THE CLINICAL SIGNIFICANCE OF TWO DIFFERENT ELECTROMYOGRAPHY NORMALISATION TECHNIQUES IN PATIENTS WITH ANTERIOR CRUCIATE LIGAMENT INSTABILITY DURING TREADMILL WALKING

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The purpose of this study is to investigate the clinical outcome of two normalisation techniques in detecting neuromuscular alterations of the quadriceps muscles between injured and non-injured patients diagnosed with ACL knee instability in their right knee during repeated gait cycles on a treadmill. The ensemble average muscle activity of the vastus lateralis and vastus medialis were normalised to either MVC or maximal activation during the gait cycle in eight male and female subjects. Results indicate that the EMG normalised to MVC was more sensitive in detecting differences in activation between the vastus lateralis and vastus medialis than the normalisation to maximal activity during repeated strides. This study indicates the importance of choosing the appropriate normalisation technique when seeking a clinical outcome measure.

KEY WORDS: electromyography, normalisation, clinical, ACL, walking, knee injury

INTRODUCTION: The use of electromyography (EMG) as a clinical evaluation tool is gaining widespread use. It's use for the evaluation of patients with anterior cruciate ligament (ACL) injury with respect to activation time and amplitude have also been reported (Shiavi et al., 1992). A recent demonstration of the clinical importance of signal normalisation for surface EMG was demonstrated by Lehman and McGill (1999) when testing the rectus abdominus muscle groups. They found that because of the inherent EMG signal variability, clinical interpretation of surface EMG signals requires normalisation of the signal for physiological interpretation and for comparison between bilateral muscles and between the same muscles on different days and between different subjects. The need for further discussion and research with regard to clinically applied EMG during movement analysis is evident.

A popular means of evaluating EMG during gait is to represent the signal as a percentage of the maximal signal during repeated gait cycles. This method is not time-consuming and easily performed with many available software packages. The procedure is more reliable (Yang & Winter, 1984) and indicates at what periods during the gait cycle the muscle is most active. It does not, however, give an indication of what this activity level means with respect to the muscle's ability to activate. Another popular technique is the use of the recorded maximum voluntary isometric contraction (MVC) as the baseline to normalise the signal. This may be done using manual maximum tests or specially designed apparatus. It has been argued that an isometric contraction does not represent dynamic contraction and that the normalisation technique is less reliable (Yang and Winter, 1984). Advantages of this technique, however, are the normalisation of the signal to some level of maximal activity based on the patients' ability to contract the muscle. Furthermore, previous studies have indicated through comparative analysis of normalisation techniques that the MVC method best represents isotonic contractions at various speeds (Burden & Bartlett, 1999).

The ability to perform a maximal voluntary contraction of the quadriceps is greatly affected by the pain perceived by the patient. In post-operative situations where the pain is inhibited via a local anaesthetic, there is an increase in the patients' ability to voluntarily contract these muscles to a maximal level (Arvidsson et al., 1986). This may be of clinical significance when using electromyography analysis for patients with ACL instability either pre or post operatively to evaluate neuromuscular function. If the patients are unable to contract the quadriceps muscles of the injured leg similarly to that of the non-injured leg the information resulting from the EMG analysis may be confounded. When considering the two normalisation techniques previously mentioned, the maximal signal recorded during repeated gait cycles may not reflect a decrease in the patients' ability to contract the muscles of the injured leg due to inhibition. Since the normalisation does not take into account the ability of the patient to maximally contract the muscle, it will chose the maximal activity of the cycles and assign them the same 'value' and 'significance' as the non-injured leg. Therefore the patients inability to contract the muscle due to pain inhibition (and therefore altered neuromuscular performance) may not be reflected. Using the MVC method, it is possible to register the maximal activity level of the injured and non-injured leg while also having information with respect to the muscles' ability to produce a moment of force about the observed joint. This will provide additional information that may affect the interpretation of the 'value' and it's 'significance' when performing repeated gait cycles. Furthermore, this technique may be more sensitive in detecting injured to non-injured leg differences as the muscles of the injured leg may have to produce more relative activation (based on the inhibited MVC) during the trials in order to perform the same work as the muscles of the non-injured leg.

The purpose of this study is to investigate the clinical outcome of two normalisation techniques in detecting neuromuscular alterations between injured and non-injured quadriceps muscles of patients diagnosed with ACL knee instability in their right knee during repeated gait cycles on a treadmill. It is hypothesised that the MVC technique will be more sensitive to detecting alterations in muscle activation due to the technique's dependence on voluntary muscular contraction.

MATERIALS AND METHODS: Eight male and female subjects (21-41 years) diagnosed with ACL knee instability in their right knee participated voluntarily in this study. Two methods of EMG normalisation were applied to the signal data after treadmill walking. Bipolar surface electrodes (Ag/AgCl) were used to collect EMG at 1000Hz (Noraxon Biotel88) from the vastus lateralis and vastus medialis of the injured and non-injured legs. Electrodes were placed over the muscle bellies and aligned along the direction of the muscle fibres after appropriate skin preparation. The frequency bandwidth was 5.5 to 600 Hz and a common mode rejection ratio (CMRR) of >80dB. The digitally converted EMG signal was saved on computer hard disk (Olidata Pentium 120) for future analysis. The EMG was then full-wave rectified and low-pass filtered (using a single pass critically damped filter) with a cut-off of 3 Hz. MVC was recorded during a maximal isometric muscle test for the knee extensor muscle groups with the subject in a reclined seated position (1000ms window). Processed EMG was normalised as a percentage of MVC and as a percentage of maximal activity during repeated gait cycles (500ms window). Full stride was determined using a foot switch located in the centre medial-laterally and posterior portion of the heel. All walking trials were performed on a treadmill (Cadence model 625). Normalised EMG was ensemble averaged over the full strides recorded during a 15 second trial then a group ensemble average was determined by pooling subject data. A two-tailed student's t-test was used to determine any difference in the total activation of the injured and non-injured leg quadriceps activity.

RESULTS: A paired students t-test was used to compare the means of the measured EMG activity during the two normalisation procedures. The data were normalised over 100 points (100% gait cycle divided into percentage blocks). Paired samples analysis of the comparison between injured and non-injured muscle activity level is presented in table 1. There was no difference in activity level for the vastus lateralis when normalised by MA or MVC between injured (Rt) and non-injured (Lt) legs. There was no difference between vastus medialis when normalised to MA or MVC, however there is an apparent trend towards a higher activation in the injured leg when normalised to MVC.

Table 1 Paired Samples t-test

	MAmedRt	MAmedLt	MVCmedRt	MVCmedLt
Mean	20,191	20,382	8,725	7,404
Variance	250,892	302,033	45,308	39,521
Observations	100	100	100	100
Pearson Correlation	-0,313		-0,301	
Df	99		99	
t Stat	-0,071		1,258	
P(T<=t) two-tail	0,944		0,211	
	MA lat Rt	**MA lat Lt**	**MVC lat Rt**	**MVC lat Lt**
Mean	20,033	19,981	9,640	9,351
Variance	298,250	362,968	66,647	71,084
Observations	100	100	100	100
Pearson Correlation	-0,453		-0,434	
Df	99		99	
t Stat	0,017		0,206	
P(T<=t) two-tail	0,987		0,837	

Another useful and often used way of interpreting the muscle activity of the vastus lateralis and medialis group is to take a ratio measure of the relative activity of the two muscles. This technique provides insight into the relative contribution of each muscle group with respect to the functional requirement to perform a given task. A paired samples analysis of the ratio data for injured and non-injured vastus lateralis-medialis muscle ratios is presented in table 2. The muscle activity ratio of the injured limb shows a significantly lower value when using the MVC normalisation technique, indicating a higher relative activity of the vastus medialis.

Table 2 Paired Samples t-test

	MARt	MALt	MVCRt	MVCLt
Mean	0,962	0,910	1,061	1,216
Variance	0,034	0,029	0,040	0,048
Observations	100	100	100	100
Pearson Correlation	-0,325		-0,192	
Df	99		99	
t Stat	1,827		-4,749	
P(T<=t) two-tail	0,071		**6,922E-06**	

DISCUSSION: The purpose of this study was to evaluate two methods of analysis of EMG in the clinical environment that may be performed quickly and that may yield clinically relevant results for the given patient population. When using normalising to maximal activity there appeared to be no difference between the injured and non-injured leg. The MVC normalisation indicated a higher activity in the injured limb vastus medialis but not in the vastus lateralis. The relationship between the vastus medialis and lateralis muscles has been associated with patellar tracking problems and anterior knee pain in the past, normally related to the ability to activate the muscles or altered muscle activation ratios (Thomee et al., 1996; Hung & Gross, 1999). In this study, the injured limb vastus medialis activity normalised to MVC was higher during gait. If the subject experienced muscular inhibition when performing the MVC then the relative level of muscle activation used to normalise the signal will be lower. This may be reflected, therefore, in a relatively higher percentage of activation when compared to the non-injured limb for activities of relatively equal work, such as gait, where the patient is attempting to produce a symmetrical motion pattern.

CONCLUSION: The results of this study indicate the increased sensitivity of the MVC methods of normalising gait EMG in detecting a possibly clinically relevant finding. This study also indicates that the activation of the vastus medialis might be altered following injury in subjects with clinically measured ACL knee instability. These findings indicate the importance in choosing the appropriate procedure when evaluating neuromuscular information in order to gain clinically relevant information. This research will aid in the development of a clinically relevant technique for evaluating neuromuscular function during gait and sport specific tasks in a sports medicine environment.

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