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Original Article

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The effect of preferred music on anxiety and pain in electrodiagnostic studies: A prospective, randomized-controlled study

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Abstract

Objectives: This study aims to investigate whether listening to preferred music via headphones during electrodiagnostic (EDX) studies, including electromyography (EMG) and nerve conduction studies (NCS), can reduce test-related anxiety and test-related pain.

Patients and methods: A total of 31 patients who were referred for EMG and NCS were included in this prospective, randomized controlled study between September 2018 to April 2021. The patients were randomized into the Music or No Music group. Patients were provided over ear headphones, a tablet with music app, and a microphone interface to allow physicians and patients to communicate. Self-report measures of pain and anxiety were administered immediately before and after each diagnostic procedure. Patient satisfaction was measured using the Patient Satisfaction Questionnaire (PSQ).

Results: A total of 22 participants were included in the final analysis. Of them, 7 were male and 15 were female with a mean age of 44.73 ± 14.35 (range, 20 to 78) years. The pain and anxiety measures were completed at baseline by 27 participants, 24 after the NCS/before the EMG, and 24 after the EMG testing. We found non-statistically significant differences between groups for pain scores; however, music showed a trend toward improving anxiety, and respondents to the PSQ reported high satisfaction with the use of music and a preference for its use in the future.

Conclusion: Listening to music during EDX testing to reduce pain and anxiety is an overall positive experience for most patients with a possible benefit to test anxiety despite a lack of statistically significant differences between Music and No Music groups.

Keywords: Anxiety, electrodiagnostic, electromyography, music, nerve conduction studies, pain, studies.

Electromyography (EMG) and nerve conduction studies (NCS) are diagnostic tests performed to identify neuromuscular pathology ranging from peripheral nerve injuries and nerve entrapments such as carpal tunnel syndrome to motor neuron diseases such as amyotrophic lateral sclerosis.[1] It is estimated that, in North America, over 8 million EMG/NCS are performed each year.[1] Unfortunately, due to the need to use electrical stimulation and needle electrode

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placement through the skin into the muscles, pain is a frequent unpleasant part of electrodiagnostic (EDX) studies.[2]

Studies have shown that pre-existing anxiety predicts EMG-related pain.[3,4] The four main contributing factors to high anxiety that have been reported in past studies include: "being worried about the test", "being worried about other issues unrelated to the test or the underlying diagnosis", "the anticipation that the test would be painful", and "taking an anti-psychotic or anxiolytic drug".[3] In addition, it has been shown that patient's pain and anxiety (and physicians perception of this) may result in alterations in the testing including avoidance of certain components of the EDX which are predicted to be most painful, spending less time studying muscles during EMG, or aborting a study prematurely.[4] These alterations may reduce the diagnostic accuracy of the test, and, therefore, techniques to reduce pain and anxiety may benefit both the patient experience and the quality of EDX.[2]

Various techniques aimed at reducing pain and/or anxiety during other diagnostic testing have been studied.[2,5-7] These include pharmacological-based interventions (vapocoolant topical spray, or oral ibuprofen, acetaminophen/tramadol) and non-pharmacological techniques (slapping or stretching the patient's skin at the time of needle insertion, minimal insertion techniques, hypnosis, acupuncture, behavioral modification, and having the patient listen to music).[2,5-7] Music has been shown to reduce postoperative pain and analgesia use and increase patient satisfaction in patients who have undergone surgery.[8] In patients with cancer, a music intervention significantly ameliorated anxiety and pain.[9] A meta-analysis on music for patients undergoing a biopsy found that music had a tendency toward decreasing systolic blood pressure and anxiety scores pre-biopsy, and diastolic blood pressure and heart rate after the biopsy.[10] Music has also been shown to reduce pain and anxiety in labour,[11] radiological procedures,[12] and colon/endoscopies.[13,14]

There is limited current literature investigating how music can be used to reduce pain and anxiety during EDX, with the results being mixed.[15-17] One study showed music could bring pain levels down to "slight discomfort", compared to the control group whose pain was between "slight pain" to "severe pain".[15] Another study involved patients listen to their choice of either classical, instrumental, or rock music from nearby speakers during EDX testing and did not observe any significant differences between the music listening group compared to the control group in terms of self-reported anxiety.[16] A further study found that the music group, who listened to either soothing pop or instrumental music played from speakers, had reduced perceptions of pain while undergoing the NCS part of testing compared to controls, but not during the EMG portion.[17]

Criticism can be placed on the way that music has been implemented in previous studies as being impractical for EDX. During an EMG procedure, the physician's ability to interpret electrical responses accurately relies on auditory feedback from the machine.[1] Therefore, use of speakers to deliver music in the room may hinder physician's identification and interpretation of these findings.[16,17] Thus, there is a need to investigate practical ways to deliver music, and evaluate its effects on pain and anxiety, in a real world EDX clinic. In the present study, we hypothesized that the presence of preferred music would reduce anxiety and pain experienced by patients undergoing EDX testing. We, therefore, aimed to investigate whether listening to preferred music via headphones during EDX studies, including EMG and NCS, reduced test-related anxiety and test-related pain.

PATIENTS AND METHODS

This single-center, prospective, randomized-controlled study was conducted at Western University, Department of Physical Medicine and Rehabilitation Electromyography Clinic between September 2018 to April 2021. All patients referred for EMG and NCS were considered for inclusion in the study. Inclusion criteria were as follows: age ≥ 18 years; referral for NCS and EMG at St. Joseph's Health Care London, Canada; a clinical indication for NCS/EMG; and an English reading level equivalent to at least sixth grade, sufficient to complete the outcome measures. Exclusion criteria were as follows: use of hearing aids that

would preclude or hinder the use of over-ear headphones; profound hearing loss; severe cognitive-communication impairment hindering the patient's ability to provide informed consent to the study. The sample size was determined *a priori* using the G* Power version 3.1.9.2 software (Heinrich Heine University Düsseldorf, Düsseldorf, Germany). Based on a moderate effect size = 0.6, a = 0.05 and power = 0.8, the sample size was calculated to be 45 in each group for a total of 90 total participants. Those who met the criteria and consented to the study, were randomly assigned at 1:1 allocation ratio to either a Music or No Music group using the research electronic data capture (REDCap) software.[18] Finally, a total of 37 participants were included. Among them, 31 were randomized into the Music or No Music group. A written informed consent was obtained from each participant. The study protocol was approved by the Western University Research Ethics Committee (Date: 10.08.2022, No: 111920). The study was conducted in accordance with the principles of the Declaration of Helsinki. The CONSORT guidelines for non-pharmacological randomized-controlled trials were followed.[19]

Procedure

This study was not blinded, as participants and physicians were aware of the group allocation prior to any testing. Prior to testing, participants provided demographic information. All participants initially underwent NCS testing and, then, if indicated by their clinical presentation, EMG testing. Self-report measures of pain and anxiety were administered immediately before and after each diagnostic procedure (Figure 1).

Patients assigned to the No Music group underwent the NCS and EMG tests as per usual. Those in the Music group were given a set of over-ear headphones (sterilized before use) and a tablet-computer, and directed to navigate Spotify, a digital music service, to select whatever music they desired.[20] The use of this app allowed patients to select music by individual songs, pre-made playlists, or by music genres based on their personal preference. A research assistant was available during this time to assist the patient in music selection, if needed. An app that limited volume was used to ensure that volume could not be raised above 80 decibels by the patient. To reduce interference in communication between the patient and technician/physician, a microphone that transmitted the technician/physician's voice directly to the patient's headphones was used (connected via Bluetooth). All surveys were completed by the patient on a tablet via REDCap,[18] allowing for a seamless transition between the research survey and the music app.

Outcome measures

All patients enrolled in this study were administered a 100-mm Visual Analog Scale (VAS) to assess pain and anxiety at three time points: before NCS (baseline, T1), after NCS (T2, which also served as the baseline for EMG), and after EMG (T3). Pain measurements collected prior to diagnostic testing served both as a baseline for

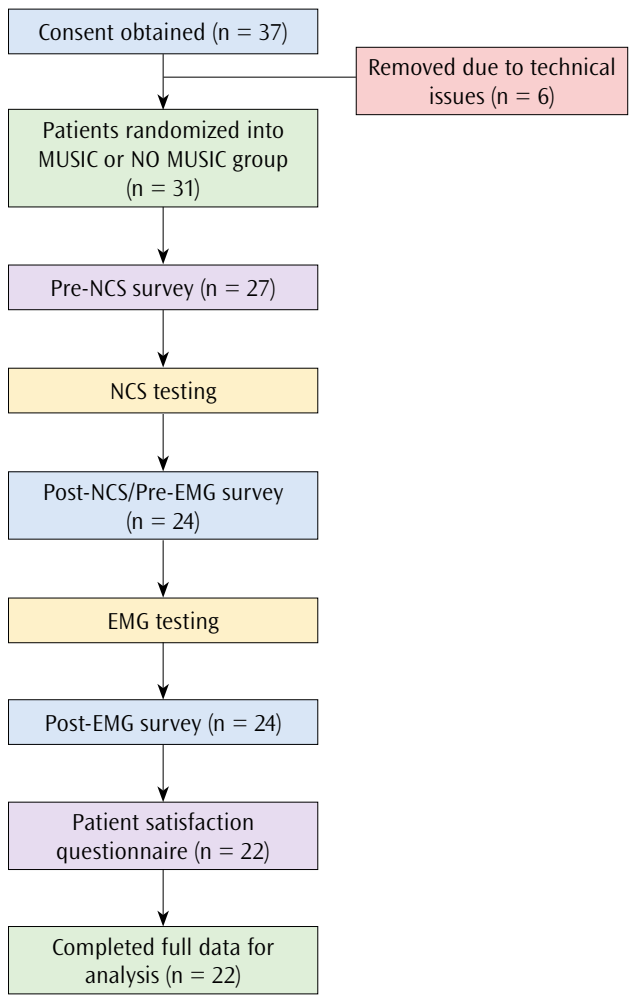

Figure 1. CONSORT diagram.
NCS, nerve conduction studies; EMG, electromyography.

comparison with post-test scores and as a control, given that the majority of individuals undergoing EDX testing have a pre-existing history of pain. The Patient Satisfaction Questionnaire (PSQ) was administered to participants after all testing was completed.

Visual Analog Scale: Pain and anxiety levels were assessed using the 100-mm VAS. For pain, participants rated their perceived pain on a 100-mm scale from 0 ("no pain") to 100 ("agonizing").[21] For anxiety, participants rated their perceived anxiety on a similar 100-mm line, with 0 indicating "not at all anxious" and 100 indicating "extremely anxious".[22]

Participants responded to specific questions designed to prompt VAS ratings. For pain, questions included: "How much pain are you currently in?", "How painful was the NCS?", and "How painful was the EMG?". For anxiety, questions included: "How anxious are you currently feeling?", "How anxious were you during the NCS?", and "How anxious were you during the EMG?". VAS responses were collected at three time points: before the NCS, after NCS, and after the EMG, for both pain and anxiety ratings.

Patient satisfaction questionnaire: A PSQ was administered to all participants after EDX testing to measure the perceived helpfulness of listening to music. To accommodate independent completion by participants and ensure item relevance, the questionnaire employed a logic-based format that tailored items based on presence of music during the examination. The questionnaire included three to six non-forced response items, beginning with a dichotomous question: "Did you listen to music during these examinations". Participants who responded "Yes" (i.e., Music group) received four subsequent Yes/No questions assessing the perceived impact of music on anxiety and pain, their willingness to listen to music in future tests, and whether they would recommend it to others. Participants who responded "No" (i.e., No Music group) were presented with the question, "Would you have preferred to listen to music during these examinations?". Finally, all participants answered a common item assessing overall experience on a three-point Likert scale (positive, neutral, negative).

Statistical analysis

Statistical analysis was performed using the SPSS version 30.0 software (IBM Corp., Armonk, NY, USA).[23] Descriptive data were presented in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. Comparisons between groups on primary outcomes (anxiety and pain) were made using repeated-measures analysis of covariance (ANOVA) across three time points (baseline, post-NCS, post-EMG) and two groups (Music *vs.* No Music). Independent samples t-tests were used to assess baseline comparisons of outcomes (anxiety and pain). Participants (n = 5) with missing data at one or more time points were excluded from the repeated measures analysis using listwise deletion. A p-value of < 0.05 was considered statistically significant.

RESULTS

The pain and anxiety measures were completed at baseline by 27 participants, 24 after the NCS/before the EMG, and 24 after the EMG testing.

A total of 22 participants were included in the final analysis. Of them, 7 were male and 15 were female with a mean age of 44.73 ± 14.35 (range, 20 to 78) years (Table 1). The primary outcome variables were pain and anxiety,

Table 1. Demographic data

	Music group (n = 10)		No music group (n = 12)		All (n = 22)	
	%	Mean ± SD	%	Mean ± SD	%	Mean ± SD
Age (year)		46.3 ± 16.2		43.4 ± 13.2		44.7 ± 14.4
Sex (Self-Identified) Female	72.7		61.5		66.7	
Have had a prior EMG	18.0		32.5		30.4	

SD, standard deviation; EMG, electromyography.

Table 2. Descriptives of main outcome measures

		Music group	No music group	
Outcome	Time point	Mean ± SD	Mean ± SD	*p*
Pain	Pre-NCS	33.6 ± 26.3	43.5 ± 26.0	0.385
	Post-NCS	23.5 ± 14.4	21.5 ± 20.9	0.796
	Post-EMG	38.8 ± 26.3	34.8 ± 15.6	0.669
Anxiety	Pre-NCS	24.4 ± 23.9	40.5 ± 23.5	0.128
	Post-NCS	21.2 ± 18.3	21.5 ± 23.5	0.974
	Post-EMG	19.4 ± 19.5	36.3 ± 26.4	0.103

SD: Standard deviation; NCS, nerve conduction studies; EMG, electromyography. Visual Analog Scale (VAS) scores range from 0 to 100. P-values represent between-group comparisons (Music *vs.* No-Music) at each time point (Pre-NCS, Post-NCS, and Post-EMG), with $p < 0.05$ considered statistically significant.

measured with the 10-0 mm VAS scale (Table 2). The independent variables were listening to music (Music or No Music) and type of study (NCS or EMG).

There were no significant differences between the Music and No Music groups at baseline, post-NCS and post-EMG for pain and anxiety using two-tailed tests (Table 2).

The repeated-measures ANOVA examined changes in pain and anxiety across three timepoints (baseline, post-NCS, post-EMG) and two groups (Music *vs.* No Music). The results revealed significant effects of time on both pain (p = 0.028, η^2 = 0.13 and anxiety (p = 0.023, η^2 = 0.14), suggesting moderate and meaningful changes during EDX. Differences between the groups for pain and anxiety over time were seen with the Music group showing a steady decline in anxiety across timepoints, whereas the No Music group experienced a sharp post-NCS drop followed by a notable rebound post-EMG (Figure 2). For pain, both groups initially improved post-NCS, but then exhibited an increase post-EMG. These trends, while not statistically significant (p = 0.35), reveal a partial η^2 of 0.22 suggesting a small-to-moderate effect worth exploring in future research with larger samples.

A PSQ was completed by the participants in both groups to measure patient-perceived helpfulness of listening to music (Table 3a, b). Of those who were in the Music group (n=10), 90% reported that they had a "positive experience", while 10% reported a "neutral experience". Of the respondents, 80% reported "music helped decrease my level of pain during the examination", and 100% of respondents agreed that "music helped decrease my level of anxiety". Importantly, all respondents agreed, "I would prefer to listen

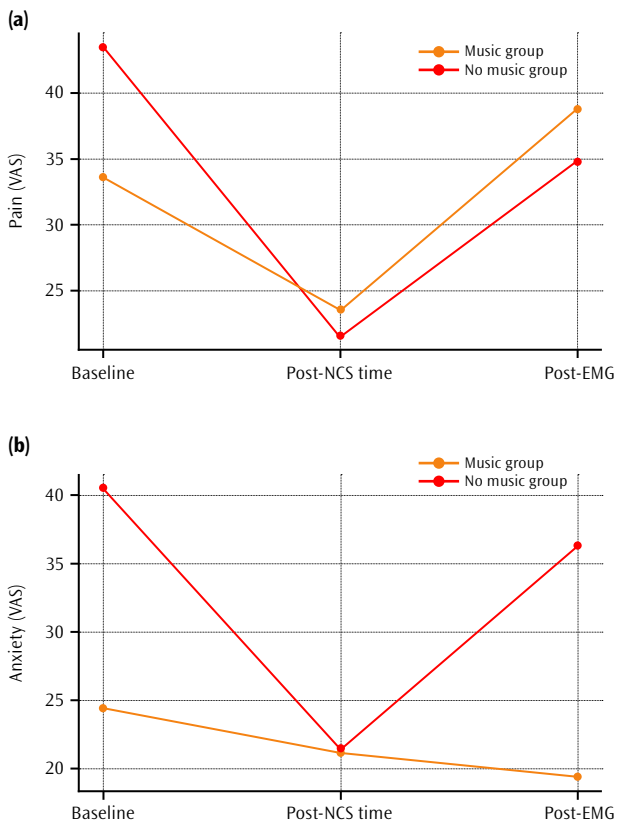

Figure 2. Pain and anxiety (VAS) scores over time. **(a)** For pain, both groups initially improved post-NCS, but exhibited an increase in pain post-EMG. **(b)** The Music group showed a steady decline in anxiety across timepoints, whereas the No Music group experienced a sharp post-NCS drop followed by a notable rebound post-EMG. These trends suggest that music may have buffered anxiety during the more distressing EMG phase.

VAS, Visual Analog Scale; NCS, nerve conduction studies; EMG, electromyography.

Table 3a. Results of Music group patient satisfaction questionnaire

Question	% Agree
Music helped decrease my level of pain during the examination	80
Music helped decrease my level of anxiety during the examination	100
Would you prefer to listen to music if you had to do these examinations again?	100
Would you recommend listening to music during these examinations to other people?	100
Overall, the provision of music was a:	
Positive experience	90
Neutral experience	10
Negative experience	0

Results from the patient satisfaction questionnaire that was administered to the Music group (n = 10 total respondents). Percentage (%) reflects the percentage of participants who responded "yes" on a dichotomous yes/no scale, or endorsed the response otherwise specified.

Table 3b. Results of Non-Music group patient satisfaction questionnaire

Question	% Agree
Would you have preferred to listen to music during these examinations?	66.7
Overall, I had a:	
Positive experience	75
Neutral experience	25
Negative experience	0

Results from the patient satisfaction questionnaire that was administered to the Non-Music group (n = 12 total respondents). Percentage (%) reflects the percentage of participants who responded "yes" on a dichotomous yes/no scale, or endorsed the response otherwise specified.

to music if they have to do the examinations again", and that "I would recommend listening to music to other people". For the No Music group respondents (n = 12), 75% reported that they had a "positive experience", while "25%" reported a "neutral experience". Out of those who responded, 66.7% agreed that "I would prefer to listen to music during these examinations".

DISCUSSION

In the present study, we investigated the impact of listening to music on pain and anxiety during EMG and NCS testing. Previous research has reported mixed results regarding the effect of music on pain and anxiety during EDX diagnostic testing.[15-17] In our study, the use of self-selected music did not show statistically significant differences in anxiety or pain during EMG/NCS testing. Despite this there were several interesting trends in the results. Taken together, these findings suggest that the use of music during testing is a positive experience for patients with the potential for it to help test anxiety.

First, the baseline pain and anxiety ratings showed that patients presenting for EMG/NCS testing had a moderate level of both baseline pain and anxiety pre-test. This likely represents a combination of the symptoms of their presenting medical complaint (i.e., patients are commonly being investigated for weakness, sensory disturbance and/or pain), as well as anticipatory anxiety prior to the medical appointment/test (i.e., The "white coat" syndrome).[24] Statistical analysis also revealed that patients (in both groups) undergoing the EMG component of testing experienced an increase in pain scores. These findings are consistent with the general trends observed in clinical practice and provide some validity that the patient sample was representative of the general population.[25,26]

More intriguingly, the baseline anxiety scores were higher in the No Music group. One explanation for this is a potential buffering or exacerbating effect of allocation-awareness as participants were made aware of which group they were in after randomization, prior to completing pre-NCS anxiety scores. Due to the awareness of their group assignment before the anxiety measure was completed, it may be possible that participants in the No Music group experienced inflated or more than usual levels of anxiety, due to knowing

they would not be in the Music group. This may explain the decrease in anxiety seen in the No Music group from pre-NCS to pre-EMG as their anxiety scores became more in line with those seen in the Music group (Figure 2). Conversely, perhaps being aware of allocation to the Music group could have buffered the participants' feelings of anxiety, reducing the potential anxiety experienced at pre-test. Furthermore, related to test anxiety, the Music group showed a steady decline in anxiety across all timepoints, including post-EMG, whereas the No Music group experienced a sharp a notable post-EMG spike in anxiety. This trend is the strongest evidence that music played a role in improving patients' procedural anxiety and is in line with patients' responses on the PSQ where they reported a strong preference for using music again during EDX if given the choice. For pain, both groups initially showed a decrease post-NCS, with an increase in pain post-EMG (Figure 2). These trends suggest that while music may have buffered anxiety, it had no effect on pain, particularly during the more invasive EMG component of EDX.

The PSQ measures collected from the Music group provide valuable insights (Table 2a). Among the respondents in the Music group (n = 10), 100% reported that music helped alleviate their anxiety during the procedure (consistent with the trend seen in Figure 2), that they would prefer to listen to music in future tests, and that they would recommend music to others undergoing similar testing. These findings suggest that the Music group had an overall positive experience and preference for the use of music during future EDX testing. In addition, despite the No Music group largely reporting a "positive" experience (75%), a majority (67%) would still prefer to use music if they had to the do the testing again. Thus, these results indicate that music may be a beneficial and preferred option for most patients during EDX testing.

The results of this study do provide an interesting comparison with the prior literature on this topic. For one, all studies appear to be aligned with patients reporting they would prefer to use music if given the choice during EDX.[15-17] This is despite non-statistically significant differences between groups for pain and anxiety measures in several studies. In addition, the most recent study by Delimar et al.[17] also reported that the music effects were not as marked with the EMG portion of testing, which is aligned with the patient experience in this study in which post-EMG pain scores trended higher despite the use of music.

Despite these important study findings, there are several factors that may have negatively impacted the pain and anxiety-relieving effects of music in the study. First, the method of administration in this study differed from that of prior research. While previous studies on the effects of music during EDX testing largely utilized speakers to deliver music,[16,17] the current study employed headphones in an attempt to allow physicians' to listen to the electrical responses during EMG testing.[2] In our pre-study planning we had found the use of speakers to administer music during EMG testing to be impractical as several physicians feared it could hinder their interpretation of EDX results. While headphones are a more practical choice for real-world applications, previous studies have also found that the use of headphones during invasive procedures may have adverse effects on anxiety.[27,28] This may be due to the isolation experienced when using headphones, and/or the lack of communication and interactions with the healthcare provider during the study.[29] This notion is further supported by the consideration that participants who did not listen to music (i.e., did not have headphones) may have experienced a more natural interaction with the physician and technician. Experienced physicians and technicians may often naturally use other techniques to put the patient at ease (i.e., calming tone of voice, reassuring language, distraction during testing).[29] The presence of natural communication and interactions with the physician administering the test may outweigh the benefit of using headphones to listen to music, and may have been another reason why the No Music group had an improvement in the anxiety scores from baseline to post-NCS.

Moreover, the role of patient-selected music (ranging from country, pop, hip-hop and hard-rock), as opposed to pre-set music, may have also played a role in the lack of effect on pain observed. Although our study utilizes patient-selected music as a method of alleviating pain and reducing

anxiety symptoms in participants as utilized in a variety of medical procedures such as cesarean section surgery and hemodialysis,[30,31] exploring the possibility that the patient-selected music may not be the most 'relaxing' and 'pain-alleviating' may be instructional. Previous work by Drzymalski et al.[31] found that classical music or lyric-less music performed better than patient-selected music while reducing preoperative pain in cesarean section surgery. Other works, such as Tan et al.[32] demonstrated the relaxing effect of pre-selected music and the role of familiarity in achieving relaxation. As such, it is unclear if the use of strictly patient-selected music played a role in the results in the present study, and future research comparing patient-selected and pre-selected music may clarify this gap.

Nonetheless, there are several limitations to this study that should be acknowledged. The most important of these was that, due to study recruitment and additional challenges during the novel coronavirus disease 2019 (COVID-19) pandemic, the study did not achieve the calculated required sample size of n = 90. As a result, despite the results showing a trend for a reduction in anxiety within the Music group, and a high rate of patient satisfaction with the use of music, the study likely was underpowered to detect other potential differences between groups, limiting our ability to draw definitive conclusions regarding the effects of music on pain and anxiety during EDX testing. As it stands, this study serves as a valuable pilot study, that could help inform future exploration of this topic. Future studies could incorporate a multi-center approach to help enhance recruitment, with modifications to the protocol to use new technologies that may allow both confinement of the music to the patient, while allowing a more natural interaction between patient and physician (use of bone conduction headphones playing calming classical music).

In conclusion, our study results showed that listening to music during EDX testing was an overall positive experience for most patients. Although pain and anxiety scores did not statistically differ between Music and No Music participants, several interesting trends were shown including reduced anxiety post-EMG. Taken together, we recommend further studies to clarify the role of music-type and delivery method on pain and anxiety management in EDX testing. Ultimately, we feel that music may be considered for clinical use as a low-cost method to enhance the patient experience, and possibly reduce patient-experienced anxiety and pain perception. Future studies are needed to confirm these preliminary findings and to better understand the role of music in managing pain and anxiety during diagnostic procedures.

Declaration of Conflicting Interests

The authors declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Author Contributions

S.M., J.S.: Idea/concept, design, literature review; S.M.: Control/supervision, materials; S.M., J.S., S.M.: Data collection and/or processing; S.M., S.M., R.V., N.W., B.R..: Analysis and/or interpretation, writing the article; S.M., S.M.: Critical review, references and fundings.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

AI Disclosure

The authors declare that artificial intelligence (AI) tools were not used, or were used solely for language editing, and had no role in data analysis, interpretation, or the formulation of conclusions. All scientific content, data interpretation, and conclusions are the sole responsibility of the authors. The authors further confirm that AI tools were not used to generate, fabricate, or 'hallucinate' references, and that all references have been carefully verified for accuracy.

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