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Autonomic Modulation in Older Women: Using Resistance Exercise as a Countermeasure

HAYDEN GERHART†[1,3], YU LUN TAI†[1], CURTIS FENNELL†[1,4], XIÁN MAYO†[1,2], and J. DEREK KINGSLEY‡[1]

[1]Cardiovascular Dynamics Laboratory, Kent State University, Kent OH, USA; [2]University A Coruña, Coruña SPAIN; [3]Kinesiology, Health, and Sport Science, Indiana University of Pennsylvania, Indiana PA, USA; [4]University of Montevallo, Montevallo AL, USA

†Denotes graduate author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 10(2): 178-187, 2017 It is unclear if resistance training (RT) can be used to alter declines in autonomic modulation associated with aging. Young women (YW; range 18-25 yrs) and older women (OW; range 50-72 yrs) were compared at baseline. Only OW underwent supervised RT 2 days a week for 12-weeks. Baseline and post-training measurements included heart rate variability (HRV) and complexity (Sample Entropy) to assess autonomic modulation. The 12-weeks of RT consisted of 9 exercises performing 3 sets of 8-12 repetitions. At baseline, group differences in maximal strength, and autonomic modulation were evaluated with a one-way ANOVA with BMI as a covariate. In the OW, the effects of RT were evaluated with repeated-measures ANOVA in order to compare baseline to after RT. The YW had significantly ($p \leq 0.05$) lower diastolic, but not systolic blood pressure. The YW also had significantly ($p \leq 0.05$) greater absolute Ln (natural logarithm) high-frequency (HF) power and normalized HF power compared to the OW. In addition, there were significantly ($p \leq 0.05$) greater levels of normalized low-frequency power (LF) (and the LF/HF ratio) in the OW compared to the YW before RT. However, no difference was found for Sample Entropy. After RT, OW significantly ($p \leq 0.05$) increased the chest press (28%) and leg extension (33%). RT had no significant effect on any autonomic parameter suggesting that it may not be a sufficient stimulus to alter the effects of aging.

KEY WORDS: Vagal modulation, strength training, heart rate variability, heart rate complexity, sympathetic activity

INTRODUCTION

Resistance training (RT) is recommended by the American College of Sports Medicine and the American Heart Association for women, both young and old, as a means to improve muscular strength, bone mass and quality of life (20, 27). In addition, it has been suggested that RT may reduce the risk for the development of cardiovascular disease (CVD) (2, 7). Although the physiological adaptations of RT are well documented in young, healthy individuals, the effect of RT on autonomic modulation in older women has not been highly investigated.

Measurements of autonomic modulation using heart rate variability (HRV) and heart rate complexity (HRC) are important such that they may predict the risk of cardiovascular disease (14, 33). The deterioration of HRV and HRC measures in older women compared to young women is significant (17, 34), indicating a reduction in autonomic modulation (vagal tone) across the lifespan in women which is directly linked to the development of CVD (37). These changes in autonomic modulation with aging is multi-faceted. Increases in sympathetic modulation with aging may stem from alterations in baroreflex responsiveness (23) possible mediated by increases in arterial stiffness (24), and/or changes in efferent neural conduction (21).

Although RT yields significant improvements in both power and strength in older women (11), it may not be a sufficient stimuli to elicit significant alterations in autonomic modulation assessed via HRV (12). In young women, RT has been suggested to have no effect on HRV (9). On the contrary, RT may increase vagal modulation in women that have autonomic dysfunction at rest (10). It has been suggested that Sample Entropy (SampEn), a measure of HRC, may be a more sensitive measure of autonomic modulation (15). While it has been demonstrated that SampEn increases in young men after a period of RT (16), we found no reports addressing SampEn after RT in young women or older women. It is clear that there are limited data comparing young women to older women in terms of autonomic modulation and in response to RT. For this reason, it is essential that researchers continue to explore measures of autonomic modulation following resistance exercise training in older women using HRV and the more sensitive measure of HRC.

Due to detrimental changes in autonomic modulation across the lifespan, it is clear that more data are needed in regards to the effects of RT, specifically in women. Therefore, the purpose of the present study was to determine if 12-weeks of RT improves autonomic modulation in older women. We hypothesized that 12-weeks of RT would improve autonomic modulation in older women compared to baseline.

METHODS

Participants

Sixteen young women (YW; range 18-25 yrs) and twenty-three older women (OW; range 50-72 yrs) volunteered for the study. Participants were recruited from the local area through flyers and newspaper advertisements. All participants were previously sedentary and none had been participating in any exercise (aerobic or resistance) for a period of at least 1 year. All participants were normotensive (<140/90 mmHg). All participants were free of any overt diseases such as any musculoskeletal conditions, coronary artery disease, diabetes, renal, adrenal, pituitary and thyroid and none had a current or recent smoking history (<6 months). No participants were taking any medications or supplements known to affect heart rate (HR) or blood pressure (BP) as assessed with a medical questionnaire. All participants gave written consent prior to collection of any data. The study was approved by the Kent State University Institutional Review Board.

Protocol

To investigate the autonomic differences between YW and OW, both groups were compared at baseline. Also, OW performed 12-weeks of RT as a countermeasure to evaluate the autonomic changes with training. For this, OW were analyzed at baseline and after the training.

Both groups performed two testing sessions in which the 1-repetition maximum (1RM) was assessed and verified. On the third day of testing, the experimental session (baseline) was carried out in both groups. For this, participants arrived at the Cardiovascular Dynamics Laboratory following a 12-hour overnight fast, and having abstained from caffeine, alcohol and strenuous physical activity for 24 hours. Height and weight were collected and body mass index (BMI) was calculated accordingly. Afterwards participants rested in the supine position for 20 total minutes. In the first 15 minutes, participants rested in a quiet, temperature controlled room prior to any data collection. Autonomic modulation was assessed during the next 5-minute period (minute 15-20). All baseline data were collected over a 14-day period of time. OW were assessed again after 12-weeks of supervised RT under the same conditions as baseline, 48 hours removed from their last training session.

Height was measured using a stadiometer and was measured to the nearest 0.05 cm. Weight was measured using a balance-beam scale and was measured to the nearest 0.1lb and then was converted to kg. Body mass index (BMI) was calculated as weight divided by the squared height (kg/m^2).

Both groups had their maximal strength assessed utilizing the 1RM on two different resistance machines: chest press, and leg extension. Each participant was asked to move their maximal weight 1 time through a full range of motion. The test protocol consisted of a total of 5 maximal attempts for each exercise, following 1-2 warmup sets. Participants began with 50% of their body weight, and were progressed to their repetition maximum over the ensuing sets. Three minutes of rest were allotted between exercises and sets. Seventy-two hours after the initial measurement participants returned to the laboratory for verification of the 1RM such that the test was repeated. The highest resistance utilized during the two sessions was used as the 1RM.

All electrocardiograph (ECG) signals were collected at a rate of 1000Hz using a modified CM5 configuration that was interfaced with ADInstruments PowerLab (AD Instruments, Colorado Springs, CO). The WinCPRS (Absolute Aliens, Turku, Finland) software was used to import the ECG signal and all subsequent analyses of HRV and HRC. All ECGs were visually inspected for ectopics, noise and artefacts prior to extraction of the beat-by-beat R-R intervals. Blood pressure was assessed in duplicate with an automated oscillometric blood pressure system (Omron, Series 3 BPN710N). All participants breathed with a metronome set at 12 breaths/minute for all data collection. HRV was measured following the guidelines established by the European Task Force on HRV (32). Fast Fourier transformation was utilized to generate the spectral power. Overall autonomic modulation was assessed using the total power of HRV. The low-frequency (LF, 0.04-0.15Hz) power of HRV is mediated by both the sympathetic and parasympathetic branches of the autonomic nervous system (22). The high-frequency (HF, 0.15-0.4Hz) power of HRV is indicative of parasympathetic modulation (25). Both power spectra (LF and HF) were calculated in absolute (ms^2) and normalized (nu) units. Normalized units of LF (LFnu) and HF (HFnu) are determined in regards to the direct proportion of the total power and are indicative of sympathetic and parasympathetic modulation, respectively (32). The LF/HF ratio of HRV is a measurement of sympathovagal balance (32). SampEn was used as a method for examining the complexity of the R-R interval after removal of the linear trend. In short, SampEn has been defined as the probability of matches or sequences being similar over a short period of time, which has a range of 0-2 (30). The more predictive the signal, the closer the value is to 0; the more chaotic, the closer to 2 (30). For a more detailed description, see Richman et al. (30).

The OW performed supervised RT that occurred twice a week for 12 weeks. Each session was separated by at least 48 hours. The RT regimen consisted of 3 sets for the leg extension, chest press, leg curl, seated row, leg press, abdominal crunch, hyperextensions, shoulder press and biceps curl. The initial intensity of training was set at a predicted 50-60% 1RM. This intensity was immediately adjusted following completion of the first set in order to induce fatigue between 8-12 repetitions. This intensity progressed to 75-85% 1RM for the upper- and lower-body for 12 weeks. Ninety seconds of rest was given between each set and each exercise. Each participant was asked to perform 8-12 repetitions per set. When the participant was able to complete 12 repetitions on 2 consecutive training days the resistance was increased by 2% to 10% based on recommendations set forth by the American College of Sports Medicine (28). Each training session lasted up to 30 minutes.

Statistical Analysis

The Shapiro-Wilks normality test demonstrated that the absolute values for total power, LF, and HF were not normally distributed ($p \leq 0.001$); thereby they were transformed to their natural logarithm (Ln), which resulted in their normal distribution ($p \geq 0.429$). A one-way analysis of variance (ANOVA) was used to observe any differences between YW and OW in terms of descriptive variables and maximal strength. A separate one-way ANOVA was used to assess group differences (YW versus OW) in autonomic modulation at baseline with BMI as a covariate due to the effect of BMI on autonomic modulation (29). In the OW, a repeated-measures ANOVA was used to assess interactions or main effects between RT and the following variables: maximal strength, HR, systolic blood pressure (SBP), diastolic blood pressure (DBP), total power, LnLF, LnHF, LFnu, HFnu, the LF/HF ratio and SampEn. If a significant interaction was observed, then paired samples t-tests were used for post-hoc comparisons. Significance was accepted a priori at $p < 0.05$. Reported values are mean ± standard deviation (SD). All statistical tests were performed using IBM SPSS Version 21 (SPSS Inc. Armonk, NY).

RESULTS

The YW were significantly (p=0.001) younger, and had significantly (p=0.001) lower body weight and BMI compared to the OW (Table 1).

Table 1. Participant characteristics in young women (YW) and older women (OW) (N=39).

	YW (n=16)	OW (n=23)
Age (yrs)	21±2*	59±6
Height (m)	1.64±0.07	1.62±0.06
Weight (kg)	65.3±14.4*	81.1±17.9
Body mass index (kg/m^2)	24.1±3.8*	30.8±6.8

Data are mean ± SD; HR, heart rate; DBP, diastolic blood pressure; SBP, systolic blood pressure; *p<0.05, significant group difference

The YW were also significantly stronger on the chest press (p=0.041) and leg extension (p=0.004) compared to the OW (Table 2).

Table 2. Maximal strength in young women (YW) and older women (OW) (N=39).

	YW (n=16)	OW (n=23)	
	Baseline	**Baseline**	**After training**
Chest Press (kg)	33±10	25±11*	32±16†
Leg Extension (kg)	39±13	27±11*	33±18†

Data are mean ± SD; *p≤0.05, significant group difference; †p≤0.05, significant difference over time

Beat-by-beat R-R interval and automated blood pressure analysis revealed significant differences (p=0.005) between the YW and the OW for HR, and DBP (Table 3).

Table 3. Heart rate and brachial blood pressure in young women (YW) and older women (OW) (N=39).

	YW (n=16)	OW (n=23)	
	Baseline	**Baseline**	**After training**
HR (bpm)	62±11‡	73±10	72±11
SBP (mmHg)	114±10	119±18	122±17
DBP (mmHg)	73±8‡	80±9	76±11

Data are mean ± SD; HFnu, normalized high-frequency power; LnHF, Natural log of high-frequency power; LFnu, normalized low-frequency power; LnLF, natural log of low-frequency power; SampEn, sample entropy (a measure of heart rate complexity); ‡p=0.005, significant group difference

There was no statistical difference (p=0.331) in SBP between the groups. The analysis of the autonomic modulation showed that YW had significantly (p≤0.001) augmented levels of Ln total power, LnHF, HFnu and the LF/HF ratio but reduced LnLF and LFnu compared to the OW (Table 4). However, no significant difference between groups (p=0.480) existed for SampEn (Table 4).

Table 4. Measures of autonomic modulation in young women (YW) and older women (OW) (N=39).

	YW (N=16)	OW (N=23)	
	Baseline	**Baseline**	**After training**
Ln Total Power (ms²)	8.1±0.85**	6.8±0.7	6.8±1.0
LnLF (ms²)	5.3±0.78**	5.1±0.9	5.1±1.2
LnHF (ms²)	7.1±0.67**	5.3±0.7	5.2±0.9
LFnu	16.5±10.5**	42.6±17.1	46.3±21.2
HFnu	83.1±10.2**	52.4±18.2	48.9±20.7
LF/HF ratio	0.21±0.04**	1.05±0.9	1.4±1.3
SampEn	1.4±0.2	1.3±0.4	1.4±0.2

Data are mean ± SD; **p≤0.001, significant group difference

In the OW, there were significant time effects for maximal strength such that there was a 28% (p=0.043) increase in the chest press and 33% (p=0.004) increase in the leg extension, which removed the significant difference compared to the YW before RT. Participants attended 92% of all of the training sessions. RT had no effect on BMI (p=0.87). There were no significant (p>0.05) effects of RT on HR, SBP, or DBP (Table 3). In addition, the analysis of the autonomic modulation showed that there were no significant (p>0.05) differences in response to RT in Ln total power, LnLF, LnHF, LFnu, HFnu, or the LF/HF ratio, or SampEn (Table 4).

DISCUSSION

To our knowledge this was the first study to examine autonomic modulation using HRV and HRC comparing YW and OW, and after a period of resistance exercise training on OW. The primary findings of the present study are that 1) aging does not appear to alter HRC, and 2) that 12-weeks of RT has no effect on autonomic modulation in OW.

Interestingly, there were no changes in BP with RT, which is contrary to previous reports (8, 31). Collier et al. (8) reported a decrease in brachial systolic and diastolic BP with RT consisting of 9 exercises performed for 3 sets of 10 repetitions at 65% 10RM for 3 days a week over a period of 4 weeks. However, the number of women in this study was small (n=5) and they were classified as pre- and stage-1 hypertensives. Taafe et al. (31) reported a reduction in brachial DBP as well as aortic SBP and DBP after 20 weeks of RT using either a single set or 3 sets of seven different upper- and lower-body exercises at the 8RM. Again, the number of females in this sample was small (n=5), and the participants were older than those in the present study (70±5 yrs). This demonstrates that the differences between the previous studies and the present study are more than likely methodological. Some of the previous studies had significantly longer RT durations, except for Collier et al. (8). In addition, many of them did not focus on women exclusively, which resulted in the number for female participants being low.

In agreement with previous studies there were differences at rest in autonomic modulation between the young, and older women (3, 13, 35) as measured by HRV, however this is inconclusive (6). Barantke et al. (3) reported significant differences in total power, absolute and normalized units of HF and LF as well as the LF/HF ratio in young women (10-33 yrs) and older women (42-56 yrs) during supine rest. Umetani et al. (35) reported significant declines in time domains of HRV with the most noticeable declines between the second and third decade. Fukusaki et al. (13) reported that aging significantly reduces vagal modulation (decreases in HF). On the contrary, work by Bonnemeier et al. (6) reported no significant differences in time domain measures of HRV between young women (20-29 yrs) and older women (40-59 yrs). Interestingly, the data in the present study also demonstrated that YW and OW had similar levels of SampEn, another measure of vagal modulation (5, 26). It has been suggested that SampEn may be a more sensitive measure of autonomic modulation compared to HRV (15). However, our data demonstrate no change in HRC across the ages, which is contrary to other measures of HRC, such as approximate entropy (4). Since we could not find any data regarding SampEn in the aging population it is possible that SampEn is a more stable measure of HRC across the lifespan. Taken together, it is clear that more data are needed to truly ascertain if reductions in vagal modulation are mediated strictly by aging or other factors associated with aging.

Similar to the present study, previous studies that have evaluated the effects of RT on autonomic modulation in healthy older adults have not shown significant changes in HRV (15, 18, 19). Karavirta et al. (18) examined the effects of RT on frequency domains of HRV in healthy men aged 40-67 years, after a period of 21 weeks. Participants underwent twice weekly training beginning at 3 sets of 15-30 repetitions at 40-60% 1RM and progressing to 3 sets of 5-8 repetitions at 75-85% 1RM. In a similar age group to the present study, Kingsley et al. (19) reported that 12-weeks of RT had no effect on resting values of HRV in healthy, older women (42 yrs). However, using healthy, young (25±1 yrs) men, Heffernan et al. (15) reported that while 6-weeks of RT did not alter indexes of HRV, it did increase SampEn. This suggests that RT may be beneficial for increasing vagal modulation in young healthy men. However, the present study demonstrated no change in SampEn with 12-weeks of RT in older women, which is a novel finding. Currently, this is the first study to highlight changes in SampEn after RT in older women. Collectively, these data add to the body of knowledge that RT has no effect on resting parameters of HRV in apparently healthy women, regardless of age.

The present study does have some limitations that need to be addressed. For one, there was no non-exercising control group for the older women to compare the effects of the RT. In addition, while none of the participants were using exogenous estrogen, we did not control for the effect of the menstrual cycle on autonomic modulation. However, investigators have suggested that the phases of the menstrual cycle do not effect autonomic modulation (36), but this is not a universally accepted finding (1). We also had participants perform paced breathing, not spontaneous breathing, which may have influenced the results. In addition, based on our questionnaire, 93% of our participants in the older women group were post-menopausal.

In conclusion, these data demonstrate that aging may decrease vagal modulation in women. In addition, these data also suggest that resistance training for 12 weeks is not sufficient to alter BP or vagal tone as measured by HRV, or HRC, at rest in healthy older women. Future studies need to examine the effects of longer resistance training interventions on BP and autonomic modulation, using both HRV and HRC, in this population to see if it can offset the decreases in autonomic modulation associated with aging.

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