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The within-day reliability of scapular and shoulder EMG measurements in asymptomatic individuals during shoulder abduction

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ABSTRACT

The purpose of this study was to assess the within-day reliability of scapular and shoulder surface electromyography (sEMG) measurements during shoulder abduction. Twenty asymptomatic individuals performed 10 repetitions of shoulder abduction, which was then retested 10 minutes later. sEMG was used to record the activity of upper and lower trapezius; anterior, middle and posterior deltoids; supraspinatus; infraspinatus; and serratus anterior muscles. Muscle activation was expressed as a percentage of maximum voluntary isometric contraction (MVIC). The intraclass correlation coefficient (ICC) and standard error of measurement (SEM) were used to assess within-day reliability for concentric and eccentric phases of shoulder abduction. For the concentric phase, ICC values ranged from 0.87 to 0.98 and SEM values from 8.6% to 18.9% MVIC. For the eccentric phase, ICC values ranged from 0.65 to 0.97, and SEM values from 9.8% to 24.4% MVIC. In asymptomatic individuals, EMG measurements of the scapular and shoulder muscles during the concentric phase of shoulder abduction had excellent reliability, and for the eccentric phase, had good to excellent reliability depending on the analysed muscle. These findings provide valuable information on reliability of sEMG for assessing muscle activity of scapular and shoulder muscles.

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INTRODUCTION

Electromyography (EMG) is used as a tool to assess muscle activity levels and recruitment patterns of muscles during functional activities (Konrad, 2005). Surface EMG (sEMG) is a non-invasive technique where electrodes are placed directly onto the skin and over the belly of the muscle that is investigated (Konrad, 2005). During joint movement or isometric muscle contraction, the electrodes detect electrical discharges from active motor units that can be used to assess neuromuscular disorders or as a research tool to identify abnormalities with motor control (Chowdhury et al., 2013).

Current literature regarding the reliability of EMG to the upper limb, specific to the shoulder complex is very limited. One study suggests that isometric maximal contraction, as a normalisation procedure, is linked to high EMG reliability for the upper limb muscles (Rota, Rogowski, Champely, & Hautier, 2013). Most published studies have assessed the reliability of EMG for measuring muscle activity of the trunk in patients with lower back pain (Dankaerts, O'Sullivan, Burnett, Straker, & Danneels, 2004) or lower limb muscles, such as vastus medialis obliquus (VMO), in patients with knee disorders (Worrell, Crisp, & LaRosa, 1998). Within-day EMG testing has excellent reliability (intraclass correlation coefficient (ICC) 0.91) in contrast to between-day reliability, which showed to have lower reliability (ICC 0.70) for vastus lateralis and VMO (Worrell et al., 1998). This variance could be due to several factors, such as, changes in the strength of contraction between tests and different placement of electrodes on different days (Oskouei, Paulin, & Carman, 2013; Worrell et al., 1998).

Findings from previous studies suggest that the method used for normalising EMG measurements can impact on reliability of measurements. Both submaximal and maximal methods were found to be linked to excellent reliability of EMG recordings (Oskouei et al., 2013). Normalising EMG recordings is not only essential for obtaining reliable measurements, but also for allowing appropriate interpretation of the EMG parameters (Burden, 2010).

The purpose of this study was to assess the within-day reliability of scapular and shoulder muscle EMG measurements in asymptomatic individuals as the evidence surrounding this topic is very limited. Findings from this study will help to interpret data from future studies assessing EMG recording when measuring muscle activity levels and recruitment patterns of scapular and shoulder muscles within the same day.

METHODS

Study Design

This was a repeated measure cross-sectional study. Scapular and shoulder muscle activity was recorded using surface electromyography (sEMG). Muscles measured included the upper and lower trapezius; anterior, middle and posterior deltoids; supraspinatus; infraspinatus; and serratus anterior muscles. Each participant performed 10 repetitions of shoulder abduction with their dominant arm. The same task was then re-tested 10 minutes later.

Participants

Twenty asymptomatic individuals from the local community were included in this study. Participants signed an informed consent form prior to taking part in the study. A screening examination involved the cervical spine and shoulder. This involved full cervical active range of motion with overpressure, active shoulder elevation with overpressure, and maximum voluntary isometric shoulder internal and external rotation strength testing. Participants were excluded from the study if they presented with any pain or discomfort during these tests. The study was approved by the University of Otago Ethics Committee (reference number: H15/020).

Equipment

We used a 16-channel wireless Noraxon TeleMyo 2400T G2 (Noraxon USA Inc., Arizona, USA) with a 3000 Hz sampling frequency, and gain of 500 to record muscle activity. Raw sEMG signals were sent wirelessly from the transmitter to a Noraxon TeleMyo EMG receiver. To record shoulder and scapular muscle activity, we used disposable, self-adhesive surface Ag/AgCl electrodes (Product SP-00-S/50, Ambu, DK-2750 Ballerup, Denmark). Electrodes were placed on the upper and lower trapezius; supraspinatus; infraspinatus; anterior, middle and posterior deltoid; and serratus anterior muscles.

We followed the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) guidelines for electrode placement on upper and lower trapezius, anterior, middle and posterior deltoid muscles, and serratus anterior muscles (Hermens et al., 1999). We followed recommendations and descriptions by Criswell (Criswell, 2010) and Waite et al. (Waite, Brookham, & Dickerson, 2010), for electrode placement on the supraspinatus and infraspinatus muscles. Surface electrodes were placed parallel with muscle fibres, with a 2 cm inter-electrode distance (Criswell, 2010; Hermens et al., 1999). We used the spinous process of the seventh cervical vertebrae for the reference electrode (Hermens et al., 1999).

We monitored the upper limb movements using a 3D motion analysis system (Motion Analysis Corporation, Santa Rosa, CA), with a frequency sample of 120 Hz. Reflective markers were placed over the acromion, lateral and medial epicondyles. During data processing, we monitored upper limb movements to identify concentric and eccentric phases of movement. We synchronised kinematic and EMG measurements using a trigger system.

Procedures

To reduce EMG baseline noise, the participant's skin was shaved, wiped with a coarse towel and rubbed with an alcohol wipe. This was repeated several times until skin impedance was verified as less than 5kΩ using a standard voltmeter, before placement of the electrodes. After this procedure, maximal isometric voluntary contraction (MIVC) was performed and measured for each individual muscle being monitored. The MIVC was then used to normalise EMG data gained during the study.

Following a rest period of 5 minutes, participants were asked to elevate their arms in the coronal plane 10 times. Participants were asked to elevate their arm until the end of the available active range of motion, without any compensatory movements. To standardise movement velocity, a metronome was used and set at 30 beats/min. This procedure was repeated 10 minutes later.

Data Processing

Processing of sEMG data was performed with MyoResearch XP Master Edition Software. Firstly, sEMG electrocardiogram artefact spikes were removed and the signal was processed using root mean square (RMS), with an average window of 50 ms. During shoulder abduction trials, sEMG data was normalised using the MIVC of muscle activity (during a 50 ms window of the 5s contraction). sEMG and kinematic data was processed using a tailored code written in MATLAB 7.12 (Mathworks, Inc., USA). EMG data were used to resample the kinematic data. The concentric and eccentric phases of shoulder abduction were identified by calculating the midpoint from the medial and lateral epicondyle reflective markers. The start and end of the concentric and eccentric phases were determined using the maximum and minimum values on the vertical axis of the midpoint. For each phase of abduction, the normalised mean muscle activity was calculated for each trial, for all participants. Following this, the mean for each of the 10 trials was calculated for every individual.

Primary Outcome Measures

The mean level of muscle activity and standard deviation across the 10 trials for each monitored muscle was calculated and expressed as a percentage of the muscle-specific MIVC magnitudes.

Statistical Analyses

All statistical analyses were performed using SPSS software.

Within-Session Reliability of Muscle Activity Levels

EMG data were used to assess the within-day reliability of muscle activity between two measurements. The intraclass correlation coefficient (two-way mixed model, consistency definition ICC) was used to assess the within-session reliability (Hsu, Ho, Ho, & Hedman, 2000). The mean value of the 10 repetitions performed, for each muscle, for baseline and follow up measurements was used as input data for this model. It was assumed that the clinical researcher was the single rater. The standard error of measurement (SEM) was calculated from the data obtained from the 10 repetitions of shoulder abduction performed by participants, and was calculated using the square root of the error mean square term, obtained from the ANOVA test. This is beneficial as the SEM can be estimated independently from the ICC value (Weir, 2005).

Interpretation of Results

For the purposes of this study, ICC values were analysed using the categories: ICC values <0.40 suggested poor reliability; ICC values ranging from 0.40 to 0.75 suggested fair to good reliability; >0.75 suggested excellent reliability (Fleiss, 1999). Currently, there are no clear guidelines explaining how to interpret SEM. Due to this, SEM values were qualitatively discussed.

RESULTS

Twenty participants took part in this study (6 males/12 females). The participants' anthropometric characteristics are reported on Table 1.

Table 1: Demographic data for the 20 participants.

Participants	Mean	SD	Range
Age (years)	28.1	7.4	22-55
Height (m)	168.6	9.5	152.5-189.1
Weight (kg)	67.1	14.5	54-118.7
Body Mass Index (kg/m^2)	23.6	3.4	19.4-33.3
Gender (M/F)	6/14		

Notes: SD, standard deviation; M, male; F, female.

The concentric phase presented ICC values ranging from 0.87 to 0.98 (Table 2). As shown in Table 3, the SEM values ranged from 8.6% MVIC to 18.9% MVIC. With reference to the eccentric phase, ICC values ranged from 0.65 to 0.97 (Table 2). The SEM values ranged from 9.8% MVIC to 24.4% MVIC (Table 3).

Table 2: Within-day reliability (intraclass correlation coefficient) of muscle activity measurements between baseline and follow-up.

Muscles	Concentric ICC (95% CI)	Eccentric ICC (95% CI)
Upper Trapezius	0.97 (0.92 to 0.99)	0.83 (0.57 to 0.93)
Lower Trapezius	0.94 (0.84 to 0.98)	0.78 (0.44 to 0.91)
Supraspinatus	0.91 (0.77 to 0.96)	0.65 (0.11 to 0.86)
Infraspinatus	0.98 (0.95 to 0.99)	0.93 (0.81 to 0.97)
Anterior Deltoids	0.87 (0.67 to 0.95)	0.79 (0.47 to 0.92)
Middle Deltoids	0.91 (0.77 to 0.96)	0.80 (0.49 to 0.92)
Posterior Deltoids	0.96 (0.90 to 0.98)	0.89 (0.71 to 0.95)
Pectoralis Major	0.97 (0.92 to 0.99)	0.94 (0.84 to 0.98)
Latissimus Dorsi	0.96 (0.91 to 0.99)	0.97 (0.93 to 0.99)

Notes: ICC, intraclass correlation coefficient; CI, Confidence Interval; SEM, standard error of measurement; MVIC, maximal voluntary isometric contraction.

Table 3: Within-day reliability (standard error of measurement) of muscle activity measurements between baseline and follow-up.

Muscles	Concentric phase			Eccentric phase		
	Mean activity (% MVIC)	SEM (%MVIC)	SEM (%mean)	Mean activity (% MVIC)	SEM (%MVIC)	SEM (%mean)
Upper Trapezius	33.01	8.6	2.8	12.0	19.8	12.0
Lower Trapezius	28.4	12.6	3.6	11.4	22.7	2.6
Supraspinatus	26.6	12.6	3.4	10.9	18.9	2.1
Infraspinatus	19.8	8.8	1.7	9.4	14.7	1.4
Anterior Deltoid	43.3	11.5	5.0	14.4	20.1	2.9
Middle Deltoid	27.3	11.2	3.1	9.9	16.4	1.6
Posterior Deltoid	14.1	9.4	1.3	5.8	15.0	1.0
Pectoralis Major	12.6	18.9	2.4	4.9	24.4	1.2
Latissimus Dorsi	10.2	10.2	1.4	5.1	9.8	1.0

Notes: ICC, intraclass correlation coefficient; CI, Confidence Interval; SEM, standard error of measurement; MVIC, maximal voluntary isometric contraction.

Values for mean activity as a percentage of the MVIC during the concentric phase range from 10.2% to 33.01% and for the eccentric phase, range from 4.9% to 14.4% (Table 3).

The SEM values expressed as a percentage of the mean for the concentric phase range from 1.3% to 5.0% and for the eccentric phase, range from 1.0% to 12.0% (Table 3).

DISCUSSION

This study assessed the within-day reliability of scapular and shoulder EMG measurements in asymptomatic individuals. Our results suggest that EMG measurements have excellent reliability for concentric contractions and good to excellent reliability during the eccentric phase of shoulder abduction. The upper trapezius, lower trapezius, infraspinatus, anterior deltoids, middle deltoids, posterior deltoids, pectoralis major and latissimus dorsi muscles had excellent reliability for both the eccentric and concentric phases of muscle contractions, with reference to their ICC values. Moreover, the SEM percentages of the MVIC for all of the muscle groups during the eccentric phase were larger compared to the concentric phase (Table 2). Therefore, the eccentric phase seems to be less reliable than the concentric phase during unloaded shoulder abduction in asymptomatic individuals.

Numerous studies support our findings on excellent reliability for the concentric phase of contraction. One study investigated test-retest reliability of EMG during maximal concentric knee extensions (Larsson, Karlsson, Eriksson, & Gerdle, 2003). The results showed excellent reliability for the vastus lateralis (ICC≥0.82), vastus medialis (ICC≥0.88) and rectus femoris (ICC≥0.83) muscles. Larsson et al. (2003) used a very similar method to our study, using maximal muscle contractions to normalise EMG data. Another study investigated test-retest reliability of onset concentric and eccentric EMG activity in stair stepping tasks and showed excellent reliability (ICC 0.91) during concentric contractions, similar to our findings (Cowan, Bennell, & Hodges, 2000). Despite both these studies assessing the activity of lower limb muscles, they both had a focus on dynamic contractions similar to our study.

Previous studies reported EMG recordings to be reliable, but with different reliability scores being reported for concentric and eccentric phases of movement. One study reported excellent reliability scores for both eccentric and concentric data when monitoring scapular and shoulder muscles (Ribeiro, Day, & Dickerson, 2017). Another study assessed the reliability of quadriceps femoris muscle (Finucane, Rafeei, Kues, Lamb, & Mayhew, 1998), and reported good to excellent reliability, with eccentric contractions associated with higher ICC scores (similar to our findings). Our results, on the other hand, showed noticeably lower ICC values and higher SEM values for EMG activity levels during the eccentric phase of movement, when compared to the concentric data. Variability on EMG recordings may arise due to electrode placement, within- and between-subject variability when recruiting muscles to perform a task. These factors might explain the different findings reported by previous studies and our study.

In contrast, some studies have identified the eccentric phase of contraction to be more reliable compared to the concentric phase. Finucane et al. (1997) observed superior intra-rater and inter-rater ICC values in participants when performing eccentric isokinetic knee extensor contractions. All eccentric results were rated as excellent (intra-rater results ranging from 0.84 to 0.97, and inter-rater results ranging from 0.78 to 0.90). In comparison, concentric values ranged from good to excellent (intra-rater results ranging from 0.62 to 0.91, and inter-rater results ranging from 0.64 to 0.96). Moreover, another study (Finucane et al., 1998) found similar results, i.e. higher ICC values (intra-rater results ranging from 0.84 to 0.97, and inter-rater results ranging from 0.78 to 0.90), and lower SEM values (0.17 for intra-rater data and 0.27 for inter-rater data) for the eccentric phase of movement. Lower ICC values (intra-rater results ranging from 0.62 to 0.91, and inter-rater results ranging from 0.66 to 0.96), and higher SEM values (0.33 for intra-rater and 0.33 for inter-rater), were found for concentric data (Finucane et al., 1998).

Limitations

One of the main limitations for the use of sEMG is the potential crosstalk between adjacent muscles. Previous studies have proposed that sEMG may detect signals generated by a number of concurrently active motor units near the electrode (De Luca & Merletti, 1988; Solomonow et al., 1994). Regarding scapular and shoulder muscles, there is concern about potential crosstalk between the supraspinatus and upper trapezius muscles. A previous study suggests minimal crosstalk between the upper trapezius and supraspinatus, and the trapezius (upper and middle fibres) and infraspinatus (Waite et al., 2010) muscles. It is suggested that sEMG overestimates fine-wire recordings for the supraspinatus muscle. However, this was not due to crosstalk between these muscles, but due to muscle fibre orientation being recorded by sEMG and fine-wire EMG, muscle size and location. It was found that the supraspinatus muscle activity recorded by sEMG is lower when measuring submaximal muscle exertion or when the muscle is the primary mover (e.g. shoulder abduction, as analysed in this study) (Allen, Brookham, Cudlip, & Dickerson, 2013; Waite et al., 2010). Another limitation of sEMG is muscle activity measurement variability during dynamic contractions. During dynamic contractions, there is potential for displacement of the electrode in regards to the muscle being recorded. Consequently, this could reduce the intensity of the signal being recorded, affecting the reliability of the data (Massó et al., 2010). Moreover, as only surface muscles can be measured and analysed using sEMG, this study does not provide findings on the shoulder complex as a whole (Massó et al., 2010).

CONCLUSION

In asymptomatic individuals, EMG measurements of the shoulder and scapular during the concentric phase of shoulder abduction had excellent reliability and for the eccentric phase had good to excellent reliability of results. This study adds to current knowledge regarding the reliability of EMG measurements to muscles of the upper limb and helps to better understand the use of EMG as a reliable tool in assessing muscle activity levels and recruitment patterns to the shoulder complex. To date, literature concerning the reliability of EMG measurements to the upper limb is very limited which allows for the opportunity of further research on this topic.

KEY POINTS

1. EMG is a reliable tool for assessing scapular and shoulder muscle activity pattern.
2. Reliability of EMG recordings for scapular and shoulder muscles was higher during the concentric phase of shoulder abduction.

DISCLOSURES

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