Comparison of the effects of aerobic and resistance training on cardiac autonomic adaptations in ovariectomized rats

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**A B S T R A C T**

We have compared the effects of two types of physical training on the cardiac autonomic control in ovariectomized and sham-operated rats according to different approaches: double autonomic blockade (DAB) with methylatropine and propranolol; baroreflex sensibility (BRS) and spectral analysis of heart rate variability (HRV).

Wistar female rats (±250 g) were divided into two groups: sham-operated and ovariectomized. Each group was subdivided into three subgroups: sedentary rats, rats submitted to aerobic trained and rats submitted to resistance training.

Ovariectomy did not change arterial pressure, basal heart rate (HR), DAB and BRS responses, but interfered with HRV by reducing the low-frequency oscillations (LF=0.20–0.75 Hz) in relation to sedentary sham-operated rats. The DAB showed that both types of training promoted an increase in the predominance of vagal tonus in sham-operated rats, but HR variations due to methylatropine were decreased in the resistance trained rats compared to sedentary rats.

Evaluation of BRS showed that resistance training for sham-operated and ovariectomized rats reduced the tachycardic responses in relation to aerobic training. Evaluation of HRV in trained rats showed that aerobic training reduced LF oscillations in sham-operated rats, whereas resistance training had a contrary effect. In the ovariectomized rats, aerobic training increased high frequency oscillations (HF = 0.75–2.5 Hz), whereas resistance training produced no effect.

In sham-operated rats, both types of training increased the vagal autonomic tonus, but resistance training reduced HF oscillations and BRS as well. In turn, both types of training had similar results in ovariectomized rats, except for HRV, as aerobic training promoted an increase in HF oscillations.

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1. Introduction

Epidemiological studies have shown that aerobic physical training has beneficial effects on morbidity and mortality resulting from cardiovascular diseases (Tsatsoulis and Fountoulakis, 2006; Warburton et al., 2006). In women, the regular practice of physical exercises is especially favourable, mainly after menopause (Bonaiuti et al., 2002), when estrogen reduction contributes to an increase in the incidence of such diseases (Gutkowska et al., 2007).

Part of these beneficial effects is the result of important cardiovascular adaptations. Such adaptations are characterized by decrease in basal heart rate (HR) and intrinsic heart rate (IHR) of cardiac pacemaker (De Angelis et al., 2004; Tezini et al., 2009), left ventricle eccentric hypertrophy (Garciaarena et al., 2009), increase in ejection volume, increase in cardiac debt during exercise (Fenning et al., 2003), improvement in baroreflex sensibility (Souza et al., 2007), and mainly, adaptations in the cardiac autonomic control, which are characterized by both decreased sympathetic autonomic influence and increased vagal influence on the heart (Carter et al., 2003; Souza et al., 2009; Tezini et al., 2009).

On the other hand, little is known about the cardiovascular benefits of resistance training. The literature shows that this type of exercise has been used as anti-hypertensive therapy as well as for control of other chronic–degenerative diseases of metabolic origin such as obesity (Ibañez et al., 2005; Warner et al., 2010) and diabetes mellitus (Svacinová et al., 2008), yielding very promising results. However, evidence showing the action of this type of exercise on cardiovascular autonomic control is still poor. The few studies existing in the literature have reported very contradictory results as they had addressed different physiological conditions and applied different protocols, thus not allowing a proper comparison of the results obtained (Selig et al., 2004; Collier et al., 2009; Hu et al., 2009).

In this sense, because of the lack of solid evidence regarding the effects of resistance training on the cardiovascular autonomic control also apply to estrogen deficiency, our objective was to investigate and
compare the effects of aerobic and resistance physical training on the cardiovascular autonomic adaptations in ovariectomized rats by using different approaches; evaluation of autonomic tonic control by means of pharmacological blockade; baroreflex sensitivity; and evaluation of cardiovascular autonomic modulation by analyzing both heart rate variability and systolic arterial pressure.

2. Methods

All experimental procedures involved in this study were reviewed and approved by the Animal Care and Use Committee.

2.1. Animals

The experiments were performed using female Wistar rats (240–260 g) that were housed in a room at 21 °C with a 12 h light/dark cycles and allowed free access to tap water and standard rat chow. The rats were divided into six experimental groups: sedentary sham-operated rats (n=12), trained sham-operated rats with aerobic exercise by swimming (n=12), trained sham-operated rats with resistance exercise (n=12), sedentary ovariectomized rats (n=12), ovariectomized trained rats with aerobic exercise by swimming (n=12) and ovariectomized trained rats with resistance exercise (n=12).

2.2. Ovariectomy

At 10 weeks of age, rats were anaesthetized (250 mg/kg, i.p. tribromoethanol) and a small abdominal incision was made. The ovaries were then located and a silk thread was tightly tied around the oviduct, including the ovarian blood vessels. The oviduct was sectioned and the ovary removed. The skin and muscle wall were then sutured with silk thread. After surgery, the rats received an injection of antibiotics (40,000 U/kg penicillin G procaine IM). Sham rats were submitted to simulated ovariectomy according to the same procedures described for ovariectomized rats, except for oviduct section and ovary removal. The rats remained in individual cages for post-surgical recovery during a period of 14 days.

2.3. Aerobic exercise

The program of physical training consisted of swimming exercises conducted in a glass aquarium (100 cm long, 80 cm wide, and 80 cm high) containing heated water (30 °C). The program was divided into two phases: the first phase consisted of a 2-week adaptation, beginning with a 10-minute swimming session that was gradually increased to 45 min for 6 days per week. The second phase consisted of a 10-week swimming training program in which the rats had 1-hour training for 6 days per week.

2.4. Resistance training

The physical resistance training was applied according to protocol already described (Hornberger and Farrar, 2004), with gradual load increase during the 10-week period of training. Prior to the resistance training itself, the rats were submitted to a 2-week adaptation program. After this adaptation period, the training was performed 3 days a week on an alternate-day basis, with the rats executing climbing procedures 6–7 times a day with 2-minute intervals between each repetition.

2.4.1. Experimental protocol

On the sixth day of the last week, under tribromoethanol anesthesia (250 mg/kg intraperitoneal), femoral venous and arterial catheters (PE-50 soldered to PE-10) filled with heparinized saline (500 IU/ml) were inserted into the animals and were exteriorized through the animal's back. Twenty-four hours after the surgical procedures, AP was measured in conscious rats kept in a quiet environment. AP was recorded with a pressure transducer (MLT0380; ADInstruments), and the amplified signal (ML110; ADInstruments) was fed to a computer acquisition system (PowerLab 8/30; ADInstruments). Mean AP (MAP) and heart rate (HR) were calculated from arterial pulse pressure.

2.5. Sympathovagal tonus and intrinsic rate of the cardiac pacemaker

Assessment of the influence of autonomic tonus, sympathetic and parasympathetic, in the HR determination was investigated by administrating propranolol (5 mg/kg) and methylatropine (4 mg/kg), respectively. After recording the basal HR for 30 min, methylatropine was injected in half of the rats of each group, and HR was recorded during the next 15 min to assess the effect of vagal blockade on HR. Propranolol was then injected in the same rats, and HR was recorded for another 15 min to determine the intrinsic HR (IHR). In the other half of the rats, the methylatropine–propranolol sequence was reversed to propranolol–methylatropine, following the same recording procedure (15 min each) for each drug as in the previous sequence used to determine the IHR. Data from the methylatropine–propranolol and propranolol–methylatropine sequences were pooled to provide basal HR (before any drugs) and IHR.

2.6. Baroreflex sensitivity

Changes in MAP were elicited by alternating bolus injections of phenylephrine (0.1 to 16.0 μg/kg) promoting bradycardic reflex responses and sodium nitroprusside (0.4 to 64.0 μg/kg) promoting tachycardic reflex responses. MAP and HR were measured before and immediately after injection of phenylephrine (or sodium nitroprusside) when the AP achieved a new steady-state level. The two parameters were then allowed to return to baseline, after which the next injection was given. A total of at least five increases and five decreases in MAP of different degrees were elicited in each rat. Changes in MAP and HR were plotted and analyzed by means of linear regression analysis, which calculated the slope (gain) of the regression line obtained by the best-fit points relating changes in MAP and HR.

2.7. Spectral analysis

The baseline AP and HR recorded during a 40-minute period were processed by customized computer software that applies an algorithm to detect cycle-to-cycle inflection points in the pulsatile AP signal, thus determining beat-by-beat values of systolic and diastolic pressures. Beat-by-beat pulse interval (PI) series from the pulsatile AP signal were also generated by measuring the length of time between adjacent systolic waves. From the baseline 40-minute recording period, the time series of PI and systolic AP (SAP) were divided into contiguous segments of 300 beats, overlapping by half. After calculating the mean value and the variance of each segment, these were submitted to a model-based autoregressive spectral analysis as described elsewhere (Malliani et al., 1991; Rubini et al., 1993; Task Force, 1996). Briefly, a modeling of the oscillatory components presented in stationary segments of a beat-by-beat time series of SAP and PI was calculated based on Levinson–Durbin recursion, with the model order chosen according to Akaike's criterion (Malliani et al., 1991). This procedure allows an automatic quantification of the centre frequency and power of each relevant oscillatory component present in the time series. The oscillatory components were labeled as having very low (0.01–0.19 Hz), low (LF; 0.20–0.75 Hz), or high (HF; 0.75–2.50 Hz) frequency. The power of the HF component of heart rate variability (HRV) was expressed in absolute units, whereas the LF component of HRV was expressed in normalized units, obtained by
both types of training were compared, the groups of resistance vagal autonomic tonus compared to sedentary rats. However, when basal HR and IHR, in association with an increase in the percentage submitted to different physical trainings presented decrease in their change in the cardiac autonomic tonus balance was observed. A decrease in basal HR and IHR compared to sedentary rats, but no ovariectomized rats, submitted to different types of training, also had Table 1 also lists the gains for baroreflex sensitivity to bradycardiac and tachycardic responses following administration of phentolamine and sodium nitroprussiate, respectively. The results showed that sedentary ovariectomized rats exhibited no change in the baroreflex sensitivity compared to the sham-operated sedentary ones. Aerobic physical training, either in sham-operated or ovariectomized rats, has also promoted no such alteration. On the other hand, the resistance physical training reduced the gain in baroreflex sensitivity to tachycardic responses in sham-operated rats compared to sedentary and aerobic trained ones. In turn, ovariectomized rats submitted to resistance training had a decreased baroreflex sensitivity gain only in relation to aerobic trained rats.

Data are reported as mean ± SEM. The results of hemodynamic values, pharmacological blockade with methylnalopine and propranolol, baroreflex sensitivity and spectral analysis were assessed by two-way ANOVA followed by Tukey’s post hoc test. Significant differences were considered at p < 0.05.

### 2. Results

#### Table 1

<table>
<thead>
<tr>
<th>Values</th>
<th>Sham</th>
<th>Aerobic</th>
<th>Resistance</th>
<th>Ovariectomized</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR, bpm</td>
<td>371 ± 3</td>
<td>329 ± 4</td>
<td>349 ± 1</td>
<td>361 ± 4</td>
</tr>
<tr>
<td>MAP, mm Hg</td>
<td>95 ± 3</td>
<td>96 ± 2</td>
<td>99 ± 3</td>
<td>97 ± 2</td>
</tr>
<tr>
<td>Tonic autonomic control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR after methylnalopine, bpm</td>
<td>443 ± 6</td>
<td>396 ± 6</td>
<td>397 ± 3</td>
<td>431 ± 10</td>
</tr>
<tr>
<td>ΔHR after methylnalopine, bpm</td>
<td>72 ± 7</td>
<td>67 ± 12</td>
<td>48 ± 5</td>
<td>70 ± 11</td>
</tr>
<tr>
<td>% HR after methylnalopine</td>
<td>67 ± 1</td>
<td>86 ± 3</td>
<td>82 ± 1</td>
<td>65 ± 2</td>
</tr>
<tr>
<td>HR after propranolol, bpm</td>
<td>330 ± 7</td>
<td>319 ± 5</td>
<td>338 ± 2</td>
<td>323 ± 4</td>
</tr>
<tr>
<td>ΔHR after propranolol, bpm</td>
<td>−41 ± 7</td>
<td>−10 ± 4</td>
<td>−11 ± 2</td>
<td>−38 ± 14</td>
</tr>
<tr>
<td>% HR after propranolol, bpm</td>
<td>36 ± 3</td>
<td>14 ± 2</td>
<td>18 ± 1</td>
<td>35 ± 2</td>
</tr>
<tr>
<td>IHR, bpm</td>
<td>366 ± 2</td>
<td>339 ± 3</td>
<td>344 ± 3</td>
<td>359 ± 5</td>
</tr>
<tr>
<td>Baroreflex sensitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bradycardic gain, bpm/mm Hg</td>
<td>−1.43 ± 0.17</td>
<td>−1.30 ± 0.14</td>
<td>−1.51 ± 0.26</td>
<td>−1.71 ± 0.16</td>
</tr>
<tr>
<td>Tachycardic gain, bpm/mm Hg</td>
<td>2.85 ± 0.02</td>
<td>3.29 ± 0.32</td>
<td>2.03 ± 0.15</td>
<td>2.71 ± 0.28</td>
</tr>
</tbody>
</table>

All values are expressed as mean ± SEM. HR, heart rate; MAP, mean arterial pressure; IHR, intrinsic heart rate.

### 4. Discussion

Our study has shown that ovariectomy altered the ability to control autonomic activity, which was verified by decrease in LF oscillations. In sham-operated rats, aerobic physical training promoted relevant cardiac autonomic adaptations characterized by sympathetic predominance of baseline component in the determination of basal HR, associated with decrease in LF oscillations. In turn, resistance physical training did not influence baroreflex sensitivity and HF ratio in ovariectomized rats in relation to LF/HF ratio.

#### Table 2 and Fig. 2 (a,b,c) show the spectral analysis mean values for HRV (pulse interval) in all groups studied. In sedentary rats, ovariectomy reduced either total variance (Fig. 2A) nor HF oscillations (Fig. 2C), but LF oscillations were found to be decreased (Fig. 2B). Fig. 2A also shows that both types of training reduced total variance in sham-operated rats, although in ovariectomized rats aerobic training promoted an increase. Fig. 2B shows that aerobic physical training promoted reduction in LF oscillations in sham-operated rats, whereas resistance training promoted an increase instead. It was also shown that ovariectomized rats had no alteration. Fig. 2C shows that resistance physical training promoted reduction in HF oscillations only in sham-operated rats, whereas aerobic physical training promoted increase only in ovariectomized rats. Analysis of LF/HF ratio showed that sham-operated rats submitted to aerobic training had reduced values, while in rats submitted to resistance training showed values increased compared to sedentary rats. No difference was observed in ovariectomized rats in relation to LF/HF ratio.

Table 2 also lists the results of the analysis of SAP variability, showing that no difference was found between the groups studies according to the parameters evaluated.

### 4. Discussion

Ovariectomy has neither caused alterations in the basal values of HR or HR ratio among those with distinct autonomic control, thus corroborating results of previous studies (Liang et al., 1997; Nickenig et al., 1998; Reckelhoff et al., 2000; Säinä et al., 2004;
Tezini et al., 2009). However, some authors demonstrated that ovariectomy might promote an increase in the arterial pressure (Dantas et al., 1999; Hernández et al., 2000; Chappell et al., 2003; Irigoyen et al., 2005; Souza et al., 2007; Sanches et al., 2009). This discrepant outcome needs to be further investigated, but it is possible that methodological procedures are involved such as time elapsed between ovariectomy and experimental physical training (Flues et al., 2010). Another interesting finding is that no change in baroreflex

![Fig. 1. Graphic representation of basal heart rate (HR; black line), intrinsic heart rate (IHR; dashed line) and respective percentage variations of HR after parasympathetic blockade with methylatropine (M: upper boundary of the white rectangle) and sympathetic blockade with propranolol (P; lower boundary of the dark gray rectangle) in sham-operated and ovariectomized sedentary rats (A); sham-operated rats divided into sedentary, aerobic trained, and resistance trained groups (B); and ovariectomized rats divided into sedentary, aerobic trained, and resistance trained groups (C). *P<0.05 vs. Sham Sedentary Rats; **P<0.05 vs. Sham Aerobic Trained Rats; ***P<0.05 vs. Ovariectomized Sedentary Rats.

Table 2

Spectral parameters of PI and SAP calculated from time series using autoregressive spectral analysis in sham-operated and ovariectomized rats divided into three groups: sedentary; aerobic trained; and resistance trained.

<table>
<thead>
<tr>
<th></th>
<th>Sham</th>
<th>Ovariectomized</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sedentary</td>
<td>Aerobic</td>
</tr>
<tr>
<td>Baseline values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI, ms</td>
<td>0.161 ± 0.002</td>
<td>0.182 ± 0.003</td>
</tr>
<tr>
<td>SAP, mm Hg</td>
<td>115 ± 2</td>
<td>113 ± 3</td>
</tr>
<tr>
<td>Spectral parameters: PI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance, ms²</td>
<td>13.3 ± 1.7</td>
<td>7.2 ± 0.9</td>
</tr>
<tr>
<td>LF,  nu</td>
<td>33 ± 4</td>
<td>9 ± 2</td>
</tr>
<tr>
<td>HF, ms²</td>
<td>5.9 ± 0.8</td>
<td>4.1 ± 0.5</td>
</tr>
<tr>
<td>LF–HF ratio</td>
<td>0.58 ± 0.11</td>
<td>0.12 ± 0.02</td>
</tr>
<tr>
<td>Spectral parameters: SAP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance, mm Hg²</td>
<td>15 ± 1.6</td>
<td>12.8 ± 1.5</td>
</tr>
<tr>
<td>LF, mm Hg²</td>
<td>109 ± 1.3</td>
<td>94 ± 1.2</td>
</tr>
<tr>
<td>HF, mm Hg²</td>
<td>2.1 ± 0.3</td>
<td>1.8 ± 0.3</td>
</tr>
</tbody>
</table>

All values are expressed as mean ± SEM. PI, pulse internal; SAP, systolic arterial pressure; LF, low frequency; HF, high frequency; nu, normalized units.

* P<0.05 vs. Sham Sedentary Rats.  
** P<0.05 vs. Sham Aerobic Trained Rats.  
*** P<0.05 vs. Ovariectomized Sedentary Rats.  
**** P<0.05 vs. Ovariectomized Aerobic Trained Rats.
sensibility was observed in the ovariectomized rats, which was pointed out elsewhere (Flues et al., 2010; Dias-Silva et al., 2009). Nevertheless, these same studies have also reported that a decrease in the baroreflex sensibility was accompanied by an increase in ovariectomized rats, an event that might be the key cause of imbalance in the reflex control of heart rate observed by these studies. On the other hand, ovariectomy promoted changes in the HRV modulation in sedentary rats, which was characterized by the reduction on LF oscillations. A previous study using single blockade of cardiac autonomic components in ovariectomized rats showed that LF oscillations were little affected by methylatropine but very reduced following administration of propranolol (Tezini et al., 2009), thus suggesting involvement of the sympathetic autonomic component as well.

Another interesting observation in the present study is that two types of physical exercises, aerobic and resistance ones, have promoted reductions in the basal values of HR and IHR in both sham-operated and ovariectomized rats. In sham-operated rats, however, aerobic physical training promoted greater reductions in basal HR values compared to resistance training, whereas no difference was found in ovariectomized rats. The cause for such a finding is uncertain and deserves further investigation.

Indeed, the mechanisms accounting for the basal HR reduction after physical training has not yet been fully elucidated, but some hypotheses have been raised though. Among the most accepted hypotheses, one can cite the increase in the cardiac vagal tonic influence (Smith et al., 1989; Hassan, 1991; Souza et al., 2007), as well as automaticity adaptations and conduction in sinus nodes impulse, thus resulting in decreased IHR (Negrão et al., 1992; Stein et al., 2002; Danson and Paterson, 2003; Tezini et al., 2009). In our study, we have observed that although ovariectomized rats presented no change in their cardiac autonomic tonic balance (Fig. 1C), they had reductions in basal HR values similar to those of sham-operated rats (Fig. 1B). This finding strongly suggests the importance of IHR in reducing the basal HR.

By comparing the effects of different types of physical exercises on the autonomic control of sham-operated rats, we have observed that aerobic training did not interfere with baroreflex sensibility but had an influence on the cardiac autonomic tonic balance, thus establishing an increase in the predominance of vagal autonomic component. Adaptations in the modulation of HRV were characterized by decreased LF oscillations. The results observed in autonomic tonus and HRV modulation suggest a reduction in the sympathetic influence and increase in vagal influence regarding the HR control, a finding already reported elsewhere (Tezini et al., 2009; Souza et al., 2009). On the other hand, resistance physical training did not promote the same effects of aerobic training. The rats undergoing this type of training showed reduction in HF oscillations and increase in LF oscillations. In fact, these results show that resistance training impairs the cardiac autonomic control by affecting mainly the parasympathetic autonomic component, thus reducing the cardiac autonomic modulation. With regard to autonomic tonus, the results observed in sham-operated rats submitted to resistance training even indicated an increase in the predominance of vagal autonomic component in the determination of HR, in percentage values. However, we observed a small increase in absolute values of HR following administration of methylatropine in relation to sedentary group, a finding possibly indicating an imbalance in either heart itself or cardiac autonomic control. The causes for such adverse results between aerobic and resistance exercises are unknown, but it is possible that the workload imposed on the latter is a determining factor. In our study, the workload was continuously incremented and had as reference the animal’s maximum movement capacity, which ensured that the exercise being performed was characterized as a high-intensity resistance training (Hornberger and Farrar, 2004). Therefore, this study provides results that can contribute to other investigations using protocols with milder workloads in order to assess at which point the workload being imposed on the resistance training can be harmful to the cardiovascular autonomic control.

The effects of aerobic physical training on the cardiac autonomic control in ovariectomized rats were different from those observed in sham-operated rats. In this case, changes occurred only in HRV, which were characterized by an increase in HF oscillations. However, resistance training did not promote any adaptation in ovariectomized rats, including the HRV. These results point to the importance of estrogen in the autonomic adaptations induced by physical exercises. In fact, the role played by estrogen in the autonomic control is not fully understood. However, several studies have demonstrated that

![Fig. 2. (A) Total variance of pulse interval. (B) Spectral power density of pulse interval in the LF bands in normalized units (nu). (C) Spectral power density of pulse interval in high frequency (HF) bands in absolute units in sham-operated and ovariectomized rats divided into three subgroups: sedentary; aerobic trained; and resistance trained. *P<0.05 vs. Sham Sedentary Rats; †P<0.05 vs. Sham Aerobic Trained Rats; ‡P<0.05 vs. Ovariectomized Sedentary Rats; ¶P<0.05 vs. Ovariectomized Aerobic Trained Rats.](image-url)
menopause is frequently associated with impairment in the cardiac autonomic control under various aspects, including the modulation of HRV (Virtanen et al., 2000; Zhang et al., 2000; Neves et al., 2007). The causes of such impairment are still unknown, but it seems to involve adaptations at central sites in the cardiovascular control resulting from estrogen deficiency (Zhang and Kosaka, 2002; Rahimian et al., 2004). This effect is supported by identifying estrogen receptors within the nucleus of cardiac myocytes and arterial smooth muscle cells (Grohé et al., 2004). Although the role of estrogen receptors in the cardiovascular system remains unclear, the identification of estrogen receptors in these cells provides evidence for the involvement of estrogen in cardiovascular control, suggesting that estrogen plays a key role in the autonomic adaptations at central sites in the cardiovascular control resulting from estrogen deficiency. However, the relationship between the role played by estrogen receptors and the mechanisms underlying this phenomenon remains to be elucidated.

With regard to SAP variability, ovariectomy and physical training promoted an alteration in neither total variance nor LF and HF oscillations. In fact, these results were corroborated by a recent study in which no differences in SAP variability were also found in ovariectomized Wistar–Kyoto female rats (Dias-Silva et al., 2009), thus supporting the notion that estrogen seems not to influence autonomic modulation of arterial pressure. However, the relationship between the role played by estrogen receptors and the mechanisms underlying this phenomenon remains to be elucidated.

In conclusion, the aerobic physical training in sham-operated female rats promotes beneficial adaptation in their cardiovascular autonomic control, mainly regarding the cardiac autonomic modulation. On the other hand, resistance-trained rats exhibited preoccupying cardiac autonomic alterations, with some cases showing even opposite results compared to those from aerobic training. Additionally, ovariectomy seems to interfere with the effects of physical training, thus suggesting that estrogen plays a key role in the autonomic adaptations resulting from physical training, although the mechanisms involved are not fully understood and thereby need to be investigated.

References


