Noise sensitivity modifies the effect of recorded noise on sympathovagal balance in young men

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ABSTRACT

Background. This is a re-analysis of the data from a large experimental study conducted in 2012 in Belgrade. The aim of the study was to assess changes in the sympathetic and parasympathetic activity of the autonomous nervous system (sympathovagal balance) provoked by recorded traffic noise in young men in relation to their noise sensitivity level.

Methods. The study comprised 35 healthy men, aged 24.8±2.6 years. Sympathovagal balance was monitored with thoracic electrical bioimpedance device (Task Force® Monitor) during a 10-minute noise exposure, and compared to quiet conditions before and after noise. All participants were categorized as weakly, moderately or highly noise sensitive (n=11, 15, 9 respectively) according to the Weinstein noise sensitivity scale. Changes were tested with Student's t-test for related samples.

Results. Moderately and highly noise sensitive participants showed significant changes in the sympathovagal balance during noise exposure in comparison to quiet conditions before and after noise exposure, unlike weakly noise sensitive men.

Conclusion. Noise sensitivity may be an important moderating factor accounting for the effects of noise exposure on the changes in the sympathovagal balance in young men.

INTRODUCTION

Sympathovagal balance is the balance between the sympathetic and the parasympathetic components of the autonomous nervous system, which are the major regulatory elements of the cardiovascular system [1]. Sympathetic activity is modulated by neurons in the limbic system, hypothalamus and the adrenal cortex [1]. Knowing that noise affects the amygdala and that it activates the hypothalamic-pituitary-adrenal axis and the autonomous nervous system, this leads to the development of "fight or flight" reactions that prepare the organism to survive in stressful situations [2-5]. As a consequence of either acute or chronic exposure, noise induces the release of stress hormones (adrenalin, noradrenalin and cortisol), the constriction of blood vessels, the retention of body fluids, and the increase of cardiac work, which result in an increase of blood pressure [2-5].

The team of researchers from Belgrade has conducted a large experimental study from 2009 through 2012, exposing young healthy normotensive volunteers to recorded road-traffic noise. As a result, we were able to demonstrate that short-term noise exposure induced a significant increase of blood pressure, which may be explained by an increase of peripheral vascular resistance and decrease of heart flow and blood volume [6-8]. Nevertheless, we failed to show the changes in the sympathovagal balance during the experiment [6-8]. We hypothesized that we may have left behind one of the possible modifiers in the noise-effect association, i.e. the noise sensitivity, defined as person's internal physiological, psychological or lifestyle-related state which increase the degree of reactivity to noise in general [9]. We decided to perform a re-analysis of the existing data, aiming to assess the changes in the sympathetic and parasympathetic activity of the autonomous nervous system (sympathovagal balance) provoked by recorded traffic noise in young men in relation to their noise sensitivity level.

METHODS

This experimental study was performed in the collaboration between the Institute of Hygiene and Medical Ecology, Faculty of Medicine, and the Multidisciplinary Center for Arterial Hypertension, Clinical Center of Serbia. In this re-analysis we present data from 35 healthy men with normal blood pressure, aged 24.8±2.6 years. The experimental study design is described in details elsewhere [6-8]. In short, participants were exposed to recorded road-traffic noise (Leq=89 dBA) for 10 minutes. Before and after noise exposure participants rested for 10 minutes in quiet conditions (Leq=40 dBA).

The sympathetic and parasympathetic activities of the autonomous nervous system were evaluated using the thoracic electrical bioimpedance device (Task Force® Monitor, CNS System Medizintechnik AG, Graz, Austria). Sympathovagal balance is assessed by power spectral analysis of heart rate variability (HRV). In this analysis, the peaks in high-frequency (HF) band (0.15–0.4 Hz) reflect mainly vagal or parasympathetic modulation of heart rate, while the low-frequency (LF) band (0.04–0.15 Hz) shows the joint action of the vagal and sympathetic components on heart rate, with a predominance of the sympathetic influences. As a principle, a ratio between these two bands (LF/HF ratio) may be considered a marker of sympathovagal balance [1, 10].

Noise sensitivity was tested with the Weinstein's Noise Sensitivity Scale – a 21-item, 6-point scale dealing with attitudes toward noise and emotional reactions to a variety of sounds [11]. All participants were categorized as weakly, moderately or highly noise sensitive (n=11, 15, 9 respectively) according to the 33rd and 66th percentile of the observed distribution of mean noise sensitivity scores (73 and 87 respectively, range of scores 52-113).

Kolmogorov-Smirnov test was used to assess the distribution of the investigated parameters. The differences between three groups of participants were analyzed with one-way analysis of variance (ANOVA) for parametric data, or with Kruskal-Wallis test for several independent groups for non-parametric data. The differences between the three experimental conditions were tested with Friedman's test for several related samples. The differences between noise exposure and the two quiet conditions were tested with Wilcoxon signed ranks test for two related samples. The authors used SPSS 15.0 for Windows software (SPSS Inc. 1989-2006).

RESULTS

Basic characteristics of the investigated groups according to their noise sensitivity level are presented in Table 1. Weakly, moderately and highly noise sensitive men were of similar age and had similar body mass index. At the baseline of the experiment they had similar blood pressure and sympathovagal balance.

Table 1: General characteristics of the investigated men by noise sensitivity level

Characteristics	Study groups			Difference between study groups (p value)
	Weakly noise sensitive	Moderately noise sensitive	Highly noise sensitive	
Number of participants	11	15	9	
Age (years)	24.18±2.52	25.60±2.92	24.67±2.12	0.384*
Body mass index (kg/m^2)	24.25±2.50	25.85±3.67	22.76±2.86	0.077*
Baseline systolic pressure (mmHg)	114.72±15.92	121.61±9.74	122.06±10.36	0.292*
Baseline diastolic pressure (mmHg)	68.69±12.33	75.20±7.75	76.42±7.77	0.138*
Baseline sympathovagal balance (LF/HF ratio)	1.62±1.50	1.49±0.78	1.90±1.37	0.780**

*One-way ANOVA

** Kruskal-Wallis test for several independent groups

Changes of sympathovagal balance during the three experimental phases according to noise sensitivity level are presented in Table 2. Weakly noise sensitive men showed no changes in sympathovagal balance during or after noise exposure.

Among moderately noise sensitive men, there was a significant decrease of sympathovagal balance after noise exposure. Among highly noise sensitive men, a significant increase of sympathovagal balance was observed during noise exposure in comparison to the quiet phase before noise exposure.

Table 2: Changes in sympathovagal balance during the experiment by noise sensitivity level groups

Study groups	Experimental phases			Difference between the three phases (p value)	Difference between noise exposure and quiet before noise (p value)	Difference between noise exposure and quiet after noise (p value)
	Quiet before noise exposure	Noise exposure	Quiet after noise exposure			
Weakly noise sensitive	1.62±1.50	1.06±0.44	1.12±0.62	0.717*	0.657**	0.859**
Moderately noise sensitive	1.49±0.78	1.52±0.84	1.41±0.59	0.466*	0.865**	0.050**
Highly noise sensitive	1.90±1.37	2.20±1.68	2.09±1.21	0.045*	0.008**	0.859**

*Friedman test for several related samples

** Wilcoxon Signed Rank test

DISCUSSION

An increased sympathetic activity is an important mechanism leading to arterial hypertension [1]. Sympathetic activity is known to be higher in men than in women, and in older than in younger persons [1]. Studies show that smoking, alcohol consumption, obesity and diabetes increase sympathetic activity, which may have modulating and prognostic significance in the development of cardiovascular diseases [1].

There is vast evidence that also link parasympathetic activity and heart rate variability with a wide range of cardiovascular risk factors, such as hypertension, obesity, diabetes, and work stress, indicating that decreased HRV precedes the development of cardiovascular events and that decreased vagal function could be a common feature of all the major risk factors for cardiovascular diseases [12].

Many researchers tried to explore the association between heart rate variability, an indicator of the activity of the autonomous nervous system, and various health parameters. For example, a strong association between HRV and objective quality of life (including the dimensions such as material well-being, physical health, productivity, intimacy, safety, place in community, and emotional well-being) was found among individuals with intellectual disabilities [13]. Reduced HRV and low vagal tone were observed in persons with panic disorder, and were consistent with the cardiovascular symptoms of the panic attack [14]. In the experimental setting, lower vagal component of HRV was observed in healthy subjects who watched film clips with emotional content (happiness, sadness, and disgust) in comparison to the neutral conditions (emotionally irrelevant visual stimuli) [15]. Similarly, a decrease of HRV and an increase of salivary cortisol level were observed in young healthy women who performed a computerized knowledge task (mental workload) [15]. In addition, a significant decrease of the LF/HF ratio (predominantly of the LF component) was observed during physical exercise in middle-aged healthy volunteers [17]. Finally, chronic work stress among hospital workers showed a negative correlation with the vagal activity of HRV. High effort at work was associated with lower daytime HRV, whereas the expression of emotions at work (stress and satisfaction) correlated with work time and irritation at work correlated with night time HRV [18].

The effect of white noise on autonomous nervous system was evaluated in 16 young healthy Chinese women, who were listening to noises ranging from 50 to 80 dBA for five minutes each. Although their blood pressure and heart rate did not change during the experiment, the low-frequency power of HRV (which reflects both sympathetic and parasympathetic activities) was significantly greater, the LF/HR ratio (which represents the cardiac sympathetic activities) correlated significantly with the noise intensity, whereas the high-frequency power (an indicator of the cardiac parasympathetic activities) remained unchanged [19].

The exposure to nature sounds or noise after a stressful mental task (arithmetic) in 40 Swedish students showed no effect of the type of sound on the high frequency domain of HRV; nevertheless, their skin conductance recovery (which was used as an indicator of sympathetic activity) was faster in natural sound environment than in noisy environments [20].

More than a few interesting experiments were conducted by Brazilian researchers exposing healthy participants to two different types of loud music – i.e. classical baroque music and heavy metal music. First, a group of 21 healthy women aged 18 to 35 years was successively exposed to loud (70-80 dBA) relaxant classical baroque music and to excitatory heavy metal music for five minutes, in a random order. Researchers demonstrated a decrease of HRV during the exposure to both musical styles. They implied that the results are transitory, and may not explain the long-term effects on autonomous nervous system, and concluded that the similarities in the effects of these types of music on HRV arise from the same sound intensity [21]. Second, 24 healthy women aged 18 to 25 years were listening to these types of music, which had three different sound levels (60-70, 70-80, and 80-90 dB). This time researchers showed that both baroque and heavy metal music at 60-70 dB decreased the low-frequency domain of HRV compared to control condition [22]. The same result was reported for 12 young healthy men [23]. In another experiment on 30 healthy women aged 18 to 30 years, participants listened to the classical baroque music (64-84 dB) and heavy metal music (75-84 dB) for ten minutes (different music on a different day). This time researches concentrated on participants' HRV after the exposure to music and monitored HRV for 30 minutes after music cessation. The results showed a significant increase in low-frequency domain of HRV and of LF/HF ratio, as well a significant decrease of high-frequency domain 25-30 minutes after the exposure to classical music. When it came to heavy metal music, the results were less obvious; i.e. only an increase in low-frequency domain of HRV 20-30 minutes later was reported [24].

The association between heart rate variability and song structure while choir singing was demonstrated among 18 young Swedish singers. During hymn singing, the participants' HRV increased significantly in comparison to humming or mantra singing, with lower LF/HF ratio compared with the other conditions; similarly, during mantra singing, the participants' HRV increased significantly in comparison to humming or hymn singing [25].

Finally, a group of researchers reviewed the publications on the association between auditory stimulation and the function of the autonomous nervous system. Authors agreed that harmonic music can increase parasympathetic activity, decrease sympathetic activity and blood pressure, improve heart rate variability, improve cardiac autonomic regulation and induce pleasure in treated individuals. Musical auditory stimuli are therefore proposed as indicators in the evaluation and identification of autonomic dysfunctions in clinical setting [26].

The presented study is not easily compared with other studies. First, the design of the study does not allow any randomization, and it is possible that a ten-minute noise exposure is not long enough to provoke the expected activation of the sympathetic nervous system. Second, we were not able to measure hormonal changes during noise exposure, but we were able to control for smoking, drinking coffee and performing physical activity for a few hours preceding the procedure, thus reducing their possible impact on blood pressure and hemodynamic changes before the experiment. Finally, to authors' knowledge, this is the first study to take noise sensitivity level into account and we would expect further studies to explore its role in the association between noise and cardiovascular system.

CONCLUSION

Noise sensitivity may be an important moderating factor accounting for the effects of noise exposure on the changes in the sympathovagal balance in young men.

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