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AUTONOMIC CONTROL OF HEART RATE AFTER EXERCISE IN TRAINED WRESTLERS

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ABSTRACT: The objective of this study was to establish differences in vagal reactivation, through heart rate recovery and heart rate variability post exercise, in Brazilian jiu-jitsu wrestlers (BJJW). A total of 18 male athletes were evaluated, ten highly trained (HT) and eight moderately trained (MT), who performed a maximum incremental test. At the end of the exercise, the R-R intervals were recorded during the first minute of recovery. We calculated heart rate recovery (HRR_{60s}), and performed linear and non-linear (standard deviation of instantaneous beat-to-beat R-R interval variability – SD1) analysis of heart rate variability (HRV), using the tachogram of the first minute of recovery divided into four segments of 15 s each (0-15 s, 15-30 s, 30-45 s, 45-60 s). Between HT and MT individuals, there were statistically significant differences in HRR_{60s} ($p < 0.05$) and in the non linear analysis of HRV from $SD1_{30-45s}$ ($p < 0.05$) and $SD1_{45-60s}$ ($p < 0.05$). The results of this research suggest that heart rate kinetics during the first minute after exercise are related to training level and can be used as an index for autonomic cardiovascular control in BJJW.

KEY WORDS: autonomic control, heart rate variability, heart rate recovery, parasympathetic reactivation

INTRODUCTION

It appears that heart rate kinetics after exercise provide valuable information on the autonomic nervous system [14]. It is generally agreed that during exercise, there is parasympathetic withdrawal and sympathetic excitation, resulting in acceleration of the heart rate (HR); these effects are reversed in recovery.

After exercise of moderate to high intensity, heart rate recovery (HRR) has been linked to vagal reactivation [22]. Recently, attenuated 1-min HRR was described as a cardiovascular risk factor and has been associated with increased all-cause mortality and sudden cardiac death in adults [12-14]. Consequently, methods of acutely improving post-exercise parasympathetic reactivation, as assessed non-invasively through analysis of heart rate variability (HRV) and HRR, are receiving great interest [4,6,10].

Traditionally, vagal adaptation after exercise in endurance athletes has been studied [4]. However, the parasympathetic reactivation in strength sports is not clear [7-8,15]. The HR kinetics of the first minute after exercise may be useful as a non invasive method to assess autonomic nervous system modulation and to provide important information about several physiological conditions [4,6,10].

The objective of this cross-sectional research is to study the kinetics of HR in the first minute after a maximal incremental test, through linear, non-linear, and time analysis of R-R intervals in two groups of Brazilian jiu-jitsu wrestlers (BJJW).

MATERIALS AND METHODS

Highly trained (HT) and moderately trained (MT) wrestlers agreed voluntarily to be part of the study (descriptive characteristics in Table 1). Institutional Review Board approval for our study was obtained, and all subjects were carefully informed about the experiment procedures, and about the possible risk and benefits associated with participation in the study, and an appropriate signed informed consent document was obtained pursuant to law before any of the tests were performed. We comply with the human and animal experimentation policy statement guidelines of the American College of Sport Medicine and in accordance with the Declaration of Helsinki. The classification of subjects as HT or MT was based on their weekly training volume. All subjects were healthy, without a history of cardiovascular or respiratory disease,

TABLE 1. DESCRIPTIVE CHARACTERISTICS OF SUBJECTS

	Highly trained (n = 10)	Moderately trained (n = 8)
Age [years]	22.0 ± 1.2	22.3 ± 0.82
Height [cm]	171.1 ± 2.51	169 ± 3.02
Body weight [kg]	69.1 ± 3.21	70.7 ± 3.56
Body mass index [$kg \cdot m^{-2}$]	24.5 ± 2.1	24.8 ± 3.2
Weekly volume of training [$h \cdot week^{-1}$]	15.7 ± 3.94	9.2 ± 0.22*

Note: * Significant differences with HT group; $p < 0.05$

and they did not consume coffee, cigarettes, alcohol or drugs 24 hours before the evaluation [27]. All subjects were competitors in the Chilean national championship of Brazilian jiu-jitsu (BJJ).

Study protocol

All subjects performed a treadmill test to voluntary exhaustion, according to a previous study [23]. The test was initiated at 7 $km \cdot h^{-1}$ and the treadmill elevation was kept constant at 5%. After a 2-min stabilization period, treadmill velocity was increased by 0.75 $km \cdot h^{-1}$ until the subject was no longer able to sustain the required pace. After finishing the exercise, the individuals were placed in a supine position with spontaneous breathing for 1 minute, following the criteria of other authors [24]. HR (beats/min) measurements were recording with a Polar S810 monitoring system (Polar Electro, Finland), which has been validated in previous studies [9,26]. The R-R intervals were converted into a tachogram and saved on a computer for further analysis using software for elimination of undesirable premature beats and noise (Polar Precision Performance SW 5.2, Polar Electro).

The HRV was analysed using linear and non-linear methods. The tachogram of the first minute of recovery was divided into four segments of 15 s each (HRV_{0-15s}, HRV_{15-30s}, HRV_{30-45s}, HRV_{45-60s}). For the analysis of R-R intervals, HRV analysis software (The Biomedical Signal Analysis Group, Finland) and Matlab® were used. Linear analysis of HRV was evaluated using the root mean square of the difference of successive R-R intervals (RMSSD) and non-linear analysis of HRV was assessed by the standard deviation of instantaneous (SD1) beat-to-beat R-R interval variability [18]. In addition, the first minute of recovery index (HRR_{60s}) was calculated [4,25]. Traditional spectral analysis of HRV (i.e. rapid Fourier transformation) was not included in this study due to the limitations of non-stationary signals [15,20].

There are different methodologies for the calculation of HRR. This study used the one presented by Buchheit et al. [4,6]. The HRR_{60s} index was calculated employing the equation:

$$HRR_{60s} \text{ index} = HR \text{ peak} - 1 \text{ minute post-exercise } HR.$$

Statistics

Descriptive statistical analyses were carried out using Prisma graphPad 5 and Matlab 6 software (The MathWorks Inc., Natick, USA). Data in the text are presented as the mean ± standard deviation (SD). Alpha level was set at $p<0.05$.

RESULTS

Table 1 shows the characteristics of study groups; we found no statistically significant differences in age, weight, height, or body mass index (BMI). The groups were statistically different in the weekly volume of training ($p<0.05$).

Figure 2 shows that HRR_{60s} differences were statistically significant ($p < 0.01$) between MT (50.7 ± 3.6 bpm^{-1}) and HT (64.6 ± 4.1 bpm^{-1}) groups. There were statistically significant dif-

A

$$RMSSD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N-1}(RR_{i+1} - RR_i)^2}[ms; -, ms, ms]$$

B

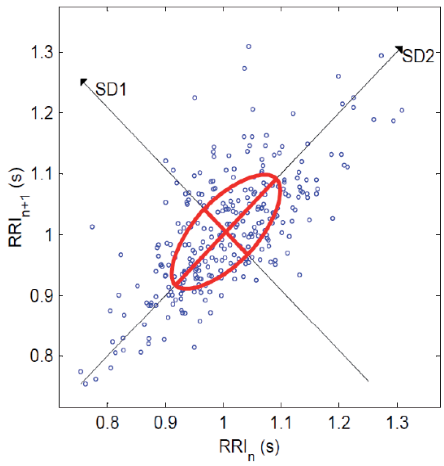

FIG. 1. STATISTICAL METHODS ANALYSIS OF HRV: RMSSD (A) AND SD1 OF POINCARÉ PLOT (B)

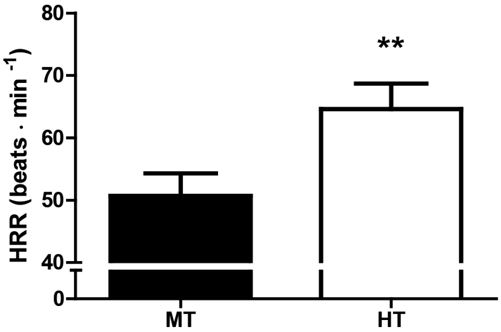

FIG. 2. HRR_{60S} ANALYSIS OF HR DURING THE FIRST MINUTE AFTER A TREADMILL TEST UNTIL VOLUNTARY EXHAUSTION IN MODERATELY TRAINED (MT) AND HIGHLY TRAINED (HT) BJJW
Note: ** Significant differences $p < 0.01$

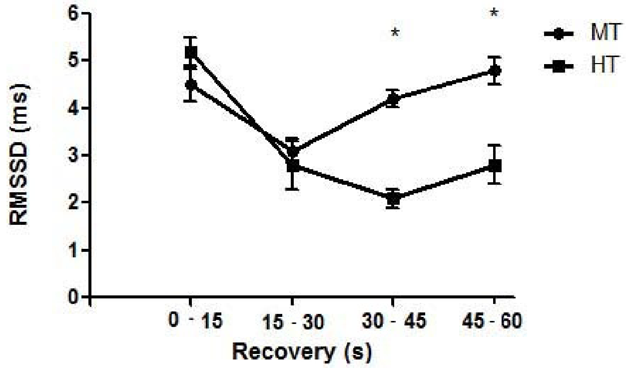

FIG. 3. LINEAR RMSSD ANALYSIS OF HRV DURING THE FIRST MINUTE AFTER A TREADMILL TEST UNTIL VOLUNTARY EXHAUSTION IN MODERATELY TRAINED (MT) AND HIGHLY TRAINED (HT) BJJW
Note: * Significant differences $p<0.05$

ferences ($p <0.01$) in the heart rate kinetics during recovery, from 30 s, until the end of the recovery period (MT=173 $\pm$ 2.5 vs. HT=164 $\pm$ 1.8 bpm^{-1}). At the end of the minute of recovery there were found statistically significant differences ($p <0.05$) between MT and HT (145 $\pm$ 1.5 vs. 129 $\pm$ 2.8 bpm^{-1}) groups.

Figure 3 shows linear statistical analysis of HRV during the recovery after exercise. The RMSSD values were not significantly different between groups in $RMSSD_{0-15s}$ and $RMSSD_{15-30s}$ segments, but significant differences were found in $RMSSD_{30-45s}$ and $RMSSD_{45-60s}$ segments ($p>0.05$).

Figure 4 shows statistically significant differences between HT and MT groups in $SD1_{30-45s}$ (HT=2.8 vs. MT=5.8 ms, $p<0.05$), and $SD1_{45-60s}$ (MT= 2.5 vs. HT=9.2 ms, $p<0.01$).

DISCUSSION

This study compared vagal parameters of HRV in the first minute of recovery after a treadmill test until voluntary exhaustion in MT and HT BJJW. The most important result of this study is that the level of training has an impact on the behaviour of HRR_{60s}, as well as linear and non-linear analysis of HRV during the first minute of recovery after exercise.

The HRR_{60s} was statistically significantly different between MT and HT groups. Although Imai et al. [17] proposed an analysis of HRR by a semi-logarithmic regression of the first 30 seconds of recovery [16], suggesting that the rapid decrease of HR is related to vagal reactivation, several studies have shown that HRR_{60s} is a marker of vagal reactivation [1,5,7]. It is interesting to note that the difference between MT and HT groups was not significant until 30 s of the recovery period. Since parasympathetic reactivation is very rapid after exercise, it may be argued that differences between groups may be explained by a faster reduction in sympathetic activity in the HT athletes, but evidence of this phenomenon is poor [10]. Thus, the difference between MT and HT groups may be explained by different autonomic behaviour after exhaustive exercise.

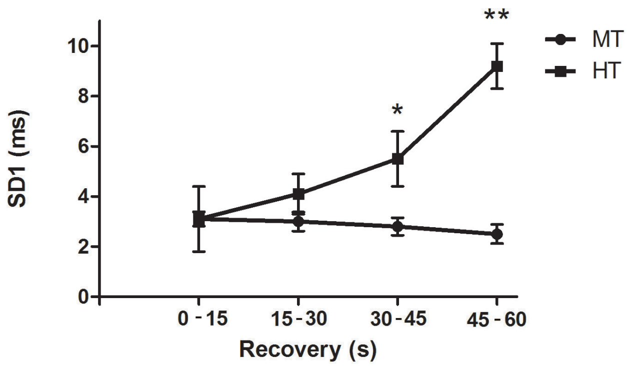

FIG. 4. NON-LINEAR ANALYSIS OF HRV DURING THE FIRST MINUTE AFTER A TREADMILL TEST UNTIL VOLUNTARY EXHAUSTION IN MODERATELY TRAINED (MT) AND HIGHLY TRAINED (HT) BJJW
Note: * Significant differences $p<0.05$, ** Significant differences $p< 0.01$

To the best of the authors' knowledge, this is the first study to develop a relatively simple method (HRR_{60s}) for evaluation of changes in cardiac control following training application in BJJW with different training levels.

Construct validity can be the first step to create a measurement protocol (i.e. the degree to which a protocol measures a hypothetical construct, in this case, performance) [1]. Therefore, our results suggest that HRR_{60s} can be used as a measurement protocol to evaluate performance in BJJW.

Traditionally, vagal adaptation in endurance athletes has been studied [21,28]; several authors suggest that HRV and HRR are useful for the study/control of endurance training [3], training status [21], work load [4,21], and overtraining syndrome [4,18]. However, this adaptation is not exclusive to endurance trained athletes. Otsuki et al. [22] noted that the adaptation of the vagally mediated HR recovery after exercise in strength-trained athletes is identical to that in endurance-trained athletes. In relation to changes produced in the autonomic system by resistance training, Cooke et al. [8]

noted no change in spectral measures of HRV after resistance training. Heffernan et al. [15-16] reported that resistance training does not affect spectral measures of HRV in young healthy men, but it increases autonomically mediated HR complexity and HRR after exercise. This study confirms this idea, and suggests that statistical and non-linear analysis of HRV and HRR can be used for the control of training in strength-power athletes.

This study has shown that, when applied during the recovery period after exercise, the SD1 component of Poincaré analysis can be considered an indicator of the level of training of BJJW. Previous investigations have suggested that HRR and HRV indices might illustrate distinct but complementary aspects of parasympathetic function; HRR may be more related to the vagal "tone", whereas HRV may be a better indicator of the parasympathetic "modulation" [2,6]. According to Buchheit et al. [2], although HRV reflects more aptly phasic fluctuations in vagal efferent activity, HRR is an index of mean cholinergic signalling at the level of the sinoatrial node.

Ostojic et al. noted that it could be that a faster ultra short-term HRR reflects a positive adaptation to high intensity intermittent training. A typical BJJ wrestling match is of short duration, high intensity, with an intermittent nature, lasting a total of five minutes for males and four minutes for females. The rapid parasympathetic reactivation may contribute to the athlete's ability to sustain effort for the duration of the combat and to recover during the brief periods of rest or reduced effort. Moreover, the rapid HR recovery in exercise-trained athletes may be one of the physiological adaptations to prevent an excessive cardiac workload [5].

Several authors suggest that HRV can be used for control of training [3,11,21], but the long-term application of daily resting or nocturnal HRV measurements can be laborious [3]. An alternative solution might be the collection of post-exercise HRR and HRV recordings, because these can be implemented during the warm-up of training sessions, an idea that is supported by the results of the present study and others [3,5,19].

The present study could have some limitations. First, it did not consider some possible factors that could be responsible for the observed differences in ultra short-term HRR between the groups. These could include vagal nerve reactivation, central command and resetting of the arterial baroreflex [6]. Second, the size of the experimental samples could be considered limited. Third, the analysis may not be representative of what may happen after a BJJ wrestling match.

CONCLUSION

The results of this research suggest that the temporal and non-linear analysis of HR during the first minute of recovery after exercise is related to training level and can be used as an index for autonomic cardiovascular control. The recording of parasympathetic reactivation parameters after exercise offers a non-invasive, relatively easy way to obtain data that can help to control the training of BJJW. This can offer important information to coaches and athletes in this emergent sport. A BJJ wrestling match, due to its characteristics (intermittent, high intensity, short rest periods), is especially suited to this type of analysis.

Future research should focus on determining the sensitivity and reproducibility of these measures. Moreover, the vagal parameters should be studied under different physiological conditions of workload (i.e. after a BJJ match) and overtraining.

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Conflict of interest: No.

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