

# A single bout of exercise with a flexible pole induces significant cardiac autonomic responses in healthy men

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**OBJECTIVES:** Flexible poles can provide rapid eccentric and concentric muscle contractions. Muscle vibration is associated with a "tonic vibration reflex" that is stimulated by a sequence of rapid muscle stretching, activation of the muscle spindles and stimulation of a response that is similar to the myotatic reflex. Literature studies analyzing the acute cardiovascular responses to different exercises performed with this instrument are lacking. We investigated the acute effects of exercise with flexible poles on the heart period in healthy men.

**METHOD:** The study was performed on ten young adult males between 18 and 25 years old. We evaluated the heart rate variability in the time and frequency domains. The subjects remained at rest for 10 min. After the rest period, the volunteers performed the exercises with the flexible poles. Immediately after the exercise protocol, the volunteers remained seated at rest for 30 min and their heart rate variability was analyzed.

**RESULTS:** The pNN50 was reduced at 5-10 and 15-20 min after exercise compared to 25-30 min after exercise ( $p=0.0019$ ), the SDNN was increased at 25-30 min after exercise compared to at rest and 0-10 min after exercise ( $p=0.0073$ ) and the RMSSD was increased at 25-30 min after exercise compared to 5-15 min after exercise ( $p=0.0043$ ). The LF in absolute units was increased at 25-30 min after exercise compared to 5-20 min after exercise ( $p=0.0184$ ).

**CONCLUSION:** A single bout of exercise with a flexible pole reduced the heart rate variability and parasympathetic recovery was observed approximately 30 min after exercise.

**KEYWORDS:** Cardiovascular System; Autonomic Nervous System; Exercise Therapy; Heart Rate.

Ogata CM, Navega MT, Abreu LC, Ferreira C, Cardoso MA, Raimundo RD, et al. A single bout of exercise with a flexible pole induces significant cardiac autonomic responses in healthy men. *Clinics*. 2014;69(9):595-600.

Received for publication on December 1, 2013; First review completed on March 14, 2014; Accepted for publication on May 15, 2014

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## ■ INTRODUCTION

Control of the cardiovascular system is partially accomplished by the autonomic nervous system. This system provides afferent and efferent nerves to the heart, i.e., parasympathetic nerves to the atrioventricular and sinus nodes and sympathetic nerves to the myocardium (1). The influence of the autonomic nervous system on the heart depends on information from the baroreceptors, chemoreceptors, atrial receptors and ventricular receptors, as well

as changes in the respiratory, vasomotor, renin-angiotensin-aldosterone thermoregulatory systems (1), as well as the brainstem (2). The cardiovascular system is influenced by internal and external factors, including physical exercise (3).

Post-exercise cardiac autonomic responses have been demonstrated for aerobic exercise. During exercise, increased sympathetic activity and parasympathetic withdrawal induce an increase in the heart rate. Immediately after exercise, the parasympathetic reactivation is responsible for heart rate recovery (4). However, this idea is still controversial because some authors have proposed that sympathetic withdrawal would be involved in post-exercise heart rate recovery (5).

Among the exercise protocols used in rehabilitation, we may include the flexible pole, which has been reported as an important treatment modality for shoulder instability (6). The flexible pole is an instrument that weighs 0.8 kg and is approximately 150 cm in length. This tool provides

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No potential conflict of interest was reported.

**DOI:** 10.6061/clinics/2014(09)04



oscillation caused by periodic movements of the upper limbs. The frequency of movements of the flexible pole provides resistance during exercises. Exercise protocols using the flexible pole provide positive results in shoulder muscle training (7). Muscle vibration is related to the "tonic vibration reflex", which is stimulated by a sequence of fast muscle stretching, activation of the muscle spindles and the stimulation of a similar response to the myotatic reflex (8).

Although previous studies have already presented the beneficial effects of the flexible pole exercise on the musculoskeletal system, the effects on cardiac autonomic regulation have not yet been shown. Furthermore, cardiac autonomic recovery after exercise has relevant physiological and clinical significance. The assessment of autonomic function after exercise provides deeper insight into the influence of the exercise protocol on the cardiovascular system (4,5). Therefore, this study was undertaken to evaluate the acute effects of a single bout of exercise with a flexible pole on cardiac autonomic regulation.

## METHODS

### Study population

We analyzed a total of 18 healthy male subjects who were nonsmokers and aged between 18 and 25 years. All volunteers were informed about the procedures and objectives of the study. After agreeing to participate, all participants signed informed consent forms. 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.

### Exclusion criteria

We considered the following exclusion criteria: cardiopulmonary, psychological, neurological and other impairments that would prevent the subject from performing the procedures and treatment with drugs that could influence cardiac autonomic regulation. We also excluded physically active subjects according to the International Physical Activity Questionnaire (IPAQ) (9).

### Initial evaluation

Before the experimental procedure, the following information was collected from the volunteers: age, gender, weight, height and body mass index (BMI). Weight was determined using a digital scale (W 200/5, Welmy, Brazil) with a precision of 0.1 kg. Height was determined using a stadiometer (ES 2020, Sanny, Brazil) with a precision of 0.1 cm and 2.20 m of extension. The body mass index (BMI) was calculated using the following formula:  $\text{weight}/\text{height}^2$ , weight in kilograms and height in meters.

### Heart rate variability analysis

The R-R intervals recorded by the portable heart rate (HR) 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 the HR and the extraction of a cardiac period (R-R interval) file in the "txt" format. Using digital filtering complemented with manual filtering for the elimination of premature ectopic beats and artifacts, at least 256 R-R intervals were used for the data analysis. Only series with

more than 95% sinus rhythm were included in the study (10,11). The heart rate variability (HRV) was analyzed at the following four time points after exercise: seated rest with spontaneous breathing, 0-5 min, 5-10 min and 10-15 min in the standing position. We evaluated the linear and non-linear indices of the HRV. To calculate the indices, we used the HRV Analysis software (Kubios HRV v.1.1 for Windows, Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland)(12).

### Linear indices of the heart rate variability

To analyze the HRV in the frequency domain, the low frequency (LF=0.04 to 0.15 Hz) and high frequency (HF=0.15 to 0.40 Hz) spectral components were used in  $\text{ms}^2$  and normalized units, which represent a value relative to each spectral component related to the total power minus the very low frequency (VLF) components; we also examined the ratio between these components (LF/HF). The spectral analysis was calculated with the Fast Fourier Transform algorithm (13).

The time domain analysis was performed with the SDNN (standard deviation of normal-to-normal R-R intervals), the percentage of adjacent RR intervals with a difference in the duration greater than 50 ms (pNN50) and the root-mean square of differences between the adjacent normal RR intervals in a time interval (RMSSD) (14).

For analysis of the linear indexes in the time and frequency domains, we used the software HRV analysis.

### Protocol

Data collection was carried out in the same sound-proof room for all volunteers with a temperature of between 21°C and 25°C and relative humidity between 50% and 60% and the volunteers were instructed to not drink alcohol or caffeine for 24 hours before the evaluation. The 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 as well as to 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. Several studies validate the use of the heart rate monitor to collect data on the heart rate variability compared with Holter (15-17). Before beginning the exercises, the volunteers received visual feedback through a monitor to maintain a neutral standing posture and they were instructed to maintain the same posture throughout the exercise (18). The systolic and diastolic blood pressures were measured before, immediately after and 30 min after the exercise. The oscillatory movement of the flexible pole (Flexibar®) was maintained by flexion and elbow extension. The flexible pole vibrated at a frequency of 5 Hz and the oscillation frequency of the flexible pole was based on an auditory stimulation through a metronome (Quartz Metronome®) calibrated at 300 bpm (6).

The exercises with the flexible pole (Figure 1) were conducted with volunteers in the standing position with feet apart (wide base) and shoulder flexion as the proposed position. To maintain the proper shoulder flexion in each upper limb, this position was used as a target visual feedback. All exercises were performed for 15 seconds with



**Figure 1** - Example of a flexible pole (Flexibar®) used in our study.

50-60 seconds of rest between each exercise. Three repetitions were performed for each exercise (6).

The exercises were performed with both arms in the following three positions: 1) with a shoulder at 90° of flexion with the flexible pole on the transverse plane (Figure 2A), 2) with the shoulders at approximately 180° of flexion with the flexible pole on the frontal plane, parallel to the ground (Figure 2B), and 3) with the shoulders at 90° of flexion with the flexible pole on the sagittal plane, perpendicular to the ground (Figure 2C). The HRV was analyzed at the following periods: control (at rest), 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 min after the exercise protocol (6).

**Statistical analysis**

Standard statistical methods were used for the calculation of the 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 the repeated measures test,

**Table 1** - Baseline heart rate, mean RR interval, weight, height and body mass index of the volunteers. Meters; kilograms; beats per minute; milliseconds.

Variable	Value
Height (m)	1.74 ± 0.07
Weight (kg)	69.4 ± 11
BMI (kg/m <sup>2</sup> )	22.2 ± 4
HR (bpm)	82.1 ± 12
Mean RR (ms)	718.2 ± 69

which was followed by the Bonferroni posttest. For non-parametric distributions, we used the Friedman test followed by the Dunns posttest. The HRV indices were compared at the following moments: rest vs. 0-5 vs. 5-10 vs. 10-15 vs. 15-20 vs. 20-25 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 GraphPad StatMate version 2.00 for Windows (GraphPad Software, San Diego California USA).

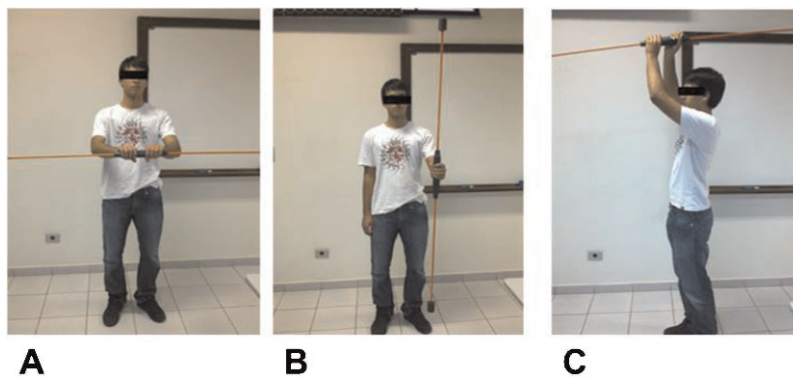
**RESULTS**

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

We observed that the flexible pole exercise protocol did not induce changes in the diastolic or systolic arterial pressures. However, in relation to the frequency domain indices, we noted significant changes only in relation to the index LF in absolute units in Table 2. The values were higher at 25-30 min after exercise compared to 5-10 min and 10-15 min after exercise with a flexible pole. No significant changes among the other indices in the frequency domain were noted.

As shown in Table 2, the SDNN index was significantly reduced at 5-10 min after exercise compared to 15-20 min after the protocol. Regarding the RMSSD and pNN50 indices, we observed increased levels of RMSSD at 25-30 min after exercise with a flexible pole compared to rest, 0-5 and 5-10 min after the exercise with flexible pole. The pNN50 was also increased at 25-30 min after exercise compared to 5-10 and 10-15 min after the flexible pole protocol.

Figure 3 shows an example of the visual evaluation of the power spectrum density analysis observed in one subject at



**Figure 2** - Exercise protocol with flexible pole at the three positions: 1) with the shoulder on 90° of flexion with the flexible pole on the transverse plane (A); 2) with shoulders at approximately 180° of flexion with the flexible pole on the frontal plane, parallel to the ground (B); and 3) shoulders at 90° of flexion with the flexible pole on the sagittal plane, perpendicular to the ground (C).



**Table 2** - Diastolic and systolic arterial pressure; the time in minutes (min) and frequency domain indices before and after exposure to exercise with a flexible pole. Low frequency; high frequency; low frequency/high frequency ratio; standard deviation of the normal-to-normal R-R intervals; percentage of adjacent RR intervals with a difference in the duration greater than 50 ms; and root-mean square of differences between adjacent normal RR intervals in a time interval. Mean ± Standard Deviation. Milliseconds; millimeters of mercury. \**p*<0.05: vs. 25-30 min. #*p*<0.05: vs. 15-20 min.

Variable	Rest	0-5 min	5-10 min	10-15 min	15-20 min	20-25 min	25-30 min
SAP (mmHg)	117.1±9	115.8±9	-	-	-	-	116.5±6
DAP (mmHg)	78.3±7	77.1±9	-	-	-	-	78.2±8
LF (ms <sup>2</sup> )	1097±743	927±674	974±806*	948±753*	1201±466	1120±394	1358±619
HF (ms <sup>2</sup> )	465±379	465±408	368±380	388±286	539±310	489±332	567±304
LF (nu)	71±8	65±18	73±9	70±11	68±15	68±16	70±14
HF (nu)	28±8	34±18	26±9	29±11	31±15	28±10	29±14
LF/HF	2±1	2±1	3±1	2±1	3±3	3±2	3±1
SDNN	49±17	47.7±16	41.9±18 <sup>#</sup>	45±11	56.5±15	49.2±8	55.2±19
RMSSD	31.2±13*	27.9±11*	28.4±15*	26.3±10	34.5±11	32.7±9	39.7±16
pNN50	12.2±10	11.8±10	9.8±12*	9.5±8*	13.3±8	12.3±7	19.7±16

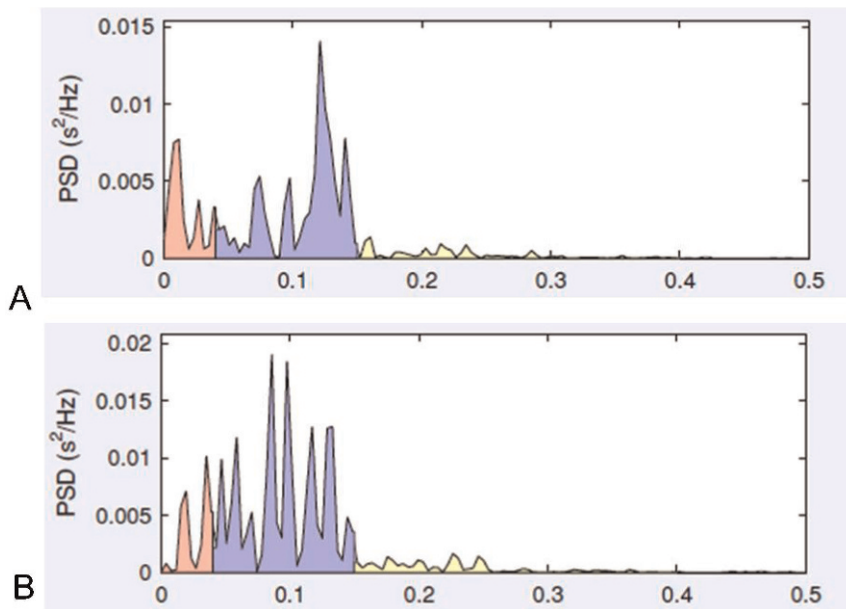
5-10 min after exercise (Figure 3A) and 25-30 min after the flexible pole protocol (Figure 3B). The LF band was increased at 25-30 min after the exercise.

**DISCUSSION**

Exercise with a flexible pole has been used to treat shoulder instability because it has been reported to be useful for shoulder muscle function (19). In this sense, resistance exercise training has become an important part of cardiac rehabilitation. It is well established in the literature that resistance exercise training, associated with endurance training, is a successful method for achieving beneficial outcomes for a physical training program (20). Nevertheless, the use of a flexible pole for cardiovascular rehabilitation has not yet been reported. We endeavored to evaluate cardiac autonomic regulation in response to a single bout of exercise with flexible pole in healthy men. Although the exercise protocol did not acutely change the diastolic and systolic blood pressures, the HRV was reduced

immediately after the exercise protocol and it recovered at approximately 30 min after the exercise protocol, indicating that this protocol can induce cardiac autonomic responses. These data indicate that the flexible pole exercise requires cardiac demands and it can be useful in exercise training.

In the frequency domain analysis, we reported that the LF in absolute units was reduced between 5-15 min after the flexible pole protocol compared to 25-30 min after the exercise. The LF index corresponds to both sympathetic and parasympathetic modulation of the heart and has a sympathetic predominance. This component of the frequency domain analysis was decreased during and immediately after an exercise protocol on a treadmill and this response lasted for more than one hour (11). On the other hand, the response of this index to strength exercises is not clear. A session of strength training exercise could not induce changes in the LF index in absolute units in healthy subjects (21,22), although single high- and low-intensity strength exercise protocols promoted systolic post-exercise hypotension in normotensive subjects, while only low-intensity strength



**Figure 3** - Power spectral density analysis observed in one subject at 5-10 minutes after exercise (A) and 25-30 minutes after the flexible pole protocol (B).





exercises decreased the diastolic blood pressure (22). Conversely, the LF index is reduced 20 min after a single bout of strength exercise (23). We demonstrated that the flexible pole exercise protocol used in our study produces significant responses in the LF time domain index, supporting the influence of this exercise protocol on cardiac autonomic regulation. Additional studies to investigate this standardized exercise protocol for use in rehabilitation are warranted.

The SDNN time domain index was significantly reduced at 5-10 min after the exercise protocol compared to 15-20 min after exercise. This index corresponds to the global variability of the heart rate, i.e., both the sympathetic and parasympathetic modulation of the heart (3). Previous studies have reported that during and after endurance exercises, the global HRV featured by the SDNN index is reduced (11,21). Considering that the LF index represents parasympathetic and sympathetic regulation of the heart, with a predominance of the sympathetic nervous system (1), these data support the involvement of both systems in the response to the flexible pole exercise protocol.

Our results may contribute to our understanding of cardiovascular responses during this specific type of exercise in healthy men, helping us develop a new rehabilitation protocol based on moderate exercise. According to our data, the parasympathetic modulation of the heart, represented by the RMSSD and pNN50 time domain indices, was significantly increased at approximately 30 min after exercise compared to approximately 5-10 min after completing the flexible pole exercise protocol. On the other hand, a previous study reported that cardiac autonomic regulation is not completely regained within 30 min after acute endurance or resistance exercise (24). It was previously observed that the parasympathetic modulation of the heart remained reduced 30 min after a single bout of endurance exercise (25,26) and full recovery may require approximately 3 hours (25). Changes in the heart towards baseline during late stages of recovery from exercise are mainly regulated through a resumption of the activities of parasympathetic nervous system in the sinoatrial node (27). Although the quick reduction in the heart rate after exercise may be induced by a progressive withdrawal of the sympathetic nervous system activity (28), this hypothesis was not supported after maximal exercise (5). Based on our results, complete recovery of cardiac autonomic activity after a single bout of flexible pole exercise may require approximately 30 min.

As a principle finding, we showed that the flexible pole exercise protocol used in our study induced changes in the HRV, which presents with an immediate reduction of the parasympathetic modulation of the heart after the exercise. Cardiac autonomic modulation is dependent on a complex interaction between the sympathetic and parasympathetic activity of the autonomic nervous system (1). During rest, parasympathetic modulation of the heart predominantly maintains the heart rate at lower values (29). On the other hand, during exercise, a decrease in the parasympathetic modulation of the heart and an increase in the sympathetic nervous system increases the heart rate to support the increased metabolism (29). Immediately after exercise interruption, there is a reduction in the inputs from mechanoreceptors and from the central nervous system (30), inducing an immediate, progressive reduction of the heart rate, i.e., vagal reactivation (29). In this context, beta blockade has no effect on the kinetics of heart rate recovery

(31) and sympathetic blockade may speed up recovery (27). This mechanism is also hypothesized to occur after a single session of flexible pole exercise.

Several physiological mechanisms may explain the changes in cardiac autonomic regulation induced by the single bout of the flexible pole exercise. Static contraction of skeletal muscle reflexively triggers sympathetic activity, increasing the heart rate and arterial blood pressure. Two mechanisms are suggested to account for the increases in cardiovascular function during and after exercise. The central command is a mechanism by which signals from the central site responsible for recruiting motor units activate cardiovascular control areas in the brainstem (32). The exercise pressor reflex is considered a peripheral neural reflex that originates from skeletal muscle. This reflex facilitates the control of the cardiovascular system during exercise. Stimulation of the group III (predominately mechanically sensitive) and group IV (predominately metabolically sensitive) afferents is involved in the activation of both mechanisms (33). Moreover, brain areas have been shown to be involved in the heart rate changes induced by exercise, such as the bed nucleus of stria terminalis, the medial prefrontal cortex and the periaqueductal gray area (34). Taken together, the peripheral and central components are suggested to be involved in the cardiac autonomic responses induced by a single bout of exercise with a flexible pole.

After a careful search of the Medline/Pubmed database, we found that this is the first study investigating the effects of flexible pole exercise on cardiac autonomic regulation. The effects of vibration were previously investigated, and its use for rehabilitation and/or training purpose was recently studied (35). Vibration may be applied to tendons and muscles or to the whole body, through the use of vibrating platforms or a flexible pole. Exercise with a flexible pole is different from the aforementioned forms of vibration exercises due to the low frequency of approximately 5 Hz (300 bpm) (6). Our findings indicate that exercise with a flexible pole can induce changes in cardiac autonomic regulation, suggesting that this form of exercise may be beneficial for neural cardiac regulation and it should be recommended for sedentary healthy subjects.

Our results have a significant level of clinical relevance because the standardized exercise protocol induced changes in cardiac autonomic regulation, indicating that this exercise should be further evaluated for use in rehabilitation protocols. Moreover, the HRV may prove valuable in investigating the severity of disorders (14,15) and evaluating the positive physiologic effects of different therapeutic interventions, such as aerobic exercise training (36). We believe that patients with severe cardiac disease should not perform the exercise protocol proposed in our study, but that subjects with moderate heart disorders, such as mild hypertension, who are able to perform moderate exercises would benefit from this standardized exercise. Additional studies should be performed to address these issues and more firmly establish the importance of HRV assessment in this chronic disease population.

Our study presents several important points. This study evaluated the effects of only a single session and the findings are related to an immediate effect of the flexible pole exercise on the heart rate dynamics. We suggest the use of follow-up investigations to evaluate the effect of flexible pole exercise training on physical capacity. We tested a group of healthy and sedentary men; extrapolating these



results to subjects with cardiac and/or respiratory disorder and subjects of different ages should be carefully considered. HRV was not analyzed during exercise because form style of exercise does not provide a stable HR for spectral analysis.

In conclusion, a single bout of exercise with a flexible pole can induce acute cardiac autonomic responses in healthy men that are characterized by a decreased HRV and parasympathetic recovery at approximately 30 min after the exercise. The flexible pole exercise protocol is an efficient method for use during exercise training.

## ■ ACKNOWLEDGMENTS

We thank FAPESP for financial support (number 2012/09043-1).

## ■ AUTHOR CONTRIBUTIONS

Ogata CM, Navega MT, Abreu LC, Ferreira C, Cardoso MA, Raimundo RD, Ribeiro VL and Valenti VE participated in the acquisition of data and revision of the manuscript. Ogata CM, Navega MT, Abreu LC and Valenti VE determined the design of the study and interpreted the data. Ogata CM, Raimundo RD, Ferreira C, Ribeiro VL, Cardoso MA and Valenti VE drafted the manuscript. All authors read and approved the final version of the manuscript submitted for publication.

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