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# Acute and Chronic Effects of Aerobic, Resistance, and Combined Training in Type 2 Diabetic

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## Abstract

The aim of this study was to evaluate the acute and chronic effects of aerobic, resistance, and combined training on hemodynamic and blood glucose parameters in patients with type 2 diabetes. Diabetic patients were allocated to an aerobic group (n=7), resistance group (n=7), and combined group (n=7). Blood pressure, heart rate, and capillary blood glucose were evaluated before and after each training session. The sessions were conducted individually and were divided into three groups, with 65 min for each group. The capillary blood glucose and systolic blood pressure showed significant decrease (respectively; aerobic group: p=0.01/p=0.01; resistance group: p=0.01/p=0.01; combined group p=0.01/p=0.01); diastolic blood pressure showed significant decreases only in the aerobic group (p=0.03). There were significant decreases in capillary blood glucose and systolic and diastolic blood pressure (respectively; aerobic group: p=0.00/p=0.00/p=0.02; resistance group: p=0.00/p=0.00/p=0.00; combined group p=0.00/p=0.00/p=0.00), but heart rate decreased only in the aerobic group (p=0.02) and resistance group (p=0.00). There were significant differences when comparing capillary blood glucose in the combined group and resistance group, systolic and diastolic blood pressure in the combined group and resistance group, and combined group and aerobic group respectively, heart rate in the combined group and resistance group. Resistance, aerobic, and combined training were effective both in the acute and in chronic phases. However, combined training showed more benefits in hemodynamic and blood glucose parameters in patients with type 2 diabetes.

**Keywords: Diabetes mellitus; Exercise; Blood glucose**

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## Introduction

Diabetes Mellitus (DM) is a chronic disease that can determine the appearance of macrovascular complications (accelerated atherosclerosis), microvascular and those related to the peripheral nervous system [1]. Insulin resistance has been considered a key factor in the pathogenesis of type 2 DM and is a cofactor in the development of Systemic Arterial Hypertension (SAH), dyslipidemia and atherosclerosis [2].

Chronic hyperglycemia can lead to SAH through several pathophysiological mechanisms not fully known [3]. The main risk factors for the development of microvascular complications are sustained hyperglycemia and SAH [4,5].

Multicenter studies have shown that the reduction of glycated Hemoglobin (HbA1c) decreases the risk of complications of DM by 35%, reduces microvascular complications by 25%, and the decrease in blood pressure significantly reduces heart failure and risks of diabetes-related deaths [6,7].

Drug treatment of type 2 DM is performed with oral anti-diabetics and/or insulin, while non-drug treatment includes controlling the diet and regular physical exercise [8]. Both aerobic exercises and resistance exercises with weights have beneficial effects in the treatment of type 2 DM [9], however, the combination of the two protocols is more effective in some parameters of blood pressure, HbA1c and lipid profile [10].

It is a consensus that physical exercise has beneficial effects on the glycemic and hemodynamic parameters of diabetics, however studies with different physical exercise protocols and the effects that are promoted by them, in an acute and chronic way, are still few reported.

Therefore, it is essential to carry out research that emphasizes several strategies of training protocols in moments of acute and chronic state. Thus, the objective of the present study was to verify the acute and chronic effects of aerobic, resistance and combined training under hemodynamic and glycemic parameters of type 2 diabetics.

## Methods

This study presented a quantitative approach with a quasi experimental design, which was duly approved by the Ethics and Research Committee of the University of Pernambuco, obtaining the opinion nº 007/09.

### Samples

The constitution of the sample groups was carried out by randomization in diabetic patients participating in the SWEET LIFE - Supervised Exercise Program for Diabetics/School of Physical Education/University of Pernambuco.

Diabetics 21 of both genders were selected, who were randomly allocated to three intervention groups; the aerobic group n=7, the resistant group n=7, and the combined group n=7.

All subjects were informed about the procedures that would be performed during the study, and after explanation, they signed the informed consent form.

Diabetic patients aged between 50 and 70 years, with a diagnosis of diabetes less than and/or equal to 10 years, who did not undergo insulin therapy and use of beta-blocking drugs, who had capillary blood glucose values below 250 mg/dL, participated in this study. Systolic blood pressure below 160 mm/Hg and diastolic blood pressure below 100 mm/Hg, all of these values at the beginning of each training session.

Exclusion criteria were signs of manifestation of chronic complications in the acute phase, diagnosis of type 1 diabetes, osteomioarticular complications, and frequency below 75% of presence in training sessions.

### Instrumentation and data collection

Blood pressure, heart rate and capillary glycemia were evaluated before and after each training session during the 48 intervention sessions, totaling a period of 16 weeks.

Blood pressure measurement was performed using double channel RAPPAPORT premium® stethoscopes and aneroid model RAPPAPORT premium® sphygmomanometers. It was measured with the subject resting for five minutes, in a calm environment, in a sitting position with his legs uncrossed, making sure that they did not drink alcoholic and caffeinated beverages, nor practiced physical exercise in the last 24 h before collection [11].

Heart recovery measurement was performed with the examiner placing the index and middle fingers in the distal region of the radius on the right wrist, with the heartbeat being felt by palpation counting by the evaluator in 10 sec, and multiplied by six [12].

Capillary glycemia was performed at the fingertips, annular or minimal, discarding the first drop glucometers from the Bayer® brand [13], model Breeze® 2, together with reagent strips, and lancets from the brand Bayer®, model Microlet. The material used for collection will be deposited in a specific box of hospital material.

The evaluation of hemodynamic and metabolic variables was performed by the same evaluator, who was properly trained to perform the studied measures. The parameters obtained at the end of the first training session will be adopted as the acute state, whereas the chronic state will be characterized by the average of the parameters obtained after the 48 training sessions.

### Protocol of training sessions

The training sessions were divided into three groups, Aerobic Group, Resistant Group, and Combined Group. The sessions were held individually and lasted 65 min.

The measurement of hemodynamic and glycemic parameters was performed at the premises of the Higher School of Physical Education/ University of Pernambuco at the Biodynamics Laboratory, between the hours of 08:00 h to 10:00 h.

Each session was supervised by physical education teachers and academics, all properly trained for specific follow-up.

All protocols were organized in the following phases: Heating, Main Part and Cooling [14].

**Warm-up:** Pectoral, great dorsal, deltoid, brachial triceps, brachial biceps, quadriceps femoral, hamstring, and gastrocnemius exercises, lasting 15 sec for each movement. Totaling 15 min for this stage and being performed by all intervention groups.

**Main part:** Aerobic group: Intervention performed at the Biodynamics Laboratory, protocol performed on treadmills and exercise bikes, with a total duration of 40 min, with 20 min for beginners, progressing gradually to the total 40 min. The selected diabetics were submitted before the training program initiation to a maximum effort test performed in the ergometry sector of the Emergency Cardiology Unit of Pernambuco, using the Bruce protocol on the treadmill, where the values obtained served for the functional evaluation, cardiovascular and determination of aerobic training intensity. The determination and prescription of the target training zone adopted for aerobic training is 50% to 75% of the Heart Rate Reserve (HRR) [15].

The HRR monitoring is performed by measuring heart rate by palpating the radial artery, on the diabetic's right arm, in the 20$^{th}$ minute of the aerobic [12].

**Resistance group:** In the Biodynamics Laboratory, eight resistance training exercises were performed (flying - pectorals, seated row - dorsal, alternating frontal lift with dumbbells - deltoid, triceps forehead - triceps brachial, alternating curl with dumbbells - biceps brachial, quadriceps femoral extending chair, flexora chair - hamstrings, bilateral calf - gastrocnemius).

Free weights (dumbbells and rings) and New Fit Equipment® machines were used to perform the exercises. The present study used, to determine the intensity of resistance training, the system of "series until failure", which consists of performing repetitions until exhaustion, that is, performing a series until the diabetic was unable to perform a repetition with the "correct" exercise technique [16].

The multiple series system was used, with three series of 8 to 16 repetitions being adopted, with a maximum execution speed of 1 sec for the concentric and eccentric phase, with intervals of 45 sec

**Table 1:** Initial characterization of participants in their respective intervention groups.

| | Intervention Group | | |
|---|---|---|---|
| **Features** | **Aerobic Group** | **Resistant Group** | **Combined Group** |
| N | 7 | 7 | 7 |
| Age (years) | 62.1 ± 8.7 | 68.5 ± 3.7 | 68.5 ± 8.4 |
| DTDM (years) | 10 ± 4.9 | 9.7 ± 3.5 | 9.8 ± 8.6 |
| DSAH (subjects) | 5 | 6 | 5 |
| BMI (kg/m²) | 26.5 ± 2.0 | 28.5 ± 4.7 | 25.2 ± 3.8 |
| Capillary Glycemia (mg/dL) | 195.1 ± 24.9 | 218.2 ± 29.4 | 202.0 ± 36.4 |
| Systolic Blood Pressure (mm/Hg) | 136.2 ± 8.4 | 143.7 ± 4.1 | 142.0 ± 7.4 |
| Diastolic Blood Pressure (mm/Hg) | 80.5 ± 8.4 | 83.4 ± 7.6 | 77.1 ± 9.8 |
| Heart Rate (bpm) | 83.1 ± 9.8 | 84.8 ± 9.8 | 75.4 ± 2.9 |

DTDM: Diagnosis Time Diabetes Mellitus; DSAH: Diagnosis of Systemic Arterial Hypertension; BMI: Body Mass Index

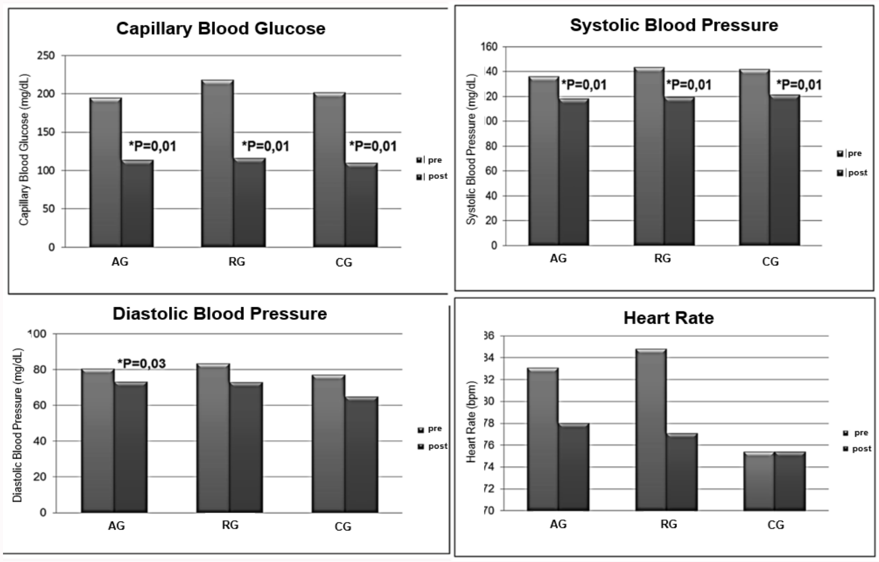


**Figure 1:** Intragroup analysis in the acute phase of physical exercise.
AG: Aerobic Group; RG: Resistante Group; CG: Combined Group; * p ≤ 0.05

between the series and the exercises. Totaling 40 min for this step.

**Combined group:** The combined training protocol was carried out at the Biodynamics Laboratory, being characterized by the combination of aerobic training plus resistance training. The order of execution of the protocols following aerobic training first and resistance training later. The total duration of the combined training is 40 min, with 20 min of aerobic training plus 20 min of resistance training.

In order for all the muscle groups that were selected to be approached, four resistance exercises called "Training A" (flying, thread on the pulley, extending chair, high row with halter) are performed plus four resisted exercises called "Training B" (low row) triangle, flexora with shin, triceps on pulley, bilateral calf) alternating the days of "Training A and B". The determination and monitoring of the intensity of the aerobic and resistance training in the combined training are identical to the previous protocols.

**Cooling:** Pectoralis, grande dorsal, deltoides, brachial triceps, brachial biceps, quadriceps femoris, hamstrings, and gastrocnemius exercises, lasting 15 sec for each movement, along with body awareness and relaxation work. Totaling 10 min for this stage, the same performed by all intervention groups.

The collections after the training session took place with the subjects at rest for five minutes after the cooling phase of each session. Blood pressure, heart rate and capillary blood glucose measurements were adopted using the same procedures as for pre-training collection.

### Statistical analysis

For statistical analysis, the SPSS for Windows 16.0 software was used. The Wilcoxon test was used for the intragroup evaluation and the Kruskal-Wallis test for intergroups, considering values of significance level of $p \leq 0.05$.

## Results

The average frequency of participation in training sessions was 81.6%. Diabetics in the Resistant Group (RG) participated in 83% of the sessions, while diabetics in the Combined Group (GG) and Aerobic Group (AG) participated in 81% and 80% of the sessions, respectively.

Table 1 shows the initial characterization of the subjects of the present study arranged in their respective intervention groups.

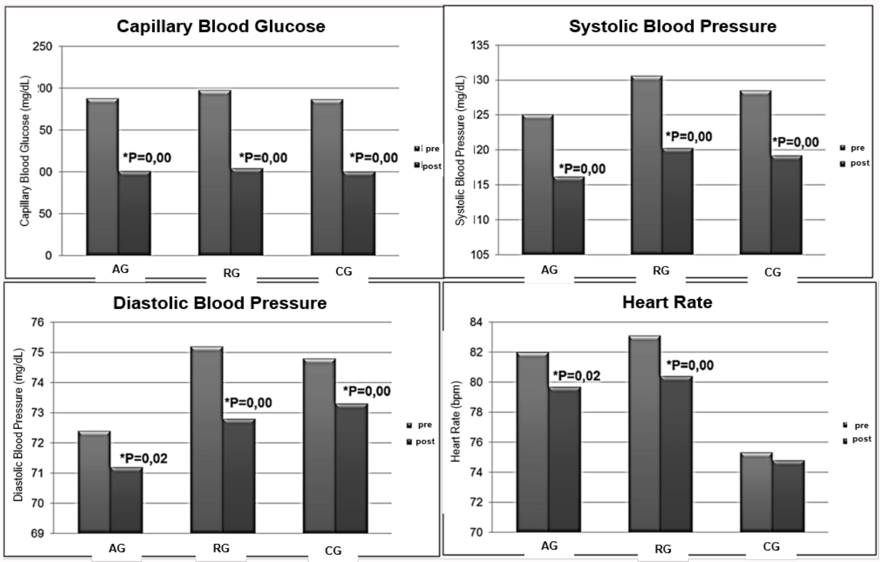


**Figure 2:** Intragroup analysis in the chronic phase of physical exercise.
AG: Aerobic Group; RG: Resistante Group; CG: Combined Group; * p ≤ 0.05

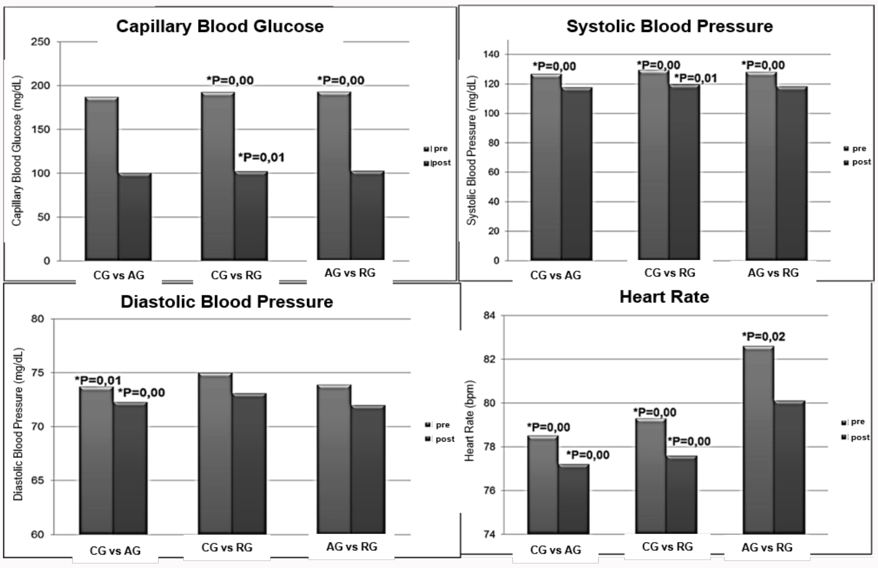


**Figure 3:** Intergroup analysis in the chronic phase of physical exercise.
AG: Aerobic Group; RG: Resistante Group; CG: Combined Group; * p ≤ 0.05

## Acute effect of physical exercise

In the intragroup analysis, in the acute phase after physical exercise, capillary glycemia (AG 195.1 ± 24.9 *vs.* 114.0 ± 19.4 p=0.01; RG 218.2 ± 29.4 *vs.* 116.5 ± 25.7 p=0.01; CG 202.0 ± 36.4 *vs.* 109.8 ± 44.8 p=0.01) and systolic blood pressure (AG 136.2 ± 8.4 *vs.* 118.2 ± 6.0 p=0.01; RG 143.7 ± 4.1 *vs.* 119.7 ± 6.3 p=0.01; CG 142.0 ± 7.4 *vs.* 121.4 ± 8.0 p=0.01) showed significant results, diastolic blood pressure showed a significant difference only in AG (AG 80.5 ± 8.6 *vs.* 73.2 ± 8.2 p=0.03), and none of the groups showed a significant difference in the heart rate variable (Figure 1).

## Chronic effect of physical exercise

In the intragroup analysis, in the conical phase of physical exercise, capillary glycemia (AG 187.6 ± 30.4 *vs.* 100.7 ± 21.0 p=0.00; RG197.9 ± 27.5 *vs.* 104.1 ± 20.5 p=0.00; CG 186.9 ± 26.6 *vs.* 100.4 ± 19.6 p=0.00), systolic blood pressure (AG 125.1 ± 12.9 *vs.* 116.2 ± 12.6 p=0.00; RG 130.6 ± 12.0 *vs.* 120.3 ± 10.9 p=0.00; CG 128.5 ± 12.0 *vs.* 119.2 ± 11.5 p=0.00) and diastolic blood pressure (AG 72.4 ± 8.5 *vs.* 71.2 ± 9.1 p=0.02; RG 75.2 ± 8.9 *vs.* 72.8 ± 7.3 p=0.00; CG 74.8 ± 10.2 *vs.* 73.3 ± 9.3 p=0.00) presented significant results. Heart rate showed significance in the AG (82.0 ± 9.7 *vs.* 79.7 ± 11.4 p=0.02) e RG (83.1 ± 10.0 *vs.* 80.4 ± 13.3 p=0.00) (Figure 2).

In the intergroup analysis, there were significant results in the pre- and post-intervention assessment of the chronic state (Figure 3). Capillary glycemia showed a significant difference only when compared to CG *vs.* RG (100.4 ± 19.6 *vs.* 104.1 ± 20.5 p=0.01) systolic blood pressure showed a significant difference when comparing CG with RG (119.2 ± 11.5 *vs.* 120.3 ± 10.9 p=0.01). Diastolic arterial pressure showed from CG with AG (73.3 ± 9.3 *vs.* 71.9 ± 9.1 p=0.00) and heart rate obtained a significant difference when CG was compared with AG (74.6 ± 15.1 *vs.* 80.4 ± 13.3 p=0.00) and the CG with the RG (74.6 ± 15.1 *vs.* 79.7 ± 11.4 p=0.00).

## Discussion

The present study analyzed the acute and chronic effects of aerobic, resistance and combined training on the hemodynamic and glycemic parameters of type 2 diabetics. The age range of the subjects selected for the study, corroborate with great researches that maintained the average of this variable between 50 and 70 years [10,17,18].

The duration of the disease proved to be similar to that presented by other studies with a similar population [6,19]. The prevalence of overweight was also similar to previous studies [17,20,21].

The intervention time for training protocols, capillary blood glucose, systolic blood pressure and diastolic blood pressure and the percentage of hypertensive subjects partially corroborate with other studies that found similar values no studies were found that showed similarities with the initial characteristics of heart rate and participation rate [6,17,18,20].

In the capillary glycemia variable, in the acute state, the glycemic response to the intervention used showed a significant reduction as reported in previous studies [21,22]. The occurrence of this glycemic response is justified by the acute effectiveness of aerobic training, resisted and combined with the promotion of increased glucose transport capacity within the muscle and the sensitivity of the cell to the action of insulin which increases similarly to blood supply allowing the regulation, availability and use of this substrate (glucose) for the muscles through the translocation of intracellular compartments of the GLUTs to the plasma membrane [23,24].

In the acute effect obtained from the aerobic group, resisted group and combined group on systolic blood pressure, hypotensive outcomes were noted [25]; however, our study differentiates the response from another study which did not show significant reductions in systolic blood pressure [22]. There was a tendency to decrease diastolic blood pressure in the combined group and in the resisted group, but the reduction was significant only in the aerobic group [21,22]. The justification for the hypotensive effect obtained by the training groups used is related to the improvement of the sensitivity of the pressoreceptors, which represents the most important mechanism of regulation of blood pressure in the short term [26]. The response of heart rate in the acute state was biased towards reductions after the training of AG and RG; however the results were not significant.

The response of the intra-group analyzes regarding the chronic state of capillary glycemia can be defended through the previous findings [6,22,27], where responses similar to the present study were obtained. But the outcomes we obtained do not corroborate with a study of a similar character to ours. Where no significant differences in capillary glycemia were reported over a period of 20 weeks [20]. The mechanisms to justify the hypoglycemic effect in the chronic phase of AG, RG and CG training are similar to the mechanisms previously described in the acute phase of physical exercise.

The systolic arterial pressure variable, presented in the chronic state, a hypotensive response similar to that found in a previous study [10], but different from other studies [20-22,27,28]. The answers presented for diastolic blood pressure corroborate the outcomes obtained by large researches [10,22], however, they do not show similarities to the effects presented by studies that do not show significant responses to this variable [20,21,27,28].

The hemodynamic parameters found by the present study, which shows the pressure drop after physical training, may be related to the influence of hemodynamic, humoral and neural factors. Physical exercise reduces blood pressure by decreasing cardiac output, decreasing heart rate, decreasing systemic vascular resistance, decreasing sympathetic tone in the heart, regulating substances vasoactive (e.g., norepinephrine, atrial natriuretic peptide) and increased release of endogenous opioids, which have a vasodilatory function [29]. The chronic effect obtained in the present study achieved hemodynamic control goals (SBP<140/90 mmHg) for diabetic population described by scientific consensus [11,30].

Heart rate showed a significant decrease as well as a similar study [21], however, even with similarity our study showed superior when it presented different results to the previous study, where there were no chronic effects in this variable [27].

In the intergroup analysis, in the chronic phase of physical exercise, significant reductions were observed in the comparisons of the combined group with the resisted group in the capillary glycemia and systolic blood pressure variable. Where the combined group showed a greater magnitude in its reduction. The combined group also showed significant reductions in the variables of diastolic blood pressure and heart rate when compared to the aerobic and resisted group. The justification for such effectiveness of the effects presented by the combined group may be related to the appropriate combination of two training competences (aerobic competence plus anaerobic competence) [10,19].

The main finding of this study was to demonstrate that different methods of physical training are effective for the glycemic and hemodynamic control of type 2 diabetics in an acute and chronic way. Considering the evidence found, we conclude that the use of resistance training, aerobic training and combined training were significantly effective for the desired goal in both acute and chronic forms, however combined training tends to have a greater magnitude of its benefits, and it may be more suitable for the treatment of type 2 diabetics, positively influencing glycemic and hemodynamic control.

## Acknowledgment

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