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Original research

Glucose control can be similarly improved after aquatic or dry-land aerobic training in patients with type 2 diabetes: A randomized clinical trial

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ABSTRACT

Objectives: To compare the effects of two aerobic training methods in water and on dry-land on glycemic, lipid, inflammatory, hormonal, cardiorespiratory, and functional outcomes in patients with type 2 diabetes.
Design: Randomized clinical trial.
Methods: Thirty-five patients with type 2 diabetes were randomly assigned to aquatic aerobic training group ($n = 17$) or dry-land aerobic training group ($n = 18$). Exercise training interventions had duration of 12 weeks, performed in three weekly sessions (45 min/session), with intensity progressing from 85% to 100% of heart rate of anaerobic threshold during interventions. All outcomes were evaluated at baseline and 12 weeks later.
Results: Patients were 56.7 ± 7.9 years old. Decreases in glycated hemoglobin were observed in both groups (AT: $-0.42 \pm 0.28\%$, DLT: $-0.35 \pm 1.8\%$). Total cholesterol, high density lipoprotein, low density lipoprotein levels, plasma renin activity, angiotensin II concentrations, C-reactive protein, systolic blood pressure, resting heart rate, and timed up and go test performed at the usual speed also decreased in both groups in response to both interventions ($p < 0.05$), without between-group differences. Both groups increased the ratio between oxygen uptake at the anaerobic threshold and oxygen uptake of peak ($p = 0.01$).
Conclusions: Aerobic training in an aquatic environment provides effects similar to aerobic training in a dry-land environment in patients with type 2 diabetes.

1. Introduction

Different modalities of structured exercise programs are associated with improved glucose control[1,2] and blood pressure reduction[3] in diabetes. Aerobic training has been the mode traditionally prescribed for diabetes management, providing acute and chronic benefits for patients,[4] although similar benefits can be obtained with resistance or combined training.[1,2] However, significant energetic contribution and expressive metabolic effects require that patients should generally be exposed to moderate to heavy impact forces on the osteomuscular system, due to the exercise duration and/or intensity, especially in running.[5]

Exercise alternatives for type 2 patients include aquatic exercises, in which the physical properties of water can provide low impact forces on the lower limb joints, probably making it safer as regards joint damage.[6] These characteristics are especially relevant

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in the case of diabetes, due to its frequent association with functional disability, especially when diabetic neuropathy is present.[7] Thus, the aquatic environment favors physical training with less risk of injuries and ulceration as caused by the impact directly absorbed by the foot in contact with the ground. Moreover, the aquatic environment allows the achievement of training with open kinetic chain, without impact on the musculoskeletal system, such as deep-water running.[8] Although some studies have evaluated functional capacity and glucose control after training in an aquatic environment in patients with diabetes, these studies[9,10] did not compare training performed in different environments.

Due to low impact on the osteomuscular system in aquatic training, which can contribute to training progress, comparing this kind of training with traditional training should be tested in well-designed randomized trials. The aim of this study was therefore to compare the effects of two aerobic training models (aquatic vs. dry-land training) on glucose control in patients with type 2 diabetes.

2. Methods

Patients with type 2 diabetes were recruited through advertisements in local newspapers. Inclusion criteria were: type 2 diabetes, not engaged in regular exercise (defined as not exercising more than 20 min on 3 or more days a week), 30 years old or more, and having had an electrocardiogram (ECG) stress test performed recently (6 months preceding the study). Exclusion criteria were severe autonomic neuropathy, severe nonproliferative and proliferative diabetic retinopathy, decompensated heart failure, limb amputations, chronic renal failure (MDRD-GFR < 30 ml/min),[11] or any muscle or joint impairment which prevented individuals from engaging in physical exercise.

All participants provided written consent prior to participation. This study was approved by the Research Ethics Committees of the Hospital de Clínicas de Porto Alegre (protocol number 54475).

Initially, 95 patients were screened. From 60 patients excluded, 43 did not meet the inclusion criteria and 17 declined to participate. Thus, 35 patients (15 men and 20 women) with ages between 37 and 71 years old were included in the study; they were randomly assigned to two groups, one group being submitted to aquatic aerobic training (AT, $n = 17$) and another submitted to dry-land aerobic training (DLT, $n = 18$). Patients were randomized by picking an envelope with predefined group numbers, using a 1:1 ratio and stratified according to gender. The randomization procedure was performed after baseline evaluations.

Patients underwent a 12-week training program with three weekly sessions. Training intensity was prescribed according to the corresponding anaerobic threshold heart rate (HR_{AT}), determined by heart rate deflection point, which was determined by progressive exercise tests conducted in the water or on land for the AT and DLT groups, respectively. The incremental test in the water was a mode-especific deep-water running test based on the study of Kanitz et al.,[12] and the incremental test on land was performed in treadmill, according Delevatti et al.[13] The modalities adopted were walking and/or running in deep water (AT), and walking and/or running on athletic track (DLT). Patients trained using heart rate (HR) monitors (RSX 300, Polar, Kajaani, Finland) during exercise to control training intensity. Each 45-min session was divided into a warm-up period (5 min), followed by the main training program (35 min) and a cool down section (5 min). Both groups underwent interval-training programs, with the following periodization: weeks 1–3, 7 sets (3 min 85–90% HR_{AT} with 2 min < 85% HR_{AT}); weeks 4–6, 7 sets (4 min 85–90% HR_{AT} with 1 min < 85% HR_{AT}); weeks 7–9, 7 sets (4 min 90–95% HR_{AT} with 1 min < 85% HR_{AT}); weeks 10–12, 7 sets (4 min 95–100% HR_{AT} with 1 min < 85% HR_{AT}). Both groups had identical training periodization, differing only with regard to the training environment.

In first week of measures, patients had a clinical evaluation including body composition evaluation and functional mobility tests, as well as having fasting (12 h) blood samples collected. Dietary control was performed by a 3-day diet record filled before and after interventions. Initially, height, body mass, waist circumference, and the sum of eight skinfolds ($\sum$ SF) were measured. These data were used to calculate body mass index (BMI) and waist/height ratio. The equations proposed by Petroski[14] were used to estimate the body density of men and women, while body fat percentages were estimated using the Siri formula.[15] After, biochemical evaluations were performed; blood samples were used for plasma glucose, glycated hemoglobin (HbA1c), lipid profile, high sensitivity C-reactive protein (CRP), angiotensin II (Ang II), and plasma renin activity (PRA). Functional mobility was evaluated by the *Timed Up and Go* test (TUG), performed at the usual speed (TUG-u) and maximum speed (TUG-m).[16]

In the second week, patients were familiarized with the training programs that they subsequently underwent, with the training environment, and with the material used during experimental sessions. In the third week of pre-training evaluation, rest blood pressure and heart rate were measured in all patients along with graded exercise test. The patients remained sitting at rest for 10 min to further analyse blood pressure levels. Heart rate at rest (HR_{rest}), was considered to be the lower value found in the last 3 min of the period. A graded maximal exercise test was conducted on a previously calibrated treadmill (Inbramed, Porto Alegre, Brazil) with initial velocity of 3 km h^{-1} for 3 min, fixed inclination (1%), and increments of 1 km h^{-1} every 2 min, until exhaustion. Heart rate was monitored every 10 s (Polar, Kajaani, Finland) and the rate of perceived exertion (Borg Scale) was measured in the final 20 s of each stage.

Before and after the 12-week intervention, all outcomes were evaluated, except the mode-specific deep-water running test. Post-training cardiorespiratory and functional measurements were performed 48–96 h after the final exercise session, and blood samples were collected 72 h after the last exercise session.

Glycated hemoglobin levels (HbA1c) was considered the primary outcome, being determined by high-performance liquid chromatography (Bio-Rad VARIANT II TURBO System, São Paulo, Brazil). Secondary outcomes included measures of lipid profile, renin–angiotensin system activity, systemic inflammation, cardiorespiratory fitness and functional mobility. Regarding cardiorespiratory outcomes, the highest VO_2 attained during the test was taken as the peak oxygen uptake (VO_{2peak}). Oxygen uptake at the anaerobic threshold (VO_{2AT}) was obtained by determining the second inflection point in the ventilation curve and it was confirmed by means of the CO_2 ventilatory equivalent (Ve/VCO_2). All outcomes were evaluated at baseline and at the end of the interventions. All analyses were performed by blinded evaluation.

Descriptive data are presented as mean and standard error or median and interquartile range (P25–P75). Baseline differences were compared using Fisher's exact test for categorical variables and unpaired *t*-test for continuous variables. Hypoglycemic episodes and osteoarticular injury or pain also were compared using Fisher's exact test.

A priori sample size was calculated based on a predicted difference of 0.4% in levels of HbA1c, $\alpha = 0.05$, power of 0.90, performed in the WinPepi (PEPI for Windows; Salt Lake City, Utah) version 4.0, based on the study of Kwon et al.[17] This calculation indicated that 13 patients in each group would be sufficient to detect significant changes in glycemic control.

A generalized estimating equation (GEE) was used to assess before and after intervention changes within and between groups. Multiple comparisons were performed with the Bonferroni