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Between-day reliability of a hand-held dynamometer and surface electromyography recordings during isometric submaximal contractions in different shoulder positions

Kathrine S. Andersen [a,b], Birgitte H. Christensen [a,c], Afshin Samani [a], Pascal Madeleine [a,*]

[a] Physical Activity and Human Performance Group, Center for Sensory-Motor Interaction (SMI), Department of Health Science and Technology, Aalborg University, Aalborg, Denmark
[b] Department of Occupational and Physical Therapy, Regional Hospital Central Jutland, Viborg, Denmark
[c] Department of Occupational and Physical Therapy, Aalborg University Hospital, Aalborg, Denmark

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ABSTRACT

Functional shoulder assessments require the use of objective and reliable standardized outcome measures. Therefore, the aim of this study was to examine the between-day reliability of a hand-held dynamometer when measuring muscle strength during flexion, abduction, and internal and external rotation as well as surface electromyography (EMG) when measuring muscle activity from m. trapezius superior and deltoideus anterior. Twenty-four healthy subjects participated and performed four isometric contractions measured with a hand-held dynamometer and EMG. Both relative and absolute reliability were calculated based on the mean of the last three of the four repetitions. EMG amplitude was assessed calculating both absolute and normalized root-mean-square (RMS) values. The reliability of the hand-held dynamometer was high (LOA = 3.2–7.6% and ICC = 0.89–0.98). The absolute reliability for EMG showed similar results for absolute RMS values (LOA = 20.0–68.4%) and normalized RMS values (LOA = 42.4–66.5%). However, the results concerning the relative reliability showed higher ICC for absolute RMS values (ICC = 0.82–0.92) compared with normalized values (ICC = 0.57–0.72).The outcome measurements of this study with healthy subjects were found reliable and, therefore, have the potential to detect changes in muscle strength and muscle activity.

1. Introduction

Functional shoulder assessments are performed by both researchers and clinicians. The changes in performance over time are often monitored among athletes over a season and among patients over interventions or treatments. The quantifications of the changes in muscle strength and muscle activity around the shoulder girdle are important to assess the risk of injuries among athletes (Hidalgo-Lozano et al., 2012). Patients with pain in the shoulder are often characterized by lower muscle strength and muscular imbalance with either weak or overactive surface electromyographic (EMG) activity (Madeleine et al., 1999; Thorn et al., 2007). Especially an undesired increased EMG activity in m. trapezius superior is present in patients with, e.g., rotator cuff injuries (Ludewig and Reynolds, 2007; Hawkes et al., 2012; Cools et al., 2007). Consequently, both muscle strength and muscle activity would be relevant to include as outcome measurements in studies evaluating changes in the functional status of the shoulder among athletes or patients suffering from, e.g., rotator cuff injuries. Prior to this, the reliability of the outcome measures needs to be addressed (Atkinson and Nevill, 1998). Muscle strength can be measured with a handheld dynamometer, but the positions in which the subjects are tested are in general not consistent and the reported reliability fluctuates (see Table 1) (Magnusson et al., 1990; Celik et al., 2012; Cadogan et al., 2011; Hayes et al., 2002). For example, Hayes et al. (2002) found an intraclass correlation coefficient (ICC) of 0.85 and 0.92 for, e.g., internal and external arm rotation tested with subjects in supine position and with 90° arm abduction. On the other hand, Cadogan et al. tested rotation in a sitting position with 0° of arm flexion and reported ICC ranging from 0.68 to 0.99 (Cadogan et al., 2011). In similar test positions Cools et al. reported a relative reliability of 0.96–0.99 whereas the absolute reliability showed a minimal detectable difference of 11.52–22.11 (Cools et al., 2014). Many of the test positions as

* Corresponding author. Address: Physical Activity and Human Performance Group, Center for Sensory-Motor Interaction (SMI), Dept. of Health Science and Technology, Aalborg University, Fredrik Bajers Vej 7, 9220 Aalborg East, Denmark. Tel.: +45 994088 33; fax: +45 98154008.
E-mail address: pm@hst.aau.dk (P. Madeleine).

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Table 1
Description and reliability results from studies using strength measured with a handheld dynamometer as outcome measure.

Study	Test positions	Shoulder	Movement	*n*	Reliability
Magnusson et al. (1990)	90° abduction with manual resistance	Non-dominant. The dominant shoulder was tested with an isokinetic machine	Isometric	9	r = 0.94–0.98
Hayes et al. (2002)	Elevation with 90° flexion in the plane of scapula (30° frontal)	Symptomatic shoulder	Isometric	8–9[a]	ICC = 0.96[b], 0.92[c]
	External rotation in supine position with 90° arm abduction				ICC = 0.92[b], 0.82[c]
	Internal rotation in supine position with 90° arm abduction				ICC = 0.85[b,c]
	Lift-off from lumbal spine				ICC = 0.70[b], 0.79[c]
Celik et al. (2012)	Test of specific muscles, among these – m. trapezius superior during elevation of the shoulder – m. deltoideus anterior during 90° flexion of the arm	Dominant and non-dominant	Isometric	35 + 22[a]	ICC = 0.45–0.97 ICC = 0.72–0.95
Cadogan et al. (2011)	Abduction 10° in the plane of scapula	Symptomatic and asymptomatic shoulder	Isometric	40[a]	ICC = 0.91–0.98[b], 0.77–0.84[c]
	External rotation during sitting				LOA = 2.2–7[b], 6.3–8.5[c] ICC = 0.91–0.99[b], 0.68–0.74[c] LOA = 1.1–3.2[b], 3.2–4.4[c]
Cools et al. (2014)	Test of internal and external rotation in different shoulder and patient positions	Not mentioned	Isometric	30	ICC = 0.96–0.99[b], 0.98[c]
	Internal rotation in sitting position with 0° abduction				MDC = 14.07–22.11[b], 7.76[c]
	External rotation in sitting position with 0° abduction				ICC = 0.96–0.97[b], 0.96[c] MDC = 11.52–12.80[b], 6.00[c]

Abbreviations:
[a] Refer to subjects with shoulder pain.
[b] Refer to intra-rater reliability.
[c] Refer to inter-rater reliability.

well as strength levels can be challenging for patients with shoulder pain (Hayes et al., 2002). Based on these inconsistencies a reliable method is required for future use in patient populations. Measurement of the EMG activity would also be relevant to include for the assessment of motor control in the shoulder girdle.

Regarding EMG activity, an investigation of the reliability of different test positions is required. To the best of the authors' knowledge, EMG from m. trapezius superior and deltoideus anterior has not been investigated in relatively common test positions like isometric submaximal contractions and dynamic arm flexion.

Therefore, the aim of this study was to investigate the reliability of (1) isometric muscle strength measured with a hand-held dynamometer in five different test positions when performing isometric submaximal contractions and (2) EMG activity from m. trapezius superior and deltoideus anterior in isometric and dynamic contractions. For that purpose, we conducted a study among healthy subjects testing the between-day reliability involving a handheld dynamometer and EMG recordings. The presentation of this reliability study follows the guidelines for reporting reliability and agreement studies (GRRAS) (Kottner et al., 2011).

2. Methods

2.1. Participants

The number of required subjects was estimated based on recommendations made by Shoukri et al. (2004) resulting in a population sample size between 18 and 29 subjects. Two calculation methods were used; (i) based on the estimated ICC values, number of measurements per subjects, alpha and beta level from a pilot study, and the existing literature resulting in N being equal to 18 subjects and (ii) based on recommendations involving the combination of the number of subjects and the number of measurements made per subject resulting in N being equal to 29 subjects (Shoukri et al., 2004). Based on these calculations, a convenient sample of 24 healthy subjects was recruited. Two subjects out of 24 were left handed. The population consisted of 14 women and 10 men. Mean age was 26.9 years (range 23–33 years) and mean BMI 22.9 (range 19.2–26.9). The inclusion criteria were: healthy volunteers aged 18–35, ability to read and understand Danish, no known neurological conditions affecting muscle strength or muscle activity, and no recent surgery or pain in shoulder, neck or upper back. A questionnaire was used to check if the subjects met the inclusion criterion. The study was approved by the local ethical committee (N-20120040) and performed in accordance with The Declaration of Helsinki. An informed consent was obtained from all subjects prior to participation.

2.2. Experimental procedure

All subjects were tested on their dominant shoulder by one single tester (intra-rater reliability) at two occasions with 1–3 days in between (between-day reliability). See Fig. 1A for details. The dominant shoulder was chosen since a more torque-efficient strategy is reported for the dominant side (Bagesteiro and Sainburg, 2002). A hand-held Commander PowerTrack II Muscle Dynamometer (PowerTrack II™, JTech Medical Industries, Salt Lake City, USA) was used to measure the shoulder strength in four different directions (i.e., flexion, abduction, internal and external rotation). The calibration procedure had been performed by the manufacturer prior to our testing. The dynamometer measures forces up to 556 N with 4.4 N increments.

The EMG signals from m. trapezius superior and deltoideus anterior were gathered using a Biovision EMG amplifier (Werheim, Germany) with the following specifications: differential mode, input impedance (1200 GΩ), common mode rejection ratio (120 dB), band-pass filter ([10–700 Hz]), gain (2000). The EMGs were sampled at 2000 Hz with a 12 bit A/D converter (input