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Effects of an Aerobic Physical Exercise Program on Blood Glucose Levels in Type-2 Diabetic Subjects, Associated with Pharmacotherapy and Diet Therapy

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Abstract— *The objective of this study was to investigate the changes caused by an aerobic exercise program, scientifically methodized, in the glycemic values of individuals with Type 2 Diabetes Melitus (DMT2), initiating pharmacological treatment and diet therapy.The sample consisted of 39 sedentary subjects, of both sexes and with DMT2, who formed 2 study groups: a) An Experimental Group (EG), composed of 22 individuals who during the experiment were regularly submitted to the exercise program physical (Age: 58.2 ± 9.42; Body weight: 75.2 ± 5.99; Height: 170.7 ± 5.93); and b) A Control Group (CG), composed of 17 subjects also with the same criteria, who did not undergo any physical exercise routine during the study (Age: 51.2 ± 7.30; Body weight: 69.9 ± 5.53; Height: 164.5 ± 7.85).The experiment lasted 8 weeks in which the SG was submitted to aerobic physical exercises controlled by the perceived effort index, during which 3 weekly training sessions were performed, each lasting 60 minutes and performed on alternate days (2nd, 4th and 6th) between 06:00 and 07:30 in the morning. The measurement of the glycemic index (GI) was performed individually and fasting, using the Flash Glucose Monitoring System, brand "FreeStyle Libre", with the data collection taking place immediately after the end of the training session. In the analysis of the results, descriptive statistics were performed to characterize the sample, and subsequently, to find significant differences in the scores related to the physical characteristics of the SG and CG, the Student "t" test was applied for independent samples, and*

finally, in order to compare the IG values of the groups studied between the pre and post-tests, the Student's "t" test was used for dependent samples. At the end of the experiment, it was found that the GI scores of the subjects composing the SG and CG showed a level of statistical significance of p <0.05, with the average value of the IG in the SG being reduced by 29.53 mg / dl and the of the GC decreasing only 14.67 mg / dl. These scores represent a percentage variation of 20.52% in the SG and 11.41% in the CG, indicating between the pre and post-test more significant improvements in the SG of the SG, and thus suggesting that an aerobic physical exercise program, built scientific basis, can be a valuable complementary tool in non-pharmacological therapy for DMT2. Student's "t" test was used for dependent samples. At the end of the experiment, it was found that the GI scores of the subjects composing the SG and CG showed a level of statistical significance of p <0.05, with the average value of the IG in the SG being reduced by 29.53 mg / dl and the of the GC decreasing only 14.67 mg / dl. These scores represent a percentage variation of 20.52% in the SG and 11.41% in the CG, indicating between the pre and post-test more significant improvements in the SG of the SG, and thus suggesting that an aerobic physical exercise program, built scientific basis, can be a valuable complementary tool in non-pharmacological therapy for DMT2. Student's "t" test was used for dependent samples. At the end of the experiment, it was found that the GI scores of the subjects composing the SG and CG showed a level of statistical significance of p <0.05, with the average value of the IG in the SG being reduced by 29.53 mg / dl and the of the GC decreasing only 14.67 mg / dl. These scores represent a percentage variation of 20.52% in the SG and 11.41% in the CG, indicating between the pre and post-test more significant improvements in the SG of the SG, and thus suggesting that an aerobic physical exercise program, built scientific basis, can be a valuable complementary tool in non-pharmacological therapy for DMT2. At the end of the experiment, it was found that the GI scores of the subjects composing the SG and CG showed a level of statistical significance of p <0.05, with the average value of the IG in the SG being reduced by 29.53 mg / dl and the of the GC decreasing only 14.67 mg/dl. These scores represent a percentage variation of 20.52% in the SG and 11.41% in the CG, indicating between the pre and post-test more significant improvements in the SG of the SG, and thus suggesting that an aerobic physical exercise program, built scientific basis, can be a valuable complementary tool in non-pharmacological therapy for DMT2. At the end of the experiment, it was found that the GI scores of the subjects composing the SG and CG showed a level of statistical significance of p <0.05, with the average value of the IG in the SG being reduced by 29.53 mg / dl and the of the GC decreasing only 14.67 mg/dl. These scores represent a percentage variation of 20.52% in the SG and 11.41% in the CG, indicating between the pre and post-test more significant improvements in the SG of the SG, and thus suggesting that an aerobic physical exercise program, built scientific basis, can be a valuable complementary tool in non-pharmacological therapy for DMT2.

***Keywords*— Diabetes Melitus, Glycemic Index, Physical Exercise.**

I. INTRODUCTION

Diabetes Melitus (DM) is a syndrome that covers a group of metabolic disorders, which share the phenotype of blood hyperglycemia. This phenomenon results from the physiological failure of the pancreas in the hormonal production of insulin, a hormone responsible for the transport of glucose molecules from food intake, from inside the blood vessel to the cellular interstitium, where after a series of chemical chain reactions is produced energy intended to meet both vital organic physiological needs, as well as to enable activities related to daily life.

The blood hyperglycemia as physiological phenomenon occurs when the kidney threshold exceeds its critical level of glucose absorption, and thus a significant proportion of it becomes eliminated in the urine (glycosuria). This fact occurs when the concentration of glucose in the blood exceeds values approximately 180 mg / dl, causing the individual an osmotic diuresis (polyuria), which in turn results in the dehydration of tissue cells (polydipsia).

This is because glucose, due to the inadequate amount of insulin present in the bloodstream, does not diffuse easily through the pores of the cell membrane, and so the osmotic pressure is increased in the extracellular fluid causing the transfer of water out of the cells, promoting extra dehydration and also intracellular. This fact can contribute significantly to the occurrence of circulatory shock, requiring, in order to recover homeostasis, a greater fluid intake by the affected subject.

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For Guyton (1998), most of the pathological characteristics of DM can be attributed to one of the following main effects resulting from the lack of insulin: a) Less use of blood glucose as an energy substrate by the body's cells, resulting in an increase in its concentration of 300 to 1,200 mg/dl; b) Increased mobilization of fats from adipocytes, causing an abnormal lipid metabolism and facilitating the deposition of cholesterol in arterial walls, causing atherosclerosis; and c) Abnormal protein depletion in body tissues, due to its high conversion to carbohydrates.

There are several types of DM, all caused by a complex interplay of genetic and phenotypological factors related to environmental aspects and the individual's lifestyle, the most common being Types 1a (DMT1a) and 1b (DMT1b), Type2 (DMT2), and also the Gestational Type (DMTG) (SOCIEDADE BRASILEIRA DE DIABETES - SBD, 2016). Other types of DM are less common, among which are the situations of genetic defects in beta cells, in the action of insulin, also in the exocrine pancreas, infections, and even chemically induced DM or other genetic syndromes (LIMA et al., 2010).

DMT1a (autoimmune) is the result of immune destruction of pancreatic beta cells, rendering the pancreas incapable of producing the hormone insulin and thus increasing the susceptibility of the subject affected by blood ketoacidosis, which can lead to coma and death. The destruction of beta cells is usually caused by an autoimmune process, which can be detected by circulating autoantibodies such as "anti-glutamic acid decarboxylase" (anti-GAD), "anti-islets" and "anti-insulin" , the same being sometimes associated with other autoimmune diseases such as “Hashimoto's thyroiditis”, “Addison's disease”, and even “myasthenia gravis” (BERTONHI & DIAS, 2018).

For the authors mentioned above, this type of DM is diagnosed mainly in childhood or adolescence, with a prevalence rate of around 5-10% of the identified cases, with its peak incidence occurring in individuals between 10 and 14 years of age, or even slowly progressive in adults, in this case being called “LADA” - *latent autoimmune diabetes in adults*. DMT1b (idiopathic) has no defined cause and corresponds to cases in which there is no presence of immune markers (MOREIRA & CARVALHO, 2016).

DMT2 is characteristic of subjects whose pancreas normally produces insulin, but due to the decrease in its action, their cells are unable to use it properly, and this condition is characterized as insulin resistance. That is, there is no effective hypoglycemic action of insulin, and thus there is a decrease in glucose uptake by cells, resulting in increased hepatic glucose production, which further contributes to the increase in blood glucose and is associated with high insulin levels. in the blood (FIGUEIREDO & RABELO, 2009).

This type of DM corresponds to approximately 90-95% of diagnosed cases and manifests itself mainly in adults, with its main causes being related to obesity and the sedentary lifestyle of the symptomatic individual (SOCIEDADE BRASILEIRA DE DIABETES, 2016).

DMTG is defined as the change in plasma glucose levels of pregnant women, almost always manifesting itself in the second or third trimester of pregnancy, with this hyperglycemic condition tending to disappear after delivery, but with high probabilities of its return later. The prevalence of this condition varies between 1 and 14% of pregnancies, with excessive weight gain during pregnancy being one of the risk factors for its development, which can cause problems for both the mother and the fetus (SOCIEDADE BRASILEIRA DE DIABETES - SBD, 2009).

Regardless of its typological classification, DM is one of the most relevant chronic non-communicable diseases today, with its prevalence increasing over the last decades due to factors such as: a) Sedentary lifestyle; b) Expanded urbanization; c) Obesity; d) Inadequate food; and e) Population aging, among other issues (SCHMIDT et al., 2009).

According to the Brazilian Diabetes Society - SBD (2016), about 382 million people have DM worldwide and these numbers are expected to reach 471 million in 2035. In 2015 in South and Central America, 247,500 people died from diabetes (122,100 men and 125,400 women), with over 42.7% of these deaths occurring in people under the age of 60, and more than half of these deaths (130,700) occurred in Brazil (INTERNATIONAL DIABETES FEDERATION - IDF, 2015).

Based on data from the Ministry of Health, Bertonhi & Dias (2018) published that the frequency of prior medical diagnosis of DM in Brazil is 6.9% in men and 7.3% in women, and that when comparing the data related to the theme in the period from 2008 to 2015, in seven years the incidence of DM increased from 5.8% to 7.1%, and in both sexes, this disease became more common after 45 years of age.

Thus, it is well known that DM, in Brazil and worldwide, stands out for its importance as a public health problem, as well as that its epidemiological impact is expressed by increasing population mortality and morbidity rates, the latter being associated with related sequelae to visual disturbances, blood arterial hypertension, nephropathy, neuropathy, lower limb amputation, sexual impotence,

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cerebral cardiocirculatory and vascular disorders (AMERICAN DIABETES ASSOCIATION - ADA, 2000).

Although better understood, and even though new drugs have appeared for the treatment of DM in recent years, it seems that its control remains unsatisfactory both in government institutions, as there is a lack of efficient public policies, as well as by the vast majority of the population.

In this context, in order to seek to minimize or even prevent the effects of DM on the body of individuals affected by this pathology, different strategies for therapeutic interventions are increasingly proposed, among which, due to their effectiveness, low cost and minimum risk, they stand out. whether the subject's behavioral changes in relation to dietary factors and also to the practice of regular physical activity (ERIKSSOM & LINDGARDE, 1991; HELMRICH et alli, 1991; MANSON et alli 1992; LYNCH et alli, 18996; PAN et alli, 1997; ERIKSSOM & LINDGARDE, 1999; TUOMILEHTO et alli, 2001; MAYER & COSTACOU, 2001; KNOWLER et alli, 2002; Lyra et alli, 2006).

With regard to this last factor, that is, the regular practice of physical activities by symptomatic subjects of DM, when it comes to considerations about the volume, intensity, repetition and frequency of such practice, it still seems not possible to establish a definite academic opinion on the subject, making it clear that the subject still needs a greater number of investigations.

On this subject, Rodrigues de Almeida et alli (1999; 2018) warns of the importance of detailed planning of the practice of physical activity, showing four basic aspects during its execution: a) intensity or quality; b) volume or duration; c) frequency; and d) repetition of stimuli. The aforementioned author suggests that an individual's systemic functional organic condition will only be expanded when such variables are properly planned and bandaged in a scientifically methodized work system in relation to the prescription and control of training loads, which he calls “physical exercise” .

This admitting, and in view of the foregoing, this research intends to collaborate for the development of non-drug strategies that prove to be efficient in the prophylaxis or therapy of DM, investigating what changes are caused by a physical exercise program scientifically methodized in the glycemic values of individuals with type-2 DM, undergoing initial pharmacological treatment and diet therapy.

II. MATERIAL AND METHODS

2.1. Population and sample

The population of this study was composed of sedentary subjects of both genders and with DMT2, who, in addition to the prescribed drug treatment and the recommended diet therapy, for medical advice should also begin the regular practice of physical activities. Initially, a first personal contact was made with those interested in participating in this study, all of whom frequent a physical space open to the general public for leisure and physical activities, located in the city of Porto Velho, capital of the State of Rondônia, Amazon Brazilian, entitled “Alternative Space”, to explain the relevance of the research to them, as well as requesting them to sign a free and informed consent term.

The sample consisted of 39 subjects undergoing drug treatment and diet therapy, who before starting the experimental procedure were randomly assigned to two study groups: a) an Experimental Group (EG), composed of 22 individuals who underwent regular experimentation a physical exercise program (PEF); and b) a Control Group (CG), composed of 17 subjects, who during the study were not submitted to any physical exercise routine.

III. TREATMENT OF THE DEPENDENT VARIABLE

3.1. Equipment and standardization of measures

In this study, according to the protocols detailed below, the anthropometric parameters Total Body Weight (PCT) and Height (EST) were initially measured, which together with the informed age were used only to characterize the investigated sample.

1. The PCT, understood as the result of the system of forces exerted by gravity on the total body mass (MATSUDO, 1987), was measured using an electronic scale of the brand Filizola with a capacity of up to 150kg and precision of 1g, and its values are expressed in kilograms - kg. The measurement was performed with the equipment positioned on level ground, being evaluated standing in the center of the platform, in an upright posture and with the head horizontal, the legs in slight lateral distance and the arms relaxed along the body (PETROSKI, 1999) ; and
2. EST, understood as the vertical linear length between the plantar region and the vertex (PITANGA, 2008), was measured using a portable Avanutri stadiometer and accurate to 1 mm, with its values expressed in centimeters - cm. The measurement was obtained with the subject barefoot, the heels, buttocks, the shoulder girdle and the occipital bone in discreet contact with

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the perpendicular ruler. As recommended by standardization, a transverse cursor was slid by the ruler to the vertex, forming a right angle. The reading was carried out with the evaluator in maximum inspiration and with the head directed towards the Frankfurt plan (PETROSKI, 1999).

Then, the Glycemic Index (GI) was measured, the dependent variable of this study, which is understood to be the numerical value that represents the levels of glucose concentration in blood plasma (ROBERGS & ROBERTS, 2009). Measurement was made with fasting subjects using the "FreeStyle Libre" Glucose Monitoring Flash System, consisting of: a) Portable monitor powered by a rechargeable lithium-ion battery, measuring 95mm x 60mm x 16mm and weighing 65g, sample volume of 1 microliter, range for blood ketone interval from 0.00 to 80mmol / L and with measurement via scanning of values between 20 to 500mg/dl; and b) Sensor powered by a silver oxide battery and water resistant, measuring 5mm high x 35mm in diameter and weighing 5g, with a memory of up to 8 hours for storage of the measurement readings,

Data collection followed the following procedures: **a)** initially, before starting physical activity, using a non-allergic adhesive layer, a "FreeStyle Libre" sensor was fixed at the midpoint of the posterior region of the arm of each component subject the sample (mesohumeral point); and **b)** Finally, individually and immediately after the end of the training session, using the portable monitor reader, glucose measurement was carried out by scanning the sensor, in a fast and painless process that takes approximately 1 second.

In order to reduce and even avoid possible failures, during the data collection there was the collaboration of 5 Physical Education professionals, each in possession of a Flash Glucose Monitoring System, who wanted them prior to the day's work, they were responsible for checking the condition of the material to be used, as well as fixing the sensors individually to the sample components.

IV. TREATMENT OF THE INDEPENDENT VARIABLE

4.1. Physical exercise program (PEF)

Before starting the PEF, two physical training sessions were instituted to allow individuals to become familiar with the mechanical aspects of the PEF component exercises, which had a total duration of 8 weeks, during which 3 weekly training sessions were applied, each lasting 60 minutes and held at 2ª, 4ª and 6ª - trade between 7:30 a.m. and 06:00 aM, which are divided into three parts teaching as is detailed below:

Preparatory Part: Aiming to increase blood supply to muscle tissues in general, initially a dynamic stimulus of the continuous type was used, which was performed in the form of a vigorous walk for 3 minutes. Subsequently, aiming to stretch the muscle groups to be most requested during training, as well as to improve the subjects' joint mobility, stagnant exercises were used and located for 7 minutes, in which individuals voluntarily sought in the anteroposterior and lateral directions, the limit functional mobility of the joints of the wrist, elbow, shoulder, hip, knees and ankle, remaining in the borderline position for a time of 10 - 12 seconds, and repeating the procedure in each joint for 2 times sequentially and with an interval of 5 seconds between them (NUNES, 1998).

Main Part: In order to promote morphological and functional improvements in the cardiovascular system, a dynamic stimulus of the continuous type was used, which was performed in the form of vigorous walking, with the intensity of the effort being controlled by the subjective feeling of tiredness (ACSM, 1995). For this, in the first week of work during the training sessions, the subjects placed the perception of fatigue at level 6 (moderate), performing the prescribed physical activity for 30 minutes, progressing weekly in one unit until reaching level 8 and increasing the time of physical effort for 40 minutes. The workload remained with this quality of training for 4 weeks, and then, in the eighth and last week of the PEF, the rate of physical effort was raised to level 9 (strong) for 40 minutes.

Final Part: Ending the training session and in order to assist in the removal of exudates from cell combustion, immediately after the end of the 40 minutes related to the main part, without interruption the subjects continued to walk for another 3 3 minutes, now in a moderate way , gradually decreasing the intensity until the displacement is smooth. Subsequently, with the objective of stretching the most requested muscle groups in the training, for 7 minutes the individuals were repeated the same stagnant exercises in a localized manner used at the beginning of the training session, performing the same procedures and in the same joints.

V. DATA STATISTICAL ANALYSIS

In this experiment the data were analyzed using the following procedures:

1. initially, descriptive statistics were performed to characterize the sample;

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2. subsequently to detect possible significant differences in the scores related to the physical characteristics of the SG and CG, the Student's "t" test was used for independent samples; and
3. finally, to compare the values of the IG between the pre and post-tests during the experimental period, the Student's "t" test was used for dependent samples. The data were processed and analyzed using the computerized statistical package "STATISTICA for windows" Version 4.3 from Starsoft Incorporation, looking for a significance of p <0.05.

VI. RESULTS AND DISCUSSION

In order to characterize the sample, Table 1 presents the result of the "Student's t test for independent samples" (mean values and their respective standard deviations), for the variables: Age (ID), Height (EST) and Total Body Weight (PCT) of the experimental (EG) and Control (CG) groups, compared to each other before starting the experiment. The statistical treatment showed significant differences between the scores of all the variables analyzed, demonstrating the heterogeneity of the sample.

Table 1: Physical characteristics of the sample.

Variables	Experimental Group	Group Control	t	P
Age years)	58.2 ± 9.42	51.2 ± 7.30	2.08	0.048*
Stature (cm)	170.7 ± 5.93	164.5 ± 7.85	2.42	0.022*
Weight (kg)	75.2 ± 5.99	69.9 ± 5.53	2.45	0.020*

***Significant at p <0.05**

In line with the objectives of this study, Table 2 presents the analysis of the "Student's t test for dependent samples" (mean values and their respective standard deviations), of the Glycemic Index (GI) of the SG and CG, in which it is observed that the scores related to the GI presented by the subjects that are part of both groups investigated, between the beginning and the end of the experiment showed statistical significance at the level of p <0.05.

Table 2: Values in mg / dl of the sample's IG at the beginning and end of the experiment.

Study Groups SG	n	Glycemic Index – GI (mg/dl)			
		Pre-Test	Post-Test	t	P
Experimental Group - EG -	22	145.88 ± 11.46	114 .35 ± 9.81	9.43	0.000*
Control Group - CG -	17	123.83 ± 4.96	109. 16 ± 4.60	8.94	0.000*

***Significant at p <0.05**

Nevertheless, it can also be seen that the mean value of the SG decreased by 29.53 mg / dl and that of the GC decreased by 14.67 mg/dl, scores that represent a percentage variation in the glycemic index of 20.52% in the EG and 11.41% in the CG, indicating a greater functional improvement in the SG of the SG during the experiment, this fact being better visualized in the figure below.

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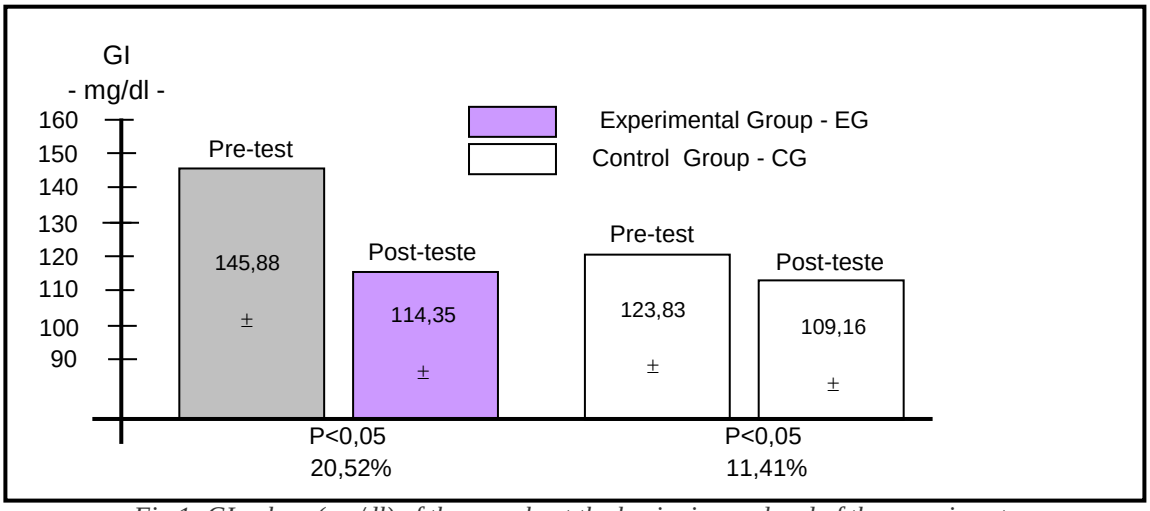

Fig.1: GI values (mg/dl) of the sample at the beginning and end of the experiment.

Thus, in view of the above, it can be assumed that the prescribed physical exercise program was responsible for the increased improvement in the GI of the subjects that make up the SGE1, which confirms the results obtained by Luciano & Bessa Lima (1997), who published about the beneficial effects of exercise and the improvement in glucose uptake that is increased during exercise, even with low insulin levels, and is also corroborated by Pratley et alli (2000) who after studying for 9 months the effects of aerobic exercise in the elderly , concluded that this type of training significantly reduces insulin concentrations stimulated by glucose.

In this sense, for some time now, other authors have shown that the effects of physical exercise in type 2 diabetic individuals are characterized by the notable increase in the use of glucose for energy production, unlike individuals with the same pathology who do not practice physical activity (Gumbiner, 1999; Leong & Wilding, 1999; Dela et alli, 1997); Hickner et alli, 1999).

Zinker ett alli (1999) in a research investigating the insulin sensitivity of individuals with DMT2, carried out an experiment with 3 study groups, one group, group 1, undergoing physical exercises and without using medication to treat diabetes , and the other two groups only undergoing drug treatment (metformin and troglitazone, groups 1 and 2 respectively), and without practicing physical activity. At the end of the experiment, they observed that the best results were presented by the group that only did physical activity in contrast to the other study groups analyzed.

Silva & Lima (2001) in an experiment with symptomatic individuals of DMT2 under treatment with oral antidiabetic and insulin, submitted them to a program of physical exercises of 10 weeks duration, with 4 weekly sessions of 60 minutes each, and at the end they observed that all subjects in the sample had a significant hypoglycemic effect ($p < 0.05$) in response to physical exercise, attesting to the importance of their daily performance for the control of the thematized pathology.

VII. CONCLUSIONS

According to the problematization of this research, as well as considering the analysis and discussion of the results found here, there is a statistically significant behavior between test and retest in the scores of both the SG and the CG ($p < 0.05$), being that the best values were found in the EG, which allows us to assume the positive effect of the independent variable of this study in reducing the GI of subjects with DMT2, a fact demonstrated by the quality of the training loads of the prescribed PEF (volume, intensity, frequency and repetition) , which in association with drug treatment and food control, proved to be a valuable complementary tool in the treatment of DMT2.

In view of these findings and aiming to extend the line of research of this investigation, it is suggested to carry out further research analyzing this time the effects of resistance training on the thematized population, at different intensities of physical effort and with a larger sample grouped by range age. It also seems important to us to study the psycho-social factors presented by the population in question, which should be considered in the development of public policies aimed at comprehensive care for people with DMT2, as well as to identify pedagogical practices that are capable of motivating their adherence. individuals in intervention programs, and thus making compatible, in addition to knowledge, also efficient personal actions for health promotion.

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