# ACUTE EFFECTS OF AUDITORY STIMULATION WITH HEAVY METAL MUSIC ON HEART RATE RESPONSES

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**Aim.** Investigate the acute effects of heavy metal musical auditory stimulation on cardiac autonomic regulation.

**Material and methods**. This is a prospective study conducted on 22 healthy women between 18 and 30 years old. All procedures were performed in the same soundproof room. The volunteers remained at rest for 20 minutes and subsequently were exposed to heavy metal (75-84 dB) music for 20 minutes. We analysed the following HRV indices: SDNN, RMSSD, pNN50, LF, HF and LF/HF ratio, RRTri, TINN, SD1, SD2 and SD1/SD2 ratio.

**Results.** During exposure to heavy metal music auditory stimulation we observed that the LF ($ms^2$) tended to increase (p=0,06) and reduce HF (nu) (p=0,07) and the LF/HF ratio increased (p=0,05). No significant changes were found for SDNN, pNN50, RMSSD, SDNN/RMSSD ratio, TINN, RRTri, SD1, SD2 and SD1/SD2 ratio.

**Conclusion**. Auditory stimulation with the selected heavy metal musical style acutely decreased HRV.

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**Keywords:** cardiovascular system, autonomic nervous system, hearing, music.

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BMI — body mass index, BP — blood pressure, DBP — diastolic blood pressure, HF — high frequency, HR — heart rate, HRV — heart rate variability, LF — low frequency, SBP — systolic blood pressure, SDNN — standard deviation of the average normal RR intervals, RMSSD — square root of the mean squared differences between adjacent normal RR intervals.

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# ОСТРОЕ ВОЗДЕЙСТВИЕ НА ЧАСТОТУ СЕРДЕЧНЫХ СОКРАЩЕНИЙ СЛУХОВОЙ СТИМУЛЯЦИИ МУЗЫКОЙ В СТИЛЕ ХЭВИ-МЕТАЛ

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**Цель.** Изучение острого воздействия на вегетативную регуляцию сердца слуховой стимуляции музыкой в стиле хэви-метал.

**Материал и методы.** Это проспективное исследование проведено на 22 здоровых женщин в возрасте от 18 до 30 лет. Все процедуры проводились в одной звук-изолированной комнате. Добровольцы оставались в покое в течение 20 минут, а затем их подвергали воздействию музыки в стиле хэви-метал (75-84 дБ) в течение 20 минут. Мы проанализировали следующие показатели вариабельность сердечного ритма: SDNN, RMSSD, pNN50, LF, HF, LF/HF соотношение, RRTri, TINN, SD1, SD2 and SD1/SD2 соотношение.

**Результаты.** При воздействии слуховой стимуляции музыкой хэви-метал мы наблюдали тенденцию к увеличению LF ($мс^2$) (p=0,06) и снижению HF (nu) (p=0,07) и увеличение соотношения LF/HF в (p=0,05). Не было обнаружено значительных изменений для SDNN, pNN50, RMSSD, сотношения SDNN/RMSSD, TINN, RRTri, SD1, SD2 и SD1/SD2 соотношение.

**Заключение.** Слуховая стимуляция музыкой в стиле резко снижала HRV.

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**Ключевые слова:** сердечно-сосудистая система, вегетативная нервная система, слух, музыка.

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The relationship between music and medicine is a fast growing area that in the past has been largely focused on the use of music as an alternative and complementary therapy [1]. Relaxant music has been reported to present positive influence on stress reduction, relaxation, pain management, neural cognition and cardiac function [2, 3]. Auditory stimulation with music is known to induce several psychological responses, leading to changes in the autonomic nervous system [4, 5].

In this context, the heart rate variability (HRV) is a non-invasive method that evaluates the cardiac autonomic control in humans, it is a conventionally accepted term to describe the fluctuations in the intervals between consecutive heart beats (RR intervals), which are related to the influences of the ANS on the sinus node [6].

Great part of studies has observed the relaxing effect of classical music. On the other hand, genres such as heavy metal, hip hop and techno music are commonly associated with physiologic excitement [7].

Although two recent studies showed reduced HRV during exposure to heavy metal musical auditory stimulation in healthy women [8, 9], others found absence of cardiac autonomic responses induced by heavy metal music in healthy men [10, 11]. In addition, the aforementioned studies used different protocols that combined heavy metal with classical baroque music styles.

Elucidating the physiological responses involved in acute musical auditory stimulation is important for the development of future therapies to help cardiovascular disorders treatment. Therefore, this study was undertaken to evaluate the acute effects of auditory stimulation with a selected heavy metal music style on cardiac autonomic regulation.

## Material and methods

**Study Population.** We analysed 22 apparently healthy student women aged between 18 and 30 years old. All volunteers were informed about the procedures and objectives of the study and, after agreeing, signed a consent form. All study procedures were approved by the Research Ethics Committee (REC) of the institution (case number. 2011/382) and followed the Resolution 196/96 of the National Health Council.

**Non-inclusion criteria.** We did not include women under the following conditions: body mass index (BMI) >35 kg/$m^2$; systolic blood pressure (SBP) >140 mmHg or diastolic blood pressure (DBP) >90 mmHg (at rest), endocrine, cardiovascular, respiratory and neurological related disorders or any condition that avoided the subject to perform the study. In order to avoid effects related to sexual hormones we did not include women on the $11^{th}$ to $15^{th}$ and $21^{th}$ to $25^{th}$ days after the first day of the menstrual cycle [12].

**Initial assessment.** The volunteers were identified by collecting the following information: age, weight, height and BMI. Anthropometric measurements were obtained according to the recommendations described in the literature. Weight was measured using a digital scale (W 200/5, Welmy, Brazil) with a precision of 0,1 kg. Height was determined using a stadiometer (ES 2020 Sanny, Brazil) with a precision of 0,1 cm and 2.20 m long. The body mass index (BMI) was calculated using the following formula: weight (kg)/height ($m^2$). We measured heart rate (HR) and blood pressure (BP). HR was measured with the Polar RS800CX heart rate monitor (Polar Electro, Finland). BP was indirectly measured by auscultation through calibrated aneroid sphygmomanometer (Welch Alyn — Tycos, New York, USA), and stethoscope (Littmann, Saint Paul, USA) with subjects seated.

**Measurement of auditory stimulation.** The measurements of equivalent sound levels were performed in a soundproof room, using an audio dosimeter SV 102 (Svantek, Finland). It was programmed measuring circuit 7 in “A” weighting, slow response [9].

The measurements were made during the session, which lasted a total of five minutes and 15 seconds for the exciting heavy metal music. We used the type of microphone insert (MIRE — microphone in real ear), which was placed inside the ear canal of the subject, just below the microphone, connected to the personal stereo.

Before each measurement, the microphones were calibrated with the acoustic calibrator CR: Model 514 (Cirrus Research plc). This tool was used to analyse the Leq (A), which is defined as the equivalent sound pressure level and the sound level corresponds to the same constant time interval. It contains the same total sound energy, which also analysed the spectrum of sound stimulation (eighth track) frequency [8] (Figure 1).

**Experimental Protocol.** Data collection was performed at a room temperature between 21° C and 25° C and with humidity between 50 and 60%. The volunteers were instructed not to ingest alcohol and caffeine for 24 hours prior to evaluation. The collection was made individually between 6 and 10 PM, and the volunteers were instructed to remain at rest, avoiding talking during the experiment.

After the initial evaluation the heart monitor belt was then placed over the thorax, aligned with the distal third of the sternum and the Polar RS800CX heart rate receiver (Polar Electro, Finland) was placed on the wrist. Subsequently, the volunteers remained at seated rest for 20 minutes with the headset off.

Then the volunteers were exposed to musical auditory stimulation with heavy metal (Gamma Ray: “Heavy Metal Universe”) style for a period of 20 minutes.

**Analysis of HRV.** The RR intervals recorded by the Polar RS800CX heart rate monitor (with a sampling rate of 1000 Hz) were transferred to the Polar Precision Performance software (v. 3.0, Polar Electro, Finland). The software allowed the visualization of the HR and the extraction of a file relating to a cardiac period (RR interval) in a “txt” file. After digital filtering supplemented with manual filtering to eliminate artefacts and premature ectopic beats, a number of 1000 RR intervals were used for data analysis. Only series with more than 95% of sinus beats were included in the study [13].

To analyse the linear indices in the time and frequency we used HRV analysis software (HRV Kubios v.1.1 for Windows, Biomedical Signal Analysis Group, University of Kuopio, Finland) [14,15].

**Analysis of linear indices of HRV.** The analysis in the time domain was performed by means of SDNN (standard deviation of the average normal RR intervals), RMSSD (square root of the mean squared differences between adjacent normal RR intervals), SDNN/RMSSD ratio and pNN50 (percentage of adjacent RR intervals with a difference of duration greater than 50ms).

For HRV analysis in the frequency domain we used spectral components of low frequency (LF: 0,04 to 0,15 Hz) and high frequency (HF: 0,15-0,40 Hz), inabsolute ($ms^2$) and normalized units and the ratio between components of low and high frequency (LF/HF). Spectral analysis was calculated using the algorithm of fast Fourier transform [6].

**Geometric indices of heart rate variability.** HRV analysis was performed by means of geometrical methods:

RRtri, TINN and Poincaré plot (SD1, SD2 and SD1/SD2 ratio). The RRtri was calculated from the construction of a density histogram of RR intervals, which contains the horizontal axis of all possible values of RR intervals measured on a discrete scale with 7,8125 ms boxes (1/128 seconds) and on the vertical axis, the frequency with which each occurred. The union of points of the histogram columns forms a shape like a triangle. The RRtri was obtained by dividing the total number of RR intervals used to construct the histogram by their modal frequency (RR interval value that most frequently appeared on RR) [6].

The TINN consists of the measure of the base of a triangle. The method of least squares is used to determine the triangle. The RRtri and the TINN express the overall variability of RR intervals [16].

The Poincaré plot is a map of points in Cartesian coordinates, constructed from the values of RR intervals obtained, where each point is represented on axis x (horizontal/abscissa) by the previous normal RR interval, and on axis y (vertical/coordinate), by the following RR interval.

For quantitative analysis of the plot, an ellipse was fitted to the points of the chart, with the center determined by the average RR intervals, and the SD1 indexes were calculated to measure the standard deviation of the distances of the points to the diagonal y=x, and SD2 measures the standard deviation of the distances of points to the line y = — x + RRm, where RRm is the average of RR intervals. The SD1 is an index of instantaneous recording of the variability of beat-to-beat and represents parasympathetic activity, while the index SD2 represents HRV in long-term records, and reflects the overall variability. Their ratio (SD1/SD2) shows the ratio between short and long variations of RR intervals [16].

The qualitative analysis of the plot was made through the analysis of the figures formed by its attractor, which were described by Tulppo et al [16] in:

Figure in which an increase in the dispersion of RR intervals is observed with increased intervals, characteristic of a normal plot.

Small figure with beat-to-beat global dispersion without increased dispersion of RR intervals in the long term is related to cardiac disorders or autonomic dysfunction [15].

**Statistical analysis.** Standard statistical methods were used to calculate the means and standard deviations. The normal Gaussian distribution of the data was verified by the Shapiro-Wilk goodness-of-fit test (z value of >1.0). For parametric distributions we applied the paired Student T test. For non-parametric distributions we used the paired Wilcoxon test. Differences were considered significant when the probability of a Type I error was less than 5% ($p \leq 0{,}05$). We used the Software Biostat 2009 Professional® 5.8.4.

## Results

Table 1 shows the values for DBP and SBP, HR, mean RR intervals, weight, height and BMI of the volunteers.

**Table 1**

**Baseline DAP and SAP, Mean RR, weight, height and BMI of the volunteers**

| Variable | Value |
|---|---|
| Age (years) | 20,8±2,7 |
| Height (m) | 1,63±0,07 |
| Weight (kg) | 59,9±10,1 |
| BMI (kg/m$^2$) | 22,51±2,9 |
| HR (bpm) | 83,2±19,4 |
| Mean RR (ms) | 708,6±81,3 |
| SAP (mmHg) | 105,4±8,4 |
| DAP (mmHg) | 69,5±8,4 |

**Abbreviations:** DAP — diastolic arterial pressure, SAP — systolic arterial pressure, HR — heart rate, Mean RR — mean RR interval, BMI — body mass index, m — meters, kg — kilograms, bpm — beats per minute, ms — milliseconds, mmHg — millimeters of mercury.

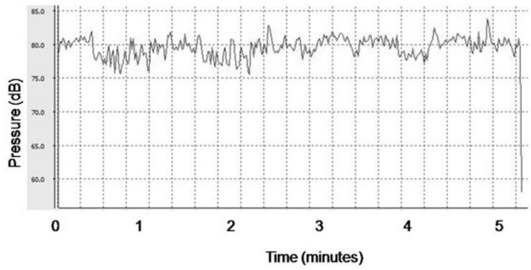


**Figure 1.** Equivalent sound level of auditory musical stimulation.

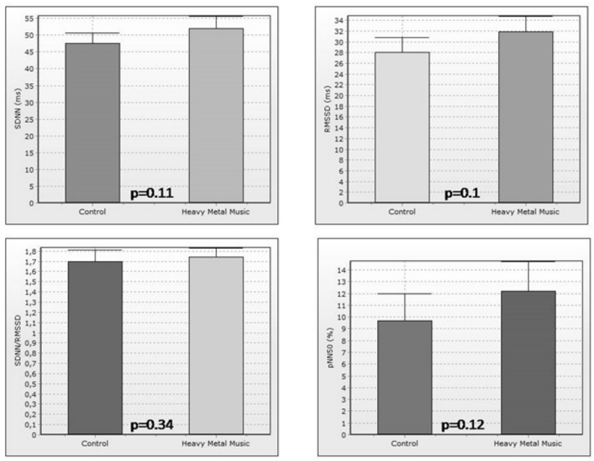


**Figure 2.** Time domain indices of HRV before and after exposure to auditory stimulation with music.

**Abbreviations:** SDNN — standard deviation of normal-to-normal R-R intervals, RMSSD — root-mean square of differences between adjacent normal RR intervals in a time interval, pNN50 — percentage of adjacent RR intervals with a difference of duration greater than 50ms, ms — milliseconds.

The time domain indices of HRV during exposure to heavy metal musical auditory stimulation are presented in Figure 2. We noted no significant difference between before (control) and during exposure to the selected music regarding SDNN, RMSSD, SDNN/RMSSD ratio and pNN50 indices.

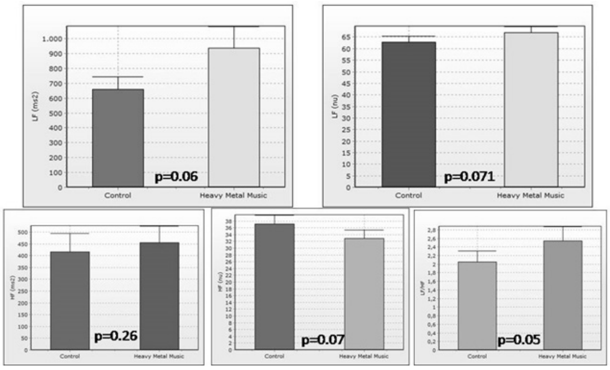


**Figure 3.** Frequency domain indices of HRV before and after exposure to auditory stimulation with music.
**Abbreviations:** LF– low frequency, HF — high frequency, LF/HF — low frequency/high frequency ratio, ms — milliseconds, nu — normalized units.

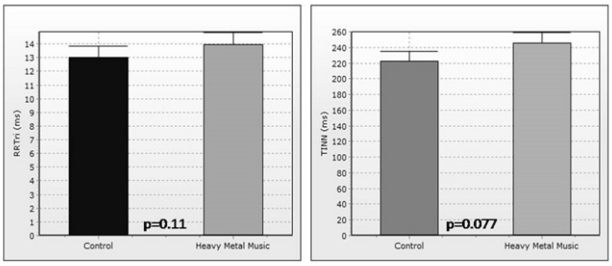


**Figure 4.** Linear geometric indices of HRV before and after exposure to auditory stimulation with music.
**Abbreviations:** RRtri — Triangular index, TINN — triangular interpolation of RR intervals, ms — milliseconds.

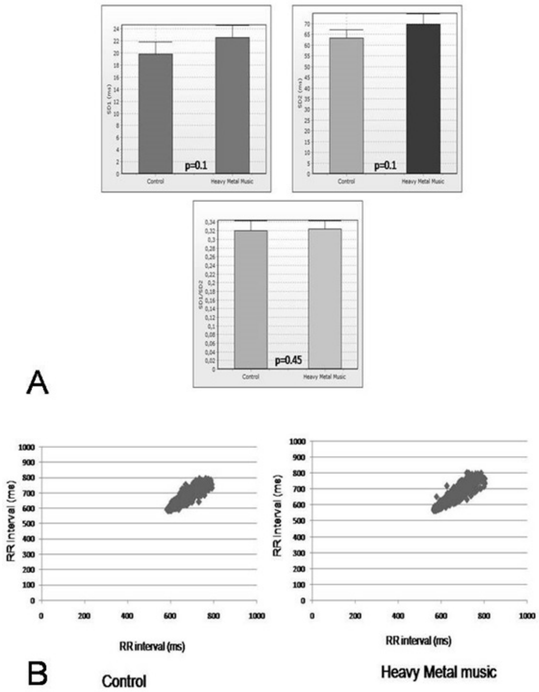


**Figure 5.** (A) Poincaré plot indices before and after exposure to auditory stimulation with music. (B) Visual pattern of the Poincaré plot observed in one subject before (Control) and during musical auditory stimulation with heavy metal style (heavy metal music).
**Abbreviations:** SD1 — standard deviation of the instantaneous variability of the beat-to beat heart rate, SD2 — standard deviation of long-term continuous RR interval variability, SD1/SD2 ratio — ratio between the short — and long — term variations of RR intervals, ms — milliseconds.

In relation to the frequency domain indices of HRV, we observed that the LF in absolute and normalized units as well as the LF/HF ratio tended to increase whereas the HF in normalized units tended to reduce during musical auditory stimulation with heavy metal style, however, it did not reach statistical significance. On the other hand, the HF index in absolute units did not change during auditory stimulus (Figure 3).

Figure 4 displays data for the geometric indices of HRV. The both TINN and RRTri did not significantly change during heavy metal musical auditory stimulation.

In Figure 5A we note that the Poincaré plot indices SD1, SD2 and SD1/SD2 ratio were not different between before (control) and during exposure to heavy metal song style.

Figure 5B shows an example of the Poincaré plot patterns from one subject during no music and excitatory heavy metal musical auditory stimulation.

## Discussion

Our study aimed to investigate the acute effects of auditory stimulation with a selected heavy metal music style on cardiac autonomic regulation in healthy women. We observed that it tended (p=0.05) to change the time domain indices of HRV increasing the LF/HF ratio. The qualitative analysis through Poincaré plot indicated that during exposure to music there was higher dispersion of RR intervals, indicating increased HRV.

We reported absence of significant changes for the time domain indices of HRV (pNN50, SDNN, RMSSD and SDNN/RMSSD ratio). There are two recent studies that support our findings. Roque et al [8] found no significant change of the time domain indices of HRV during exposure to the same heavy metal music. The same authors reported absence of significant changes in the time domain indices of HRV during exposure to Heavy Metal Universe from Gamma Ray in another study [9]. In this sense, we hypothesize that the statistical method applied on RR interval during this selected musical auditory stimulation is not able to detect significant changes.

According to our data, the selected heavy metal music slightly increased the LF index in absolute units. The same music was shown to reduce that index [8]. However, in the mentioned investigation the authors used a different protocol that was based on consecutive exposure to heavy metal and classical baroque music styles. The volunteers were randomly exposed to the both music styles in the same day. In this line, a recent study [10] that used the same experimental protocol of Roque et al [8], reported reduction of global HRV in men during exposure to Heavy Metal Universe from Gamma Ray. Taken together, we hypothesize that the mix of the music styles have influenced on their data.

The visual analysis through the Poincaré plot showed that during exposure to heavy metal musical auditory stimulation there was a decrease in the dispersion of RR intervals compared to the moment with no auditory stimulation, indicating higher HRV during music exposure. This result is supported by the increased LF/HF ratio during exposure to music. The Poincaré plot analysis is a simple method used as a qualitative tool [17] and also as a geometrical analysis by fitting an ellipse to the shape of the Poincaré plot in order to calculate HRV indices [18]. This analysis is considered nonlinear, because it performs a description of the nonlinear dynamics of a mechanism that can identify the hidden correlation patterns of a time series signal. It is suggested that nonlinear analysis is more sensitive to detect changes not recognized through linear analysis of HRV [19].

In our study the selected heavy metal music ranged between 75 and 84 dB. The intensity of musical auditory stimulation is an important issue to be raised. Lee et al [20] observed that white noise exposure above 50 dB enhanced sympathetic cardiac component of HRV. It was noted cardiac accelerative reaction that habituated over trials in subjects exposed to repeated 60 dB and 110 dB white-noise stimuli. The authors found a strong correlation between the noise intensity and LF/HF ratio, indicating the higher the noise intensity the higher the cardiac sympathetic tone. Nevertheless, there are differences between musical auditory stimulation and white noise. White noise is characterized by a small range of intensity [21], while the intensity of music fluctuates. Musical auditory stimulation influences the limbic system [22], but it has not yet been established whether white noise induces a positive or negative response in the cognitive system. In this context, it may be postulated that the effects of auditory stimulation on the cardiac autonomic regulation depend on the type of auditory stimulation.

The acute effects of music on cardiac autonomic regulation may be explained by proposed physiological mechanisms. Evidences from neurochemical studies revealed that emotional responses induced by music are related to reward circuitry, depending on dopamine release in the nucleus accubens [23]. Musical auditory stimulation in rats was shown to increase calcium/calmodulin-dependent dopamine synthesis in the brain, inducing a blood pressure decrease [24]. The suprachiasmatic nucleus of the hypothalamus was also reported to be involved in sympathetic and pressoric responses in anesthetized rats induced by music (“Träumerei” from Kinderszenen Op.15-7) [25].

An important highlight was the use of women for investigation of cardiac autonomic responses induced by music in order to avoid sex-dependent effects. Investigations regarding differences between men and women in relation to emotional manifestation and involvement showed conflicting results [26, 27]. Recently, it was reported that the same selected heavy metal music style reduced the global indices of HRV in men [10]. A previous study indicated that sex-based differences in psychophysiological responses to auditory stimulation with music are intensely influenced by sexual hormones [27]. Nonetheless, a different study showed women to be more stress reactive compared with men in reaction to musical auditory stimulation [26].

Another relevant point to be raised is the exclusion of volunteers during specific phases of the menstrual cycle, because the menstrual cycle was also indicated to affect baseline nonlinear properties of HRV [12]. In order to exclude the interference of the follicular and luteal phases of the menstrual cycle on cardiac autonomic regulation we did not evaluate volunteers on 10-15 days and 20-25 days after the first day of the menstrual cycle. In this context, a previous study from da Silva et al [28] reported no significant effect of Heavy Metal Universe from Gamma Ray on HRV indices in the time and frequency domain. However, the authors did not exclude women in the luteal and follicular phases of the menstrual cycle.

## Conclusion

Acute auditory stimulation with a selected heavy metal music style slightly decreased HRV.

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