AUTONOMIC, CARDIOVASCULAR & PHYSIOLOGICAL RESPONSES IN STRENGTH TRAINING PROTOCOLS

RESPOSTAS AUTONÔMICAS, CARDIOVASCULARES E FISIOLÓGICAS EM PROTOCOLOS DE TREINAMENTO DE FORÇA

RESPUESTAS AUTONÓMICAS, CARDIOVASCULARES Y FISIOLÓGICAS EN PROTOCOLOS DE ENTRENAMIENTO DE FUERZA

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Andressa Formalioni[1]
(Physical Education Professional)
Rousseau Silva da Veiga[2]
(Physical Education Professional)
Aline Xavier Tuchtenhagen[2]
(Physical Education Professional)
Léo Dutra Cabistany[2]
(Physical Education Professional)
Fabricio Boscolo Del Vecchio[2]
(Physical Education Professional)

1. Universidade de São Paulo (USP), School of Physical Education and Sports, São Paulo, SP, Brazil.
2. Universidade Federal de Pelotas (UFPel), Higher School of Physical Education and Sports, Pelotas, RS, Brazil.

Correspondence:
Andressa Formalioni.
Av. Corifeu de Azevedo Marques, 5680, Vila Lajeado, São Paulo, SP. Brazil, 05340-002.
andressaformalioni@usp.br

ABSTRACT

Introduction: Strength training is a recurrent practice among several publics and the topic of several studies, yet there is a shortage of previous studies that analyzed these parameters in the same subjects in training sessions involving volume, interval and different repetitions maximum ranges. Objective: The study was aimed at measuring and comparing the acute effect of different ST (strength training) protocols on HR (heart rate), HRV (heart rate variability), [LAC] (lactate concentration), [CK] (creatine kinase) and SPE (subjective perceived exertion). Methods: Eleven individuals with previous experience were recruited and in three sessions they performed three different training models, namely: high load (4 sets at 90% of 1RM, 180s rest between sets), medium load (3 sets at 75% of 1 RM, 90s rest between sets), and low load (2 sets at 50% of 1 RM, 45s rest between sets) in free squat, bench press, deadlift and bent-over row exercises. Results: There was no difference in CK between low load (resistance) and medium load (hypertrophy) ($p = 0.60$), between resistance and high load (strength) ($p = 0.84$), and between hypertrophy and strength ($p = 0.91$), while there was higher lactate accumulation in training with medium and low loads in comparison to training with high loads ($p < 0.001$). Conclusion: It can be noted that workouts with high loads, few repetitions and longer intervals (maximum strength) generate lower blood lactate concentrations and SPE values when compared to training with lower loads and shorter intervals (resistance training and hypertrophy). Additionally, when evaluating autonomic and cardiovascular variables, it would appear that manipulating the percentage of 1RM and the interval time does not generate significant changes in HRV, blood pressure (BP) and HR when the repetitions are executed until failure. ***Level of evidence II; Prospective comparative study.***

Keywords: Strength training; Physiology; Heart rate control; Training programs.

RESUMO

Introdução: O treinamento de força é prática recorrente entre diversos públicos e alvo de diversos estudos, contudo há escassez de estudos prévios que analisaram esses parâmetros nos mesmos indivíduos em sessões de treino envolvendo volume, intervalo e faixas distintas de repetições máximas. Objetivo: Mensurar e comparar o efeito agudo de diferentes protocolos de TF (treino de força) sobre a FC (frequência cardíaca), VFC (variabilidade da frequência cardíaca), [LAC] (concentração de lactato), [CK] (creatina quinase) e PSE (percepção subjetiva de esforço). Métodos: Foram selecionados 11 indivíduos com experiência prévia e, em três sessões, os mesmos realizaram três diferentes modelos de treino, isto é: carga alta (4 séries a 90% de 1RM, 180s de descanso entre séries), carga média (3 séries a 75% de 1 RM, 90s de descanso entre séries) e carga baixa (2 séries a 50% de 1 RM, 45s de descanso entre séries) em exercícios de agachamento livre, supino reto, levantamento terra e remada curva. Resultados: Não houve diferença da CK entre a carga baixa (resistência) e a carga média (hipertrofia) ($p=0,60$), entre resistência e carga alta (força) ($p=0,84$) e entre hipertrofia e força ($p=0,91$) e houve maior acúmulo de lactato nos treinos com carga média e baixa em relação ao treino com cargas altas ($p<0,001$). Conclusão: Observa-se que os treinos com cargas altas, poucas repetições e intervalos mais longos (força máxima) geram concentrações de lactato sanguíneo e PSE menores quando comparados aos treinos que utilizam cargas mais baixas e intervalos mais curtos (treinos de resistência e hipertrofia). Adicionalmente, quando avaliadas as variáveis autonômicas e cardiovasculares, parece que manipular o percentual de 1RM e o tempo de intervalo não é capaz de gerar alterações significativas na VFC, pressão arterial (PA) e FC quando as repetições são executadas até a falha. **Nível de evidência II; Estudo prospectivo comparativo.**

Descritores: *Treinamento de força; Fisiologia; Controle da frequência cardíaca; Programas de treinamento.*

RESUMEN

Introducción: El entrenamiento de fuerza es práctica recurrente entre diversos públicos y objetivo de diversos estudios. Sin embargo, hay escasez de estudios previos que analizaron esos parámetros en los mismos individuos en sesiones de entrenamiento abarcando volumen, intervalo y franjas distintas de repeticiones máximas. Objetivo: Medir y comparar el efecto agudo de diferentes protocolos de EF (entrenamiento de fuerza) sobre la FC (frecuencia cardíaca), VFC (variabilidad de la frecuencia cardíaca), [LAC] (concentración de lactato), [CK] (creatina quinasa) y PSE (percepción *subjetiva de esfuerzo). Métodos: Fueron seleccionados 11 individuos con experiencia previa y, en tres sesiones, los mismos realizaron tres modelos de entrenamiento, a saber: carga alta (4 series a 90% de 1RM, 180s de descanso entre series), carga mediana (3 series a 75% 1RM, 90s de descanso entre series), y carga baja (2 series a 50% de 1RM, 45s de descanso entre series) en los ejercicios de agachamiento libre, supino recto, levantamiento tierra y remada curva. Resultados: No hubo diferencias de la CK entre la carga baja (resistencia) y la carga mediana (hipertrofia) (p = 0,60) entre resistencia y carga alta (fuerza) (p = 0,84) y entre hipertrofia y fuerza (p = 0,91) y hubo mayor acumulación de lactato en los entrenamientos con carga mediana y baja con relación al entrenamiento con cargas altas (p <0,001). Conclusión: Se observa que los entrenamientos con cargas altas, pocas repeticiones e intervalos más largos (fuerza máxima) generan concentraciones de lactato sanguíneo y PSE menores cuando comparados a los entrenamientos que utilizan cargas más bajas e intervalos más cortos (entrenamientos de resistencia e hipertrofia). Además, cuando evaluadas las variables autonómicas y cardiovasculares, parece que manipular el porcentaje de 1RM y el tiempo de intervalo no es capaz de generar alteraciones significativas en la VFC, presión arterial (PA) y FC cuando las repeticiones son ejecutadas hasta la falla.* **Nivel de evidencia II; Estudio prospectivo comparativo.**

Descriptores: *Entrenamiento de fuerza; Fisiología; Control de la frecuencia cardíaca; Programas de entrenamiento.*

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INTRODUCTION

Strength training has been widely employed to improve fitness levels of athletes[1] and healthy people,[2] and in the prevention of and recovery from different health conditions. Besides increased strength endurance, maximum strength and power,[3] improvements in bone mass,[4] muscle hypertrophy[5] and weight loss[6] can also be identified as a result of its practice. However, ST protocols are quite diverse,[7] as they involve several variables and studies of acute physiological responses in different training protocols predominantly analyze creatine kinase [CK],[8] blood lactate ([LAC]),[9] subjective perceived exertion (SPE)[10] and total training volume.[11] In contrast, there is a shortage of previous investigations analyzing these and other physiological parameters in ST sessions with different repetitions maximum ranges.

Additionally, the use of SPE to modulate ST intensity appears feasible, and it has a good relationship with heart rate (HR).[12] From the metabolic point of view, a greater elevation of [LAC] can be observed in training with lower loads and a higher number of repetitions compared to training with higher loads and a lower number of repetitions.[13] Moreover, sessions of greater intensity tend to produce greater tissue damage,[14] based on creatinine kinase [CK] levels.

On the other hand, recent studies have indicated that ST may impact the central nervous system, and to quantify this action, heart rate variability (HRV) has proven an effective tool for quantifying autonomic activity.[15] Previous investigations analyzing the acute effect of strength training on HRV behavior have indicated a decrease in variables related to the domain of time[16] and high frequency,[17] while low frequency values increase.[18]

However, data on the impact of different ST protocols on different physiological variables are scarce and contradictory, thus highlighting the relevance of studies on the topic. Accordingly, the purpose of this particular study was to measure and compare the acute effect of different ST protocols on HR, HRV, [LAC], [CK] and SPE.

MATERIALS AND METHODS

The study is characterized as experimental. Eleven normotensive male subjects, aged 18 to 35 years and with more than six months of experience in strength training, recruited as a convenience sample, were involved. Determination of sample size considered previously published data on [CK] in ST, due to the less responsive variable among those investigated in this particular study. Considering mean of the differences of 90 U•L^{-1}, standard deviation of the differences of 105 U•L^{-1},[19] power of 80% and significance level of 5%, ten observations per group would be necessary. Thus, after adding 10% for losses, eleven participants were recruited. Individuals with heart conditions, severe respiratory diseases or a recent history of seizures, and subjects with musculoskeletal disorders that prevented them from undertaking the training routines were excluded from the sample. Participants read and signed an Informed Consent Form and the research project was approved by the local institutional review board (68577917.0.1001.5313).

The participants made four visits to the laboratory. During the first of these, a one repetition maximum (1RM) test was performed in the free squat, bench press, deadlift and bent-over row exercises, in this respective order. In the three subsequent sessions, the participants performed three different training models, namely: high load (4 sets at 90% of 1RM, 180s rest between sets), medium load (3 sets at 75% of 1RM, 90s rest between sets), and low load (2 sets at 50% of 1 RM, 45s rest between sets).[20] Participants were asked to perform repetitions until momentary concentric failure in all sets, which was defined as the inability to complete the concentric phase of a repetition without changing the movement pattern of the prescribed exercise. All exercises were performed with a 20kg Olympic dumbbell bar and rubber washers (Ziva™, Beijing, China).

To determine the training load, a prior session was held to identify the load corresponding to 1RM.[3] After standardized warm-ups with submaximal loads, using between 10-15 repetitions, the subject attempted the load for 1RM. When successful, the subject was allowed to recover for 3 minutes before the load was increased. In the event of failure, the subject was allowed to recover for 3min and the load was reduced by up to 5% for upper limbs and up to 10% for lower limbs before attempting the RM once again.

Prior to the execution of the protocols employed, participants performed standardized general warm-up using complex training adaptation[21] composed of squats, bench press, deadlift and bent-over row exercises, with two sets of six repetitions in each exercise, no break for rest between them and 50 jumping jacks between sets.[22] The warm-up load corresponded to the Olympic bar (20kg).

To undertake the sessions (table 1), subjects needed to have spent at least 48h without performing any type of exercise, and the interval between the three experimental sessions was supposed to be 5-7 days. For all sessions, which occurred in pre-defined order (low load, medium load and high load, respectively), the exercises performed were: free squat, bench press, deadlift and bent-over row, in the respective sequence.

Table 1. Description of the training sessions.

Session 1 – low load	Session 2 – medium load	Session 3 – high load
2 sets	**3 sets**	**4 sets**
45s interval between exercises and sets	90s interval between exercises and sets	180s interval between exercises and sets
50% of the load of 1RM	75% of the load of 1RM	90% of the load of 1RM

Data collection and recording procedures

Lactate Concentration: [LAC] was measured before, immediately after, and 5min after each protocol. The collection involved puncturing the earlobe to draw 15μL of blood, which was immediately analyzed using Yellow Spring Instruments electrochemical equipment, model 2300 Sport (OH, USA).

Creatine Kinase Concentration: To measure [CK], 32μL of capillary blood was drawn by puncturing the earlobe, and transferred to reagent strip (ANVISA 10287410157, Reflotron®), which was read by portable analyzer (Reflotron Analyser®, Boehringer-Mannheim, France). This procedure was performed immediately before the first session and 24h after each training session.

Subjective Perceived Exertion: SPE was measured using the Borg Scale[23] after each training session.

Heart rate variability: A cardiac monitor (Polar RS800CX; Kempele, Finland)[24] was used to record HRV. The data were recorded at the following time points: pre-warm-up, soon afterwards and 24h after each training session held. Samples were collected with the subject lying in the dorsal decubitus position and remaining immobile for 5min.[15] The data were processed using version 5.0 of the Polar Pro Trainer software, and were then exported to Kubios HRV Software, v.2, where the variables of the following domains were analyzed: I) time, with the mean time between two heart beats (Mean RR), mean number of heart beats per minute (Mean HR), standard deviation of normal-to-normal RR intervals (SDNN), root mean square of successive RR-interval differences (RMSSD);II) frequency, high (HF), low (LF), very low (VLF), and LF/HF ratio; III) nonlinear with the variables standard deviation between instantaneous points (SD1) and standard deviation of long-term trend (SD2).[15]

Blood Pressure: BP was measured at rest (before warm-up) and at the end of the last set of each exercise in the three sessions. Measurements were taken using an aneroid sphygmomanometer and stethoscope (P.A. MED® KPA200).

Statistical analysis

Descriptive data are presented as mean and standard deviation. One-way ANOVA was used to analyze the variables that were collected at up to two time points (SPE and CK), while two-way ANOVA was used for the others, considering training and timing. The Bonferroni post hoc test was used. Data were tabulated in Excel and statistical procedures were conducted in SPSS, version 20.0.

RESULTS

Regarding the characteristics of the sample, the eleven study participants were aged 25±4 years, with a height of 179.5±7 cm and weight of 78.9±6 kg. As regards to practice time, the mean time was 54±35.7 months (minimum = 12 and maximum = 120 months), with weekly frequency of 4±0.8 sessions.

Regarding the weight used and respective range of repetitions, Table 2 shows a significant difference between the protocols adopted in terms of the number of repetitions (F = 57.81) ($p<.0001$) and total weight adopted (F = 25.91) ($p<.0001$).

The results of the mean values of [LAC] are presented in Figure 1 and indicate a difference between the workouts with high load and the others. Training (2.30) = 30.264; $p<0.001$; timing (2.60) = 296.414; $p<0.001$; interaction (4.60) = 15.138; $p<0.01$. Training with high load had inferior results at the two post-training time points when compared to resistance and hypertrophy training ($p<0.001$), yet there were no differences between resistance and hypertrophy (p = 0.15).

Table 2. Total weight and range of repetitions for each training protocol (mean±sd).

Type of load	Session weight	Range of repetitions
Low	220.4±29.27	130.3±20.24
Medium	318.0±53.98	104.0±6.48
High	382.55±70.81	71.82±7.78

Weight for all the exercises proposed in the session.

With regards to [CK] (Figure 2), the three training models showed no differences when the post-training time points were compared between low load (resistance) and medium load (hypertrophy) (p = 0.60), resistance and high load (strength) (p = 0.84), and between hypertrophy and strength (p = 0.91).

With regards to SPE (Figure 3) there was significant difference (f = 10.266 and $p<0.001$) for maximum strength training (mean = 14), where lower values were found for both resistance training (mean = 17.8; $p<0.001$) and hypertrophy training (mean = 16.3; $p<0.05$). There were no differences between resistance and hypertrophy training (p = 0.17).

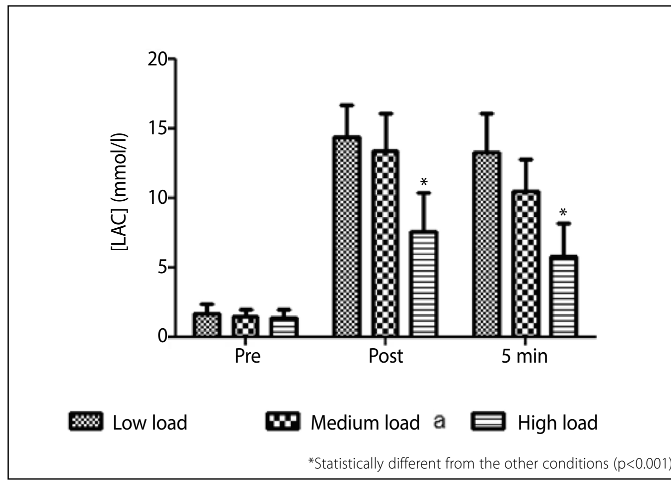

Figure 1. Blood lactate concentration for each training protocol.

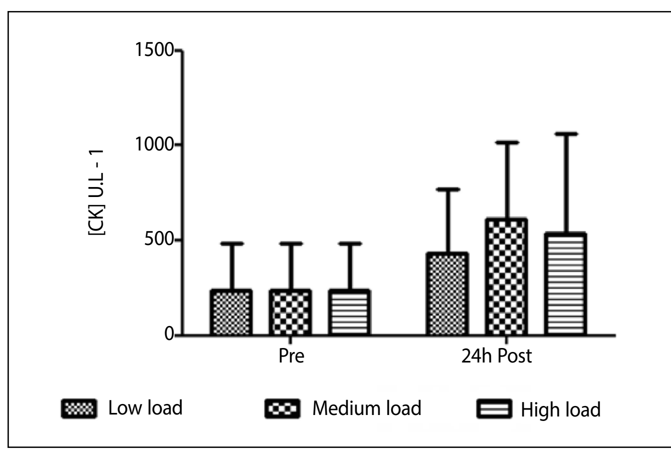

Figure 2. CK concentration for each session.

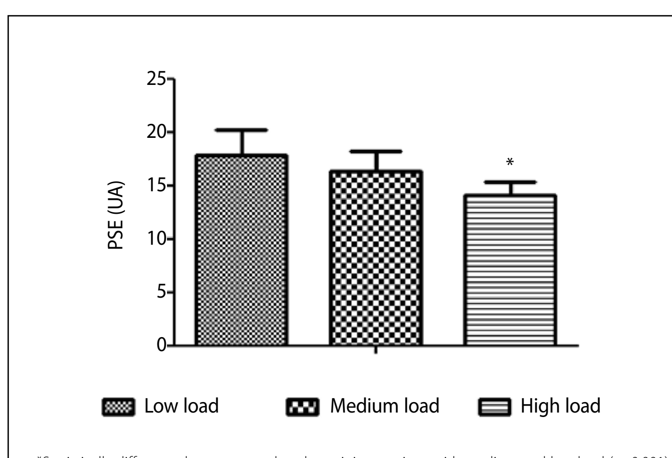

Figure 3. Subjective perceived exertion in different training sessions.

With regards to HRV in medium, low and high load training (Table 3), the results indicate differences between the pre and post-training time points for the time domain, frequency and nonlinear domain responses.

HR values are expressed in Table 4, and showed no significant differences when the three protocols were compared for resting heart rate (RHR) ($p = 0.51$), MeanHR ($p = 0.26$) and MaxHR ($p = 0.87$) either.

In the SBP analysis, no differences were observed between training sessions ($F = 0.98$; $p = 0.38$), but instead between time points ($F = 7.75$; $p<0.001$), and there were no significant interactions ($F = 1.95$; $p = 0.06$). The Bonferroni post-hoc test indicated that mean SBP at the post-squat time point (142±15 mmHg) was statistically different from rest (131± 11 mmHg; $p = 0.01$), and from the post-bench press (125±12 mmHg; $p <0.001$), deadlift (126±22 mmHg; $p = 0.001$) and bent-over row exercise (124±27 mmHg; $p = 0.003$) time points. For DBP, no effect of training type ($F = 1.62$; $p = 0.21$) and timing ($F = 0.52$; $p = 0.71$) was observed. Mean resting values were 69 ± 7 mmHg, post-squat 70 ± 9 mmHg, post-bench press 70 ± 10 mmHg, post-deadlift 67 ± 13 mmHg, and end-of-session values were 69 ± 17 mmHg.

DISCUSSION

The purpose of this study was to measure and compare the acute effect of different ST protocols on HR, HRV, [LAC], [CK] and SPE. Among the main findings, it is important to note that training with high loads generated lower values [LAC] when compared to the other training protocols. Regarding [CK], no differences were observed in the measurement 24h after the training protocol, and for SPE higher values were recorded for the training sessions with medium and low load. For BP and HR and HRV no differences were observed between the training protocols.

Thus, it is understood that intervals of less than 3min between sets can cause greater accumulation of [LAC] in physically active subjects in the bench press exercise with workload at 70% of maximal strength.[25] Similarly, our study showed that in training with shorter intervals (45s and 90s respectively), [LAC] values were higher when compared to training with an interval of 180s.

As regards [CK], in a study that used 2 protocols for individuals undertaking ST, one group performed the protocol with a 1min interval between sets and the other with a 3min interval. For the 1min interval group, the serum concentration of [CK] before the training session averaged less than 200 U/L, increasing significantly 24h after the training session (mean greater than 350 U/L). Conversely, the group that trained with a 3min interval showed no significant difference between times before and after the training session. In this particular study, no differences were found between protocols when comparing [CK] values 24h after training, which may be due to the reduced monitoring time.

With regards to SPE, in terms of the variable interval between sets, a study that evaluated oxygen consumption during different interval periods (1, 2, 3 and 5min) between sets in the bench press exercise, in individuals accustomed to resistance training, showed that the shorter the interval (in the study in question this was 1min), the higher the oxygen consumption of the subjects,[26] which is associated with a higher rate of fatigue, and is directly related to an increase in SPE. This is consistent with our research study, where the subjects reported higher SPE in resistance training (low load) and hypertrophy (medium load), even though these were performed with the lowest total weight.

Regarding the use of HRV in different strength training protocols, it would appear that performing submaximal workouts (four sets of eight repetitions

Table 4. Heart rate values for each training protocol (BPM) (mean ± sd).

Type of load	$_{Rest}$HR	$_{Mean}$HR	$_{Max}$HR
Low	62±10	106±10	173±16
Medium	61±12	118±11	178±8
High	62±12	112±10	174±9

$_{Rest}$HR= Resting heart rate; MaxHR= Maximum heart rate; MeanHR= Mean heart rate.

Table 3. Behavior of heart rate variability in three weight training protocols (n=11).

		Low load			Medium load			High load			Time	
	Pre-training	Post-training	24h after	Pre-training	Post-training	24h after	Pre-training	Post-training	24h after	F	P	η^2_p
Time domain												
MeanRR (ms)	867.3±185.62	547.6±63.52	866.1±124.00	875.4±170.78	575.6±40.63*	883.1±183.84	898.9±179.64	623.5±75.52	841.3±132.20	86.11	<0.001*	0.74
MeanHR (ms)	72.4±14.80	111.3±13.02	70.9±10.47	71.6±14.77	104.9±7.62*	71.5±15.92	69.2±23.85	98.7±12.85	73.6±11.91	144.84	<0.001*	0.83
SDNN (ms)#	61.4±28.91	25.8±18.89	52.9±22.82	73.6±33.15	19.7±6.28*	55.1±23.68	57.6±19.80	53.3±33.42	60.0±30.86	14.89	<0.001*	0.33
RMSSD (ms)	27.8±11.82	5.6±2.96	22.9±5.55	25.2±6.94	5.8±2.58*	23.5±7.73	27.0±10.44	12.8±6.09	23.1±5.80	79.9	<0.001*	0.72
PNN50 (%)	5.5±4.63	0.0±0.06	4.5±3.83	4.4±4.19	0.0±0.00*	5.9±6.20	5.0±3.78	1.3±1.90	4.2±3.39	24.07	<0.001*	0.45
Frequency Dom.												
VLF (ms²)	2228.0± 3443.14	269.3± 221.86	1706.9± 1034.00	8609.9± 18455.73	157.6± 112.43	1373.7± 918.90	1602.5± 1415.88	2918.3± 4110.89	2287.3± 1842.67	2	0.17	0.06
VLF (%)	60.1±22.15	80.6±9.58	64.3±17.75	74.0±17.46	67.5±12.98	62.9±13.44	65.9±14.21	73.0±17.65	67.9±17.98	3.4	0.04***	0.1
LF (ms²)#	458.3±309.93	45.3±39.77	548.9±355.40	478.3±230.05	67.0±56.00*	456.7±331.50	399.4±166.34	291.0±197.23	455.9±256.56	26.94	<0.001*	0.47
LF (%)	27.5±18.30	16.9±8.19	24.9±13.96	19.6±16.13	29.2±13.01	27.8±14.13	21.3±10.76	21.1±16.09	21.8±12.27	0.37	0.7	0.01
LF (n.u)	67.8±18.18	86.0±9.76	69.3±15.72	72.79±16.27	88.1±8.49*	71.3±16.67	64.6±17.87	79.2±19.03	69.5±19.62	14.13	<0.001*	0.32
HF (ms²)	210.7±139.26	5.9±5.13	203.6±90.62	182.2±116.11	7.7±5.95*	181.4±111.95	199.4±94.45	83.4±93.77	159.2±70.38	41.04	<0.001*	0.58
HF (%)	12.4±10.77	2.5±1.83	10.7±7.61	6.3±4.24	3.2±1.36	9.2±4.01	12.8±10.78	5.8±7.37	33.5±81.22	2.16	0.12	0.07
HF (n.u)	32.1±18.15	14.0±9.74	30.6±15.61	27.2±16.26	11.7±8.06*	29.0±16.76	35.3±17.78	27.3±27.01	30.5±19.59	10.86	<0.001*	0.27
Total (ms)	2897.5± 3584.46	320.5± 254.07	2459.6± 1189.94	9270.2± 18587.74	233.1± 142.13	2012.1± 1148.01	2201.9± 1493.81	3293.2± 4180.35	2828.8± 1972.97	2.47	0.12	0.08
LF/HF (%)	3194.9± 2417.99	8560.5± 4449.31	3887.4± 4688.59	4483.5± 3959.65	11261.3± 7461.33*	3999.9± 3219.30	3275.1± 4299.65	6532.8± 4661.35	2820.6± 1629.32	19.23	<0.001*	0.39
Nonlinear dom.												
SD1 (ms)	19.7±8.38	3.9±2.12	16.2±3.94	17.9±4.92	4.1±1.85*	16.6±5.47	19.2±7.40	9.0±4.33	16.5±4.11	79.74	<0.001*	0.73
SD2 (ms)#	82.9±39.93	36.0±26.71	72.9±32.38	101.9±46.95	27.4±8.83*	75.6±34.00	78.1±26.94	74.5±47.26	82.8±44.7	13.19	<0.001*	0.31

There was interaction, $p <0.05$; MeanRR = Mean intervals between heart beats; SDNN = Standard deviation of normal-to-normal RR intervals; RMSSD = Root mean square of successive RR-interval differences; PNN50 = Percentage of intervals between heart beats over 50ms in comparison to subsequent heart beat; LF = Low frequency band; HF = High frequency band; LF/HF = LF/HF ratio.

with a 3min interval between sets with the load for 12 repetitions maximum) involves greater post-exertion sympathetic activity than training with maximum intensities (four sets with load for 12 repetitions maximum with a 3min interval between sets, until voluntary failure).[27] In addition, sessions at 80% of 1RM, when compared with sessions at 60% and 70% of 1RM, generated an increase in sympathetic tone and a decrease in parasympathetic tone. Moreover, the session at 80% of 1RM can activate a higher number of motor units, with greater activation of the sympathetic nervous system to maintain a consistent number of repetitions in each set.[28] However, in this study similar behavior was observed between the training protocols performed until failure, with a reduction in HRV at the post-exertion time point and a return to baseline levels measured 24h after the intervention.

Regarding BP, when comparing different strength training volumes (three or six sets in five different exercises) in terms of hypotensive responses, the group that executed a higher workload was seen to benefit from the hypotensive effects of the exercise.[29] Moreover, when maximal and submaximal strength training models are used, both protocols show statistically significant decreases in BP with a tendency for post-exertion blood pressure reductions, characterizing reductions in both SBP and DBP in both experimental groups, with more SBP reduction time points in the maximum intensity group.[29] However, in this particular study no differences were observed between the protocols used, which featured variations in the load used, thereby implying the total volume of repetitions that the subject was able to perform until failure. This fact may be linked to the characteristics of the sample, given that a significant part of the population is not sensitive to the hypotensive effects of physical exercise.

CONCLUSION

It is suggested that training with high loads, few repetitions and longer intervals (maximum strength) generates lower blood lactate and SPE concentrations when compared to training using lower loads and shorter intervals (resistance training and hypertrophy). In addition, when the autonomic and cardiovascular variables are evaluated, it would appear that the act of manipulating the 1RM percentage and interval time is not capable of generating significant changes in HRV, BP and HR when repetitions are performed until failure.

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