Association between blood lactate and heart rate variability in type 2 diabetics during resistance exercise

Associação entre o lactato de sangue e a variabilidade da frequência cardíaca em diabéticos do tipo 2 durante o exercício de resistência

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ABSTRACT
Introduction: During exercise, the branchs sympathetic and parasympathetic, central and peripheral mechanisms interact inducing adjustments on of heart rate (HR) responses according to the intensity, which can be changed in the presence of type 2 diabetes mellitus. Those changes may occur during the time after resistance exercise recovery. Objective: To to compare the method of determining the LA by the blood lactate dosage and HRV, RMSSD and SD1 rates, in individuals with DM2. Results and conclusion: The results of our study show that you have more than 30% of 1RM for the GC as well as for the DM2 group, the latter containing more expressive when compared also with as 40 and 50% loads of 1RM. What is a HRV was observed a significant reduction in relation to the rest in the RMSSD and SD1 indices of CG and soon without a GM2 group, showing in both groups a tendency of stabilization after 30% of 1RM and not being possible to find the LA, determined by HRV, in this specific population submitted to an incremental protocol of resisted lower limb exercise.

Keywords: autonomic modulation, heart rate variability, diabetes mellitus type 2, anaerobic threshold, resistance exercise.

ABSTRACT
Introdução: Durante o exercício, os ramos simpáticos e parassimpáticos, os mecanismos centrais e periféricos interagem induzindo ajustes nas respostas da frequência cardíaca (FC) de acordo com a intensidade, que pode ser alterada na presença de diabetes mellitus tipo 2. Essas alterações podem ocorrer durante o tempo após a recuperação do exercício de resistência. Objectivo: Comparar o método de determinação da LA pela dosagem de lactato de sangue e as taxas de VHS, RMSSD e SD1, em indivíduos com DM2. Resultados e conclusão: Os resultados do nosso estudo mostram que se tem mais de 30% de 1RM para o GC, bem como para o grupo DM2, este último contendo mais expressivo quando comparado também com 40 e 50% de cargas de 1RM. O que é um HRV foi observado uma redução significativa em relação ao resto nos índices RMSSD e SD1 de CG e em breve sem um grupo GM2, mostrando em ambos os grupos uma tendência de estabilização após 30% de 1RM e não sendo possível encontrar o LA, determinado pelo HRV, nesta população específica submetida a um protocolo incremental de exercício resistido dos membros inferiores.

Palavras-chave: modulação autónoma, variabilidade da frequência cardíaca, diabetes mellitus tipo 2, limiar anaeróbico, exercício de resistência**.**

1 INTRODUCTION

Autonomic regulation has been the target of many investigations, through the most varied methods [1,2] among which, the study of heart rate variability (HRV) stands out, method reproducible, non-invasive and low cost, which has been used to quantify the modulation of the autonomic nervous system and to evaluate cardiac autonomic neuropathy [3,4] .

According to studies by Ziegler et al (2005)[5], about 34.3% of people with type 2 diabetes mellitus (DM2) had abnormal HRV results, being even more reduced when nephropathy and / or retinopathy is present [6].

In diabetic individuals, the autonomic control of heart rate (HR) is impaired and this reduces parasympathetic function or increases sympathetic activity favoring the propensity for lethal arrhythmias[3]. It is assumed that at this stage, many individuals will experience changes in test results and initial characteristics of cardiac involvement within five years. The next phase is characterized by parasympathetic denervation and sympathetic compensation, resulting in symptomatic changes in the ANS, whose clinical manifestations become evident [2].

The decrease in HRV predicts all these causes of cardiovascular mortality[7,8] and impaired autonomic function, which may indicate an increased risk for developing cardiovascular diseases. DM2 patients with low HRV, on the other hand, have twice the risk of mortality compared to those with normal HRV [7].

However, autonomic dysfunction cannot always be identified in the resting condition, but it becomes evident during or after physical effort[9], due to the need for complex and intense adjustments mediated by the sympathetic and parasympathetic systems, which can and should be investigated, both during exercise and in the recovery period, as they affect the ability of diabetic individuals to perform daily physical activities and are associated with an increased relative risk of myocardial infarction[10] and sudden death[11].

The increase in sympathetic activity in response to the increase in exercise intensity stimulates the production of catecholamines, resulting in increased blood glucose levels and, consequently, lactate[12] whose blood concentration remains stable until the anaerobic threshold (LA), a moment when production exceeds the organism's removal capacity [13]. During resistance exercise, this point generally occurs at moderate intensities, approximately 30% of 1 maximum repetition (1RM), for both active and sedentary individuals [14]. These findings have contributed to new approaches for prognostic and / or therapeutic purposes with this type of exercise.

The literature states that with increasing exercise intensity, there is a decrease in vagal modulation and an increase in sympathetic activity, that is, a decrease in HRV, as the exercise intensity increases, until reaching a plateau that is related to the lactate threshold[15,16].

However, diabetic individuals generally have intolerance to physical exercise, as a result of altered responses of the sympathetic and parasympathetic systems [4, 17,18] that would normally increase cardiac output and result in targeting blood flow to skeletal muscles efficiently [4]. In general, it has been shown that for diabetic individuals, the increase in HR during exercise is reduced and there is also a reduction during recovery [19].

The gold standard method for investigating metabolic stress during exercise (ie identification of anaerobiosis threshold), and even in the recovery period, is the measurement of blood lactate. About LA and aerobic exercise, there is already a vast literature covering this area and investigating its acute and chronic effects [20, 21, 22].

Recently, the use of HRV indices has been proposed [23, 24, 25, 26, 27], which besides being a safe method and evaluating the autonomic modulation of heart rate in a situation of physical stress, has the advantages of not being invasive, minimizing health risks and having a low cost, when compared to invasive methods that involve blood collection, biochemical measures and the use of high-cost and difficult-to-access devices [28] for clinical use.

Studies [29, 30, 31] have shown that HRV indices are adequate for the study of autonomic modulation during exercise [27] and in the recovery phase [29], even if HR stationarity is not observed in these phases [27]. These indices include the RMSSD, the square root of the mean of the square of the differences between adjacent normal RR intervals [32] and the SD1 index, standard deviation of one of the diagonals of the Poincaré plot [27] both related to parasympathetic activity.

During exercise there is a progressive reduction in the modulation of this autonomic branch [27] and reactivation in the recovery period, which can be identified in short periods [31]. Based on this principle, Sales et al (2011)[28] found high correlations and good agreement between the methods of identifying LA by the blood lactate dosage and by the autonomic indices RMSSD and SD1.

During the ER there is a loss of the steady state of HR due to the progressive increase in effort, favoring the slow, progressive increase and consequent change in its variability. The decrease in HRV according to a study by Marães et al (2003)[33] has been projected as a possible marker of LA in healthy individuals. Lower HRV values are attributed to greater sympathetic activity, which stimulates the production of catecholamines and results in elevated glycemic and lactate levels in the bloodstream [16].

Machado-Vidottiet al (2014)[34] studied healthy elderly people who underwent RE exhaustion tests, their results demonstrated an association between the change in the response pattern in cardiac autonomic modulation, with depreciation of the vagal component, in the 30% load of 1RM both in Upper limb and lower limb ER. This workload according to Sousa et al (2013) is close (27.9% of 1RM) to LA in the elderly.

The recent study by Simões et al (2013)[35] involving healthy young and elderly people, correlated HRV indices with blood lactate responses during RE protocol and, concluded that the HRV responses were consistent with those of blood lactate in relation to the determination of LA during ER in legpress. Therefore, it appears that HRV can also be considered a useful tool in clinical practice to determine the intensity corresponding to LA in ER for both young and elderly individuals (Simões, 2013)[35].

Sales et al (2011)[28] in their study with type II diabetics, during incremental exercise on a cycle ergometer, correlated the HRV threshold, based on the adjustments of the RMSSD and SD1 indexes, the LA and ventilatory threshold. Their results elucidated significant correlations between LA and the HRV threshold and ventilatory threshold. However, this study was not carried out using the RE protocol, which demonstrates that there is a shortage in the literature when LA, HRV and ER are related in diabetic individuals.

In addition, the presence of risk factors for cardiovascular disease such as obesity, hypertension and diabetes can influence the absolute and relative intensities of occurrence of LA (MATTERN et al., 2003)[36]. Thus, the metabolic, cardiovascular and respiratory adjustments involved in the LA process can present changes in their response patterns at lower levels of effort due to weakened health (PASCHOAL & FONTANA, 2011)[37].

However, currently there are few studies that relate the autonomic response, through parasympathetic indices, and the metabolic dynamics of blood lactate during ER performance in patients with Diabetes Mellitus and, since diabetics, as already described, may have the answers of altered autonomic function, it is relevant to study this population to verify, through the proposed method, a correlation between LA, HRV and the occurrence of DM since situations of daily life that require muscular maturity with a strength component, often repeated over time considerable, it becomes critical for people with metabolic changes to sustain them (AACVPR, 2013)[38], which justifies the importance of knowing the repercussions of this effort on the cardiovascular system to minimize the risks. So the aim of this research was to compare the method of determining

the LA by the blood lactate dosage and HRV, RMSSD and SD1 rates, in individuals with DM2.

2 MATERIAL AND METHODS

2.1 SAMPLE

For the sample size calculations, the pilot study was carried out with 8 sample elements taking as reference the difference between the moments of rest and exercise for the RMSSD values. There was an average difference between the moments of exercise and rest of 5.65ms and standard deviation of 3.34ms. Considering a type I error of 1% (0.01) and a power of 90%, a sample of 8 sample elements was estimated. Considering a possible sample loss of up to 30%, a sample of 11 sample elements was considered.

Sample size calculations were performed using Software Primer of Biostatistics verson 7 (Glantz, 2011).

The sample consisted of 14 diabetic individuals, constituting the DM2 group and 10 apparently healthy individuals constituting the control group (CG).

2.2 LOCAL

The research took place on the premises of the Center for Studies in Education and Health (CEES) of Universidade Estadual Paulista - UNESP in Marília - SP.

2.3 ETHICAL ASPECTS

The project was submitted to the Research Ethics Committee Involving Humans, according to Resolution 466/2012 and its Complements of the National Health Council and was approved (opinion nº 083602/2016).

All volunteers were informed about the experimental procedures, as well as the fact that they did not affect their health. They were also clarified about the confidentiality of information and their identities. After reading and agreeing, they signed an informed consent form.

2.4 SELECTION CRITERIA

Subjects with fasting blood glucose> 100 mg / dL (pre-diabetics) and>

110 mg / dL (diabetics) (American Diabetes Association, 2011) and with optimized medication. Those with: diagnosis of diabetes before the age of 30 or gestational; heart, lung and neurological diseases; anemia; pacemaker; smokers; consume

30g / day or more of alcohol; motor limitations that compromise the execution of physical tests; pregnant women; ER practitioners in the last 6 months; menstrual irregularity.

2.5 STUDY PROCEDURES

Blood samples were collected after 12 hours of fasting and analyzed for blood glucose, triglycerides (TG), total cholesterol (CT), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), in addition to addition, medications in use were investigated.

The experiments were carried out in the same period of the day, to standardize the influences of circadian variations on the organism (BILAN et al 2005)[39]. The volunteers wore comfortable clothes the day before and on the day of the tests, were instructed not to drink alcoholic beverages and / or stimulants (tea, coffee, chocolate and others), did not perform strenuous physical activities and ate a light meal at least 2 hours before the tests. On the day of the tests, the conditions related to the volunteer's health status were observed, to verify the occurrence of a regular night's sleep and to confirm that the HR and BP variables were within normal limits. In order to reduce anxiety and expectation on the part of volunteers, familiarization with the test protocol, with the technical group of researchers and with equipment. The experimental room was monitored and maintained at a temperature of 23 ± 2ºC and the relative humidity at 50 ± 10%.

After the interview (personal data and physical activity level questionnaire), pilot tests were carried out with the participants so that they understand the data collection routine, familiarizing themselves previously with the environment and the resources used.

The protocol for data collection was applied in 3 days with an interval between them from 48 to 72 hours. Following is the brief description of each assessment:

Day 1: Blood pressure measurement, anthropometry, HR record and RR intervals at rest and familiarization for the component tests of cardiac autonomic assessment.

Day 2: Collection of HR data and iRR intervals. And on this day, the participant will receive instructions and will be familiarized with the maximum load test (1RM). The maximum load obtained in this familiarization was a reference for the definitive test to determine the 1RM.

Day 3: Maximum load test (1RM): the volunteer performed the 1 RM test (described later in detail). After a 30-minute rest, the volunteer underwent blood lactate thresholds (described in detail later) and HRV. The submaximal loads evaluated corresponded to 10, 20, 30, 40 and 50% of the obtained RM.

2.6 ANTHROPOMETRY AND BODY COMPOSITION

Anthropometric measurements were performed with bare feet, men in shorts and women in shorts and top. The following conditions were respected for the assessment of fat percentage and body composition: minimum interval of three hours after waking up; not having consumed alcohol in the last 24 hours; not having practiced physical exercises;

Not having eaten food or caffeine in the last 4 hours; having ingested 2 to 4 glasses of water in the last 2 hours before the test. Body mass was measured using an anthropometric scale (Welmy, São Paulo, Brazil), which has an accuracy class 3. To check height, a stadiometer was used and the participants were barefoot and with their heads in an orthostatic position. From these data, the Body Mass Index (BMI) was calculated using the formula: body mass (kg) / height2 (m) (WHO, 2000)[40]. Measurements of waist and hip circumference were performed with the individual standing with a relaxed abdomen and relaxed arms beside the body. A measuring tape with a precision of 1 mm was used, which was placed horizontally on the skin, positioned at half the distance between the last ribs and the iliac crest, for the measurement of the waist circumference, and in the region with the largest protuberance of the buttocks for the measurement of the hip circumference (TAYLOR et al 2000)[41]. From these measurements, the ratio between them to obtain the waist-to-hip ratio was calculated.

A bioimpedance body composition analyzer was used. (Biodynamics, 450 class I TBW, São Paulo, Brazil) The volunteer remained on the stretcher in the supine position and the electrodes were positioned as follows: on the right foot, distal electrode at the base of the middle finger and the proximal electrode between the medial and lateral malleoli; in the right hand, distal electrode at the base of the middle finger and the proximal electrode coinciding with the styloid process and the percentage of fat was analyzed.

2.7 HR AND IRR RECORDING AND ANALYSIS OF CARDIAC AUTONOMIC MODULATION AT REST

The HR and the instantaneous RR intervals were recorded during the protocol using a previously validated digital telemetry system [42, 43], which consists of a transmitter positioned at the height of the xiphoid process and a monitor / receiver (Polar RS800CX, Polar ElectroOy, Kempele, Finland). The system detects ventricular depolarization, which corresponds to the R wave of the electrocardiogram, with a sampling frequency of 500 Hz and temporal resolution of one millisecond [44]. Initially, the subject remained

seated at rest, with minimal movement and without talking, until the physiological variables stabilized. Subsequently, records were made for 20 minutes in spontaneous breathing in the supine position.

The data were transmitted to a computer using Polar PrecisionPerformance software (version 3.02.007) and converted into text files that were analyzed only for series with more than 95% sinus beats and 256 more stable points were selected (Kubios Software HRV, version 2.0, University of Kuopio, Finland).

In the time domain, the following statistical calculations were made: mean and standard deviation of the instantaneous HR values in beats per minute (bpm); mean and standard deviation of RR intervals (iRR and SDNN) in milliseconds (ms); square root of the mean of the squares of the differences between the successive normal intervals (RMSSD), expressed in ms; and the percentage of adjacent iRR with a difference in duration greater than 50 ms (pNN50). The last two indices are representative of parasympathetic modulation [3, 45, 46].

For the analysis in the frequency domain, the cubic splines interpolation method with a frequency of 4 Hz was applied and the spectral power density of the most stable stretch was calculated using the Fast Fourier Transform (TRF) that decomposes the signal in the following bands: high frequency (AF - 0.15 to 0.4 Hz) which corresponds to respiratory and vagus (parasympathetic) modulation over the heart; low frequency (BF - 0.04 to 0.15Hz) which represents sympathetic and parasympathetic modulation, but with a predominance of sympathetic; and the BF / AF ratio that represents the sympathovagal balance[3, 45, 46]. BF data were presented in absolute values (ms2) and AF data in normalized units (un). Normalized data were calculated by dividing the power spectral density of a given band (ie AF) by the total power, subtracting the very low frequency band and multiplying by 100 [47].

The non-linear analysis was obtained by the Poincaré plot, which is a map of points in Cartesian coordinates, where each point is represented, on the horizontal X axis (abscissa), by the previous normal RR interval and, on the vertical Y axis (ordered), for the next RR interval. The standard deviation of the perpendicular points and along the identity line give rise to the SD1 and SD2 indices, respectively. The SD1 index measures the standard deviation of distances from points to the diagonal y = x, is related to short-term variability, is influenced by respiratory sinus arrhythmia and represents parasympathetic activity. SD2 measures the standard deviation of the distances from the

points to the line y = -x + RRm, where RRm is the average of the RR intervals, with long-term variability and reflects the global variability.

2.8 MAXIMUM LOAD TEST AND DETERMINATION OF LA AND HRV

Previously, a warm-up was performed as follows: a) 5 minutes of cardiorespiratory exercise on a cycle ergometer with an intensity of 50% of the reserve HR [(220 - age - rest) x 0.5) + rest)]; b) 2 sets of 15 seconds of stretching for each of the muscle groups to be tested. c) 10 repetitions of the exercise with the weight of the device, without adding load. Tests for determination of MR were started five minutes after heating.

Then, a maximum load test (1-RM) of knee extension (Roman table) was performed, where the volunteer remained seated as hips and knees at 90º of flexion, with the back resting on the back of the machine, foam pads on the arm lever supported on the front of the legs, two centimeters above the lateral malleoli of the ankles. To determine the maximum load, the weight obtained in the familiarization of the test was the initial one. The resistance was progressively increased every 5 kg until the volunteer was unable to complete the subsequent attempt, and when this occurred, 50% of the added load was subtracted in the last attempt. A maximum of five attempts were made, with three-minute retreat intervals between attempts,

The LA determination test was performed after thirty minutes of determining the 1RM load. The individuals performed 20 repetitions during one minute with 10, 20, 30, 40 and 50% of the load obtained in the 1RM test with a 3-minute recovery interval between them. Right after the completion of each submaximal load, in the first minute, asepsis was performed with alcohol in the ear lobe and, using a lancet and disposable procedure gloves, the first drop of blood was discarded and quantified (mMol.L) of the lactate using an analyzer (Accutrend Plus - Roche, USA). The object of study with this procedure is to observe the loss of linearity with an abrupt and exponential increase in the lactatemia curve, which will be considered to be the LA [48].

Throughout the performance of the tests with exercise, the iRR (ms) and HR (bpm) data were collected continuously, beat by beat. To determine the HRV threshold, the SD1 indices were used, when the intensity in which the smallest difference occurred between two consecutive stages, the HRV-SD1 threshold was determined [49] and the RMSSD when it presents stability between two consecutive phases [23].

BP data were obtained using the auscultatory method using a stethoscope and sphygmomanometer according to the recommendations of the VI Brazilian Guideline for Hypertension [50].

2.9 TESTS WITH LOADS BELOW AND ABOVE THE LA

After warming up, as previously described, individuals remained at rest in the test posture until HR stabilized and performed two voluntary contraction tests, with 10% below and above LA, lasting one minute each, maintaining breathing spontaneous and without apnea.

The equipment and methods of collecting RR intervals and measuring blood pressure were as previously described. However, the following moments were analyzed: a measurement at pre-test rest; a measure in the final 30s of the year; a measurement in the 1st, 2nd and 3rd minute of the recovery period.

The following heart rate data were obtained: a) HR at rest: average HR obtained in the 30 s of rest of the respective test; b) Variation of resting HR / exercise: difference between resting HR and instantaneous HR obtained at 10s, 20s, 30s, 40 and 60s of the exercise;

c) Percentage of reserve HR (maximum estimated HR for age - resting HR), reached during the resisted tests; d) Variation of HR exercise / recovery: difference between the highest HR value at the end of the exercise and the instantaneous obtained at 60s, 120s and 180s of the recovery period.

The following HRV data were obtained: a) SD1 and RMSSD index: last 30s of pre-effort rest; last 30s of the year; sections 30-60s, 90-120s and 150-180s of the recovery period; b) Adjustments of the SD1 and RMSSD rest-exercise indices: difference between the respective data obtained during exercise and rest; c) Adjustments of the SD1 and RMSSD exercise-recovery indices: difference between the respective data obtained during the exercise and the recovery.

2.10 DATA ANALYSIS

The variables are described by the distribution of absolute (f) and relative (%) frequency for qualitative variables, and by the mean, standard deviation and standard deviation (95% CI) for quantitative variables. The variations are described by the delta variation (Δ) which corresponds to the difference between the measurement moments. The normality distribution was verified by the Shapiro-Wilk test with Liliefors correction.

Pearson's test was performed to analyze the correlation between lipid profile, HR and HRV. To compare the values of HR, RMSSD, SD1 and lipid profile regarding the presence of morbidity, the t test for independent samples was performed. An Anova of Repeated Measures was carried out to analyze the effect of the group (diabetic and control), the moment (rest, overload and recovery) and the interaction. Levene's test was used to test the homogeneity of variances. The Box M test was used to verify whether the covariance matrices of the observed dependent variables are the same for both groups and the Mauchly's test was used to test the sphericity hypothesis. In case of rejection of the sphericity hypothesis, the analyzes will be based on the Greenhouse-Geisser multivariate test. When the interaction effect was significant, the Bonferroni multiple comparison test will be performed to find the differences. The level of confidence adopted was 5%. The data were analyzed using SPSS software version 24.0 for Windows. The Box M test was used to verify whether the covariance matrices of the observed dependent variables are the same for both groups and the Mauchly's test was used to test the sphericity hypothesis. In case of rejection of the sphericity hypothesis, the analyzes will be based on the Greenhouse-Geisser multivariate test. When the interaction effect was significant, the Bonferroni multiple comparison test will be performed to find the differences. The level of confidence adopted was 5%. The data were analyzed using SPSS software version 24.0 for Windows. The Box M test was used to verify whether the covariance matrices of the observed dependent variables are the same for both groups and the Mauchly's test was used to test the sphericity hypothesis. In case of rejection of the sphericity hypothesis, the analyzes will be based on the Greenhouse-Geisser multivariate test. When the interaction effect was significant, the Bonferroni multiple comparison test will be performed to find the differences. The level of confidence adopted was 5%. The data were analyzed using SPSS software version 24.0 for Windows. When the interaction effect was significant, the Bonferroni multiple comparison test will be performed to find the differences. The level of confidence adopted was 5%. The data were analyzed using SPSS software version 24.0 for Windows. When the interaction effect was significant, the Bonferroni multiple comparison test will be performed to find the differences. The level of confidence adopted was 5%. The data were analyzed using SPSS software version 24.0 for Windows.

3 RESULTS

3.1 AUTONOMIC MODULATION AT REST

HRV data at rest are shown in table 3.

Table 1.Heart rate variability data at rest.

	GC (n10)		DM2 (n14)		
	Average	DP	Average	DP	p-value
SDT_RR	24.15	8.17	20.63	7.81	0.297
MeanHR	71.04	6.01	74.78	8.87	0.261
RMSSD	17.62	8.47	14.49	5.90	0.296
NN50	5.30	10.04	1.29	2.23	0.244
Pnn50	2.08	3.92	0.51	0.87	0.242
RR_trian	6.62	2.02	5.53	1.58	0.152
Tinn	112.00	44.55	91.07	45.54	0.275
LF_ms	227.80	194.17	113.64	100.19	0.072
LF_nu	59.45	16.07	49.68	20.57	0.224
HF_ms	158.50	147.45	113.36	114.71	0.408
HF_nu	40.53	16.06	50.26	20.59	0.226
LF_HF	2.04	1.77	1.37	1.05	0.256
SD1	12.48	6.00	9.47	4.89	0.189

Note: * p≤0.05 significant difference between groups for independent t test; ** p≤0.05 difference significant difference between groups for the Mann-Whitney test.

3.2 AUTONOMIC MODULATION DURING EXERCISE AND BLOOD LACTATE VALUES

Table 2. Comparison of the mean and standard deviation of the RMSSD at rest (R) and in loads of 10 to 50% of 1 RM for Diabetics (DM2) and non-diabetic control.

GC (n10)			DM2 (n14)		The new (p-value)		
Average		DP	Average	DP	Group	Time	Interaction
RMSSD_Rep10		16.67.6	14.3	7.3			
RMSSD_10		11.6r6.1	12.6	7.2			
RMSSD_20	9.9r	5.5	12.9	6.3	0.444	0.002 *	0.109
RMSSD_30	10.6	7.4	11.8	6.1			
RMSSD_40		10.57.2	11.2	5.7			
RMSSD_50	9.3	7.3	10.5	5.2			

Note: * p≤0.05 significant effect of the group; r significant difference within the group in relation to rest by the Bonferroni Post-Hoc test.

Table 3. Comparison of mean and standard deviation of SD1 at rest (R) and in loads of 10 to 50% of 1 RM for Diabetics (DM2) and non-diabetic control

GC (n10)		DM2 (n14)		The new (p-value)		
Average	DP	Average	DP	Group	Time	Interaction
SD1_Rep10	12.65.7	9.55.0				
SD1_10	8.4r4.4	8.94.9				
SD1_20	7.1r4.0	9.14.3				
SD1_30	7.6r5.3	8.34.3	0.853		0.029 *	0.049 **
SD1_40	7.35.3	8.13.9				
SD1_50	6.75.1	7.73.6				

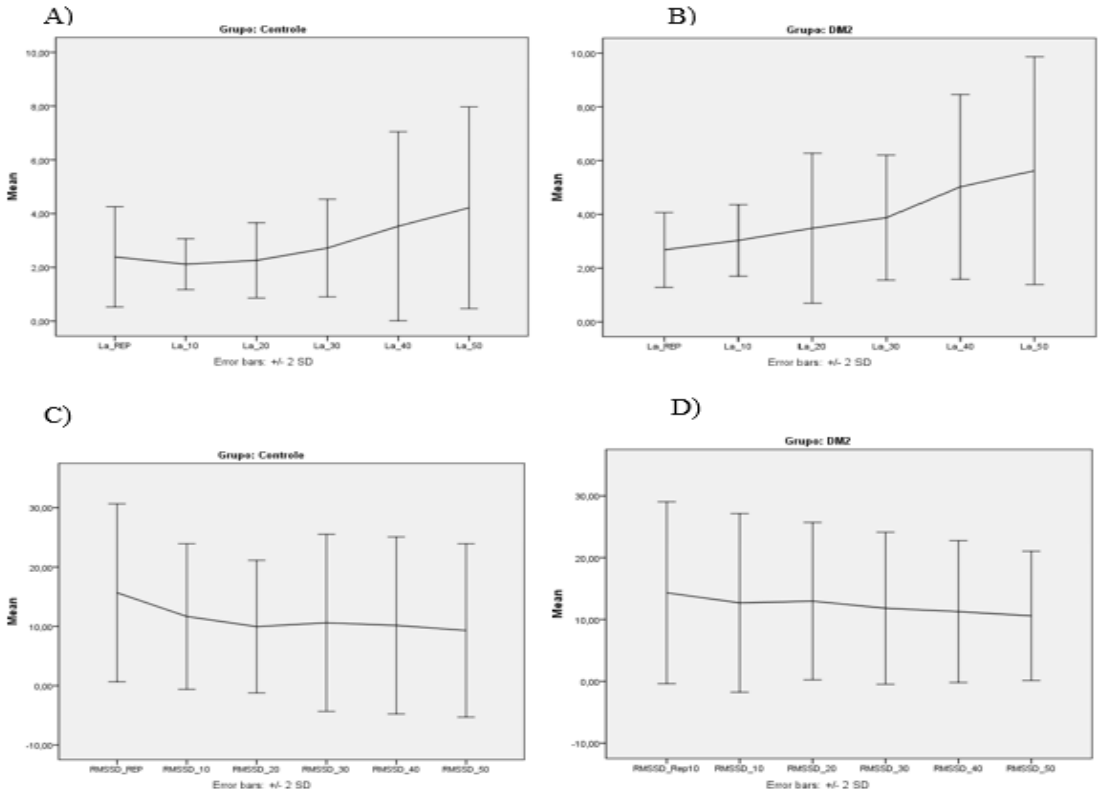
Note: * p≤0.05 significant effect of the group; ** p≤0.05 significant effect of time; c significant difference within the group in relation to the load by the Bonferroni Post-Hoc test; r significant difference within the group in relation to rest by the Bonferroni Post-Hoc test.

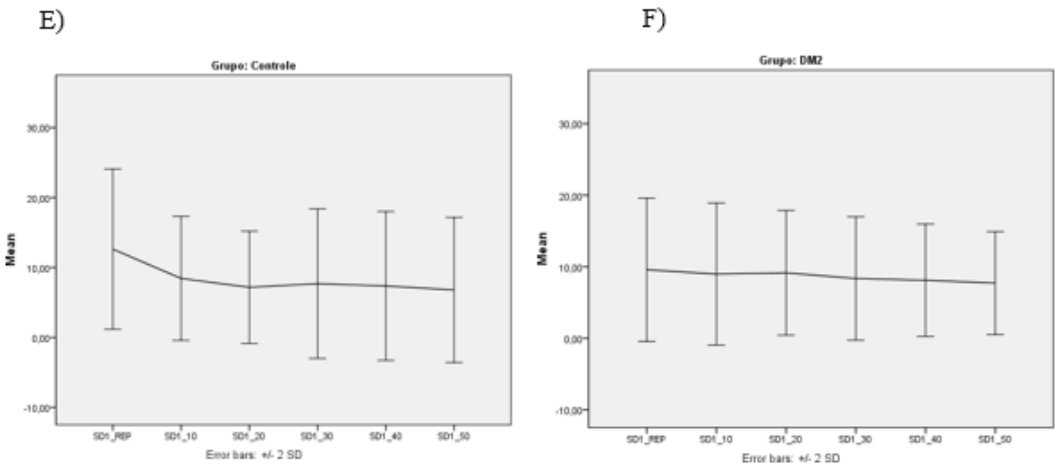
Table 4. Values of mean and standard deviation of blood lactate at rest and during loads of 10 to 50% of 1RM for Diabetics (DM2) and non-diabetic control.

GC (n10)			DM2 (n14)		The new (p-value)		
Average		DP	Average	DP	Group	Time	Interaction
La_REP	2.3	0.9	2.6	0.6			
La_10	2.1c	0.4	3.0†,CD	0.6			
La_20	2.2c	0.6	3.4†,CD	1.3			
0.018 *	0.0001 *						0.716
La_30	2.7c	0.9	3.8 †r, c, d	1.1			
La_40	3.5	1.7	5.0r	1.7			
La_50	4.2	1.8	5.6r	2.1			

Note: * p≤0.05 significant effect of the group; c significant difference within the group in relation to the 50% load by the Bonferroni Post-Hoc test; d significant difference within the group in relation to the 40% load by the Bonferroni Post-Hoc test; r significant difference within the group in relation to rest by the Bonferroni Post-Hoc test. † significant difference in relation to the Control group by the Bonferroni Post-Hoc test.

Figure 3. Data expressed as mean and standard deviation. Behavior of the variables during the percentage load increase of a maximum repetition. Graphs A and B respectively represent the lactate values of GC and GDM2 at rest and during submaximal loads of 10% to 50%. Graphs C and D respectively represent the values of the RMSSD index of the CG and the DM2 group at rest and during submaximal loads of 10 to 50%. Graphs E and F respectively represent the SD1 index values of the GC and GDM2 at rest and during submaximal loads of 10 to 50%.





4 DISCUSSION

As shown in Table 1, the HRV indices at rest were reduced in both groups. In the study by Stein et al (1997)[51], elderly and healthy men presented RMSSD of 22ms and in the study by Novais (2006)[52] the healthy sample presented 22.7ms, our sample presented values slightly below these (17.6), however it must - taking into account the most advanced age of our sample as well as the sedentary lifestyle of individuals in this group. In the DM2 group, the RMSSD values were reduced as expected, due to changes in the pathology itself plus the non-practice of physical activity.

Our results showed that both indexes, in the control group, showed a significant decrease in RMSSD in 10 and 20% and SD1 in 10, 20 and 30% of 1RM when compared to rest. This regressive character, as the loads increase, represents a decrease in parasympathetic activity and a predominance of sympathetic activity over the sinoatrial node [53, 33].

Lima and Kiss (1999)[16] pointed out in their study that HRV decreased progressively in healthy men submitted to incremental loads on the exercise bike and that from 50% it tends to stabilize. Similar results were found in our study, in which the HRV values were reduced as the load increased in the resistance exercise, but it tended to stabilize from 30% of 1RM, both in the CG and in the DM2.

However, in the DM2 group, no significant differences were found between the loads proposed by our protocol. The values of 10 to 50% of 1RM, when compared to rest, did not show considerable reduction. A plausible justification for both indices not showing attenuation is that, as explained by Kraus et al (2002) [54] and Must (1999)[55], high levels of glucose cause damage to peripheral nerve fibers, causing changes in the

autonomic nervous system of these individuals and as exposed by the study by Ziegler et al (2005)[5], about 34.3% of people with DM2 show abnormal HRV results.

Research by Voss et al (2016)[56], Liao et al (1998)[57] and Howorka et al (1997)[58] also pointed out that diabetic patients commonly present silent involvement of the SNA branches, affecting the small fibers of the CNS and SNP, characterizing alteration and reduction of HRV.

Pagkalos et al (2007)[59] reports in his study the changes in HRV presented by diabetic individuals with and without diabetic neuropathy during aerobic exercise, also evidencing that in this population there are changes in the responses of the cardiac autonomic nervous system to exercise. In view of these findings and knowing that the DM2 pathology is capable of altering HRV both at rest and during physical exercise, the results of this study may suggest that in this specific population the HRV adjustments are altered.

HRV has been used to identify the intensity of effort where the first threshold of physiological transition occurs, defined as LA [60, 27]. This is possible through the balance between vagal and sympathetic ANS activity, thus the HRV threshold (LiVFC) is considered a marker of cardiac parasympathetic decrease and a sympathetic accentuation [61].

The study by Sperling (2015)[62] submitted coronary disease to progressive resistance exercise in the leg-press and aimed to determine the LA by HRV in this population. The LA, considered by the blood lactate, was found in 30% of 1RM, agreeing with the our results, while the HRV responses were consistent with the blood lactate responses, concluding in this study that the determination of LA through the HRV indices was effective in this population. Corroborating these results, a recent study by Simões et al (2016)[63] found similar results in coronary disease individuals, showing that HRV is an effective tool for determining LA.

Novais (2006)[52] submitted infarcted individuals to an incremental cycle ergometer protocol and also proposed to identify the LA by HRV, the results found in this study proved to be effective in identifying the pattern of change in the responses of the studied variables allowing the quantification of the LA by HRV indices.

With this objective in mind, Simões (2010)[23] found that it is possible to identify the transition point of aerobic-anaerobic metabolism, both by means of lactacidemia and by HRV in healthy elderly people submitted to resistance exercise.

When we observe the results of the present study, we perceive an agreement in the identification of LA by blood lactate with the studies previously mentioned, however, when looking at figure 1, we perceive an attenuated response of HRV indices, after 30% of 1RM in both CG and DM2 , it is not possible to identify, in this study, the LA through the HRV indices, using the three methods found in the literature: Lima & Kiss (1999)[60] criterion, identified in the first exercise intensity to present SD1 below 3ms on the curve of decrease in HRV as a function of intensity; Tulppo et al (1998)[27] criterion, which considers LiVFC to be the first stage in decreasing the curve, in which the difference between the SD1 of two consecutive stages is less than 1 ms and the Multiple Linear Regression criterion:

Although the CG showed a significant difference in loads in relation to rest, we believe that it was not possible to identify the LA by HRV in this group due to our sample showing reduced values of HRV indices already in the resting situation, this was probably due to the combination of sedentary lifestyle and aging process, since these are known to be factors that reduce vagal activity in the atrial bell node [64, 53, 65].

The DM2 group presented, at baseline, reduced values of RMSSD and SD1 and did not show a significantly different response from rest, so this population tends not to present significant adjustments during incremental resistance exercise, which can be justified by the fact, in addition to age and age. sedentary lifestyle, the pathophysiology of the installed disease.

5 CONCLUSION

Our results suggest that cardiac parasympathetic modulation was reduced during dynamic resistance exercise of lower limbs in both groups. In diabetic individuals, the responses of the autonomic nervous system are attenuated when faced with physical exercise and, in addition, we conclude that it was not possible to find LA by analyzing HRV indices in this specific population submitted to resistance exercise with incremental loads.

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