ANALYSIS OF HEART RATE VARIABILITY AFTER EXERCISE WITH OSCILLATORY POLE

Ogata C. M.[1], Abreu L. C.[2], Vanderlei F. M.[3], Navega M. T.[1], Valenti V. E.[1,4]

Aim. To evaluate the acute effects of exercise with oscillatory pole on cardiac autonomic modulation.

Material and methods. The study was performed on 18 young adult males aged between 18 and 25 years old. The subjects remained at rest for 10 minutes, after the rest period, the volunteers performed the exercises with the oscillatory pole. Immediately after the exercise protocol, the volunteers remained seated at rest for 30 minutes. We evaluated the geometric indexes of heart rate variability.

Results. The SD1 index increased 25-30 minutes after exercise compared to rest and the SD2 index decreased 5-10 minutes and 10-15 minutes compared with 15-20 minutes after exercise.

Conclusion. A single session of exercise with oscillatory pole increased the parasympathetic component of heart rate variability and reduced the overall variability of heart rate in the initial 15 minutes after exercise.

Russ J Cardiol 2016, 12 (140): 64–69
http://dx.doi.org/10.15829/1560-4071-2016-12-64-69

Key words: cardiovascular system, autonomic nervous system, exercise therapy, heart rate, oscillatory pole, young.

[1]Centro de Estudos do Sistema Nervoso Autônomo (CESNA), Programa de Pós-Graduação em Fisioterapia, Faculdade de Ciências e Tecnologia, UNESP Presidente Prudente, SP, Brasil; [2]Departamento de Morfologia e Fisiologia, Faculdade de Medicina do ABC, Santo André, SP, Brazil; [3]Departamento de Fisioterapia, Faculdade de Ciências e Tecnologia, UNESP, Presidente Prudente, SP, Brazil; [4]Programa de Pós-Graduação em Fisioterapia, Faculdade de Ciências e Tecnologia, UNESP, Presidente Prudente, SP, Brazil.

Corresponding author. Vitor E. Valenti. Programa de Pós-Graduação em Fisioterapia, Faculdade de Ciências e Tecnologia, UNESP, Rua Roberto Simonsen, 305 CEP 19060-900. Presidente Prudente, SP, Brazil. Marília, SP, Phone: +55 (18) 3221-4391. E-mail: vitor.valenti@marilia.unesp.br

HRV — heart rate variability.

Received September 27, 2016.
Revision received October 10, 2016.
Accepted October 17, 2016.

АНАЛИЗ ВАРИАБЕЛЬНОСТИ РИТМА СЕРДЦА ПОСЛЕ УПРАЖНЕНИЙ С ГИБКИМ ШЕСТОМ

Ogata C. M.[1], Abreu L. C.[2], Vanderlei F. M.[3], Navega M. T.[1], Valenti V. E.[1,4]

Цель. Оценить непосредственное действие упражнений с гибким шестом на кардиальную автономную модуляцию.

Материал и методы. Мы исследовали 18 взрослых мужчин в возрасте от 18 до 25 лет. Испытуемые оставались в покое в течение 10 минут. После периода покоя, они выполняли упражнения с гибким шестом. Сразу после осуществления упражнения, добровольцы отдыхали сидя в течение 30 минут. Мы оценивали геометрические показатели вариабельности сердечного ритма.

Результаты. Индекс SD1 увеличился до 25-30 минут после тренировки, по сравнению с периодом покоя, а индекс СД2 снизился за 5-10 минут и 10-15 минут по сравнению с 15-20 минут после тренировки.

Заключение. Один сеанс упражнения с гибким шестом увеличивает парасимпатическую составляющую вариабельности сердечного ритма и снижает общую вариабельность сердечного ритма в первые 15 минут после тренировки.

Российский кардиологический журнал 2016, 12 (140): 64–69
http://dx.doi.org/10.15829/1560-4071-2016-12-64-69

Ключевые слова: сердечно-сосудистая система, нервная система, лечебная физкультура, частота сердечных сокращений, гибкий шест, молодой возраст.

[1]Centro de Estudos do Sistema Nervoso Autônomo (CESNA), Programa de Pós-Graduação em Fisioterapia, Faculdade de Ciências e Tecnologia, UNESP Presidente Prudente, SP, Brasil; [2]Departamento de Morfologia e Fisiologia, Faculdade de Medicina do ABC, Santo André, SP, Brazil; [3]Departamento de Fisioterapia, Faculdade de Ciências e Tecnologia, UNESP, Presidente Prudente, SP, Brazil; [4]Programa de Pós-Graduação em Fisioterapia, Faculdade de Ciências e Tecnologia, UNESP, Presidente Prudente, SP, Brazil.

Isometric exercising has been increasingly recommended as part of rehabilitation, it improves musculoskeletal disorders and chronic diseases such as cardiovascular and/or metabolic [1, 2]. Currently, an isometric exercise protocol used in rehabilitation includes oscillatory pole [3], an instrument with 0,8 kg and around 150 cm in length that provides muscle contractions generated by co-contraction of the muscle groups of the upper limb, inducing isometric contractions of the shoulder and trunk muscles [3, 5]. The oscillation frequency of the oscillatory pole is responsible for the resistance observed during exercise [6].

The achievement of isometric exercises promotes adaptations in various organs and systems [1, 7], among which stands out the adaptations in autonomic nervous system [8-10]. The regulation of the autonomic nervous system may be evaluated through heart rate variability, a noninvasive method that evaluates the oscillations between consecutive heart beats (RR intervals) and that can be used to identify phenomena related to this system [11].

Several studies have evaluated heart rate variability indices after the performance of conventional exercises [8-10]. Heffernan et al. [8] found a decrease in HF index and increased LF and LF/HF ratio after resistance exercise and endurance exercise, however greater reductions in total power were observed only after the achievement of resistance exercises. Predominance of sympathetic modulation and reduced parasympathetic modulation after global resistance exercise [9] and resistance specific exercises for upper limbs and trunk [10] executed at different intensities were also reported.

It is noteworthy that studies have shown that reduced parasympathetic modulation and increased cardiac sympathetic modulation represent an important clinical condition, mainly because it is related to increased cardiovascular risk [8-10].

Despite the changes described in the literature regarding the acute influence of resistance exercise on autonomic modulation, those responses induced by the exercise with oscillatory pole are still unknown. It represents an important gap in the literature since this type of exercise has been used as a therapeutic resource.

Therefore, we aimed to evaluate the acute effects exercise with oscillatory pole on cardiac autonomic modulation.

Material and methods

Study Population. This article is a non-randomized clinical trial. We analyzed a total of 18 male healthy subjects, nonsmokers, aged between 18 and 25 year old. The study was performed according to the Good Clinical Practice guidelines and the Declaration of Helsinki. All volunteers were informed about the procedures and objectives of the study and, after agreeing, have signed a term of informed consent. All study procedures were approved by the Ethics Committee in Research of the Faculty of Sciences of the Universidade Estadual Paulista, Campus of Marilia (Protocol No. 0554-2012) and followed the resolution 196/96 National Health 10/10/1996.

We considered the following exclusion criteria: cardiopulmonary, psychological, neurological and other impairments that prevent the subject known to perform procedures, and treatment with drugs that influence cardiac autonomic regulation. We also excluded physically active subjects according to the International Physical Activity Questionnaire [12].

Procedures

Initial Evaluation. Before the experimental procedure, volunteers were identified by collecting the following information: age, gender, weight, height and body mass index. Weight was determined by using a digital scale (W 200/5, Welmy, Brazil) with a precision of 0,1 kg. Height was determined by using a stadiometer (ES 2020, Sanny, Brazil) with a precision of 0,1 cm and 2,20 m of extension. Body mass index was calculated using the following formula: weight/height^2, weight in kilograms and height in meters.

Heart rate variability analysis. The R-R intervals recorded by the portable heart rate monitor (with a sampling rate of 1000 Hz) were downloaded to the Polar Precision Performance program (v. 3.0, Polar Electro, Finland). The software enabled the visualization of heart rate and the extraction of a cardiac period (R-R interval) file in “txt” format. Following digital filtering complemented with manual filtering for the elimination of premature ectopic beats and artifacts, at least 256 RR intervals were used for the data analysis. Only series with more than 95% sinus rhythm was included in the study [13, 14]. We evaluated the geometric indices of heart rate variability. For calculation of the indices we used the heart rate variability Analysis software (Kubios HRV v.1.1 for Windows, Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland) [15].

Geometric analysis of heart rate variability. The heart rate variability analysis was performed using the following geometrical methods: RRtri, TINN and Poincaré plot (SD1, SD2 and SD1/SD2 ratio). The RRtri was calculated from the construction of a density histogram of RR intervals, which contains the horizontal axis of all possible RR intervals measured on a discrete scale with 7.8125 ms boxes (1/128 seconds) and on the vertical axis, the frequency with which each occurred. The union of points of the histogram columns forms a triangle-like shape. The RRtri was obtained by dividing the number of RR intervals used to construct the histogram by their modal frequency (i.e., the RR interval that most frequently appeared on RR) [16].

The TINN consists of the measure of the base of a triangle. The method of least squares is used to determine the triangle. The RRtri and the TINN express the overall variability of the RR intervals [16].

The Poincaré plot is a map of points in Cartesian coordinates that is constructed from the values of the RR intervals. Each point is represented on the x-axis by the previous normal RR interval and on the y-axis by the following RR interval [16].

For the quantitative analysis of the plot, an ellipse was fitted to the points of the chart, with the center determined by the average RR interval. The SD1 indices were calculated to measure the standard deviation of the distances of the points from the diagonal y=x, and SD2 measures the standard deviation of the distances of points from the line y=-x+RRm, where RRm is the average RR interval. The SD1 is an index of the instantaneous recording of the variability of beat-to-beat and represents the parasympathetic activity, whereas the SD2 index represents the long-term heart rate variability and reflects the overall variability. The SD1/SD2 shows the ratio between the short- and long-term variation among the RR intervals [16].

The plot was qualitatively analyzed using HRV analysis software based on the figures formed by its attractor. The expected shapes were described by Tulppo e cols. [17] as:

1) Figures in which an increase in the dispersion of RR intervals is observed with increased intervals, characteristic of a normal plot.

2) Small figures with beat-to-beat global dispersion without increased long-term dispersion of RR intervals.

Protocol. Data collection was carried out in the same sound-proof room for all volunteers with the temperature between 21° C and 25° C and relative humidity between 50 and 60% and volunteers were instructed not to drink alcohol and caffeine for 24 hours before evaluation. Data were collected on an individual basis, between 6 and 9 PM to standardize the protocol. All procedures necessary for the data collection were explained on an individual basis and the subjects were instructed to remain at rest and avoid talking during the collection.

After the initial evaluation the heart monitor belt was then placed over the thorax, aligned with the distal third of the sternum and the Polar RS800cx heart rate receiver (Polar Electro, Finland) was placed on the wrist. Before starting the exercises, the volunteers received visual feedback through a monitor to maintain neutral posture standing and

A B C

Fig. 1. The exercises were performed with both arms on three positions.

Table 1

Baseline heart rate, mean RR interval (Mean RR), weight, height and body mass index of the volunteers

Variable	Value
Height (m)	1,71±0,05
Weight (kg)	64,5±9,0
Body mass index (kg/m^2)	21,1±3,0
Heart rate (bpm)	80,3±14,0
Mean RR (ms)	747,1±71,0

Legend: m: meters; kg: kilograms; bpm: beats per minute; ms: milliseconds

were instructed to maintain the same posture throughout the exercise [18]. Systolic and diastolic blood pressure was measured before, immediately after exercise and 30 minutes after exercise. The oscillatory movement of the oscillatory pole (Flexibar®) was held by flexion and elbow extension. The oscillatory pole vibrated at a frequency of 5 Hz, and the oscillation frequency of the oscillatory pole was based on an auditory stimulation through a metronome (Quartz Metronome®) calibrated at 300 bpm [3].

The exercises with the oscillatory pole (Fig. 1) were conducted with volunteers at standing position with feet apart (wide base) and shoulder flexion as the proposed position. To maintain the proper shoulder flexion in each upper limb it was used as a target visual feedback. All exercises were performed for 15 seconds with 50-60 seconds of rest between each exercise. Three repetitions were performed for each exercise [3].

The exercises were performed with both arms on three positions: 1) with the shoulder on 90° of flexion with the oscillatory pole on the transverse plane (Fig. 1A), 2) with shoulders at approximately 180° of flexion with the oscillatory pole on the frontal plane, parallel to the ground (Fig. 1B), and 3) shoulders at 90° of flexion with the oscillatory pole on the sagittal plane, perpendicular to the ground (Fig. 1C). Heart rate variability was analyzed at the following periods: control rest, 0-5 min, 5-10 min, 10-15 min, 15-20 min, 20-25 min and 25-30 min after the protocol exercise [3].

Statistical Analysis. Standard statistical methods were used for the calculation of means and standard deviations. Normal Gaussian distribution of the data was verified by the Shapiro-Wilk goodness-of-fit test (z value >1,0). For parametric distributions we applied ANOVA for repeated measures test followed by the Bonferroni posttest. For non-parametric distributions we used Friedman test followed by the Dunns posttest. Heart rate variability indices were compared at the following moments: rest vs. 0-5 min vs. 5-10 min vs. 10-15 min vs. 15-20 min vs. 20-25 min vs. 25-30 min after exercise. Differences were considered significant when the probability of a Type I error was less than 5% ($p<0,05$). We used the Software Biostat® 2009 Professional 5.8.4.

Results

Table 1 shows the values for baseline heart rate, mean RR intervals, weight, height and body mass index of the volunteers.

Table 2 shows the values of systolic and diastolic blood pressure at rest, immediately and 30 minutes after the standardized exercise with oscillatory pole. No significant differences were observed between those moments.

Figure 2 displays the results for the RRtri and TINN indices at rest and during the recovery period after exercise. No significant alterations were observed between rest and recovery times for both indices ($p>0,05$).

The values at rest and during the recovery period for the SD1 and SD2 indices are seen in Figure 3. The SD1 index increased 25-30 minutes after exercise compared with rest ($p=0,01$), while the SD2 index significantly reduced 5-10 minutes and 10-15 minutes compared to 15-20 minutes after exercise ($p<0,05$).

Figure 4 presents examples of the patterns of Poincaré plot 5-10 minutes, 10-15 minutes and 15-20 minutes after exercise.

Table 2

Average values followed by their standard deviation for analysis diastolic arterial pressure and systolic arterial pressure before, immediately and 30 minutes after a standard exercise with oscillatory pole

Variables	Rest	Immediately	30 minutes	p value
Systolic arterial pressure (mmHg)	117,1±9,0	115,8±9,0	116,5±6,0	0,68
Diastolic arterial pressure (mmHg)	78,3±7,0	77,1±9,0	78,2±8,0	0,7

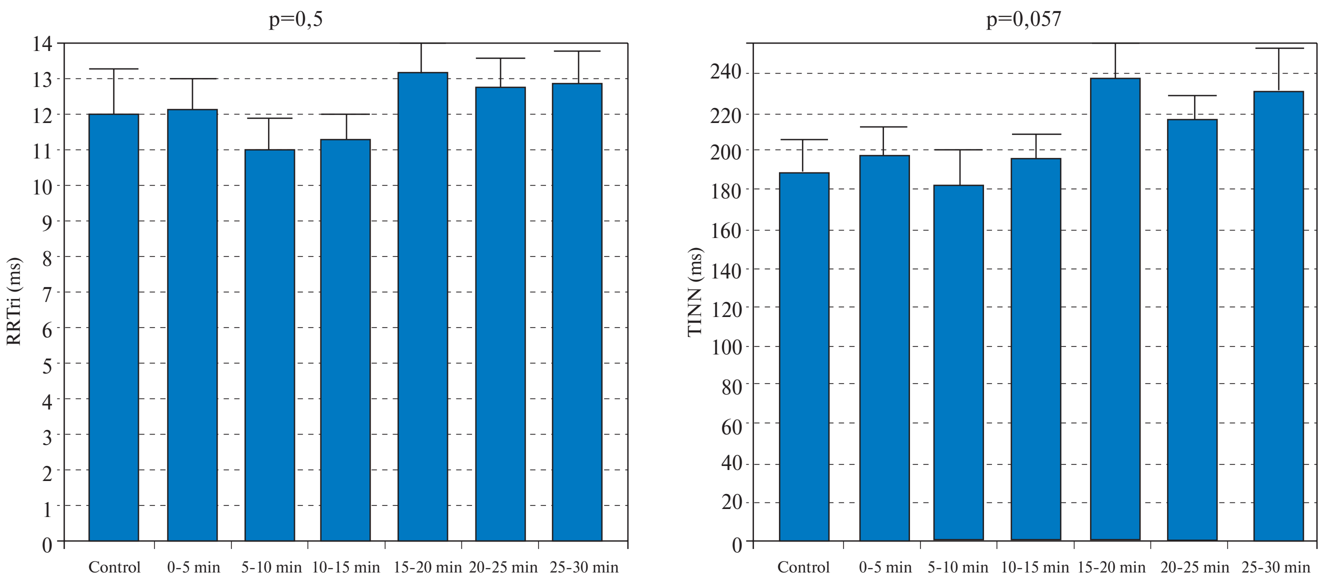

Fig. 2. The results for the RRtri and TINN indices at rest and during the recovery period after exercise.

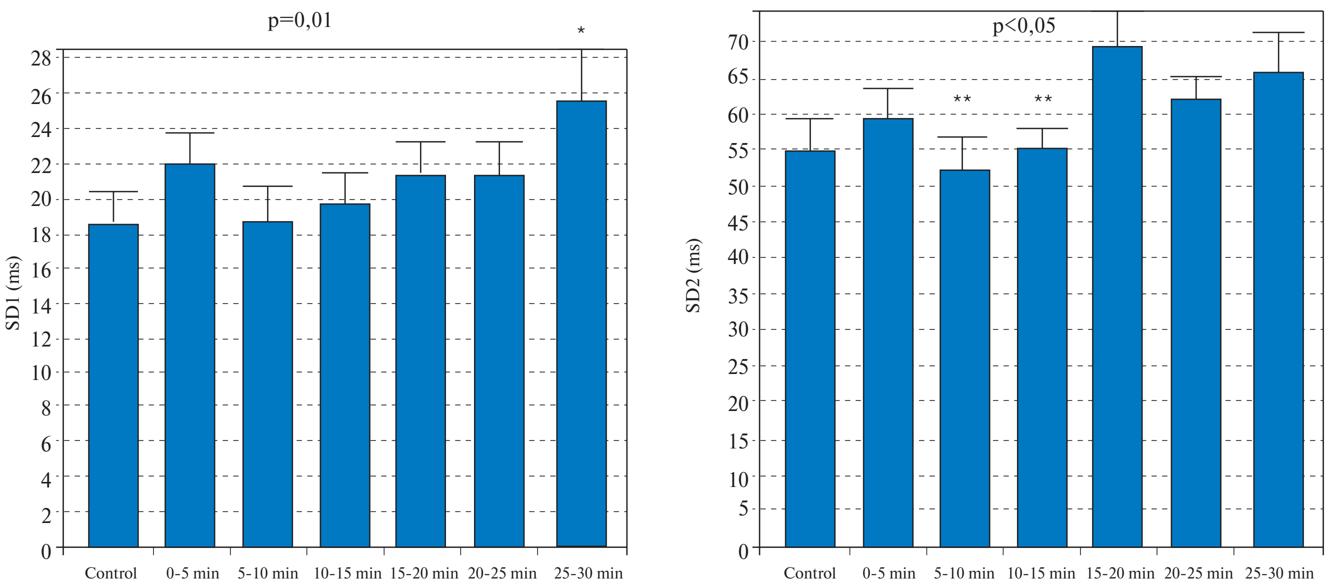

Fig. 3. The values at rest and during the recovery period for the SD1 and SD2 indices.

Discussion

This study was undertaken to investigate the effects of a single bout of isometric exercise with oscillatory pole on cardiac autonomic modulation. We observed that after the exercise there was an increase in parasympathetic tone (SD1 index) 25-30 minutes after exercise compared to rest and a decrease in overall variability (SD2 index) 5-10 minutes and 10-15 minutes after exercise compared to 15 to 20 minutes after exercise. Furthermore, no significant differences were

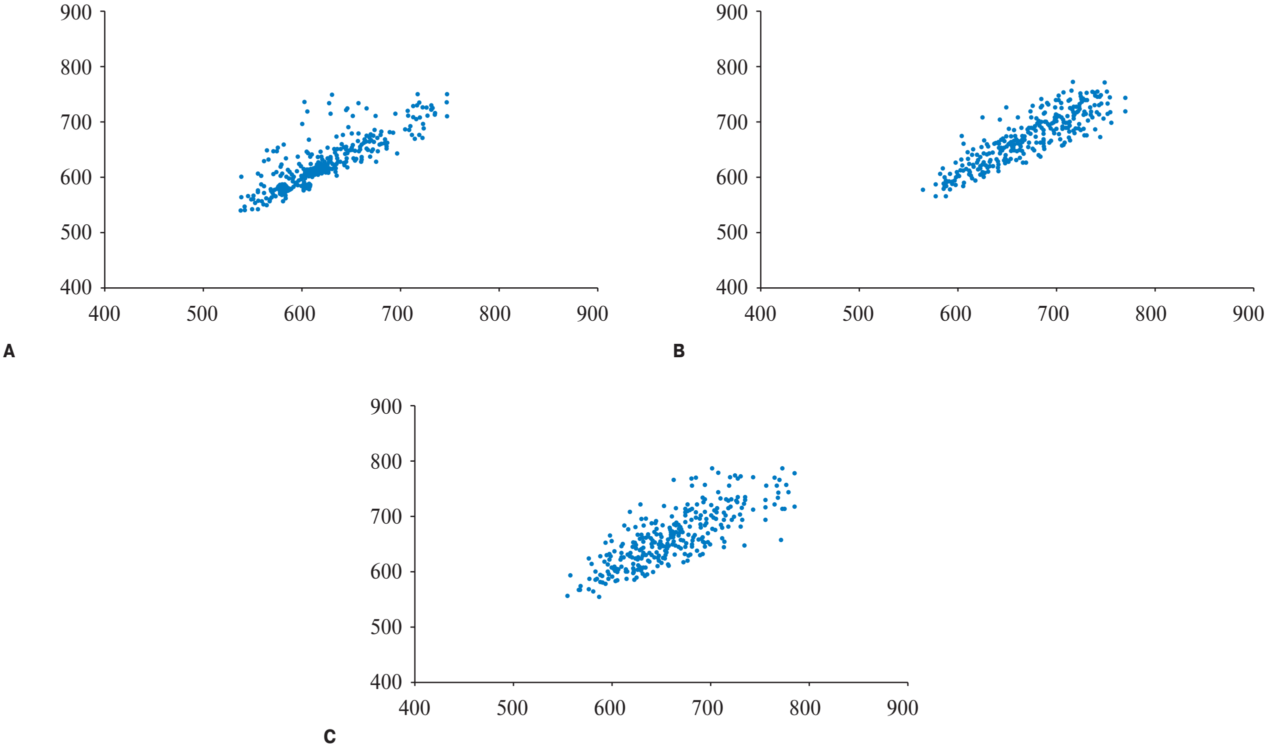

Fig. 4. The examples of the patterns of Poincaré plot 5-10 minutes, 10-15 minutes and 15-20 minutes after exercise.

observed for systolic and diastolic blood pressure and RRtri and TINN indices.

Previous studies reported that exercise with oscillatory pole is considered an isometric anaerobic exercise that provides the contraction of the muscles of the shoulder and trunk [3, 5]. In this sense, during the execution of static exercise for lower limbs with 40% of maximum voluntary contraction Mitchell and cols. [19] observed an increase in blood pressure in young men and there is evidence that sustained isometric contractions activate the muscle chemoreceptors and, as a consequence it increases blood pressure through activation of sympathetic nerves [20].

However, in this study, no significant alterations were observed in systolic and diastolic blood pressure between the points before, immediately and 30 minutes after the exercise protocol, suggesting that the exercise protocol used was not able to promote changes in blood pressure. Despite the intensity of the exercise with the oscillatory pole used in our study have been based on previous studies [3, 5] it may be, at least partly, related to the absence of blood pressure responses during the evaluation period.

Regarding the autonomic modulation this is the first study to describe the responses of the autonomic modulation of recovery against a resistance exercise performed with oscillatory pole using geometric indices of heart rate variability for analysis.

The SD1 index, which represents the parasympathetic modulation of autonomic nervous system, did not present statistically significant changes immediately after the exercise with the oscillatory pole. However, it can be observed that 0-5 minutes, even without statistical difference, this index slightly increased.

It is known that cardiac autonomic modulation depends on the interaction between the sympathetic and parasympathetic autonomic nervous systems [16]. During the rest before exercise there is a prevalence of vagal modulation that keeps the heart rate at lower values [21]. In contrast, during exercise, it is observed a reduction of parasympathetic modulation and an increase of sympathetic modulation, to adjust the metabolic demands required by the effort [21]. Immediately after the exercise end, the suppression of signals coming from the central nervous system and the cessation of mechanoreceptors action on skeletal muscles provide a reactivation of the parasympathetic nervous system as observed in SD1 index 0-5 minutes after exercise [22, 23].

Moreover, it is observed that the SD1 index decreased 5-10 minutes after exercise and gradually increased over the period of recovery (10-15 minutes, 15-20 and 20-25 minutes after exercise).

The significant elevation of SD1 index 25-30 minutes after exercise compared to rest may be associated with a beneficial effect that exercise with oscillatory pole promotes by increasing vagal modulation. However, we cannot discard the hypothesis that this may also be related to an effect of relaxation, since on recovery period, subjects remained seated action and at rest.

Regarding the SD2 index, which reflects the overall variability, we observed a decrease 5-10 minutes and 10-15 minutes after exercise compared to 15-20 minutes after exercise, suggesting that in these moments there was a transient increase in sympathetic tone. This fact is supported by the qualitative analysis through of the Poincaré plot, in which is observed in 5-10 and 10-15 minutes after exercise a less dispersion of points when compared to the plot of 15-20 minutes after exercise, indicating that in these two moments there was a reduction of heart rate variability.

In relation to the RRtri and TINN indexes that also indicate the overall variability [16] of heart rate, a single session of exercise with oscillatory pole did not cause significant changes in these indices during the recovery period. Nevertheless, as the SD2 index reduced 5-10 and 10-15 minutes after exercise compared to other periods analyzed, suggesting that in these periods there were minor changes in cardiac autonomic modulation. In this context, Kingsley and cols. [24] reported that during and after resistance exercise there is a trend of decreasing of overall variability.

There are some points to be addressed in our investigation. The study sample was composed only by males, which is an important aspect of methodological point of view, because it avoids the sex-dependent effects on heart rate variability responses induced by exercise, since there is scientific evidence showing differences between men and women in relation to cardiac autonomic responses after a section of exercises [25]. Nonetheless, it should be attention to extrapolating these data to populations with different profile.

Another aspect to be considered is the fact that heart rate variability was not analyzed during the execution of the exercise, which could provide important information for the interpretation of the findings. However, we should point out that during the performance of this exercise style it cannot be obtained an appropriate cardiac tracing due to the oscillatory frequencies generated by the oscillatory pole, which limits the analysis of heart rate variability.

Further studies to investigate the long-term effects of a training program with the use of an exercise protocol with the oscillatory pole on cardiac autonomic modulation should be conducted to better understand the effects of this exercise modality. In addition, it is important to evaluate the effects that this type of exercise can provide on different populations with chronic diseases such as hypertension.

Conclusion

In conclusion, a single session of exercise with oscillatory pole acutely increased the parasympathetic component of heart rate variability and acutely decreased overall variability of heart rate.

Acknowledgments. We thank FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for financial support.

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