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FACTORS CONTRIBUTING TO THE REDUCTION OF PAIN DURING ELECTROMYOGRAPHY AND NERVE CONDUCTION STUDIES

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SUMMARY

Background: *Electromyography (EMG) and nerve conduction studies (NCS) are an unpleasant and sometimes painful examinations. Pain can reduce patient's compliance and have a negative effect on the examination results. Different studies report that music affects pain perception by acting as a distractor, by inducing positive emotional valence or through the concept of convergence of different sensory modalities. The aim of this study was to explore the effect of music and different environmental and sociodemographic factors on pain perception during EMG and NCS.*

Subjects and methods: *Sixty patients with suspected neuromuscular disease were randomized into music and control group. Specific questionnaire assessed sociodemographic characteristics, medical history, examination waiting time, examination extent and biometeorological forecast. The numerical rating scale was used for the evaluation of pain. The examiner evaluated patient's compliance after the examination.*

Results: *NCS was less painful for patients in the music group (p=0.03), as well as for more cooperative patients (p=0.011). For patients who previously underwent EMG/NCS, present NCS was more painful (p=0.001), regardless of the music intervention (p=0.019). EMG was more painful for older patients (p=0.041). Patients with lower level of education reported lower pain during NCS (p=0.026). Gender, financial satisfaction, biometeorological forecast, diabetes, depression or malignant disease, use and dosing of analgesics or antidepressants, symptoms, examination waiting time and the examination extent had no effect on pain perception.*

Conclusions: *Music significantly decreased the perception of pain associated with NCS, but not the EMG portion of the examination. During EMG pain level was not significantly reduced, but the median of pain was still lower. Generally, the pain level during NCS, unlike the one during EMG, was affected by patients' compliance, level of education and painful predetermination. We propose using music during EMG/NCS because it can make the examination more comfortable for the patient and thus contribute to better quality of this examination.*

Key words: *music – pain – electromyography - nerve conduction studies - electromyoneurography*

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INTRODUCTION

Electrodiagnostic examination, which includes electromyography (EMG) and nerve conduction studies (NCS), is an essential tool in the evaluation of neuromuscular disorders, however, it can be painful and unpleasant for the patient. Pain can reduce patient's compliance during examination, which is important since it can negatively affect the interpretation of the test results. In order to make this examination more comfortable, we have to understand the underlying pain mechanisms and factors contributing to the origin and perception of pain.

Pain perception is very complex and involves many cortical areas. Nociceptive somatosensory stimuli selectively activate neurons in insular cortex and cingulate gyrus. The insular cortex has a role in reflex autonomic response to pain, while the cingulate gyrus is involved in processing of emotional states and for integration of sensory, affective and cognitive components of pain. A concept of pain regulation by convergence of afferent sensory information was developed in the 1960s by Melzack and Wall. This "gate-control theory" presumes that activation of non-nociceptive sensory neurons "closes the gate" for central transmission of nociceptive signals (Melzack & Wall 1965). Today, it is generally accepted that these interactions can occur at the spinal and supraspinal level. This concept of convergence of different sensory modalities presents an important point in creating new pain therapies and opens new directions for pain management in clinical practice (Bassbaum & Jessell 2013).

Different studies report that music can affect pain perception through the concept of convergence of different sensory modalities. It can also serve as a distractor,

or by inducing positive emotional valence (Price 2000, Mitchell et al. 2006, Roy et al. 2008, Bradshaw et al. 2012). Study of Abraham and Drory reported no effect of music on anxiety and pain level during EMG (Abraham & Drory 2014). However, many other studies affirm pain alleviation by using music during various invasive diagnostic procedures (Rudin et al. 2007, Nilsson 2008, Li et al. 2011, Kulkarni et al. 2012, Chuang et al. 2019, Ko et al. 2019). To the best of our knowledge, the effect of contributing factors such as environmental and sociodemographic factors on pain perception during EMG and NCS has not yet been investigated. The aim of this study was to explore the effect of music, as well as different sociodemographic and environmental factors on pain perception during EMG and NCS.

SUBJECTS AND METHODS

This prospective study was conducted from March 2011 to April 2013 at the Department of Neurology, Clinical Hospital Centre Zagreb, Zagreb, Croatia. Patients with suspected neuromuscular disease who underwent EMG and NCS were prospectively enrolled in the study. Each patient signed informed consent prior to inclusion and the study was approved by the responsible Ethics Committee. The study has been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Simple randomization was done by determining the even dates of the month as the "music day" and the odd dates of the month as the "control day", consequently the music and the control groups were formed. We used broadcast speakers for playing slow, low volume, soothing pop or instrumental music. Each examination lasted for approximately 45 minutes. A questionnaire that was developed specifically for this study assessed the following data: sociodemographic characteristics (sex, age, level of education, occupation, financial satisfaction), medical history, symptoms, waiting time for the examination, examination extent (only upper extremities, only lower extremities, upper and lower extremities), biometeorological forecast on the examination day (the data from the Croatian Meteorological and Hydrological Service website were used) and perceived discomfort during the examination. The numerical rating scale (NRS) was used for the evaluation of pain during each portion (EMG and NCS) of the examination, the maximum pain in the past 3 months and the average pain before the examination. Patients who previously underwent EMG/NCS were also asked to grade the level of pain on NRS during previous examination. After the examination, the examiner evaluated patient's compliance level on a scale from 1 to 10, with 1 being least and 10 most cooperative.

Table 1. Clinical and demographic characteristics

Patient characteristics	Number of patients - N (%)
Sex	
female	38 (63.3%)
male	22 (36.7%)
Level of education	
elementary school diploma	13 (21.7%)
elementary and high school diploma	34 (56.7%)
university degree	13 (21.7%)
Occupation	
employed	33 (55%)
unemployed	4 (6.7%)
retired	19 (31.7%)
Financial satisfaction	
poor	22 (36.7%)
good	38 (63.3%)
Biometeorological forecast	
bad forecast	21 (35%)
intermediate forecast	21 (35%)
good forecast	18 (30%)
Medical history	
diabetes	4 (6.7%)
malignant disease	3 (5%)
depression	15 (25%)
Drug usage	
antidepressants	11 (18.3%)
analgesics	46 (76.7%)
Amount of used drugs	
0-2 drugs	56 (93.3%)
3-5 drugs	4 (6.7%)
Symptoms	
pain	50 (83.3%)
paresthesia	29 (48.3%)
muscle weakness	28 (46.7%)
Waiting time for the examination	
0-2 weeks	15 (25%)
2 weeks-3 months	28 (46.7%)
3-6 months	17 (28.3%)
Examination extent:	
upper extremities	19 (31.7%)
lower extremities	21 (35%)
upper and lower extremities	20 (33.3%)
Perceived discomfort during examination	
more during EMG	41 (68.3%)
more during NCS	14 (23.3%)
both equally	5 (8.3%)
Prior EMG/NCS	29 (48.3%)

EMG = electromyography; NCS = nerve conduction studies

Table 2. Patient's pain and cooperation levels

Pain and cooperation	Median, range
Pain maximum in the past 3 months	7 (0-10)
Average pain before EMG/NCS	5 (0-10)
Pain during EMG	5 (0-9)
Pain during NCS	3 (0-8)
Cooperation level	10 (7-10)

EMG = electromyography; NCS = nerve conduction studies

Statistical analysis

Statistical analysis was performed in the IBM SPSS Statistics 20 program. Descriptive statistics were used to describe continuous and categorical variables. Kolmogorov-Smirnnoff test was run to determine the normal distribution of the data. Medians and ranges, or means and SD were determined where applicable and relative frequencies were computed for all variables. The major statistical examinations applied were: Mann-Whitney test for comparison of two independent groups, Kruskal-Wallis test for comparison of three or more independent groups and quantitative determination between variables was expressed by Spearman's correlation. A value of $p<0.05$ was deemed statistically significant.

RESULTS

A total of 60 patients participated in the study, 38 (63.3%) female and 22 (36.7%) male, with a mean age of 51.75±15.28 years, randomized into music group of 29 (48.3%) and control group of 31 (51.7%) patient. Majority of patients (41, 68.3%) perceived the EMG portion of the examination as more uncomfortable. Clinical and demographic characteristics are shown in Table 1. Patient's pain and cooperation levels are shown in Table 2.

Effect of music on pain during EMG/NCS

Significantly lower pain was recorded during NCS in the music group (p=0.031) (Table 3). Pain during EMG correlated positively with pain during NCS in both groups (control group: rs=0.621, p=0.001; music group: rs=0.553, p=0.002).

Differences in pain between patients who previously underwent EMG/NCS and patients naive to the examination

A total of 29 (48.3%) patients had previously underwent EMG/NCS ("prior EMG/NCS" group). These patients, with respect to the "naïve EMG/NCS" group, reported significantly higher pain during NCS portion of the examination (p=0.001). There were no significant differences considering EMG portion of the examination (Table 4). Pain reported for prior EMG/NCS examination correlated positively with reported pain during present examination (NCS: rs=0.469, p=0.010, EMG: rs=0.612, p=0.001).

For patients from the "prior EMG/NCS" group, NCS were still significantly more painful in comparison with "naïve EMG/NCS" group, regardless of the music intervention, although the median pain level was slightly lowered (control group: p=0.048, music group: p=0.019). No significant difference was found in pain during EMG between the groups (Table 5). In the control group, pain during "prior EMG/NCS" examination correlated positively with present NCS and EMG pain, given that statistical significance was reached for present NCS pain (rs=0.614, p=0.007) and almost reached for EMG pain (rs=0.466, p=0.051). In the music group, pain during "prior EMG/NCS" examination correlated positively only with present EMG pain (rs=0.705, p=0.015).

Table 3. Pain level during EMG and NCS regarding music intervention

	Control group (n=31)		Music group (n=29)		p-value
	Median	Range	Median	Range	
EMG pain level	5	0-9	4	1-8	0.792
NCS pain level	4	0-8	2	0-8	0.031*

*statistically significant; EMG=electromyography; NCS=nerve conduction studies

Table 4. Pain level during EMG/NCS in patients with prior experience and those naïve to the examination

	"Prior EMG/NCS" group (n=29)		"Naive EMG/NCS" group (n=31)		p-value
	Median	Range	Median	Range	
EMG pain level	5	1-9	4	0-9	0.171
NCS pain level	4	0-8	2	0-6	0.001*

*statistically significant; EMG=electromyography; NCS=nerve conduction studies

Table 5. The effect of music intervention on reported pain levels during electrodiagnostic examination between patients with prior experience and those naïve to the examination

	Control group (n=31)					Music group (n=29)				
	"Prior EMG/NCS" patients (n=18)		"Naive EMG/NCS" patients (n=13)		p- value	"Prior EMG/NCS" patients (n=11)		"Naive EMG/NCS" patients (n=18)		p-value
	Median	Range	Median	Range		Median	Range	Median	Range	
EMG pain level	5	1-9	5	0-9	0.597	5	2-8	4	1.6	0.125
NCS pain level	5	0-8	3	0-6	0.048*	4	0-6	2	0-4	0.019*

*statistically significant; EMG=electromyography; NCS=nerve conduction studies

Influence of contributing factors on pain

We found that age, level of education and patient compliance during the examination had significant correlation with the pain level during the examination. Patients' age correlated positively with pain during EMG (r_s=0.264, p=0.041), while no significant correlation was found regarding NCS. Patients with elementary and high school diploma reported lower pain during NCS (p=0.026). Patient compliance score correlated negatively with pain during NCS, i.e. more cooperative patients felt less pain (r_s=-0.328, p=0.011). There was no significant correlation found between pain during EMG and patient compliance.

Gender, financial satisfaction, biometeorological forecast, history of diabetes, depression or malignant disease, use and dosing of analgesics or antidepressants, patient's symptoms and difficulties (pain, paresthesia, muscle weakness), waiting time for the examination and the examination extent had no effect on pain during EMG or NCS.

DISCUSSION

Pain is a complex sensory condition. It integrates sensory information and has a significant emotional component. A number of studies reported positive effect of music on pain and anxiety reduction in different diagnostic and surgical examinations and procedures (Rudin et al. 2007, Nilsson 2008, Tam et al. 2008, Li et al. 2011, Kulkarni et al. 2012, Lee 2016, Ko et al. 2019). The beneficial effect of music on neurobiological, neuropsychological and neurophysiological factors was shown in clinical practice - a positive effect of music and music therapy was found in different neurological and psychiatric conditions, like Parkinson's disease, some forms of epilepsy and schizophrenia and in treatment of patients with dementia (Brotons & Koger 2000, Pacchetti et al. 2000, Jausovec & Habe 2003, Gold et al. 2005, Mossler et al. 2011). Music listening activates different pathways in insular and cingulate cortex, hypothalamus, hippocampus, amygdala and prefrontal cortex. Functional auditory projections can be routed from the auditory thalamus to the amygdala and medial orbitofrontal cortex, a set of regions associated with processing of emotional behaviour (Koelsch & Siebel 2005, Phelps & LeDoux 2005, Boso et al. 2006, Koelsch et al. 2006). Brain areas involved in pain processing significantly overlap with areas involved in cognitive and music processing (anterior cingulate cortex, orbitofrontal and prefrontal cortex) and emotional arousal (insula, amygdala) (Wiech et al. 2005, Buhle & Wager 2010, Bradshaw et al. 2012). Using fMRI Koelsch et al. showed that listening to pleasant and unpleasant music activates different brain areas, which is consistent with several other studies that indicate a different neuronal response considering listening of pleasant music (Blood et al. 1999, Boso et al. 2006, Koelsch et al. 2006). It is also described that experiencing fear, anxiety and stress before the medical examination may have negative impact on pain perception during the examination (Lee et al. 2011). It was shown that patients rather choose to listen to music or read, than to take excessive medication before invasive examinations, in order to lower their anxiety (Hyde et al. 1998).

In this study we used broadcast speakers instead of headphones for music intervention because of the needed communication between the examiner and the patient, and literature data have shown that music listening was equally effective in reducing pain perception regardless the usage of speakers or headphones (Lee et al. 2011). Patients reported a significantly lower present pain level during NCS if they were listening to music. For EMG, music intervention did not have statistically significant influence on pain, but the median of reported pain level was nevertheless lower. The explanation for this could be the fact that patient communicates and cooperates with the examiner during EMG and the EMG device creates a strong background noise, so the perception of music is somewhat interrupted. This is explained in the study of Dunbar et al., who proposed that interruptions can reduce any positive effect of music (Dunbar et al. 2012). On the other hand, during NCS there is no background noise and the patient has to be completely relaxed, calm and quiet, which creates excellent conditions for concentrating solely on music. Patient compliance showed to have an important impact on pain during NCS. More cooperative patients felt less pain, as opposed to patients who were nervous and agitated. Bradshaw et al. also showed that successful pain control greatly depends on the level of mental engagement or cooperation that patient provides (Bradshaw et al. 2011). The group of patients that had prior experience with EMG/NCS reported higher pain during NCS than the group of "naïve EMG/NCS" patients. Also, music intervention in these patients did not affect the present NCS pain level. For reported EMG pain level, we found no significant differences in either group. The reported pain level for "prior EMG/NCS" patients correlated positively with present pain during EMG and NCS. Interestingly, when we compared the pain level of "prior EMG/NCS" with present pain levels taking into account the music intervention, "prior EMG/NCS" pain level of controls correlated positively with both present EMG and NCS pain level. With the music intervention, "prior EMG/NCS" pain level correlated significantly only with present EMG pain level. Looking at the pain medians, it can be noted that music intervention has slightly lowered the NCS pain level in "prior EMG/NCS" patients, as well as EMG and NCS pain level medians for "naïve EMG/NCS" patients. It has already been explained how one's previous experience affects their

perception of pain (Wiech et al. 2008). Although pain perception includes several cortical areas whose activity directly depends on the stimulating factor, it also depends on the person's previous experience (Wiech et al. 2008). This can also be explained by a model of learning, the classical conditioning or "Pavlovian" conditioning (Domjan 2005). Patients from the "prior EMG/NCS" group have "learned" to respond automatically to certain pain stimuli, in this case, the electrodiagnostic examination. This could be the main reason why patients with prior experience of pain during EMG and NCS, which are focused on painful stimuli, develop greater fear of pain and, in our study, report higher present pain during NCS. There is still no consensus on the influence of patient's age on pain perception in the literature. Some studies suggest a loss of pain perception with age, while others suggest increasing of pain sensitivity. Our findings were similar to the ones of Harkins et al., who reported that older patients showed increased pain sensitivity during higher intensity heat stimuli, apropos our EMG, and they underrated low intensity contact heat stimuli, apropos our NCS (Harkins et al. 1986). These results relate to the study of Chakour et al., who suggested that aging may have a different impact on C-fibre-mediated protopathic pain, versus epicritic pain mediated by A-fibres. They showed that elderly patients rely mostly on C-fibre when notifying pain stimuli and that they reported a significant elevation in thermal pain threshold (Chakour et al. 1996). Patients with lower education level reported lower level of pain during NCS. More educated people tend to be more informed about medical procedures and examinations, so this could again be the case of predetermined fear. There was no significant influence on pain perception during EMG or NCS regarding gender, diagnosis of depression, usage of antidepressants and analgesics or amount of these drugs used, biometeorological forecast, number of investigated limbs and waiting time for the examination. Of the 8 studies that measured electrical pain threshold, half of them observed a significant difference between female and male, while the other half did not (Riley et al. 1998). Racine et al. summarized results of a 10 years research on pain and sex and found out that there are no sex differences in human pain perception of thermal, pressure, ischemic, muscle, electrical, chemical and visceral pain stimuli (Racine et al. 2012). During EMG and NCS patient feels short phasic pain, which is less under modulation of the central nervous system in contrast to the chronic pain which could be decreased by taking antidepressants, exposure to the light and other external factors. It is well known that different mechanisms are responsible for management of phasic versus chronic pain (Wiech et al. 2005). There was no evidence that biometeorological forecast has any influence on pain perception during electrodiagnostic examination. Our findings are similar to those in the study of Fors et al., who did not find any relation between weather and pain in fibromyalgia (Fors & Sexton 2002).

The limitation of the present study was that the patients with prior experience in EMG/NCS were reminded about their previous experience. Secondly, because of simplification, we asked them to give a joint grade of the perceived pain during the prior examination. Given that patient's predetermination on painful experience and its influence were targeted here through sensory memory, we think that different grading did not have an impact on the observed results. Because sensory memory, an ability to remember impression of sensory stimuli that have already happened, is an ultra-short-term memory and lasts less than a second after the perception of an item.

Previous studies approved positive influence of music on pain and there are several theories of how this happens (Koch et al. 1998, Nilsson 2008, Tam et al. 2008, Kulkarni et al. 2012, Lee 2019). During emotional processing of music brain releases different neurotransmitters, neuropeptides and other biochemical mediators, like endorphins and endocannabinoids. Dopamine is considered to have the main role and it is released from ventral striatum and ventral tegmental area in patients who listen to pleasant music (Blood et al. 1999, Blood & Zatorre 2001, Menon & Levitin 2005). Dopamine projections from ventral tegmental area are involved in regulation of motor, motivational and affective processes and cognitive functions. Music listening may also have positive influence outside the CNS. Salamon et al. showed that music has influence on releasing of nitrogen oxide (NO) into the bloodstream, where it has important role in induction of vasodilatation, local skin heating, lowering blood pressure and relaxation of smooth muscles. It has a protective role in thrombogenesis, atherogenesis and in the immune system. NO stimulates synthesis of inflammatory prostaglandins, it is a very important antioxidant and has a part in regulation of synaptic plasticity (Salamon et al. 2003). Accordingly, there is a possible link between listening to pleasant music and positive impact on various organ systems through discharging of NO (Salamon et al. 2003). It is showed that listening to music may provide an emotionally engaging distraction from pain (Mitchell et al. 2006). Distraction from pain increases blood flow in the anterior cingulate lobe and decreases it in another limbic areas (Yamasaki et al. 2000, Frankenstein et al. 2001). The cingulate gyrus is a part of paralimbic areas which control the activity of hypothalamus and autonomic nervous system, thereby synchronizing autonomic activity with present spiritual and motivational state. They are important in affective perception, in experiencing pain and have a crucial role in higher forms of emotional behaviour (Price 2000, Boso et al. 2006, Bassbaum & Jessell 2013).

CONCLUSION

Music may only be a distractor in the process of pain perception, but it is also possible that pleasant emotions triggered by music participate in decreasing of pain level. Music could have analgesic effect if the patients are able to fully concentrate on music listening, which is in accordance with the "gate-control" theory and with our results. In this study we showed that listening to music during NCS significantly reduces the perceived pain, when patients are relaxed and concentrated on music listening. Interestingly, the pain level during NCS was shown to be more modifiable, not only by music intervention, but also by painful predetermination, level of patient compliance and level of education. Pain level during EMG was not susceptible in that extent to modifications, although the median of pain was lower in the music group. It is possible that music listening can be valuable help for both patients and clinicians, still, further research is needed in order to determine the optimal implementation of music in everyday clinical practice.

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Contribution of individual authors:

Valentina Delimar: study design, data collection, first draft, approval of the final version, statistical analysis.

Olga Miloš & Ervina Bilić: study design, data collection, first draft, approval of the final version.

Mirea Hančević, Hrvoje Bilić, Iva Milivojević, Barbara Sitaš & Katarina Bilić: first draft, approval of the final version.

Magdalena Krbot Skorić: study design, statistical analysis, approval of the final version.

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