10)] and also started exercise with blood glucose levels on average ~2.0 mmol/L lower than those who took part in the studies of fasting resistance exercise. The participants in all studies, however, consisted mostly of males (no more than 2 females in any one studies), who were physically active, with mean ages for the samples falling between 32 ± 15.3 (8) and 38 ± 6yrs (10). While the sample in the present study was similar to previous studies in terms of sample size (n=12), age (31.3 ± 8.9 years), and HbA1c [7.4 ± 0.8 (57.4±8.5 mmol/mol)] it had a greater proportion of female participants (9 out of 12). In spite of this major difference, trajectories of blood glucose change were similar to previous studies with respect to fasting versus fed exercise, and the randomized repeated measures design removes the potential confounding effect of physiological factors such as age, sex, and fitness level.

Strengths of this study include its randomized repeated measures design, the use of blinded CGM to assess post-exercise blood glucose levels, and the strict timing/structure of the exercise sessions. The interpretation of the data are limited, however, due to the lack of hormone measurements necessary to determine the cause of the divergent blood glucose outcomes during morning and afternoon resistance exercise. Thus it cannot be determined if the respective blood glucose trajectories are due to a) natural increases in blood glucose in the morning due to the "dawn phenomenon", b) differences in circulating insulin due to administration in the hours before exercise, or c) potential differences in insulin sensitivity throughout the day. It should be noted, however, that both scenarios tested in this study are ones that individuals with type 1 diabetes who exercise are likely to encounter, thus making the study design ecologically valid. An additional limitation is that the sample is small (n=12), consisting of relatively young healthy, habitually active individuals with type 1 diabetes, and may therefore not be applicable to those who are sedentary or of advancing age. It is also possible that those using multiple daily injections could have slightly different responses than those using insulin pumps, however this could not be determined from such a small sample. Further studies are required to elucidate potential differences in these insulin delivery methods, as well as the potential impact of the timing of basal insulin injections in those using multiple daily injections.

The results of this study help expand the existing evidence related to type 1 diabetes and exercise, and offer information on two different options related to exercise timing. The magnitude of counter-regulatory (especially catecholamine) responses to resistance exercise may vary greatly by age and level of fitness (young fit individuals are likely to have the most pronounced response) (34). As such some individuals will struggle with hyperglycemia during and after resistance exercise. These individuals may want to consider performing resistance exercise later in the day where the activity seems to result in less hyperglycemia. Conversely, for those who struggle with hypoglycemia during exercise, resistance exercise performed in the morning may be a better option. It should be noted, however, that the present study only examined one intensity of resistance exercise (3 sets of 8 repetitions at the participants' 8 RM), and results may vary with different durations and intensities of resistance exercise. Further studies to examine the impact of time of fasting on blood glucose responses to a variety of resistance exercise programs in individuals with type 1 diabetes are warranted. Finally, it should be noted that several of the current exercise guidelines recommend a decrease in basal insulin for physical activity and exercise. The results of the present study and of those discussed above, would indicate that this recommendation may not be appropriate for activities performed in a fasting state. However, patients should always be advised to monitor their glucose closely upon starting or changing an exercise routine, to ensure that they understand their individual responses.

ACKNOWLEDGEMENTS

Hand-held glucometers and test strips for the study were provided by LifeScan Canada. Glucerna bars were provided by Abbott Nutrition Canada. We would like to thank Shaelyn Houlder for her assistance in processing CGM data for the purpose of the study analyses.

FUNDING

This project was supported by the Provost's Special Funding at the University of Alberta.

CONTRIBUTION STATEMENT

JEY contributed to the conception and design of the project, as well as data collection and manuscript drafting and editing. SRT contributed to data collection and analysis in addition to drafting and editing of the manuscript.

JEY is the guarantor of this work. Data related to the study were presented at the Diabetes Canada Professional Conference and Annual Meetings in Edmonton, Alberta, November 1-4, 2017 (Can J Diabetes 41 (Suppl 1): S64).

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## TABLE AND FIGURE LEGENDS

*Table 1 - Participant characteristics*

*Table 2*. Continuous glucose monitoring data the 6-hours post-exercise, as well as overnight (midnight to 6 am) after exercise

*Figure 1* - Change in blood glucose during exercise and recovery. Gray boxes represent morning exercise, black boxes represent evening exercise. Data are presented as mean ± SEM

*Figure 2* - CGM glucose. Panel A represents CGM glucose in the 6 hours following exercise. Panel B represents overnight blood glucose values. Data are presented as mean ± SEM.

*Table 1 - Participant characteristics*

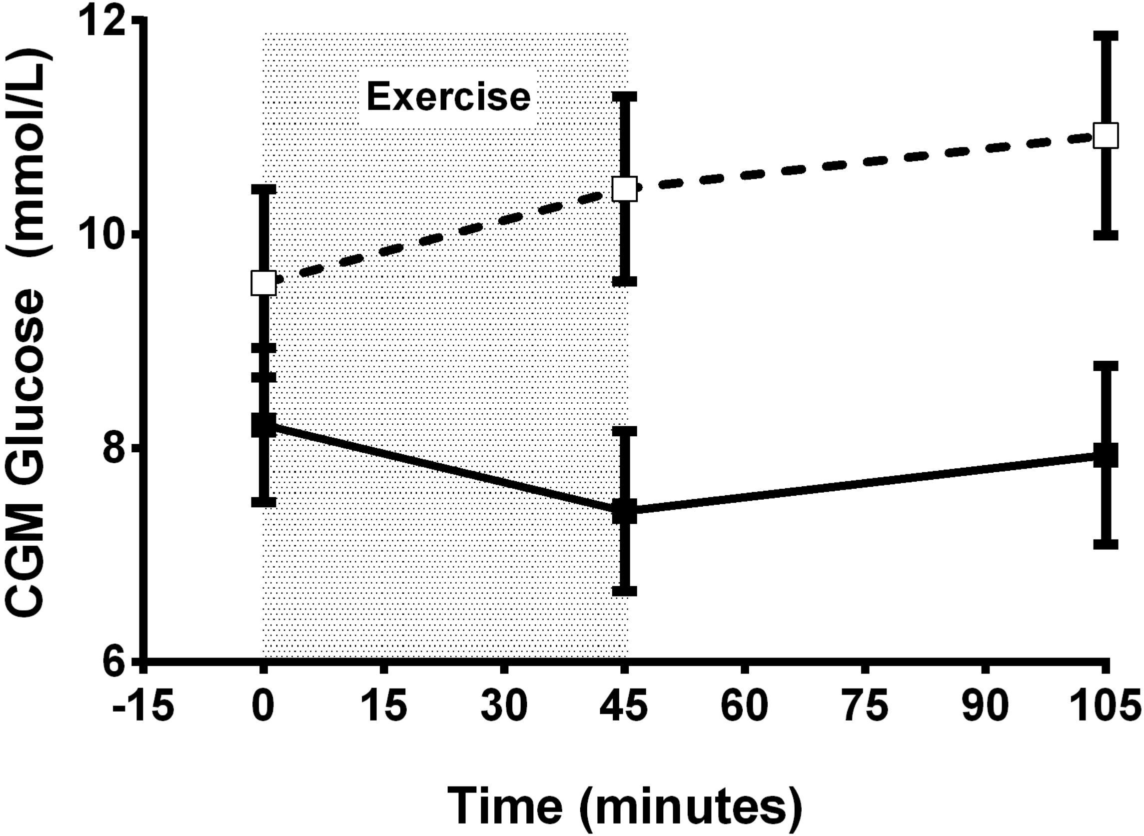
| Characteristic | N or mean ± SD |
|---|---|
| Male/Female | 3/9 |
| Age (yrs) | 31.3 ± 8.9 |
| Height (m) | 1.7 ± 0.1 |
| Weight (kg) | 78.1 ± 15.0 |
| BMI ($kg \cdot m^{-2}$) | 26.6 ± 3.8 |
| Predicted VO2max (mL $O_2 \cdot kg^{-1}$) | 39.1 ± 8.2 |
| HbA1c (%) | 7.4 ± 0.8 |
| HbA1c (mmol/mol) | 57.4 ± 8.5 |
| Diabetes Duration (years) | 19 ± 8 |
| MDI/CSII | 4/8 |
| Systolic Blood Pressure (mmHg) | 117 ± 12 |
| Diastolic Blood Pressure (mmHg) | 81 ± 9 |
| Resting Heart Rate (bpm) | 74 ± 13 |

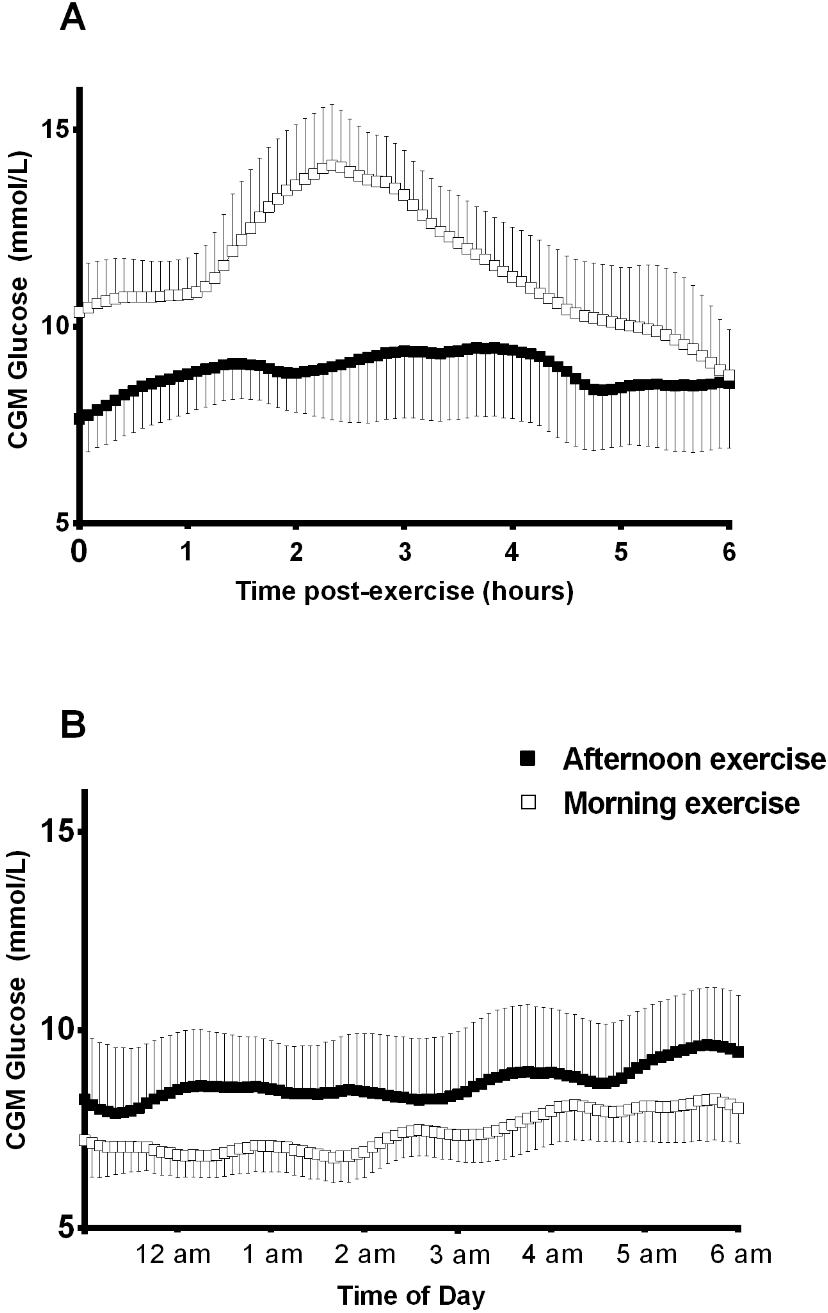
MDI = multiple daily insulin injections; CSII = continuous subcutaneous insulin infusion (insulin pump)

*Table 2*. Continuous glucose monitoring data the 6-hours post-exercise, as well as overnight (midnight to 6 am) after exercise

| | Morning | Afternoon | p-values |
|---|---|---|---|
| 6-hr mean glucose (mmol/L) | 11.5 ± 3.3 | 9.1 ± 3.9 | 0.126 |
| 6-hr MAG (mmol/L) | 2.7 ± 1.1 | 2.0 ±0.7 | 0.076 |
| Nocturnal mean glucose (mmol/L) | 7.4 ± 1.7 | 8.6 ± 4.1 | 0.428 |
| Nocturnal MAG | 1.2 ± 0.8 | 1.0 ± 0.1 | 0.105 |
| % high (6 hr) | 61.64 [36.30-82.53] | 11.64 [0.00-36.03] | 0.037 |
| % low (6 hr) | 0.00 [0.00-0.00] | 0.00 [0.00-4.17] | 0.181 |
| % in range (6 hr) | 33.56 [27.37-62.84] | 82.88 [55.01-100.00] | 0.064 |
| # of events ≤ 3.9 mmol/l (6hr) | 1 | 4 | 0.081 |
| # of events ≥ 10 mmol/l (6hr) | 12 | 5 | 0.025 |
| % high (nocturnal) | 0.00 [0.00-4.41] | 15.29 [0.00-47.94] | 0.205 |
| % low (nocturnal) | 0.00 [0.00-0.00] | 0.00 [0.00-6.48] | 0.418 |
| % in range (nocturnal) | 100.00 [94.41-100.00] | 65.17 [45.59-97.93] | 0.107 |
| # of events ≤ 3.9 mmol/l (nocturnal) | 2 | 4 | 0.343 |
| # of events ≥ 10 mmol/l (nocturnal) | 4 | 7 | 0.434 |

*Data are mean±SD for mean glucose and MAG, otherwise data are presented as median ± [IQR]. SD=standard deviation, MAG = mean absolute glucose change, % high = % of time spent ≥10.0 mmol/L; %low = % of time spent ≤3.9 mmol/L; % in range = % of time spent between 3.9 and 10.0 mmol/L*


Exercise
CGM Glucose (mmol/L)
12
10
8
6
-15
0
15
30
45
60
75
90
105
Time (minutes)


A
CGM Glucose (mmol/L)
15
10
5
0
1
2
3
4
5
6
Time post-exercise (hours)
B
Afternoon exercise
Morning exercise
CGM Glucose (mmol/L)
15
10
5
12 am
1 am
2 am
3 am
4 am
5 am
6 am
Time of Day