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THE INFLUENCE OF MUSIC ON CARDIOPULMONARY PARAMETERS DURING A DIFFERENT INTENSITY OF PHYSICAL EXERCISE IN THE POPULATION OF STUDENTS

Abstract:

Introduction: It is known that music can reduce the sense of fatigue and pain during physical exercise as well as to affect the motivation. Physiological effects of music during submaximal intensity cardiopulmonary exercise tests can be examined using a treadmill.

Aim: In this study we examined the impact of asynchronous music on cardiopulmonary parameters of students, while they were running on the treadmill on the moderate to high load. Also we examined the difference between these two conditions.

Materials and methods: This study involved 6 students from the Faculty of Medicine in Belgrade, which were tested in the conditions with and without music. In order to determine maximal oxygen consumption, maximal exercise tests were conducted in advance. During the testing phase, cardiopulmonary parameters were measured in two different conditions: on 70% of maximal measured VO_2 values and on 90% of previously measured maximal VO_2 values respectively.

Results: The breathing frequency, ventilation, exhaled CO_2 volume, blood pressure were significantly increased ($p < 0.05$) in terms of music on a moderate rate of 70% VO_{2max} . On high rate of 90% VO_{2max} , there has been no significant changes to the parameters ($p > 0.05$) except a decrease in blood pressure and minimal increase in VO_2/kg .

Conclusion: This study confirmed the influence of music on cardiopulmonary parameters and demonstrated that it can affect respiratory variables only on moderate loads. Results showed that music does not affect respiratory variables on high loads, but there was a significant decrease in blood pressure in both, moderate and high loads.

Key words: music, sport, breathing, ventilation, VO_2 , VCO_2 , blood pressure

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Introduction

It is known that music can reduce the feeling of fatigue and pain during physical exercise (1) and influence the motivation in the population of athletes (2–4). Music achieves its ergogenic effects in several ways. It can affect thoughts by decreasing feeling of exhaustion through motivation, directing attention away from unpleasant stimuli such as pain and peripheral fatigue (5, 6). Also, music over the limbic nervous system can act as stimulant or sedative to motor and autonomous nerve centers in the cortex and brain stem by regulating their functions (7, 8). Finally, we should mention the synchronization of the movement and rhythm of the music during the exercise as one of the factors that may have beneficial psychological effects (4). However, in studies on the influence of music on exercise results, it has been proven that music can have both a positive and negative impact on the functional and psychological parameters, which depends on the selection of used songs. When we discuss about music and exercise, it is important to reflect the cumulative impact of the factors that affect the results: type and form of exercises, music characteristics, synchronization of steps and rhythms. Some of the scientific studies found that music has no effect in high load exercise (higher than 80% maximum functional abilities, i.e. maximum oxygen consumption during exercise, $VO_2\text{max}$), while in moderate and lower loads it has positive results influenced by the adequate selection of music (9). The results of these studies emphasize the selection of music. Based on the preceding results, we can conclude that the results during the exercises are influenced by the load and used protocol during testing phase and the characteristics of music such as tempo and harmony (6, 11). Given the lack of literature that directly compares the influence of music to moderate and high loads, in this study we wanted to examine the impact of the music on a change of cardiopulmonary parameters during cardiopulmonary exercise test (CPET) on a treadmill under moderate and high loads. Also, we examined the difference between testing conditions, with music and without music.

Materials and methods

Subjects

The research involved 6 students from the Faculty of Medicine in Belgrade aged from 20 to 22 years. All participants were thoroughly aware of the procedures and objectives of the research and their signature gave the consent for testing. Before the survey, each participant filled out a document with personal data, medical and athletic anamnesis

Study design

Before the CPET, all participants made personal playlist of 5 songs that they considered motivational during exercise. Test was performed in three phases, i.e. each participant had performed 3 tests separated by a daily break. The first phase of the study was to determine maximum oxygen consumption ($VO_2\text{max}$) during the maximum, progressive, continuous test on the treadmill. The test was preceded by anthropological measurements, ECG, blood pressure measurements (TA) and physical examination. After determining $VO_2\text{max}$ for each person, we calculated the speed of the treadmill in which the oxygen consumption of 70% and 90% of $VO_2\text{max}$ was reached. This speed was a referent load for performing a second phase of research, or a submaximal test. After a day of pause, our subjects were tested again, but this time on moderate and high submaximal loads. Participants were in a random choice divided into two groups: a group running at a moderate load of 70% $VO_2\text{max}$ and a group that ran at a high load of 90% $VO_2\text{max}$. The submaximal tests were carried out in each group 2 times, in conditions with the individual selection of stimulating music and in conditions without music. During all tests we measured cardiopulmonal parameters.

Anthropological measurements

Following anthropometrical parameters were measured for each subject: body weight (BW) in accuracy of 0.1 kg (Body Composition Analyzer, Seoul, Korea), body height (BH) measured (Seca709, Hamburg, Germany) with the accuracy of 0, 1cm. The percentage of body fat and muscles were evaluated using InBody230 scales.

Cardiopulmonal measurements

Measured functional parameters were: heart rate (HR – in peace, at maximum load, and after three minute recovery), consumption of oxygen (VO_2/kg), respiratory exchange ratio (RER), ventilation (VE), breathing frequency (BF), the volume of the Exhaled CO_2 (VCO_2), blood pressure (TA) which was manually measured (immediately before the test and 3 minutes after the test was ended). The parameters were measured using the portable ergospirometer (The Oxycon Mobile OM, Jäger, Würzburg, Germany).

Maximal Load Test

Before performing each test, the calibration of the volume sensors was performed, for the sensor for oxygen and carbon dioxide (with a syringe of known volume

and with the known gas mixture, respectively). All participants performed maximal progressive protocol on the treadmill (*HP Cosmos Ltd, Nussdorf, Germany*).

The protocols were individually adapted for each participant based on the previous questionnaire, which have provided insight into the physical possibilities of the subjects, so that the expected maximal values could be reached in the interval between 8-12 minutes of testing. Installation of the gas analysis equipment and 3 minutes warm up on treadmill at speed up to 5 km/h, was followed by the phase of gradual increase in treadmill speed up to the end of the testing phase. The analysis of the gas exchange was carried out using breath by breath method (The Oxycon Mobile OM, Jäger, Würzburg, Germany) with continuous monitoring of the 12 channel ECG. Heart rate was determined through ECG recording. Indicators for the ending of the test were: subjective fatigue of participants, achievement of estimated maximal heart frequency and the value of the respiratory exchange ratio (RER_{max}) ≥ 1.10 .

Submaximal Load Test

The submaximal load test was performed using a protocol that included 1 minute and 30 seconds of warm up period on a treadmill. After the warm up period, we have increased the speed of treadmill up to the previously calculated values. The referent speed value was the one at which the subject has reached 70% or 90% of the previously established VO_2 max. After the warm up, subjects ran for the following six minutes on a given load. Three participants ran at a moderate load of 70% while the second group of three participants ran at a high load of 90%. Six minutes of running were followed by a 3-minute resting phase on the treadmill. The test was repeated in 2 phases that were separated with a minimum of 24h break. During the first arrival, participants listened to the music during the testing phase. Personalized playlists made in the telephone application (Deezer, Paris, France) were applied by wireless headphones (Sony WH-CH400, Japan).

Statistical analysis

All data is displayed using standard descriptive statistics, presented as an arithmetic mean with standard deviation. The differences of arithmetic mean of parameters during testing in the presence and absence of music are presented using T test for dependent samples and non-parametric test for dependent samples in case of a normal distribution absence. All statistical analyses were made using the Statistic package for social Sciences 15 (SPSS15) program.

Results

Anthropometric measurements

The demographic and anthropometric parameters of participants are presented in the Appendix I.

Cardiopulmonal measurements

The implementation of statistical tests for two related samples showed that there is a statistically significant difference in the breathing frequency (BF), ventilation (VE), the volume of exhaled CO₂ (VCO₂), blood pressure (TA) at the load of 70% VO₂max ($p < 0.05$). The average breathing frequency in the presence of music was 39.89 ± 6.04 breaths per minute, while in the absence of music amounted to 33.07 ± 5.81 breaths per minute (appendix, III). In the presence of music, the average ventilation has reached the value of 77.256 ± 28.56 L/min, while in the absence of music it was 68.15 ± 26.85 L/min (appendix, IV). Exhaled CO₂ volume in the presence of music was 2303 ± 959.20 mL/min, while in the absence of music was 2122.1 ± 955.57 mL/min (appendix, V). The average systolic blood pressure in the presence of music was 153.33 ± 5.33 mmHg and in the absence of music was 166.67 ± 11.54 mmHg (appendix, VIII). The average diastolic blood pressure in the presence of music showed the value of 83.33 ± 5.33 mmHg, and 90 ± 11 mmHg in the absence of music (appendix IIc, VII). Statistically significant difference for the consumption of oxygen per kilogram and respiratory volume was not found ($p = 0.05$).

The application of the student T test for two related samples showed statistically significant difference in oxygen consumption (VO₂/kg) and blood pressure at the load of 90% VO₂max ($p < 0.05$). The arithmetic mean of oxygen per kilogram in the presence of music was 34.96 ± 3.97 mL/min/kg, while in the absence of music it was 34.46 ± 4.87 mL/min/kg (appendix, IIb, VI). The average systolic blood pressure in the presence of music showed value of 163.33 ± 5.77 mmHg, while in the absence of music it was 173.33 ± 5.77 mmHg (appendix IId, VIII). The average diastolic blood pressure in the presence of music was 84.67 ± 5.50 mmHg, and 90 ± 0.00 mmHg in the absence of music (appendix IId, VII). The other parameters have not showed a statistically significant difference.

Discussion

The aim of this study was to examine the influence of music on the functional parameters of the cardiovascular and respiratory system during submaximal CPET

at different levels of intensity. We posted the hypothesis that stimulating music will lead to changes in gas exchange parameters during a moderate load test. We did not expect this change at a high-load test. The results showed that there is a significant increase in breathing frequencies when running in conditions with music on the load of 70% VO_2max . Our result is in accordance with the results of the studies of Salimpoor (12,13) and Benedek (14) who have proven that music that causes a positive emotion, increases the respiratory frequency, cardiac frequency and reduces blood pressure. It is considered that music achieves this through the limbic system activity, by causing dopamine release and a consequentially caused positive emotional state is affecting autonomous nerve centers through the connections that these two systems share (13–15). As the breathing frequency is controlled through the signal of an autonomous nervous system originating from the respiratory center at the level of the prolonged spinal cord (16,17) we can assume that the music indirectly had an impact on the increase of the breathing frequency of 20.61% during the test at 70% load compared with the same load, but without music. Increased breathing frequencies were followed by increased ventilation of 13.35% at the load of 70% VO_2max values. Based on this increase, we can see that the amount of air inhalation per minute corresponds to the increase of the respiratory frequency while listening to stimulating music during running. During the load of 90% of VO_2max , as we expected, there was no change in these parameters. Despite the numerical increase of ventilation in the results, no statistical difference was obtained in the consumption of oxygen when subjects had listened to stimulating music at 70% test, while on the test of 90% VO_2max , value had an increase of 1.75%. Oxygen consumption in the same load was examined by Lim (18) and Terry (19) during the test on treadmill and cycling. In the study of Lim (18), there was no difference in the consumption of oxygen on the submaximal strain, while in the Terry (19) study, it was proven. Based on the results of previously mentioned studies and our research we see that there is a disagreement on the influence of music on VO_2 consumption, which is likely due to different conditions in which the test was performed, the selection of exercises, music and adaptations of subjects to the test. By comparing each other's changes in the respiratory variables, we can confirm that the impact of stimulating music to increase in the frequency of breathing and ventilation does not have to be in a correlation with the increase of VO_2 . This indicates that a change in the number of breaths per minute does not affect the VO_2 (20). However, the results showed that there was an increase in the amount of the exhaled CO_2 during test with the music due to the increasing of ventilation in the same conditions (appendix V). It is evident that the chosen motivational music during the test raises an emotional response that affects the respiratory center by increasing the breathing frequency, ventilation and the amount of exhaled CO_2 . This was not the case at the load of 90% VO_2max because the influence of music is dominated by increased physical effort.

The Tenenbaum (10) study showed that music does not have a significant impact on the autonomous nervous system and the regulation of breathing during the exercise on the load higher than 80% VO₂max which our scores have confirmed. In cases of 70% and 90% of VO₂max, there was a difference of 2.25% and 2% in the RER, but it is was not statistically significant and cannot be attributed to the impact of music on the respiratory ratio. The influence of music on hemodynamic parameters was investigated in many studies, both in rest and exercise (1, 21). In studies conducted by Noguchi (22) and Loomba (21) it was proven that music can lower the blood pressure through the already mentioned relax effects that it achieves through the connection of the limbic and autonomous nervous system. The results of our studies have confirmed that there is a significant difference both on high and moderate loads in blood pressure, but the difference is more noticeable at lower load. According to our findings, in the available literature, there is no difference in the selection of music and the manner of its effect on the breathing frequency during exercise, but the available results are limited (22) so a future research needs examine the influence of motivational, stimulating and demotivational, sedative music and compare them. Also, in this survey we examined only motivating factor of music with the absence of running and rhythms. Sound wave is made of frequency, strength, color, spread speed, while music as a sum of audio stimuli consists of melody, rhythm, harmony, tempo. Due to the extensive complexity of the music itself and the effect on physiological parameters, it is not simple to explore and explain its influence through one research due to the cumulative effects of the previously mentioned characteristics that must be individually examined and compared.

Conclusion

This research confirmed the impact of the music on cardiopulmonal parameters. It has showed the change in frequency of breathing, ventilation, the amount of exhaled CO₂ the reduction of pressure on moderate load, while the changes of other parameters were not statistically significant. On high loads, there was a minimal increase in oxygen consumption and the reduction of blood pressure, without significant differences in other parameters.

Our plan research is to examine the effect of music on a larger group of subjects. We believe that the expansion of research methodology (including the analysis of EEG, EMG signal, lactates and hormone measurements) will improve the understanding of influence of music on different functional parameters during physical exercise.

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Appendix I

Table 1. Demographic and anthropometric characteristics of subjects

Subject	Sex	Age	BH (cm)	BW (kg)	BMI (kg/m ²)	%BF	%muscle
1	f	21	167	54.4	19.5	15.9	45.95
2	f	21	173	61.1	20.4	21.7	43.69
3	m	21	180	79.6	24.6	13	49.49
4	m	20	180	78.6	24.3	13.4	49.9
5	m	21	173	66.5	22.2	14	48.72
6	m	22	192	91.8	24.9	19.8	45.75

BH – Body Height; BM – Body Mass; BMI – body mass index; %BF – percent body fat; sex–f–female; sex–m–male

Appendix IIa

Table 2. Functional parameters of the subjects at the load of 70% VO₂max values

Variables	Music	Without music	p
BF	39.89 ± 6.04	33.07 ± 5.81	<0.05*
VE (L/min)	77.25 ± 28.55	68.15 ± 26.85	<0.05**
VO ₂ /kg (ml/min/kg)	34.96 ± 3.97	34.46 ± 4.87	>0.05
VCO ₂ (ml/min)	2304.43 ± 798.5	2122.1 ± 797.45	<0.05**
RER	0.88 ± 0.06	0.89 ± 0.06	>0.05

Variables are displayed as X ± SD; BF (Breathing Frequency) - respiratory frequency; VE (Ventilation) – ventilation; VO₂/kg-oxygen consumption per unit of body mass; VCO₂ – volume of exhaled CO₂; RER (Respiratory Exchange Ratio)

Student T test *p<0,05

Wilcox test

Appendix IIb**Table 3. Functional parameters of respondents in the load of 90% VO₂max values**

Variables	Music	Without music	p
BF	47.48 ± 5.80	47.10 ± 7.17	>0.05
VE (L/min)	112.71 ± 19.23	108.05 ± 22.94	>0.05
VO ₂ /kg (ml/min/kg)	43.15 ± 2.71	42.41 ± 2.78	<0.05*
VCO ₂ (ml/min)	3117.33 ± 259.04	2999.43 ± 348.62	>0.05
RER	0.99 ± 0.02	1.01 ± 0.04	>0.05

Variables are displayed as X ± SD; BF (Breathing Frequency)-respiratory frequency; VE (Ventilation); VO₂/kg – oxygen consumption per kg; VCO₂ – volume of exhaled CO₂; RER (Respiratory Exchange Ratio)

Student T test *p<0,05

Wilcox test **p<0,05

Appendix IIc**Table 4. The value of blood pressure of respondents in the load of 70% VO₂max values**

Variables	Music	Without music	p
SP (mmHg)	153.33 ± 5.77	166.67 ± 11.54	<0.05*
DP (mmHg)	83.33 ± 5.77	90.00 ± 0.00	<0.05*

Variables are displayed as X ± SD;

SP-systolic pressure; DP-Diastolic pressure

Student T test *p<0,05

Appendix II d**Table 5. The value of blood pressure of respondents in the load of 90% VO₂max values**

Variables	Music	Without music	p
SP (mmHg)	163.33 ± 5.77	173.33 ± 5.77	<0.05*
DP (mmHg)	84.67 ± 5.50	90.00 ± 0.00	<0.05*

Variables are displayed as X ± SD;

SP-systolic pressure; DP-Diastolic pressure

Student T test *p<0,05

Appendix III

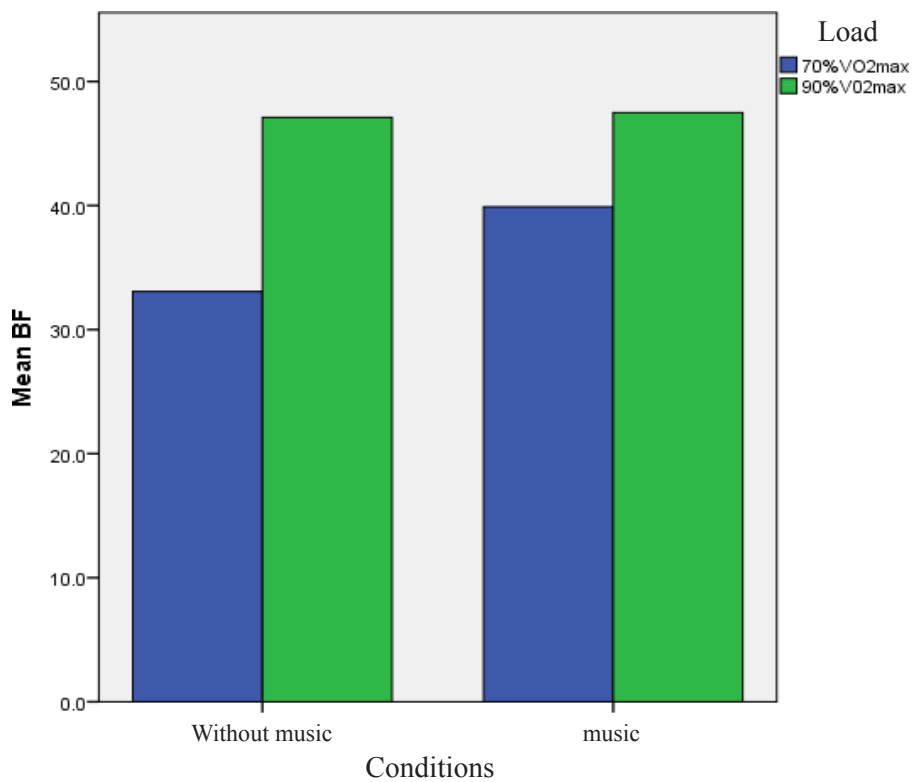


Figure 1. Breathing frequency (BF) in conditions with music and no music at different loads

Appendix IV

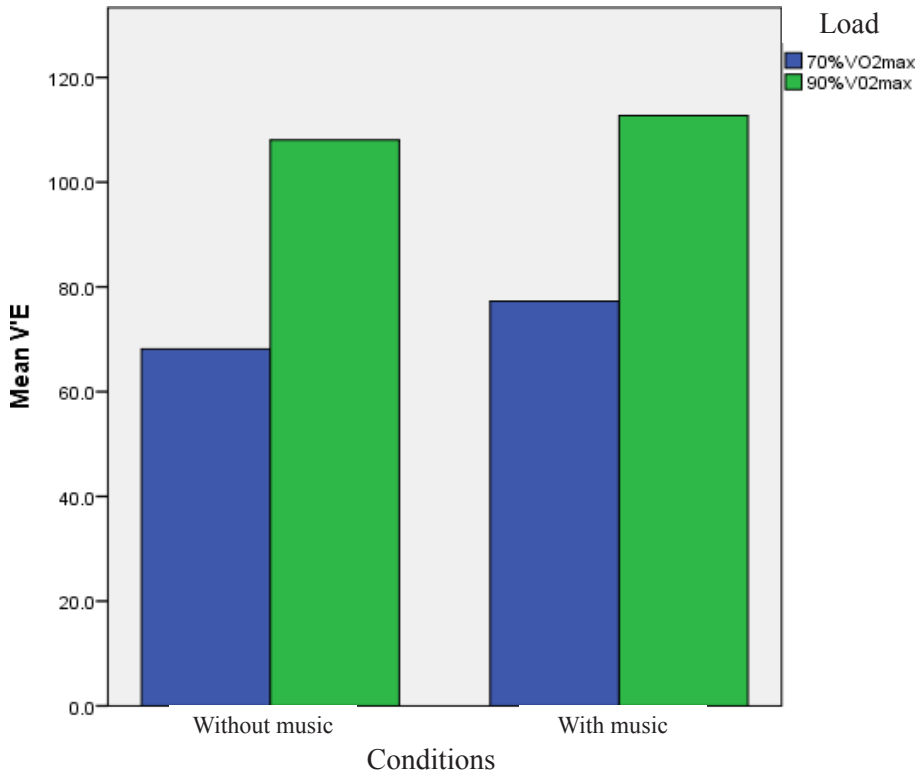


Figure 2. Ventilation ($v'e$) in conditions with music and no music in loads of 70% and 90% VO_{2max} values

Appendix V

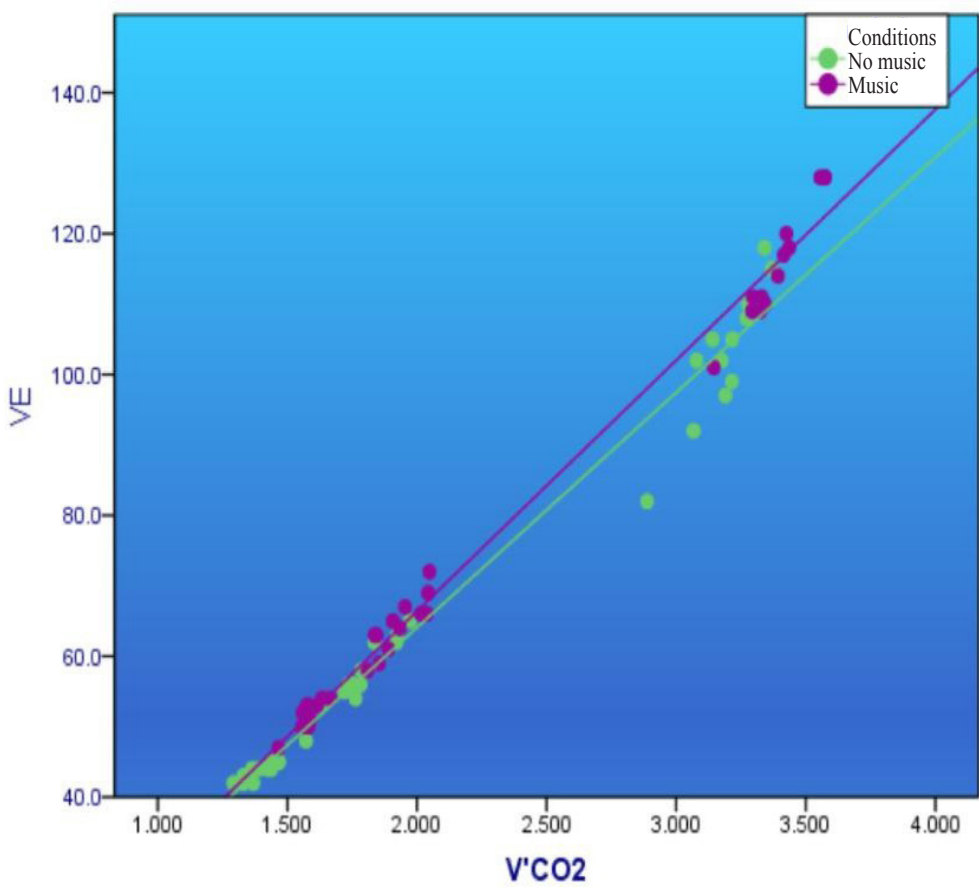


Figure 3. Ratio of exterminated CO₂ ($V'CO_2$) and inhaled air in conditions with and without music in the load of 70% VO_{2max} values

Appendix V

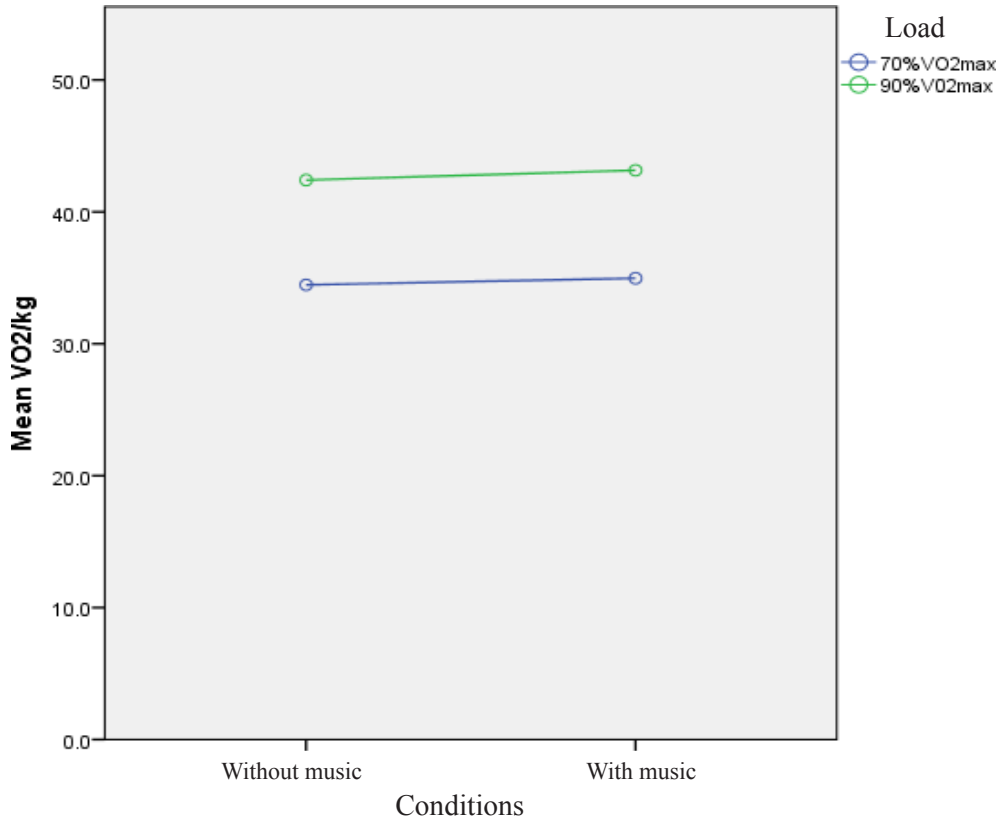


Figure 4. Average consumption of oxygen per kg of body mass (VO₂/kg) in conditions with music and without music at loads of 70% and 90 VO₂max values

Appendix VII

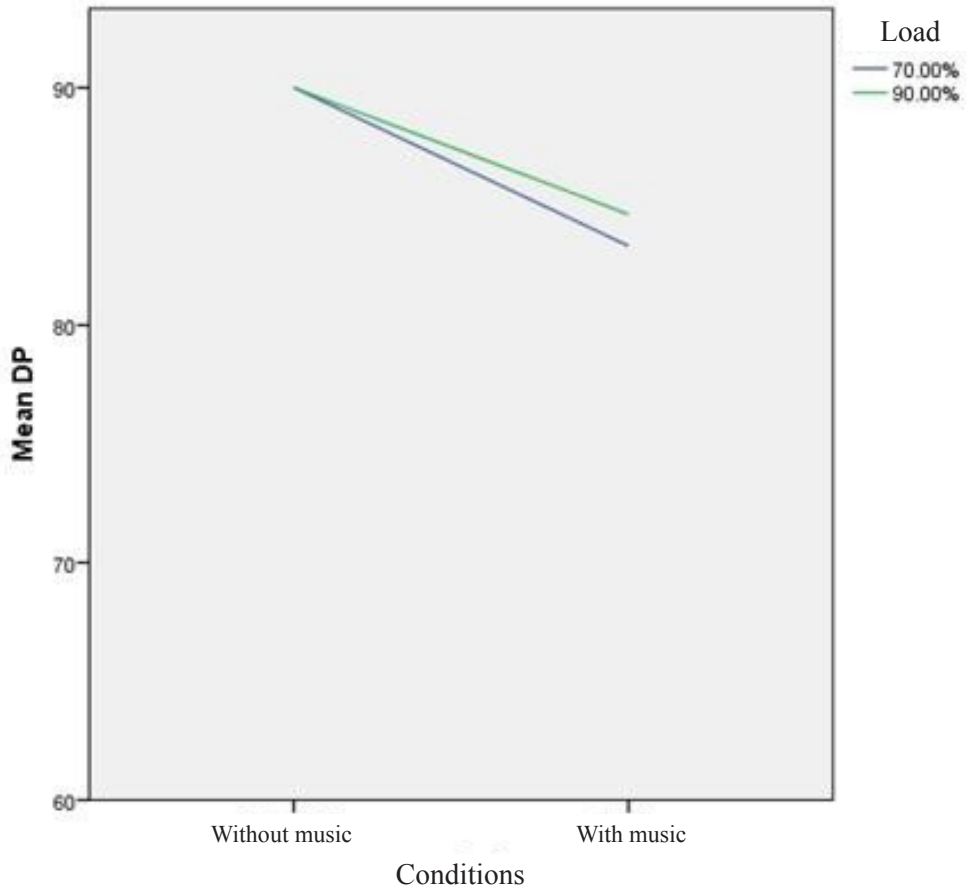


Figure 5. Change of diastolic pressure (DP) in conditions with music and without music in the load of 70% and 90% VO_2 max values

Appendix VIII

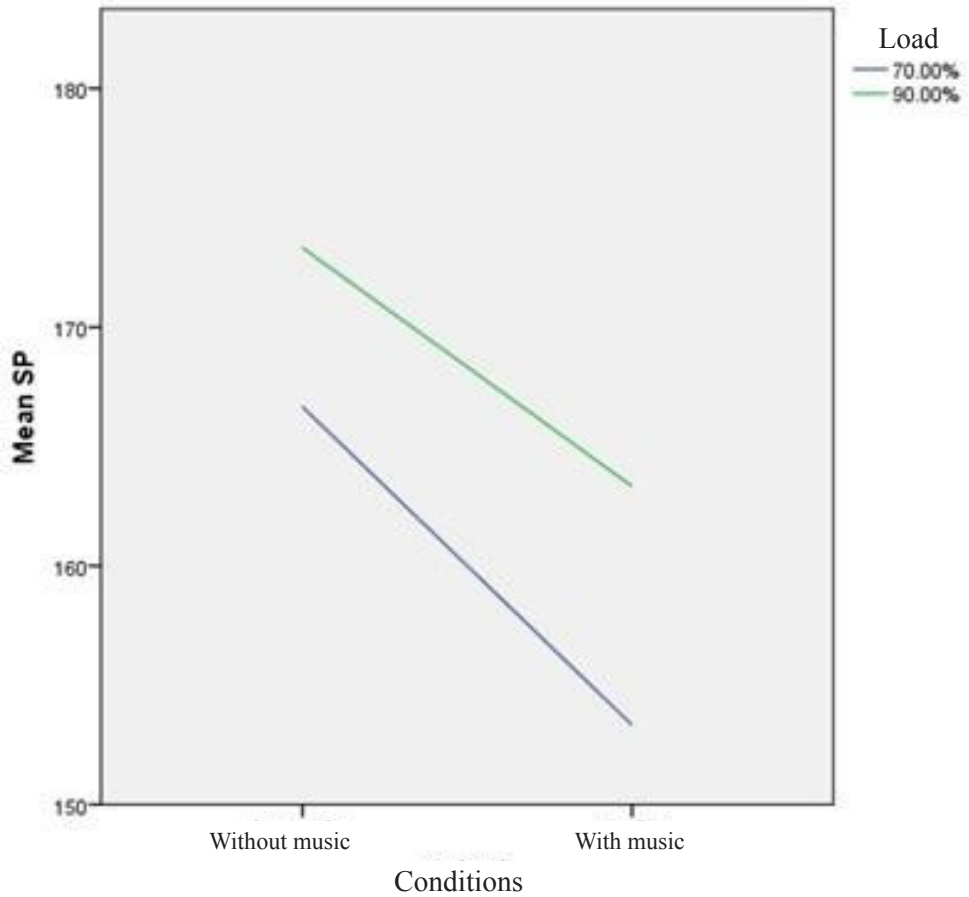


Figure 6. Change of System pressure (SP) in conditions with music and without music at loads of 70% and 90% VO_2 max values