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HEALTH SCIENCES

The Physical Capacity of Rowing Athletes Cannot Reverse the Influence of Age on Heart Rate Variability during Orthostatic Stress

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Abstract: The current study was undertaken to test the hypothesis that the high physical capacity of rowing athletes may not reverse the influence of age on cardiac autonomic control decline estimated by heart rate variability (HRV). Forty-four male subjects divided in four groups: 11 young athletes (YA; 18 ±1 year), 11 young non-athletes (YNA; 20 ±1 year), 11 middle age athletes (MAA; 43 ±6 years) and 11 middle age non-athletes (MNA; 44 ±8 years) participated in the study. Heart rate (HR) was recorded beat-by-beat for 10 minutes in supine (SUP) and 10 min in orthostatic (ORT) positions. HRV was analyzed in the frequency domain to obtain the spectral power in the high (HF) and low frequency (LF) bands, and the changes to ORT (%ΔHRV) were calculated (ORT – SUP / SUP). During SUP, HF was lower in MNA and MA compared to YA and YNA, while LF was lower in MNA than YA. For %ΔHRV, %ΔHF was higher in YA than YNA, MA and MNA. The %ΔLF was not different among groups. In conclusion, aging seems to overcome the influence of physical fitness on neural regulation of the heart, as highlighted by the HRV response to active standing.

Key words: aging, active standing, heart rate variability, physical fitness, rowing.

INTRODUCTION

Heart rate variability (HRV) is a non-invasive and selective tool for the assessment of the sympathetic and parasympathetic contributions on cardiac autonomic regulation (Montano et al. 1994). The current literature supports that HRV at rest decreases during aging, and the physically active lifestyle can attenuate this process (Sandercock et al. 2005). Older (over 65 years) and middle-aged (40-60 years) individuals presented reduced vagal-mediated HRV compared to young's (Laitinen et al. 2004). HRV indexes are also impaired in the middle-aged group compared to an age-matched trained group (masters' athletes; 40-60 years). Otherwise, former masters' athletes showed similar HRV markers compared to the sedentary young group at rest (Sotiriou et al. 2013). Despite of some studies have investigated aging and physical fitness influences on cardiac autonomic control, the full course of aging and physical (in) activity remains a matter of debate.

HRV is often obtained from recordings at rest (i.e., supine or sitting positions), providing reference values of cardiac autonomic modulation in different populations. It was shown previously that the orthostatic (ORT) stress test is a autonomic maneuver that may better describe the sympatho-vagal balance response in subjects of different ages and physical fitness profiles (Gonçalves et al. 2015). The HRV responses from orthostatic stress are commonly reduced in the older compared to younger individuals (Mellingsaeter et al. 2015). Indeed, during ORT the elders seem to increase the peripheral resistance to maintain adequate cardiac output (CO) and blood pressure (BP) because their baroreflex sensitivity is lower than younger subjects (Laitinen et al. 2004). It is not known if former athletes that stay physically active up to middle-age may preserve autonomic markers similar to younger athletes.

Some problems arise from the investigation of the aging process: 1) aging itself provokes changes in regulatory cardiac mechanisms; 2) aging also tends to induce great reductions in physical activity levels; and 3) inactivity alone, contributes negatively to autonomic control. Most studies compare the combined effect of aging and the inherent inactivity, since physical capacity is generally disregarded, that is a typical handicap of aging. Thus, the current study was undertaken to test the hypothesis that, in master rowing athletes, high physical capacity cannot reverse the influence of age on cardiac autonomic modulation. The current study aimed to compare HRV changes from the supine position (SUP) to active standing (ORT) among young and middle-age athletes or non-athletes.

METHODS

The study included 44 male subjects divided into groups of 11 young athletes (YA), 11 young non-athletes (YNA), 11 middle age athletes (MA), and 11 middle-aged non-athletes (MNA). Both groups of athletes, YA and MA, were club rowers participating in regular training schedules and competing in open class and master categories at a regional and national level. All volunteers were instructed to avoid strenuous physical activity (≥ 5METs) on the day before the testing, have a good night's sleep, have a regular meal three hours preceding the test, and not to drink beverages containing caffeine on the day of the test. The entire experiment was executed in the morning between 7:00 - 9:00 A.M., in a silent room with the temperature controlled between 22 and 24ºC.

After the procedures were approved (851.371/2014), the volunteers performed anthropometric measurements and responded to self-reported questionnaires, so to exclude those with positive answers to cardiovascular, respiratory, or metabolic diseases or medications in use which may interfere with the study outcome.

The habitual physical activity and physical capacity were assessed by Baecke et al. (1982) and Wísen et al. (2002) questionnaires, respectively. The Baecke questionnaire is a widely used instrument, which provides indexes for activities performed at home, work, and free time, including sports and leisure practices within the last 12 months. The Wisén questionnaire is a non-exercise instrument often used to estimate the cardio-respiratory capacity, the maximal oxygen uptake (estimated VO_{2max}), in clinical and epidemiological sets. After that, HR was recorded beat-by-beat using a cardiac monitor (RS810 Polar Electro Oy, Finland) at rest for 10 min either in SUP and ORT positions (Gamelin et al. 2006).

R-R time series were submitted to the Fast Fourier Transform using a Hanning window with a 50% overlap by a customized algorithm (Matlab 6.0, Mathworks Inc., USA) to access the HRV, which was analyzed in time and frequency domains (Gonçalves et al. 2015). Time-domain measurements were determined by the length of the dispersion of normal RR intervals, evaluated by the standard deviation of all normal R-R intervals (SDNN) and the root mean of the sum of the squared differences between adjacent normal R-R intervals (rMSSD).

The power in low frequency (LF: 0.04 - 0.15 Hz) and high frequency (HF: 0.15 - 0.40 Hz) bands were obtained from spectral analysis. The HF is used as the index of vagal modulation whereas, LF is influenced by both the sympathetic and vagal branches of the autonomic nervous system in the supine position, while during orthostatic stress LF oscillations are determined mainly by sympathetic modulation. The LF/HF ratio represented the sympatho-vagal balance. The percentage variation (%Δ) of HRV (ORT-SUP/SUP) indices during the postural change maneuver were calculated.

The Shapiro-Wilk test was used to evaluate the samples' normality and two-way analysis of variance (ANOVA) for independent measures to compare all variables among groups with the Tukey's post hoc was employed. The sample enrolled provided a statistical power of 0.95 for the main outcome variable (HF).

All variables were described as mean and standard deviation. The software used for normality test and comparisons was the GraphPad Software (San Diego, CA, USA), and G-Power version 3.1.9.2 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) was used for statistical power calculation.

RESULTS

The current study included only males divided into four groups paired by age- and $\dot{V}O_{2max}$. The habitual physical activity (Baecke questionnaire) and physical capacity (estimated $\dot{V}O_{2max}$ by Wisén questionnaire) were used to screen the groups' physical condition. As expected, athletes' groups showed a higher sports activity score and estimated $\dot{V}O_{2max}$ compared to non-athletes' groups (Table I). The groups did not show any differences in body mass index (YA 23.5 ±2.8; YNA 24.3 ±2.6; MA 26.6 ±3.4 and MNA 24.8 ±1.3 kg/m^2 p>0.05).

Table I shows the HRV indexes at rest. SDNN was lower in MNA than other groups (YA $p_{post\text{-}hoc}$ = 0.001 and YNA $p_{post\text{-}hoc}$= 0.01), and MA than YNA ($p_{post\text{-}hoc}$= 0.03). The rMSSD was lower in MNA than YA ($p_{post\text{-}hoc}$= 0.001) and YNA ($p_{post\text{-}hoc}$= 0.001), and MA than YNA ($p_{post\text{-}hoc}$= 0.04). In frequency domain, HF was lower in middle-aged groups in comparison to the both YA (MA $p_{post\text{-}hoc}$= 0.03 and MNA $p_{post\text{-}hoc}$= 0.004) or YNA (MA $p_{post\text{-}hoc}$= 0.001 and MNA $p_{post\text{-}hoc}$= 0.001). The LF was lower in MNA than YA ($p_{post\text{-}hoc}$= 0.001), but not different among others groups (MNA vs. MA $p_{post\text{-}hoc}$= 0.10; MNA vs. YNA $p_{post\text{-}hoc}$= 0.10; YA vs. YNA $p_{post\text{-}hoc}$= 0.26).

Autonomic markers changes from SUP to ORT (Figure 1) showed that the %ΔrMSSD and the %ΔHF were higher in YA than YNA, MA and MNA ($p_{post\text{-}hoc}$= 0.001). The %ΔLF was not different for any group (YA -0.18±0.62; YNA -0.45±0.80; MA -0.19±0.93; MNA 0.22±1.18 ms²; $p_{interaction}$= 0.28).

DISCUSSION

The results confirm our hypothesis that rowing athletes' high physical capacity cannot reverse the influence of age on HRV responses to active standing. The vagal modulation at rest was similar in age-matched groups independently of physical fitness status. However, the vagal-mediated HRV response to active standing was greater for young athletes than young non-athletes, middle-aged athletes, and non-athletes.

A study, which evaluated groups of different ages and physical fitness, showed that older and middle-aged sedentary adults have an impaired vagal modulation at rest than sedentary young individuals. Besides, except for the endurance-trained older individuals, who showed a higher vagal modulation at rest compared to the

Table I. **Comparison of cardiac autonomic modulation in the supine position.**

	YA	YNA	MA	MNA	p-value (age)	p-value (pc)	p-value (int.)
Participants characteristics’							
Age (years)	18 ±1[c,d]	20 ±1[c,d]	43 ±6[a,b]	44 ±8[a,b]	0.001	0.35	0.90
N (male/female)	11/0	11/0	11/0	11/0	.	.	.
Baecke questionnaire							
Work index	2.6 ±0.3	2.8 ±0.7	2.2 ±0.8	2.6 ±0.6	0.19	0.30	0.64
Sport index	3.9 ±0.6	2.8 ±0.6	3.8 ±0.3	2.5 ±0.7 [a,c]	0.22	0.003	0.37
Leisure Index	2.9 ±0.6	2.8 ±0.6	3.3 ±0.2	2.8 ±0.8	0.15	0.05	0.36
Total index	9.4 ±1.2	8.5 ±0.8	9.4 ±1.2	8.0 ±1.5[c]	0.40	0.01	0.44
Wisén questionnaire							
$\dot{V}O_{2max}$ (ml.kg.$^{-1}$min.$^{-1}$)	62.0 ±3.5	41.1 ±3.5[a,c]	58.6 ±9.0[b]	39.5 ±3.5[a,c]	0.29	0.001	0.33
Heart rate variability							
RMSSD (ms)	70 ±30	73 ±24	47 ±15[b]	31 ±9[a,b]	0.32	0.001	0.16
SDNN (ms)	82 ±32	68 ±16	58 ±10[a]	41 ±11[a,b]	0.01	0.0001	0.83
Total power (ms^2)	6381 ±4424	4295 ±2229	2556 ±940[a]	1682 ±928[a]	0.001	0.03	0.58
LF (ms^2)	2120 ±1560	1197 ±1054	1063 ±571	922 ±397[a]	0.01	0.04	0.44
HF (ms^2)	1350 ±815	1988 ±1032	474 ±284[a,b]	285 ±189[a,b]	0.28	0.0001	0.05
LF/HF	1.8 ±0.9	0.7 ±0.5	3.4 ±3.2[b]	3.3 ±2.3[b]	0.004	0.39	0.45

Note: SDNN = standard deviation of normal RR intervals; RMSSD = square root of successive differences between adjacent normal RR intervals squared; Total power = total power of RR intervals; LF = low frequency component; HF = high frequency component; LF/HF = sympatho-vagal balance; YA= young athletes; YNA= young non-athletes; MA= middle age athletes; MNA= middle age non-athletes; a= differences from YA; b= differences from YNA; c= differences from MA; d= differences from MNA pc= physical capacity; int.= interaction. Mean ±SD; Two-way ANOVA (showed by int., age, and pc) with Tukey’s post hoc (showed by letters a, b, c and d). α<0.05.

age-matched group, the authors did not find differences in vagal-mediated HRV at rest among groups, neither between middle-aged and young trained when compared to age-matched sedentary nor within trained groups (Martinelli et al. 2005).

HRV was improved by regular aerobic exercise in middle- or older-aged individuals (Monahan et al. 2000). However, a meta-analysis showed that the effect size of HRV adaptations after moderate exercise training was smaller in middle-aged or older compared to young individuals. Thus, diminished trainability of the heart and blunted neural input with age could explain the low HRV gain by exercise training in older individuals (Sandercock et al. 2005).

HRV in masters’ athletes have been particularly investigated because their cardiac autonomic control may be impaired by aging but improved by physical training. Recently, a study compared groups of middle-aged former soccer players who maintained regular physical activity or not. Masters, which still train, showed higher vagal modulation at rest than former athletes and the age-matched sedentary group. The authors suggested that cardiac autonomic

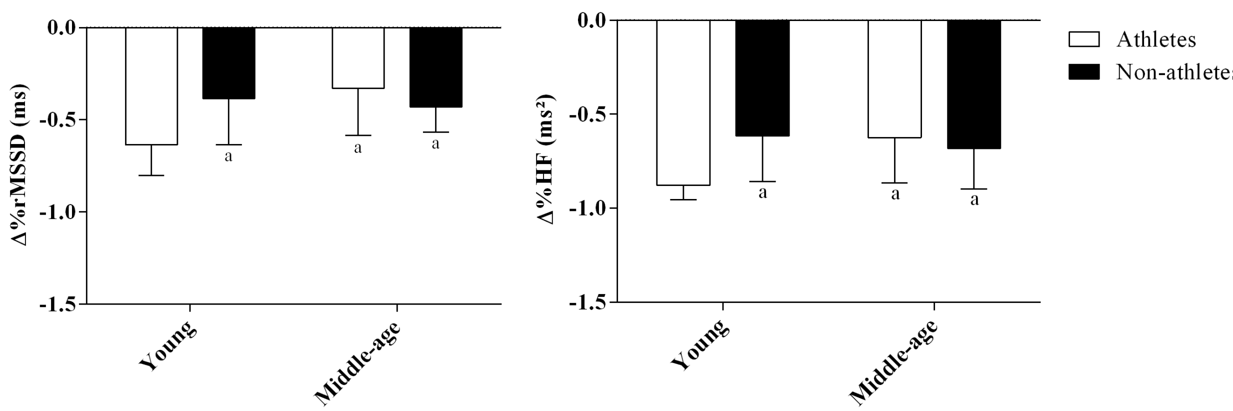

Figure 1. Comparison of %ΔrMSSD and %ΔHF among in young and middle age individuals athletes or not. a= differences from young athletes. %Δ= ORT-SUP/SUP. Mean ±SD; Two-way ANOVA with Tukey's post hoc. α<0.05.

modulation worsening with advancing age is observed when physical training is absent (Sotiriou et al. 2013).

It was recently shown that endurance training was not positively associated with the autonomic response during orthostatic stress among elderly endurance athletes. The athletes presented a higher blood pressure fall during tilt tests compared to aged-matched non-athlete controls. Thus, blood pressure might be a determinant of orthostatic tolerance in older athletes (Mellingsaeter et al. 2015). Indeed, older healthy adults increase peripheral vascular resistance to maintain blood pressure during postural stress because of decreased vagal withdrawal and sympathetic responsiveness. However, young individuals may compensate for the blood pressure drop during a postural change due to an increase in sympathetic activity and vagal withdrawal (Laitinen et al. 2004).

In current results, orthostatic stress revealed some differences in HRV between the groups that were not observed at rest. The young athletes showed a higher vagal-mediated reduction to orthostatic stress than young non-athletes, and middle-age groups, athletes or not. Although exercise training enhances cardiac autonomic modulation (Sandercock et al. 2005), differences in HRV indexes between young athletes and non-athletes is not a consensus in the literature. Previous studies did not find differences in HRV between athletes and non-athletes of the same age (Monahan et al. 2000, Martinelli et al. 2005). A study that showed a greater HRV for young athletes at rest, compared to their sedentary pairs, did not match the groups by age (Rossi et al. 2014).

Regarding study's limitations, the absence of a cardiopulmonary exercise test to obtain the VO_{2max} was the major limitation. Otherwise, the non-exercise model to estimate maximal oxygen consumption employed in the current study, is widely used in literature, validated, and presented good reliability as compared to direct VO_2 measurements (Wisén et al. 2002).

In summary, the differences in HRV between groups were highlighted after changes from supine to orthostatic position, suggesting that physical capacity may not reverse the age effects on autonomic markers in healthy individuals. Active standing can be a simple method to challenge the cardiovascular system and provide relevant information regarding the heart rate control that would not be detected at rest.

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GDR, TRG, and PPSS conceived and designed research. GDR and TRG conducted experiments. GDR, JLG, TRG and PPSS analyzed the data. GDR, JLG, TRG, and PPSS wrote the manuscript. All authors read and approved the manuscript.