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The use of surface electromyography in the diagnosis of childhood hypertonia: a pilot study

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Abstract

In children, increased tone in a joint can be caused by spasticity, dystonia, rigidity, or mechanical limitations such as contracture. Determination of the cause of hypertonia is important for selection of appropriate therapy, but distinction between the types of hypertonia is difficult in a clinical setting. We present results of a pilot test of the use of a portable surface electromyography (EMG) device for the evaluation of hypertonia. Seven children age 5-17 years with hypertonia due to cerebral palsy were each examined by 6 clinicians, both with and without the use of surface EMG. The use of surface EMG resulted in an increase in inter-rater agreement as well as an increase in the self-reported confidence of the clinicians in their assessment. These results support the importance of further testing of surface EMG as an adjunct to the clinical examination of childhood hypertonia.

Introduction

Childhood hypertonia is associated with many different disorders such as cerebral palsy or other static or degenerative disorders¹. The neurological causes of hypertonia can be classified into at least three different types: spasticity, dystonia, and rigidity². In addition, hypertonia can be due to mechanical issues such as joint contracture or muscle-tendon shortening³⁻⁵. In many cases, treatment depends upon the correct classification of the type of hypertonia⁶. For example, the effectiveness of anti-spasticity or anti-dystonia medication depends on the correct determination of whether spasticity or dystonia is present. Similarly, the use of neurological treatment or neuro-muscular blocking agents (such as botulinum toxin) is effective only when tone is due to active muscle shortening and is unlikely to be effective when hypertonia is due to mechanical limitations.

The assessment of hypertonia in the clinical setting is difficult, since the only available information is the relation between passive joint movement and torque that can be felt by the examiner. An important element of information that is missing on routine clinical examination is the state of muscle activation. Muscle activation is not visible, and it may not be easily possible to distinguish increased tone due to changes in passive muscle properties from increased tone due to active contraction of the muscle. Assessment of the contribution of individual muscles to hypertonia in a joint is important, because most interventions act at the level of the neurological input to muscles (eg: baclofen, botulinum toxin) or the mechanical effect of muscles (eg: myotomy, tenotomy, or tendon transfer procedures) rather than at the level of joints.

The purpose of this study was to provide a preliminary evaluation of whether measurement of muscle activation using surface electromyography (EMG) could contribute to improved

clinical assessment of hypertonia. Surface EMG is commonly used in the laboratory evaluation of hypertonia^{7, 8}, and needle EMG is commonly used for clinical assessment of neuromuscular disorders. However, EMG is not commonly used in the routine inpatient or outpatient assessment of hypertonia. We hypothesized that the use of surface EMG would increase the inter-rater reliability of the assessment of hypertonia in children with increased tone due to cerebral palsy.

Methods

All procedures were approved by the Stanford University human subjects board, parents signed written informed consent for their child's participation and authorization for use of protected health information, and all children who were able signed written assent. The trial was registered with clinicaltrials.gov (NCT00472914). Seven children (age 5-17, 2 girls) with hypertonia due to cerebral palsy were recruited from the movement disorders clinic at Lucile Packard Children's Hospital (see table 1). Prior to testing, a single muscle was selected for each child based upon the presence of hypertonia during passive stretch on routine clinical examination.

Six clinicians with experience in the evaluation of children with cerebral palsy (four child neurologists, one pediatric physiatrist, and one physical therapist) evaluated each child. Clinicians had not previously examined the children. Clinicians were instructed to focus their examination on the identified muscle and its associated joint. Each clinician examined each child for two minutes without using the EMG device and recorded the examination on a 20-question case report form (see appendix). Immediately following the initial examination, the clinician re-examined the same child using the EMG device and recorded the examination on another case report form. For each question the examiner was required to indicate either yes or no (two alternative forced choice), as well as indicate the confidence in the answer using a visual analog scale. When not using the EMG device, examiners were instructed that they should respond to questions concerning muscle activity using their best clinical judgment based on tone and palpation of the muscle.

Clinicians were provided with the device approximately one year prior to the testing and permitted to familiarize themselves with its use in the clinic. However, no specific instructions for use were given. Immediately prior to testing, they were shown a brief videotape indicating use of the device and the types of responses that could be expected in different children. No further instruction or practice was provided.

The device provides audio amplification of the EMG signal, with bandpass filtering between 20hz and 450hz. It consists of an active bipolar surface electrode (Model DE2.3, Delsys Inc, Boston, MA) powered by two 6-volt alkaline miniature camera batteries. The electrode includes the bandpass filter and a 1000 gain amplifier. The electrode output drives a battery-powered speaker (JBL "On Tour" audio amplifier, Harman International Industries, Washington DC) (see figure 1). The speaker was chosen based on high input impedance and good audio response in the low frequency range. Ground reference is provided by attaching a copper plate to the top surface of the electrode, and soldering a small wire from the copper plate to the ground reference wire from the electrode. To use the electrode, the examiner places the two active contacts on the bottom of the electrode on the skin overlying the muscle belly and holds the electrode in place with his or her own hand. The examiner's hand must simultaneously contact the copper plate on the top surface of the electrode and the patient's skin. In preliminary device testing this was found to provide an adequate reference contact, and it simplifies examination by eliminating the need for a separate reference electrode. (Note that the DE2.3 electrode is not electrically isolated, so for patient safety it is essential that all

electronics be battery-powered, with no connection between the patient and any line voltage equipment such as outlet-powered audio amplifiers, oscilloscopes, or computers.)

Statistical analysis was performed using the R statistical package⁹. The primary outcome is the change in inter-rater agreement. In order to compare inter-rater agreement for multiple examiners, we calculate the entropy of the yes/no responses for each question and each subject. Entropy for a particular subject and question is calculated as:

$$-p_{\text{no}} * \log(p_{\text{no}}) - p_{\text{yes}} * \log(p_{\text{yes}})$$

where p_{no} is the fraction of “no” responses and p_{yes} is the fraction of “yes” responses. The entropy is maximized when $p_{\text{no}} = p_{\text{yes}} = 0.5$, meaning that half the examiners gave each response. Entropy is minimized when all examiners give the same answer ($p_{\text{no}}=1$ and $p_{\text{yes}}=0$, or $p_{\text{no}}=0$ and $p_{\text{yes}}=1$). The lower the entropy, the better the agreement between examiners. The difference in entropy with and without the device is equal to the mutual information between the examiner ratings and the device response, and a significant difference in entropy indicates a significant contribution of the device to the examiner ratings. A paired t-test was used to determine significance of the difference in entropy with and without the EMG device.

Confidence was scored by measuring the location of marks on the visual analog scale, and the results were scaled to 0-100% confidence. Significance of confidence changes was analyzed using repeated-measures analysis of variance with both the subject and the examiner as factors.

Questions 14 through 20 represent diagnostic and intervention decision-making. In order to determine the dependence of these responses on specific features of the examination, chi-squared tests were performed to assess for non-independence of responses to pairs of questions. The Chi-squared statistic was calculated over all subjects, examiners, and conditions (device or no device), and significance was Bonferroni-corrected for multiple (20) comparisons.

Results

The use of the EMG device significantly increased inter-rater agreement as measured by a decrease in response entropy over all questions ($t=2.3$, $p=0.02$, mean change in entropy: 0.04, confidence interval: -0.006 to -0.08). The self-reported confidence over all questions increased significantly ($F=68$, $p<0.0001$, grand mean change 1.19, confidence interval: +0.88 to +1.50). Change in entropy and confidence were both significant when data from all questions were combined, but due to the low number of examiners (6) the changes were not significant for individual questions.

Assessment of the presence of spasticity was significantly associated with Q3 (effect of stretch), Q5 (position dependence), Q6 (velocity dependence), and Q7 (spastic catch) (chi-squared, all $p<0.04$ after Bonferroni correction). Assessment of the presence of dystonia was not associated with specific signs. Assessment of the presence of contracture was significantly associated with Q8 (clonus) (chi-squared, $p=0.003$ after Bonferroni correction).

Assessment of the potential efficacy of botulinum toxin was significantly associated with Q3 (effect of stretch) and Q14 (presence of spasticity) (chi-squared, all $p<0.04$ after Bonferroni correction). Assessment of the potential efficacy of baclofen and trihexyphenidyl was not significantly associated with specific signs. Assessment of the potential efficacy of surgery was significantly associated with Q8 (clonus) and Q16 (presence of contracture) (chi-squared, all $p<0.02$ after Bonferroni correction).

Discussion

The primary outcome measures (change in confidence and inter-rater agreement) both demonstrated significant improvement with use of the EMG device. Improvement occurred despite very limited experience or training using the device. This suggests that use of surface EMG could improve the inter-rater and intra-rater reliability of assessment of hypertonia in children.

Correlations between responses to different questions suggest that raters associated spasticity with increased response to stretch, position or velocity-dependent reflexes, and the presence of a catch. This corresponds with current research on the origins of spasticity^{7, 8, 10, 11}. There was no consistent association with dystonia, perhaps because the assessment of dystonia often includes observation of movement and the presence of specific recognizable postures, neither of which were evaluated in this test.

Decisions on treatment will necessarily be based upon a careful assessment of multiple factors that contribute to disability, and decisions may vary between different clinicians. Within the limited context of this study, the use of botulinum toxin was associated with presence of spasticity, but the use of baclofen or trihexyphenidyl was not associated with any specific sign. As expected, the use of surgical muscle or tendon release was associated with contracture¹².

This study has several important limitations. The number of children assessed and the number of clinicians performing the assessments were both small. The design was open-label, so both the children and the examiners were fully aware of whether or not they were using the EMG device. Testing with the device was always performed after testing without the device, and therefore improvement in assessment could be partly due to performance of a second assessment in the same child. Due to the significant differences between children and the small number of children tested, this repeated-test study design was needed in order to be able to determine the effect of the device on reliability and confidence. Nevertheless, we expect that in routine practice the device would be used following initial assessment without the device, and therefore the test procedure we employed may predict the effect of its use in clinical practice.

During routine clinical examination, clinicians are able to assess passive and active torque about joints. However, muscle activity responsible for the torque is not directly observable. By using a portable surface EMG device, the presence or absence of muscle activity can be determined. Our results suggest that assessment of muscle activity may be helpful in the diagnosis of the type of hypertonia present in children. It may also be helpful in the selection of medical or surgical treatments, and further experience with the use of surface EMG may lead to additional diagnostic possibilities for both neurological and neuromuscular disorders.

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Figure 1. Circuit diagram for EMG device. The batteries were enclosed in a separate connector box. DE2.3 is the pre-packaged active electrode with the ground contact attached to the top surface. The pin-out shows connections looking into the hypertronics connector attached to the electrode. JBL is the portable battery-powered amplifier and speaker that connects to the connector box through a standard mini headphone jack.