BMJ Neurology Open

Tolerability of electrodiagnostic studies in patients: a prospective study

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To cite: Chang C-H, McClellan TM, Lopez KD, *et al*. Tolerability of electrodiagnostic studies in patients: a prospective study. *BMJ Neurology Open* 2024;**6**:e000706. doi:10.1136/bmjno-2024-000706

Received 08 March 2024
Accepted 04 April 2024

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ABSTRACT

Introduction Nerve conduction study (NCS) and electromyography (EMG) are electrodiagnostic studies that are highly tolerated by patients despite their nature of causing pain and discomfort. However, few studies have focused on the true tolerability of these procedures in patients. This study aimed to determine the true tolerance rate of NCS and EMG in patient populations and the factors that might be associated with them.

Methods Participants scheduled for electrodiagnostic studies were prospectively recruited between March 2023 and September 2023. After completion of the study, the physicians completed a questionnaire on each patient's tolerance of the studies.

Results Of the 103 patients enrolled in the study, 98 were able to tolerate both tests, and 5 patients were intolerant to 1 or both tests. The overall tolerance rate of NCS and EMG was 95.1% (0.951, 95% CI 0.897 to 0.981). Age, sex, ethnicity, the type of NCS performed and the type of EMG performed were not associated with NCS or EMG intolerance.

Conclusion Most patients tolerated the NCS and EMG; however, a small percentage of patients were intolerant. Clinicians should recognise the intolerance of certain patients when introducing and performing electrodiagnostic tests.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Electrodiagnostic studies are important studies to diagnose many neuromuscular diseases.
⇒ Electrodiagnostic studies can cause patient discomfort, which might result in termination or alternation of the studies.

WHAT THIS STUDY ADDS

⇒ This study quantifies the tolerance rate of nerve conduction study (NCS) and electromyography (EMG), providing insight into how tolerable patients are to electrodiagnostic studies.
⇒ This study proves that patient tolerance to electrodiagnostic studies is not affected by age, gender, ethnicity or type of study performed.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study raises the awareness of the existence of patient intolerance to electrodiagnositic studies and provides objective data to physicians when explaining electrodiagnostic studies to patients, which can potentially alleviate patient anxiety and further enhance their tolerance to NCS and EMG.

INTRODUCTION

Nerve conduction study (NCS) and needle electromyography (EMG) are both electrodiagnostic studies that are essential for the diagnosis of many neuromuscular diseases.[1 2] NCS is considered a non-invasive study that applies an electrical stimulus to either a motor or sensory nerve and generates an action potential. Recorded action potentials can help clinicians identify injuries to the peripheral nervous system and diagnose peripheral nerve diseases. EMG is an invasive technique that requires the insertion of a needle electrode into the muscles, which generates electrical signals that are recorded on a computer. By interpreting these signals, clinicians can determine the function of the muscle fibres and motor units. While NCS and EMG can be conducted independently, these two studies are commonly performed together to provide a comprehensive clinical assessment.[1] EMG and NCS are generally considered safe techniques when performed with appropriate skill and expertise[3–5]; however, despite their low risk of adverse effects, NCS and EMG are known to result in discomfort in patients.[6–12] Even though studies have reported that the pain caused by electrodiagnostic studies is usually only mild to moderate and the majority of patients have no difficulties undergoing NCS and EMG, the real tolerance rate of NCS and EMG among patients remains unknown.[6–12] The goal of this study was to assess patients' tolerability of NCS and EMG, and the factors that are associated with intolerance to the tests.

METHODS

Study population

This study was conducted in an outpatient clinic located at a single acute rehabilitation hospital after obtaining ethical approval from

the appropriate institutional review board. Four attending physicians and three resident physicians provided written consent to participate in this study as objective examiners of NCS and EMG. To mitigate potential biases, the objective examiners were considered participants in the research instead of part of the research team. The research team consisted of four additional physicians who solely engaged in obtaining consent from patients, as well as in data collection and data analysis, but not in the performance of NCS or EMG. Patients must have met the following criteria to be eligible for the study: patients who were scheduled to our outpatient clinic for NCS and EMG every Monday and Tuesday afternoon from March 2023 to September 2023 with tests performed by one or more of the objective examiners participated in this study. The research was only conducted on Monday and Tuesday due to the availability of the research team. The date of the scheduled NCS and EMG for every patient was solely decided based on their preferences and the availability of physicians, rather than the indications for NCS and EMG or the specific limbs that required the procedures. The exclusion criteria were as follows: patients who did not attend the clinic for the scheduled tests, patients who did not provide consent to participate in the research, NCS and EMG deferred because the attending physicians thought the procedures were not indicated for the patients, patients who refused to undergo NCS and EMG before the start of the procedures, patients who lacked the capacity to consent for participation in the research, and NCS and EMG were performed when any research team member was present in the room. To avoid the Hawthorne effect, we excluded patients who underwent NCS and EMG when any research team member was present in the room.

Written consent for participation in this study was obtained from each patient by a research member before the start of the NCS and EMG sessions. The NCS and EMG recording of each patient were completed independently by an attending physician or with the assistance of a resident physician. For NCS and EMG conducted with the assistance of a resident physician, at least half or more of the tests were performed by the resident physician. The NCS and EMG were performed by examiners in their usual clinical practice. All of the examiners used a Cadwell Sierra Summit EMG machine, and NCS recordings were obtained using standard bipolar surface electrodes. The needles used for the EMG examination were all disposable Teflon-coated monopolar needle electrodes; however, needle electrodes of different sizes (50 mm ×26 G, 25 mm ×28 G and 45 mm×28 G) were used based on the preferences of the individual attending physicians. All attending physicians were certified by the American Board of Physical Medicine and Rehabilitation and had more than 10 years of experience in performing NCS and EMG.

NCS and EMG tests were considered complete when the examiners thought sufficient nerves and muscles were examined to make a proper clinical diagnosis. NCS and EMG tests were considered incomplete when insufficient nerves or muscles were examined due to patients' intolerance to NCS or EMG. Patients were defined as intolerant to NCS or EMG in the following situations: (1) patients voluntarily requested that certain essential parts of the NCS or EMG be skipped or ceased due to discomfort during the procedures; (2) patients who adamantly expressed their refusal to continue with certain parts of the NCS or EMG procedures due to discomfort when asked by the examiners about their willingness to proceed during the tests. The decision to initiate a discussion on whether to proceed with the tests or not depended on the examiner's clinical judgement. The examiners neither completed the tests against the patient's will nor terminated them without the patient's request or approval. Attending physicians were requested to report to the research team if intolerance occurred during the NCS and EMG. In addition, attending physicians were asked by the research team whether the patient was tolerant to the NCS and EMG using a standard questionnaire after each patient encounter.

Independent variable

All information concerning independent variables was obtained using an electronic medical record system. The independent variables included: age, sex, ethnicity, assistance of a resident physician and type of NCS and EMG performed. NCS and EMG were divided into three types: upper extremity, lower extremity and both (upper and lower extremities). If NCS or EMG was not completed due to patient intolerance, the type of NCS or EMG performed was determined based on the type of NCS or EMG that the examiner intended to perform.

Dependent variable

The outcomes of the NCS and EMG procedures were categorised as successful completion of the required tests (tolerance group) or failure to complete either the NCS, EMG or both due to intolerance (intolerance group).

Statistical analyses

Statistical analyses were performed using SPSS V.29.0 (SPSS Corp.). Tolerance and intolerance rates are reported as percentiles with CIs. When calculating the overall tolerance rate of the NCS and EMG for each patient, the NCS and EMG were combined and considered as a single procedure instead of two separate tests. CIs were calculated using the Jeffery formula. The Mann-Whitney U test was used to compare continuous variables, and Fisher's exact test was used to compare discrete variables for patient demographics, type of NCS performed and type of EMG performed. Group t-tests were applied to assess the average number of nerves and muscles tested between the tolerance and intolerance groups. Z-tests of independent proportions were conducted to compare the rate of tolerance and intolerance for NCS and EMG performed with or without the assistance of resident physicians. $P < 0.05$ was considered statistically significant.

Table 1 Patient demographic and types of NCS and EMG performed

Variable	Intolerance, n=5	Tolerance, n=98	P value
Age, mean (SD), year	44.20 (17.70)	56.43 (17.61)	0.143
Sex, count (%)			0.417
Male	3 (60.0)	44 (44.9)	
Female	2 (40.0)	54 (55.1)	
Ethnicity, count (%)*			0.119
White	3 (60.0)	80 (84.2)	
Black	0 (0.0)	2 (2.1)	
Hispanic	1 (20.0)	11 (11.6)	
Other	1 (20.0)	2 (2.1)	
Type of NCS performed, count (%)†			0.576
Upper extremity	4 (80.0)	56 (57.1)	
Lower extremity	1 (20.0)	36 (36.7)	
Both	0 (0.0)	6 (6.1)	
Type of EMG performed, count (%)‡			0.548
Upper extremity	4 (80.0)	55 (56.1)	
Lower extremity	1 (20.0)	36 (36.7)	
Both	0 (0.0)	7 (7.1)	

*Three patients were excluded from the ethnicity analysis due to unknown ethnicity.
†For the two patients who were intolerant to NCS, the type of NCS performed was determined based on the type of NCS the examiner intended to perform.
‡For the four patients who were intolerant to EMG, the type of EMG performed was determined based on the type of EMG the examiner intended to perform.
EMG, electromyography; NCS, nerve conduction study.

RESULTS

A total of 173 patients were eligible for the study based on the inclusion criteria. Among them, 70 were excluded after applying the exclusion criteria, and 103 patients were ultimately enrolled in the analyses.

The enrolled study population consisted of 47 men and 56 women with a mean age of 55.83 ±17.73 years. Patients were referred for electrodiagnostic studies due to limb paraesthesia or weakness (n=61, 59.2%), suspicion of carpel/cubital/tarsal tunnel syndrome (n=21, 20.4%), suspicion of radiculopathy (n=11, 10.7%), suspicion of nerve injury (n=9, 8.7%) and suspicions of myopathy (n=1, 1.0%). All 103 patients received both NCS and EMG, and a total of 98 patients tolerated both tests. Four patients failed to complete either NCS or EMG due to intolerance and one patient showed intolerance to both tests. The causes of intolerance were related to pain and discomfort that developed during the tests. The overall tolerance rate of the NCS and EMG was 95.1% (0.951, 95% CI 0.897 to 0.981). Patient demographics and the types of NCS and EMG performed are shown in table 1. There were no significant differences between the tolerant group and intolerant groups in terms of age, sex, ethnicity, type of NCS performed or type of EMG performed.

Table 2 Outcomes of the NCS performed

NCS	n (%)	Average number of nerves tested (SD)	P value
Tolerant	101 (98.1)	6.34 (2.42)	0.002
Intolerant	2 (1.9)	1.50 (0.71)	

NCS, nerve conduction study.

The details of the NCS and EMG outcomes are displayed in table 2 and table 3. The tolerance rate of NCS was 98.1% (0.981, 95% CI 0.939 to 0.996) and the tolerance rate of EMG was 96.1% (0.961, 95% CI 0.910 to 0.987). The two patients who showed intolerance to NCS were intolerant to multiple nerve tests. Of the four patients who were intolerant to EMG, one patient was intolerant to a specific muscle test (first dorsal interossei) and three patients exhibited intolerance to multiple muscle tests. For the 98 patients who tolerated both NCS and EMG, the final electrodiagnoses are shown in table 4.

Table 5 shows the outcomes of the NCS and EMG procedures that were performed by the attending physicians with and without resident assistance. The overall intolerance rate of the NCS and EMG tests performed by the attending physicians with and without resident assistance was 3.4% and 5.4%, respectively. There was no significant

Table 3 Outcomes of the EMG performed

EMG	n (%)	Average number of muscles tested (SD)	P value
Tolerant	99 (96.1)	8.99 (3.59)	<0.001
Intolerant	4 (3.9)	1.50 (2.38)	

EMG, electromyography.

Table 4 Final electrodiagnosis after electrodiagnostic studies (n=98)*

	n (%)
Normal	35 (35.7)
Carpel/cubital/tarsal tunnel syndrome	26 (26.5)
Polyneuropathy	9 (9.2)
Radiculopathy	5 (5.1)
Plexopathy	1 (1.0)
Myopathy	1 (1.0)
Other types of neuropathy	10 (10.2)
More than one electrodiagnoses	11 (11.2)

*Five patients who were intolerant to electrodiagnostic studies were excluded because no electrodiagnosis could be made.

Table 5 Outcomes of the NCS and EMG performed with and without resident assistance

Test	Outcome	Without resident assistance (%)	With resident assistance (%)	P value
NCS	Tolerance	72 (97.3)	29 (100.0)	
	Intolerance	2 (2.7)	0 (0.0)	0.372
	Total	74 (100.0)	29 (100.0)	
EMG	Tolerance	71 (95.9)	28 (96.6)	
	Intolerance	3 (4.1)	1 (3.4)	0.869
	Total	74 (100.0)	29 (100.0)	
NCS and EMG*	Tolerance	70 (94.6)	28 (96.6)	
	Intolerance	4 (5.4)	1 (3.4)	0.670
	Total	74 (100.0)	29 (100.0)	

*NCS and EMG combinations were considered as a single procedure.
EMG, electromyography; NCS, nerve conduction study.

difference between the intolerance rate of NCS (p=0.372), the intolerance rate of EMG (p=0.869) and the overall intolerance rate of NCS and EMG (p=0.670) performed with or without the assistance of resident physicians.

DISCUSSION

It is common for patients to experience a certain degree of discomfort during NCS and EMG, and many patients describe their discomfort as a form of pain. Prior studies have primarily focused on exploring patient pain levels during NCS and EMG tests, or identifying factors associated with pain perception during NCS and EMG.[6–12] To our knowledge, this is the first study to evaluate patients' overall tolerability of NCS and EMG.

In this study, the overall tolerance rate of the NCS and EMG procedures was 95.1% with a CI ranging from 89.7% to 98.1%. This suggests that the actual overall tolerance rate for NCS and EMG was likely to fall below 99%. Given the absence of a definitive benchmark for categorising a test or procedure as highly tolerable, we conclude that NCS and EMG are generally well tolerated by patients with an overall tolerance rate below 99% based on our findings. The five patients who were not tolerant of the procedures in this study underscore the importance of acknowledging that intolerance can occur during NCS and EMG in clinical practice.

The subjective perception of pain and the preservation of patient autonomy are the two main factors that contribute to the occurrence of intolerance in electrodiagnostic studies. A prior study suggested that the pain perceived by patients during NCS and EMG might be underestimated by observers.[13] Furthermore, other research has reported patients who experienced severe pain during electrodiagnostic studies and instances in which examiners had to terminate the studies due to patient pain.[6 14] In terms of patient autonomy, it is both unethical and illegal for physicians to continue NCS or EMG when a competent patient strongly requests the test to be aborted due to pain.[15–17]

NCS is considered a safe and non-invasive procedure with no known contraindications.[1] Some concerns have been raised about the potential risk of NCS interfering with pacemakers or implanted cardiac defibrillators, which can result in arrhythmia. However, prior studies have proven that routine NCS is safe in patients with pacemakers or implanted cardiac defibrillators.[18 19] In contrast to NCS, EMG is an invasive test and has more instances of serious complications reported in the literature.[1 20 21] There have been case reports of pneumothorax and haematoma associated with EMG in patients who required chest tube insertion and surgical intervention, respectively.[20 22 23] However, similar to NCS, EMG has been recognised as a safe procedure with no known contraindications, despite its potentially serious complications. Our study revealed NCS and EMG tolerance rates of 98.1% and 96.1%, respectively. While these results showed a higher tolerance rate for NCS than EMG, the difference was not statistically significant (p=0.392). One study found that patients tended to expect EMG to be more painful than NCS; however, conflicting evidence exists regarding whether one test elicits greater pain than the other.[9–12 24]

The impact of learners on patient pain during NCS and EMG has been inconclusive. Paiz *et al* discovered that a higher percentage of patients rated their pain as moderate to severe when EMG was performed by neurology residents with less than a year of experience in EMG.[12] On the other hand, two studies showed that the involvement of learners did not significantly increase the discomfort or pain during EMG.[10 25] Paiz *et al* believed that the difference in the outcomes could be attributed to the fact that the EMG in the other two studies was predominantly performed by fellows, who were more experienced in EMG than residents. In our study, the assistance of a resident during NCS and EMG did not lead to a higher overall intolerance rate of NCS and EMG. A likely explanation is that two of the residents who were involved in our study had more than 1 year of exposure to NCS and EMG, which reduced the effect of the learning curves.

Inconsistent results have been reported in the literature regarding the effects of age and sex on pain perception during NCS and EMG.[8–12 26] However, more recent studies have suggested that sex does not correlate with pain during NCS and EMG.[8–12] Furthermore, a systematic review has shown that there are no clear sex differences in human pain sensitivity.[27] Since pain was the main reason that patients could not tolerate NCS and EMG, these studies support our results and confirm that the tolerability of NCS and EMG is not influenced by sex.

Prior similar research did not incorporate ethnicity or race as a dependent variable.[8–12] Notably, our results showed that ethnicity was not associated with the tolerability of NCS or EMG. While some studies have found lower pain tolerance among African Americans and Hispanics than among non-Hispanic Caucasians, the evidence supporting such a distinction is weak.[28 29] The consensus is that the relationship between pain tolerance and ethnicity has not been firmly established.[28 29]

The type of NCS and EMG performed were found to be non-significant factors in determining the tolerability of NCS and EMG in our study. This finding is not surprising because although some body regions might be more sensitive to pain, the difference is likely not of sufficient clinical significance to lead to differences in tolerance between various types of NCS or EMG.[30] In addition, patients in the intolerance group underwent significantly fewer nerve or muscle tests and the majority of them demonstrated intolerance to more than one nerve or muscle test. This suggested that the intolerance was not provoked by a specific painful nerve or muscle test, but rather by a general intolerance to the usual pain and discomfort associated with the tests.

In this study, a 60-min appointment was scheduled for an upper or lower extremity NCS and EMG, and a 90-min appointment was scheduled for NCS and EMG that involved both upper and lower extremities. Examiners were able to complete the tests within the time allotted for most patients but the exact time it took to complete NCS and EMG tests for each patient was not documented. Given that the intolerance group underwent a lower average number of nerve and muscle tests than the tolerance group, it is logical to infer that a longer duration of the examinations was not a primary factor contributing to intolerance in our study. However, exploring the potential correlation between the length of electrodiagnostic tests and patient tolerance to the tests warrants further research.

This study had several limitations. Our small sample size may have prevented us from detecting certain risk factors associated with NCS or EMG intolerance. Additionally, it was difficult to standardise how each examiner explained, interacted with and performed the tests. Physician communication skills, needle-handling techniques and muscle selection for EMG could affect how patients perceive pain or discomfort during the tests. Furthermore, there was no specific intervention implemented for patients to alleviate the pain and discomfort experienced during the tests. Finally, our study was based on a single institution; therefore, the generalisability of the results could not be determined. Future studies with larger sample sizes and more standardised protocols should be considered.

Through this study, we found that a subset of patients exhibited intolerance to NCS or EMG procedures even though the tests usually only cause mild-to-moderate pain and are well tolerated by most patients. Clinicians should be aware of the intolerance in patient populations when performing electrodiagnostic tests. Furthermore, the findings of this study can serve as a valuable resource for physicians to elucidate NCS and EMG content in patients. Offering patients a comprehensive explanation using objective data before commencing the tests may alleviate patient anxiety and pain during the tests, which could potentially enhance patient tolerance to the NCS and EMG procedures.

Acknowledgements We would like to thank the department of Physical Medicine and Rehabilitation of Tower Health for their support and contributions to the completion of this research

Contributors C-HC conceptualised the study, collected and analysed the data, and wrote the manuscript. TMM was involved in the data collection. KDL was involved in the data collection. TW contributed to statistical analysis and data interpretation. SH supervised the research project. C-HC is the guarantor of the paper.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Ethics Committee of Tower Health, Pennsylvania (2023-009) before the initiation of the study. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; internally peer reviewed.

Data availability statement Data are available upon reasonable request.

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REFERENCES

1 Preston DC, Shapiro BE. *Electromyography and Neuromuscular Disorders: Clinical-Electrophysiologic-Ultrasound Correlations*. 4th edn. Philadelphia, PA: Elsevier, 2021.
2 Kothari MJ, Preston DC, Plotkin GM, *et al*. Electromyography: do the diagnostic ends justify the means *Arch Phys Med Rehabil* 1995;76:947–9.
3 Rubin DI. Needle electromyography: basic concepts. *Handb Clin Neurol* 2019;160:243–56.
4 Tavee J. Nerve conduction studies: basic concepts. *Handb Clin Neurol* 2019;160:217–24.
5 Tankisi H, Burke D, Cui L, *et al*. Standards of instrumentation of EMG. *Clin Neurophysiol* 2020;131:243–58.
6 London ZN. Safety and pain in electrodiagnostic studies. *Muscle Nerve* 2017;55:149–59.
7 Lai YL, Van Heuven A, Borire A, *et al*. The provision of written information and its effect on levels of pain and anxiety during

electrodiagnostic studies: a randomised controlled trial. *PLoS One* 2018;13:e0196917.
8 Sasaki T, Nimura A, Kuroiwa T, *et al*. Assessment of pain during nerve conduction studies in patients with Carpal tunnel syndrome. *J Hand Surg Glob Online* 2022;4:89–92.
9 Yalinay Dikmen P, Ilgaz Aydinlar E, Karlikaya G. Expected and experienced pain levels in electromyography. *Noro Psikiyatr Ars* 2013;50:364–7.
10 Jerath NU, Strader SB, Reddy CG, *et al*. Factors influencing aversion to specific electrodiagnostic studies. *Brain Behav* 2014;4:698–702.
11 Wee AS, Boyne RL, Abernathy SD, *et al*. Pain perception to nerve conduction and needle electromyographic procedures. *J Miss State Med Assoc* 2004;45:327–30.
12 Paiz F, Midroni G, Kassardjian CD. Pain perception during electrodiagnostic studies and the impact of learners. *Muscle Nerve* 2022;66:621–4.
13 Verson J, Haig AJ, Sandella D, *et al*. Patient perception of pain versus observed pain behavior during a standardized electrodiagnostic test. *Muscle Nerve* 2015;51:185–91.
14 London ZN, Hazan R, Burke JF, *et al*. Altering electromyography studies: importance of the electromyographer's perception of patient pain. *Arch Phys Med Rehabil* 2014;95:39–42.
15 Teoli D, Ghassemzadeh S. Patient self-determination act. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing, 2022.
16 Pirotte BD, BensonS. Refusal of care. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing, 2023.
17 Varkey B. Principles of clinical ethics and their application to practice. *Med Princ Pract* 2021;30:17–28.
18 Schoeck AP, Mellion ML, Gilchrist JM, *et al*. Safety of nerve conduction studies in patients with implanted cardiac devices. *Muscle Nerve* 2007;35:521–4.
19 Cronin EM, Gray J, Abi-Saleh B, *et al*. Safety of repetitive nerve stimulation in patients with cardiac Implantable electronic devices. *Muscle Nerve* 2013;47:840–4.
20 Al-Shekhlee A, Shapiro BE, Preston DC. Iatrogenic complications and risks of nerve conduction studies and needle electromyography. *Muscle Nerve* 2003;27:517–26.
21 Gertken JT, Patel AT, Boon AJ. Electromyography and anticoagulation. *PM R* 2013;5:S3–7.
22 Kassardjian CD, O'gorman CM, Sorenson EJ. The risk of iatrogenic pneumothorax after electromyography. *Muscle Nerve* 2016;53:518–21.
23 Gechev A, Kane NM, Koltzenburg M, *et al*. Potential risks of iatrogenic complications of nerve conduction studies (NCS) and electromyography (EMG). *Clin Neurophysiol Pract* 2016;1:62–6.
24 Gans BM, Kraft GH. Pain perception in clinical electromyography. *Arch Phys Med Rehabil* 1977;58:13–6.
25 Strommen JA, Daube JR. Determinants of pain in needle electromyography. *Clin Neurophysiol* 2001;112:1414–8.
26 Khoshbin S, Hallett M, Lunbeck R. Predictors of patients' experience of pain in EMG. *Muscle Nerve* 1987;10:629–32.
27 Racine M, Tousignant-Laflamme Y, Kloda LA, *et al*. A systematic literature review of 10 years of research on sex/gender and experimental pain perception - part 1: are there really differences between women and men? *Pain* 2012;153:602–18.
28 Edwards CL, Fillingim RB, Keefe F. Race, ethnicity and pain. *Pain* 2001;94:133–7.
29 Shavers VL, Bakos A, Sheppard VB. Race, ethnicity, and pain among the U.S. adult population. *J Health Care Poor Underserved* 2010;21:177–220.
30 Tracy LM, Georgiou-Karistianis N, Gibson SJ, *et al*. Location, location, location: variation in sensitivity to pain across the body. *Eur J Pain* 2016;20:1721–9.