

Impact of Musical Auditory Stimulation Applied during and after Aerobic Exercise on Vagal Reentry in Recovery Period

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ABSTRACT

AIM: To investigate the influence of musical auditory stimulation, through classical music, applied during and after submaximal aerobic exercise on vagal reentry in the immediate recovery period.

MATERIALS AND METHODS: 33 adult volunteers young and

healthy, between 18 and 30 years underwent a protocol divided into three phases: I) Maximal Test procedure for determining the load that was applied in stages II and III; II) Control Protocol: rest for 15 minutes in the supine position, followed by 30 minutes of aerobic exercise on a treadmill (5 minutes at a speed of 6.0 km/h followed by 25 minutes with 60% of V_{max} + 1% slope) and finally recovery standing for 3 minutes on the treadmill; III) Music protocol: similar to the control protocol, but with exposure to musical auditory stimulation during exercise and recovery phase. For analysis of the vagal reentry were analyzed RMSSD index of 30 seconds and recovery heart rate.

RESULTS: No differences were found between protocols and interaction moments vs. protocols ($p > 0.05$) both RMSSD index of 30 seconds and for recovery heart rate, but differences were found between the moments of each protocol ($p < 0.05$). Regarding $\Delta 1$ and $\Delta 2$, significant differences were observed between $\Delta 1$ relative to $\Delta 2$ ($p < 0.05$) in both protocols, between $\Delta 1_{music}$ and $\Delta 1_{control}$ and between $\Delta 2_{music}$ and $\Delta 2_{control}$.

CONCLUSION: The musical auditory stimulation, through classical music, applied during and after submaximal aerobic exercise was not able to influence the vagal reentry in the immediate recovery period.

Key words: Music; Autonomic nervous system; Exercise and recovery

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INTRODUCTION

During exercise and your recovery period, the autonomic nervous system (ANS) acts significantly in cardiovascular adjustments^[1-3].

In exercise, there is a predominance of sympathetic modulation causing increased heart rate, blood pressure and cardiac output^[1]. In the recovery period which aims to make the body return to its initial state^[3], it is vagal reentry which promotes the reduction of these parameters^[2].

The recovery period is susceptible to various complications such as disorders in heart rhythm, decreased or increased blood pressure outside the standards considered physiological and pulmonary hyperventilation making alkaline the pH of the body, especially if there is no restoration of systems to its original condition^[2].

There are some resources that can be used to optimize post-workout recovery, long-term we can mention the fluid replacement and electrolyte^[4,5], massage application^[6], combined intake of carbohydrate and protein^[7], and the short term we can mention cryotherapy^[8,9].

The use of musical auditory stimulation (MAS) at rest, through classical music has positive effects on the cardiovascular system, producing adjustments in cardiac output^[10], heart rate^[11] and blood pressure^[12]. In addition, MAS can also influence the autonomic nervous system (ANS), promoting changes in their sympathetic and parasympathetic components^[10]. In this context, we hypothesized that use of MAS can also optimize the recovery of cardiovascular and autonomic system in the immediate recovery period.

In exercise using MAS reduces the feeling of fatigue^[13] and perceived exertion^[14], but in recovery there are still few studies that verify their influence^[15], especially regarding the autonomic system.

In the literature, they can be found authors evaluated the music in the immediate recovery period^[16,17]. The study of Tan *et al*^[16] compared the influence of classical music with silence on heart rate recovery and found no significant differences between the mean values. Already Bigliassi *et al*^[17] rated vagal reentry through RMSSD index of 30 seconds in the immediate recovery period of an exercise with music and also did not obtain significant differences^[17].

Other studies have evaluated the influence of MAS with larger recovery periods^[15,18]. Lee *et al*^[15] pointed out that MAS was able to lead to an acceleration in HR recovery rate after 20 minutes of aerobic exercise^[15]. However, Eliakim *et al*^[18] not observed differences in average HR during recovery with and without music.

Thus, taken together the data presented, notes the importance of more contributions on the actual effect of MAS on the immediate recovery period, especially on the ANS.

Therefore, this study aimed to investigate the influence of MAS through classical music applied during and after submaximal aerobic exercise on vagal reentry in the immediate recovery period through the heart rate recovery (HRR)^[19,20] and RMSSD index of 30 seconds^[21].

MATERIALS AND METHODS

Nature Study and Patients

For this study, data from 31 apparently healthy volunteers with a mean age of 22 ± 2.59 years were analyzed. There were not included in the study smokers, alcoholics, patients with cardiovascular disorders, respiratory and neurological disorders or other pathological conditions that prevented the realization of protocols.

To define the size of the sample was carried out the sample calculation based on the study of Moreno *et al*^[22] considering like variable RMSSD index, that was found on control protocol. The magnitude of the significant difference was taken 11 ms, considering a standard deviation of 16.2 ms, with an alpha risk of 5% and 80% beta, the sample size resulted in 33 subjects in each group.

The volunteers were informed about the study objectives and procedures, and after agreement signed a confidential and informed consent form. The project was approved by the Research Ethics Committee of the Paulista State University, Campus of Marilia, Simoni Aparecida Capellini, Case No. CEP-2200/11, March 14, 2012.

Study Design

The protocols running time was always set between 5:30 PM and 9:30 PM, to avoid circadian influences. In addition to these, temperature was fixed between 23°C and 24°C and humidity between 60% and 70%^[22].

Before being inserted in the study, all volunteers signed a confidential and informed consent form and they were told not to drink alcohol or caffeine-based for 12 hours before the protocols to consume light meal two hours before and to avoid vigorous physical effort the day before the experimental procedure.

The experimental procedure was divided into three stages, all performed on a treadmill, with a minimum interval of 48 hours between them, in order to allow recovery of volunteers. Before the start of the first stage of the experimental protocol volunteers were identified and had the certain anthropometric data. Body weight was measured using a digital scale (Plenna, TIN 00139 MAXIMA, Brazil) and height using a stadiometer (ES 2020 - Sanny, Brazil). After these procedures, the volunteers were subjected to the stages that make up the experimental procedure are:

(I) Maximal exercise test: We undertook this to record the maximum velocity (Vmax) reached by the volunteer. This was then applied to indirectly determine the anaerobic threshold via the Conconi threshold^[23]. Intensity of 60% of the Vmax obtained in the test was lesser than that found in the anaerobic threshold, and this intensity was enforced to perform subsequent stages.

(II) Control Protocol (CP): In this period the volunteers were at rest, in the supine position for 15 minutes, followed by 30 minutes of aerobic exercise on a treadmill (five minutes at a speed of 6.0 km/h followed by 25 minutes with 60% of Vmax + 1% grade) and then a recovery period lasting 3 minutes standing on the treadmill.

(III) Music Protocol (MP): Volunteers accomplished the same activities of the CP, but with exposure to MAS during exercise and recovery.

Stage I of the experimental protocol (maximal exercise test) was obligatorily carried out before the stages II and III, since through the maximal stress test performed in stage I was obtained intensity of effort that was used in the other stages. The order of the stages II and III (control and music protocols) was determined by a randomization process. For this determination was made a draw card with the name of the described protocol. The researcher was not blinded in any time of the study.

During the stages II and III, the HR was recorded by a beat to beat heart rate monitor Polar RS800CX (POLAR, Finland), which was used for analysis of HRR and RMSSD index of 30 seconds.

Assessment of maximal aerobic capacity

For this assessment we calculated the anaerobic threshold indirectly through the Conconi threshold^[23]. For this purpose, we applied the speed and HR achieved at each stage of an exhaustive incremental test performed on a treadmill (ATL Inbrasport 2000, Brazil) with initial velocity of 8 km/h and load increments of 1 km/h every two minutes with fixed inclination of 1% to voluntary exhaustion^[24]. During the test execution speed and HR, monitored by the heart rate monitor Polar RS800CX (POLAR, Finland) throughout, were recorded at the end of each stage. To be established as a maximum

effort, volunteers should reach 90% of maximum heart rate, calculated by the formula $220 - \text{age}^{[25]}$.

Indirect anaerobic threshold determination was achieved by identification of the HR Deflection Point (HRDP) with the use of the Dmax method^[25]. HR points and corresponding speeds were plotted; subsequently, the values were adjusted by a linear first-degree equation and a polynomial function of third degree, which were derived from the data of each individual^[25]. We then considered the difference between the HR values obtained by the respective equations and calculated a curve with these values, considering the HRDP as the largest value before the existence of a change in direction of the curve^[25].

The HRDP value corresponded to the speed at which the volunteer reached the anaerobic threshold^[23]. This value was equated to 60% of Vmax reached on maximum exercise test, and for all volunteers the intensity of 60% of the Vmax obtained in the test was less than that achieved in the anaerobic threshold. This intensity was used to execute the subsequent stages.

Protocol Control and Music

Before the CP (stage II) and MP (stage III) was placed in volunteers with a heart rate monitor Polar RS800CX (POLAR, Finland) to record the HR beat to beat over the protocols and the same remained at rest in the supine position, and they remained at rest in the supine position, comfortably for 15 minutes to adequacy of cardiovascular parameters.

In both protocols, after these measurements the volunteers performed exercise on a treadmill with an intensity of 6.0 km/h + 1% slope in the first 5 minutes to warming-up, followed by 25 minutes with intensity equivalent to 60% of Vmax found in maximal exercise test and with the same inclination. At the end of the activity, the volunteers remained standing on the mat until the 3rd minute of recovery.

In MP, MAS was produced during exercise and recovery through a classical music playlist, randomly determined with a duration of 33 minutes (30 minutes + 3 minutes exercise recovery) with an intensity of 70-75 dB given the fact that sound stimuli intensities above 60 dB cause cardiovascular responses^[26]. The stimulation was done through headphones^[26].

Analysis of Heart Rate Variability

After the explanation of the procedures for data collection, was placed in the distal third of the sternum a capture strap and handle a heart rate monitor Polar RS800CX (POLAR, Finland), previously validated equipment to capture heart rate beat to beat and the use of their data for analysis of HRV indexes^[27].

For the analysis of heart rate variability (HRV), the pattern of their behavior was recorded beat-to-beat during the experimental protocol and was made a digital filtering complemented by manual to eliminate premature ectopic beats and artifacts, and only series with more 95% of sinus beats were included in the study^[28].

It was used for analysis of HRV the RMSSD index, which corresponds to the square root of the sum of the square differences between RR intervals on record, divided by the number of RR intervals in a given time (-) one RR interval^[29]. For the proposed study, we used RMSSD index of 30 seconds, where the intervals were 30 seconds. This analysis has been used in studies evaluating the vagal reentry^[30,31].

In order to compare the moments and evaluating the vagal reentry, the last 30 seconds were selected from the initial rest, 30 final seconds of exercise and immediately after recovery, 2 minutes divided into four windows of 30 seconds (REC1, REC2, REC3 and REC4).

The HRV analysis software (Kubios, Biosignal Analysis and Medical Image Group, Department of Physics, University of Kuopio, Finland) was used to calculate the index^[32].

Analysis of Heart Rate Recovery

To determine the HRR, HR was measured by heart rate monitor Polar RS800CX (POLAR, Finland), on three occasions: at peak exercise (HRpeak) at the end of aerobic exercise, in the first initial minutes of the recovery period (HR1) and the second minute recovery (HR2)^[33].

The value of HRpeak was set from the average of 5 intervals R-R. Were added 2 values before and after the HRpeak, then the arithmetic average was taken to determine the value of Hrpeak^[33]. For determination of values HR1 and HR2 was made the same procedure^[34]. The value of HRR was defined as the difference between HRpeak and HR1 ($\text{HRpeak} - \text{HR1} = \text{HRR1}$) and between HRpeak and HR2 ($\text{HRpeak} - \text{HR2} = \text{HRR2}$)^[33].

Statistical analysis

Descriptive statistics were implemented to characterize the sample and the results were presented as mean values, standard deviation, minimum and maximum.

Comparisons of the values of HRR and RMSSD index of 30 seconds between protocols (CP and MP) and moments (rest vs. exercise vs. recovery periods) were accomplished through the analysis of variance technique to model repeated measures on two factors scheme. Data from repeated measurements were verified for evaluation of sphericity using the Mauchly test. Greenhouse-Geisser correction was applied when the sphericity was violated.

To analyze the moments (rest vs. exercise vs. recovery periods) we applied the Bonferroni post-test for parametric distribution or, Dunn's post-test for non-parametric distribution.

To compare the intragroup deltas was performed Student's *t* test for paired data or Wilcoxon test and comparison of intergroup deltas was used the Student's *t*-test for unpaired data or the Mann-Whitney test. Statistical significance was set at 5% for all tests.

RESULTS

Anthropometric variables of the volunteers are shown in Table 1.

The values of RMSSD index of 30 seconds protocols at rest, exercise and recovery can be seen in Table 2. There is a difference between the moments ($p = 0.000$), however there was no difference between protocols ($p = 0.561$) and the interaction moments vs. Protocol ($p = 0.843$).

In both protocols significant differences were observed between the exercise value and the 4 recovery windows (REC1, REC2, REC3 and REC4) when compared to the rest. In MP there were also significant differences in REC2 and REC4 values in comparison to exercise ($p < 0.05$).

Table 3 shows average values of the respective row standard deviations of HRR of the first and second minute in both protocols. In both protocols were significant differences compared to the $\Delta 1$ $\Delta 2$. Lower values $\Delta 1$ as of $\Delta 2$ were observed in the CP compared with their respective MP ($p < 0.05$).

Figure 1 shows HR values obtained from control and music protocol at the peak, 1 and 2 minutes. Significant differences between the moments were observed ($p = 0.000$), however there was no difference between protocols ($p = 0.933$) and the interaction moments vs. Protocol ($p = 0.686$). In both lower values of HR of 1 minute as the HR of 2 minutes protocols were observed in relation to HR peak. Lower values of HR of 2 minutes compared to HR of 1 minute were also observed for both protocols.

DISCUSSION

This study evaluated the influence of exposure to MAS, through classical music, applied during and after submaximal aerobic exercise on the ANS behavior, through the HRR and HRV in the immediate recovery period. The results showed that the MAS was not able to influence the ANS behavior in the proposed period.

The results for the RMSSD index 30 seconds showed no significant differences between the protocols and the interaction moments vs protocols, but significant differences were found between the exercise value and all recovery times analyzed compared to resting values. In MP there were also significant differences between the values of REC2 and REC4 compared to exercise.

This behavior is similar to the behavior described by Bigliassi *et al.*^[17]. In this study, the volunteers performed a protocol composed of sitting rest (10 minutes), warm-up (5 minutes) and exercise (30 minutes) in cycle simulator, ending with recovery (10 minutes). MAS was selected on the basis of musical preference and was applied during the exercise and in the immediate recovery period. Corroborating the results of our study, the authors observed no significant differences of the RMSSD index 30 seconds in the recovery period. The absence of significance was attributed to the fact that exercise stimulus is greater than the MAS to modulate the ANS activity. The authors concluded that the music chosen by the volunteers was not able to modulate psychophysiological variables in a submaximal activity performed in cycle simulator^[17].

Cunha *et al.*^[35] rated vagal entry after holding three stress tests with different intensities, but without application of MAS, and observed a faster vagal entry after exercise with lower intensity compared to high and moderate exercise, suggesting that the intensity influence vagal reentry. As in our study, the volunteers performed an intensity classified as moderate seems plausible to suggest that the stimulus of exercise is stronger than the music and that this may be related to lack of significance observed in RMSSD index of 30 seconds values.

In addition, the authors found that parasympathetic reactivation seems to be influenced by vagal control at rest, ie, individuals who have greater parasympathetic activity at rest tend to have a faster vagal reactivation in the recovery period^[35]. The vagal control of the participants at rest was observed in our study, but was not carried out the separation of the volunteers into groups depending on the modulation at rest.

There was no influence of MAS for RMSSD index of 30 seconds, but there was a decrease in RMSSD values in exercise and recovery when compared to the rest. This response is considered physiological and indicates a reduction in the parasympathetic modulation with exercise, which associated with increased sympathetic modulation are essential to meet the new metabolic demand and thus maintain homeostasis^[12].

For HR peak, first and second minutes of recovery, differences were observed when comparing the moments in both protocols, but no differences were observed between the protocols and interaction moments vs. protocols, also suggesting that the music did not influence the HR behavior.

This behavior was similar to that found by Tan *et al.*^[16], who did not observe significant differences between the mean values of HR in the first and second minutes of recovery in sessions where participants were exposed to classical music compared with exposure to silence^[16]. According to this study, the use of standardized MAS regardless of the participant's preferences, may have interfered in the results^[16]. In our study we were also standardized the application of classical music, which was not well received by most of the participants,

Table 1 Mean values, standard deviations (DOS), minimum and maximum values of anthropometric variables.

variables	Mean \pm SD	Minimum/maximum
Age (years)	22 \pm 2.59	(18 - 29)
Weight (kg)	76.85 \pm 10.03	(57 - 97)
Height (m)	1.75 \pm 0.07	(1.60 - 1.88)
BMI (kg/m ²)	24.90 \pm 2.41	(20.45 - 28.81)

BMI: body mass index; kg: kilogram; in: meter.

Table 2 Mean values, standard deviations of the respective row, the index RMSSD 30 seconds.

Index	Moments	Protocol	
		Control	Music
RMSSD (ms)	Rest	47.05 \pm 22.77	48.76 \pm 21.91
	Exercise	4.25 \pm 1.62 ^a	4.98 \pm 2.24 ^a
	REC1	4.28 \pm 1.88 ^a	4.39 \pm 2.57 ^a
	REC2	4.21 \pm 1.90 ^a	4.37 \pm 2.56 ^{ab}
	REC3	4.25 \pm 1.89 ^a	4.39 \pm 2.55 ^a
	REC4	4.25 \pm 1.88 ^a	4.38 \pm 2.53 ^{ab}

^aValue with statistical difference in relation to rest (Friedman test followed by Dunn's test: $p < 0.05$); ^bValue with statistical difference for the financial year (Friedman test followed by Dunn's test: $p < 0.05$). Legend: RMSSD: square root-mean-square of the differences between successive RR intervals; ms: milliseconds; REC: recovery.

Table 3 Mean values and respective standard deviations recovery heart rate.

Index	Moments	Protocol	
		Control	Music
Heart Rate (bpm)	$\Delta 1$	24.34 \pm 10.13 ^{a,c}	34.91 \pm 13.39 ^b
	$\Delta 2$	21.98 \pm 9.79 ^d	33.62 \pm 8.78

^a Valor with statistical difference compared to the control group $\Delta 2$ (Wilcoxon test, $p < 0.05$) ^b Valor with statistical difference compared to $\Delta 2$ music group (Student's t test for paired data; $p < 0.05$); ^c Valor with statistical difference compared to $\Delta 1$ music group (Student's t test for unpaired samples, $p < 0.05$); ^d Valor with statistical difference compared to $\Delta 2$ music group (Mann-Whitney test, $p < 0.05$). Legend: bpm: beats per minute; $\Delta 1$: heart rate recovery first minute; $\Delta 2$: heart rate recovery in the second minute.

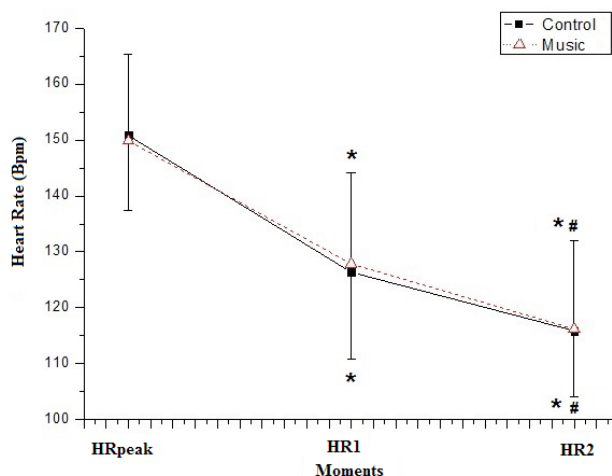


Figure 1 Mean values followed by their standard deviations in heart rate (HR) obtained from control protocols and music at the peak, 1 and 2 minutes of recovery. Legend: *Values with significant difference to HRpeak (ANOVA for repeated measures followed by Bonferroni test, $p < 0.001$). #Values with a significant difference from FC1 (ANOVA for repeated measures followed by Bonferroni test, $p < 0.001$).

which may have influenced the results.

During exercise occurs predominance of sympathetic modulation resulting increase in HR, while in post-exercise recovery period there vagal reentry, which generates decreased HR^[2]. This fall HR in the recovery period immediately can be demonstrated in this study with a similar pattern to the music and control protocols.

Regarding HR deltas, significant differences were observed in both protocols between $\Delta 1$ and $\Delta 2$ and also between $\Delta 1$ control and $\Delta 1$ music and between $\Delta 2$ control and $\Delta 2$ music.

Although the MAS does not influence the HR, average values of HR delta in the first minute ($\Delta 1$) for both protocols were greater than 12 beats, according to Cole *et al.*^[33] demonstrating good recovery of HR^[33]. These authors reported that in the first minute of recovery the fall of the HR is less than 12 beats this is an abnormal vagal reactivation, indicating a strong predictor of overall mortality^[33].

Even finding no increased vagal reentry using the MAS immediately after exercise, study points out that MAS was able to lead to an acceleration in recovery rate of HR after 20 minutes from the end of an aerobic exercise^[15]. These findings indicate that possibly the intensity of exercise also generates greater effects that MAS immediately after performing the same, since in the course of recovery when we are back to the initial state before the exercise, MAS is able to speed up the recovery rate.

This study has potential limitations that can be reported, as the standardization of MAS for classical music, not taking into account the musical preferences of the volunteer, which could influence the responses analyzed. We believe that further studies should be performed using the MAS by musical preference volunteer and evaluating longer times post-exercise recovery, which will provide clearer data regarding the effects of MAS on the recovery of ANS.

The results show that MAS, through classical music, applied during and after submaximal aerobic exercise was not able to influence the ANS behavior in the immediate recovery period.

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