

**Artigo original**

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BLOOD GLUCOSE RESPONSES OF TYPE-2 DIABETICS DURING AND AFTER EXERCISE PERFORMED AT INTENSITIES ABOVE AND BELOW ANAEROBIC THRESHOLD**RESPOSTA GLICÊMICA DE DIABÉTICOS TIPO 2 DURANTE E APÓS EXERCÍCIOS REALIZADOS EM INTENSIDADES ACIMA E ABAIXO DO LIMIAR ANAERÓBIO****RESUMO**

Com o propósito de analisar a resposta da glicose sanguínea durante e após exercício a 90 e 110% do limiar anaeróbio (LA), 10 voluntários diabéticos tipo 2 ($56,9 \pm 11,2$ anos; $80,3 \pm 14,4$ kg), realizaram um teste incremental (TI) em cicloergômetro. Após a realização do TI para identificação do LA, os voluntários realizaram 3 sessões experimentais em dias distintos: 20 minutos em bicicleta ergométrica a 90 e 110% LA e uma sessão controle (CON). A glicemia foi mensurada no repouso, aos 10 e 20 min de exercício ou na situação controle, bem como a cada 15 minutos durante 2 horas do período de recuperação pós-exercício (Rec) e CON. ANOVA não identificou diferenças significantes nas concentrações de glicose sanguínea durante e após as sessões de 90 e 110% LA. Comparado ao controle, redução significativa da glicemia foi observada aos 20 min de exercício (-41 ± 15 mg.dl⁻¹), aos 15 min (-48 ± 21 mg.dl⁻¹) e 60 min da Rec pós sessão a 90% LA, sendo também observada diminuição significativa da glicemia aos 10 e 20 min do exercício e aos 15, 30, 45, 60 e 90 min da Rec após sessão de 110% LA. O exercício de maior intensidade (110% LA) resultou em tendência de maior e mais duradouro efeito hipoglicemiante e pode ser uma alternativa para melhor controle da glicose sanguínea em diabéticos tipo 2 que não possuam problemas cardiovasculares ou outras complicações e restrições ao exercício realizado acima do LA.

Palavras-chave: Diabetes tipo 2; Intensidade de exercício; Controle da glicemia.

ABSTRACT

With the objective of analyzing the blood glucose responses during and after exercise performed at 90 and 110% of anaerobic threshold (AT), 10 type-2 diabetes patients (56.9 ± 11.2 years; 80.3 ± 14.4 kg) performed an incremental test (IT) on a cycle ergometer. After an initial IT to identify AT, the volunteers participated in three experimental sessions on three different days: 20 minutes' of cycling at either 90 or 110% of AT, and a control session (CON). Blood glucose was measured at rest, and at the 10th and 20th minutes of exercise or control condition, as well as every 15 minutes during a 2-hour post-exercise recovery period (Rec). One-way ANOVA did not detect significant differences in blood glucose levels between the sessions at 90 and 110% of AT. Compared to CON, a significant decrease was observed at the 20th minute of exercise, and at the 15th and 60th minutes of Rec from the 90% AT session. Significant reductions were also observed at the 10th and 20th minutes of exercise and at the 15th, 30th, 45th, 60th and 90th minutes of Rec from the session at 110% AT. Exercise performed at the higher intensity (110% AT) resulted in a tendency of a more pronounced and prolonged hypoglycemic effect during and after exercise, and may be an alternative intensity for glycemic control in type 2 diabetics who do not have cardiovascular complications or other contraindications to exercising at intensities above the AT.

Key words: Type 2 Diabetes; Exercise intensity; Glycemic control.

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INTRODUCTION

Diabetes mellitus (DM) is a disorder of carbohydrate metabolism, characterized by chronic hyperglycemia due to insufficient insulin secretion and/or deficiency in the activation of post-receptors involved in the action of insulin¹. According to Barceló *et al.*², DM is the chronic non-transmissible disease with the fastest growing rate in the world, and approximately 95% of diabetic patients have Type 2 DM (DM₂).

Prevention and control of DM₂ may be achieved through simple means, including balanced food intake associated to a regular and supervised physical exercise regular, supervised, physical exercises³. Physical exercise is one non-pharmacological option for controlling blood glucose, which in turn is essential for preventing functional complications related to DM₂⁴.

Simões *et al.*⁵⁻⁷ observed that, during an incremental exercise test (IT) at intensities below the AT blood glucose concentrations are maintained or decrease mildly, whereas at intensities above AT there is an increase in blood glucose concentration in healthy individuals, possibly due to an increased secretion of counter-regulatory hormones such as epinephrine and glucagon, which induce hepatic glycogenolysis. Therefore, it is possible that the exercise intensity corresponding to AT may be also the maximal intensity at which an equilibrium between blood glucose output and uptake can be observed. The exercise performed at intensities above AT would increase blood glucose while intensities below AT should induce it to fall. Such information could be useful when prescribing exercise intensities for DM₂.

The purpose of this study was to analyze the blood glucose kinetics of type 2 diabetes patients during and after exercise performed on a cycle ergometer at intensities below (90%) and above (110%) AT.

METHODS

Subjects

Ten sedentary DM₂ patients from Brasilia, DF, Brazil, (56.9 ± 11.2 years; 80.3 ± 14.4 Kg; 1.68 ± 0.09 m; 18.0 ± 3.6 ml.kg.min⁻¹ VO_{2max}) who were not insulin users and were free from macroangiopathy, retinopathy, nephropathy, neuropathy and wounded diabetic foot participated in the study on a voluntary basis. All participants were recruited by convenience through fliers distributed to hospitals and social clubs and by word-of-mouth. The methods used were approved by the local Human Research Ethics Committee (doc. no.103/2005). The nature, purpose, and risks of the study were fully explained to all participants, and informed written consent was obtained before the experiment was conducted.

Preliminary testing

Initially, all volunteers underwent an IT until exhaustion on a cycle ergometer (Lode Excalibur) in order to evaluate their AT and for cardiologic assessment. The electrocardiogram allowed for monitoring of potentially abnormal responses during exercise and also to indicate the need to interrupt the test before the participant has

attained volitional exhaustion. The IT was performed with an initial load of 15 W at 60 rpm and 15 W increments every 3 minutes. Blood glucose and blood lactate were analyzed at rest prior to exercise and at the end of each stage of IT by an electroenzymatic method (YSI 2.700 STAT).

Lactate threshold (LT), glyceic threshold (GT) and ventilatory threshold (VT) were determined and AT was considered as a mean of the three parameters (Figure 1). The intensity corresponding to LT was identified as the moment at which an abrupt increase in blood lactate concentrations occurred. The GT was identified as the exercise intensity related to the lowest blood glucose concentration observed during IT (Simões *et al.*, 5; 6; 7). Expired gases were analyzed continuously (Cortex Metalyzer 3B System) and VT was identified as the exercise intensity at which there was a disproportional increase in VE/VO₂ in relation to VE/VCO₂⁸.

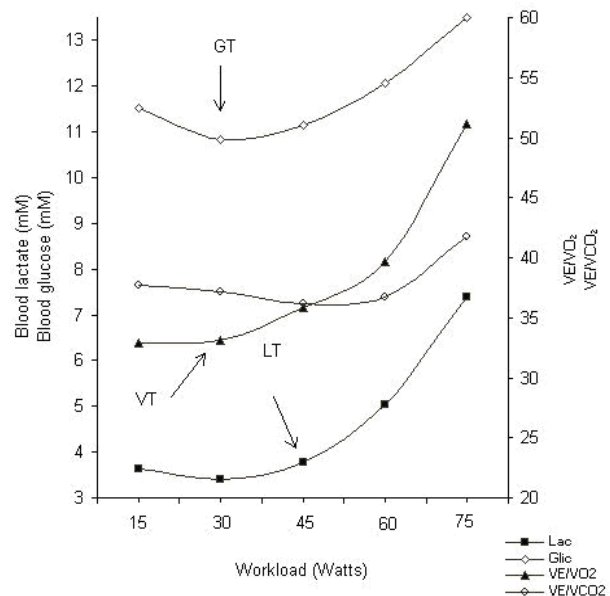


Figure 1. Determination of LT, VT and GT for a single type 2 diabetic subject.

Experimental design

After AT had been determined, the volunteers performed, on different days and in a randomized order, 2 exercise sessions lasting 20 min each on a cycle ergometer with a constant load corresponding either to 90 or 110% of AT, plus 1 control session in which participants remained a rest in a seated position. Capillary blood samples (25 µL) were collected from the ear lobe for blood glucose analysis at rest, at the 10th and 20th minutes of exercise and every 15 minutes during a 2 hour post-exercise recovery period after both sessions, as well as at the corresponding moments during the control session. All the experimental sessions were performed at the same time of day and with at least a 48 h interval between them, over a 2-week period.

A breakfast kit containing a packet of whole meal salt donuts, a mini cake and juice, with a total of 256 Kcal (28% fat, 64% carbohydrate and 8% proteins), was standardized by a nutritionist and distributed to the volunteers to eat 2h before the 20-min exercise session and control session. This 2h period was chosen since it is considered to be adequate for DM₂ individuals to

practice physical exercise and allow for a true analysis of the effects of exercise on these patients' glycemic control^{9,10}. In common with the IT, during the constant load sessions electrocardiographic analysis was performed in order to monitor possible cardiovascular abnormalities during exercise.

Statistics

Blood glucose concentration (mg.dL⁻¹) was expressed either in absolute or delta values (exercise or recovery values minus the pre-exercise rest values). The normality of the data was confirmed by exploratory analysis and so the results within each session, as well as between corresponding moments of the 3 different sessions, were compared by two-way ANOVA for repeated measures. The Tukey test was applied *post hoc* and the level of significance adopted was $p < 0.05$. Beta analysis (Power) was applied to the blood glucose results, and the result of a Power of 0.8 indicated that, although the number of participants was the major limiting factor, the statistical procedures were adequate for the sample being studied.

RESULTS

When the values at rest were compared with the results from the 90% of AT session (10th and 20th minutes of exercise and 15, 30, 45, 60, 75, 90, 105 and 120 minutes of post-exercise recovery), significant differences were observed between: a) rest and the 10th minute of exercise ($P < 0.05$), b) rest and 20th minute of exercise and c) from the 15th to the 120th minutes of recovery ($P < 0.001$), with the greatest decreases at the 90th (-63 ± 30 mg.dL⁻¹) and 120th minutes (-63 ± 33 mg.dL⁻¹) of post-exercise recovery. For the 110% of AT session, differences were found between rest and the 10th and 20th minutes of exercise and 15th to 120th minutes ($P < 0.001$), with the highest decreases being observed at the 90th (-64 ± 38 mg.dL⁻¹) and 120th minutes (-70 ± 45 mg.dL⁻¹) of the recovery period. During the control session, differences were found between rest and 15th ($P < 0.01$) and 30th to 120th minutes of recovery ($P < 0.001$), with higher decreases being observed at the 90th (-44 ± 28 mg.dL⁻¹) and 120th minutes (-54 ± 32 mg.dL⁻¹) of recovery (Figure 2).

The absolute blood glucose values at resting, at the 10th and 20th minutes of exercise and at the 15th, 30th, 45th, 60th, 75th, 90th, 105th and 120th minute of post-exercise recovery were, respectively: 164, 141, 123, 116, 118, 114, 107, 103, 102, 104 and 101 mg.dL⁻¹ for the 90% of AT session; 174, 142, 124, 120, 119, 122, 114, 113, 110, 109 and 104 mg.dL⁻¹ for the 110% of AT session and 160, 152, 149, 136, 133, 129, 124, 116, 116, 109 and 106 mg.dL⁻¹ during the control session.

When the blood glucose delta values (mg.dL⁻¹) at the intensities of 90% AT, 110% AT and the control condition (CON) were compared, no differences were observed between 90% of AT and 110% AT. Differences were observed between 90% of AT and CON at 20 min of exercise for the exercise session and after 20 minutes seated for the CON session ($P < 0.01$); 15 and 60 min of recovery ($P < 0.05$); and between 110% AT and CON at the 10th and 20th minutes of the experiment and the 15th, 30th ($P < 0.01$), 45th, 60th and 90th ($P < 0.05$) minutes of recovery (Figure 2).

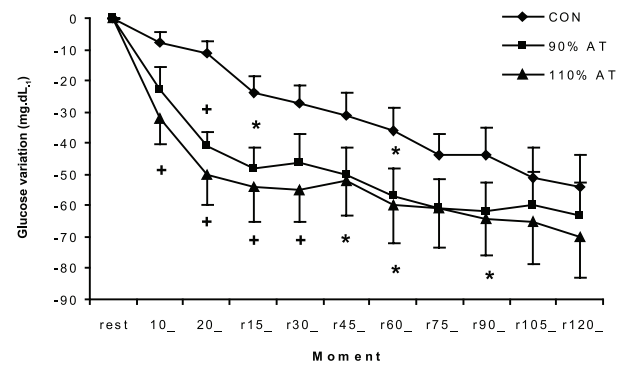


Figure 2. Blood glucose levels (mg.dL⁻¹) during 20 minutes of exercise or CON in a seated position (10' and 20'), and during the post-exercise recovery period (r15 – r120) for the 90% and 110% AT and CON sessions (n = 10). * $P < 0.01$ in relation to CON; * $P < 0.05$ in relation to CON.

DISCUSSION

The main finding of this study was that the blood glucose reduction effect of 20 minutes of exercise performed at 90% and 110% of AT lasted for at least 2 hours. Although the blood glucose reduction did not differ between the studied intensities, the exercise performed at 110% AT resulted in a more significant blood glucose reduction in relation to CON. These results suggest that exercise sessions performed at intensities slightly above AT (110%) may promote a higher glucose uptake (Figure 2).

Similar results were found by Kang et al.¹¹, who subjected 6 obese men with DM₂ and 6 obese men without DM₂ to an exercise session of 70 min at 50% of VO_{2max} and an exercise session of 50 min at 70% of VO_{2max}. In obese non-DM₂ individuals, at the end of exercise sessions the blood glucose had decreased by 11 and 10% in relation to rest values, for the intensities of 50 and 70% of VO_{2max}, respectively. On the other hand, in obese DM₂ individuals, the blood glucose had decreased 17 and 19%, respectively, evidencing that higher exercise intensities (70% VO_{2max}) may result in a higher percentage decrease in blood glucose, even with lower exercise durations (50 min).

In this study, the significant decrease in blood glucose during the recovery from exercise sessions might be due to an increase in glucose uptake during the exercise. During the post-exercise period, the blood glucose decrease was similar for both exercise sessions, with the difference also being observed at the 120th minute of recovery in relation to the 20th minute of exercise at 90% AT (-22 mg.dL⁻¹) and 110% AT (-20 mg.dL⁻¹). The reduction in blood glucose observed in the control session is the result of medication (oral hypoglycemics) used by the volunteers during all experimental sessions. The medication was maintained because during daily life the volunteers do not perform exercise without using medication. Therefore, it is important to maintain the external validity of the study and to observe the glycemic response in the same conditions that DM₂ individuals find themselves in during their daily lives, which means fed and under hypoglycemics use.

Despite a tendency to higher glucose uptake at higher exercise intensities, the results of the present study indicate that exercise at moderate intensity (below AT) is also beneficial for glycemic control in diabetic individuals. Giacca *et al.*,¹² found similar results in a group of 7 people who were not overweight, 7 obese non-diabetics and 7 obese people with DM₂, where they analyzed the acute responses of blood glucose to aerobic exercise (45 minutes at 50% of VO_{2max} on a cycle ergometer) and at the 150th minute of post-exercise recovery. In the non overweight and obese individuals, blood glucose had not been modified during exercise and recovery in relation to rest values; however, in the obese DM₂ individuals, blood glucose decreased 18 mg.dl⁻¹ during exercise and was maintained below baseline levels throughout the recovery period.

Exercise intensities corresponding to AT may be also estimated by using the Rate of Perceived Exertion Scale (Borg Scale) and % of Heart Rate Reserve. It has been observed that AT is around scores 12 to 14 on the Borg scale and at around 70% of Heart Rate Reserve in diabetic patients¹³. This information is important since it allows for exercise to be prescribed in terms of intensities relative to AT, as in the present study, optimizing the benefits of exercise and minimizing the associated risks. It is important to emphasize that both exercise intensities resulted in effective glycemic control in DM₂ patients, nevertheless exercise performed at 110% of AT presented a greater hypoglycemic effect during exercise (Figure 2). This exercise intensity slightly above AT may be an alternative for the glycemic control in DM₂ individuals without cardiovascular complications, since intensities above AT may result in greater sympathetic nervous system activity. Care must be taken when prescribing exercise at intensities above AT for DM₂ patients, since most of them are elderly and have cardiovascular complications associated with the pathology.

The main limitations of the present study were that blood hormones were not measured, the number of participants was low, and the age range was high. Information on epinephrine, insulin and glucagon responses would provide valuable data on the mechanisms responsible by glycemic responses during and after exercise below and above AT. Also, a higher number of participants and a stricter age range probably would reveal a more significant blood glucose reducing effect of exercise. However, although the number of participants may be the major limiting factor to this investigation, the statistical procedures were adequate for the sample studied as revealed by Beta Analysis (Power).

CONCLUSION

We conclude that both exercise intensities (90% and 110% of AT) induced a significant decrease in blood

glucose when compared to a control session. However, the exercise performed at a higher intensity (110% of AT) resulted in a more significant reduction in blood glucose. Therefore, this intensity might be an alternative for glycemic control in DM₂ patients who do not exhibit cardiovascular complications or other contraindications to exercise at intensities above AT.

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