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Muscle strength assessment in critically ill patients with handheld dynamometry: An investigation of reliability, minimal detectable change, and time to peak force generation ☆

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Abstract

Purpose: Dynamometry is an objective tool for volitional strength evaluation that may overcome the limited sensitivity of the Medical Research Council scale for manual muscle tests, particularly at grades 4 and 5. The primary aims of this study were to investigate the reliability, minimal detectable change, and time to peak muscle force, measured with portable dynamometry, in critically ill patients.

Materials and methods: Isometric hand grip, elbow flexion, and knee extension were measured with portable dynamometry.

Results: Interrater consistency (intraclass correlation coefficient [95% confidence interval]) (0.782 [0.321-0.930] to 0.946 [0.840-0.982]) and test-retest agreement (0.819 [0.390-0.943] to 0.918 [0.779-0.970]) were acceptable for all dynamometry forces, with the exception of left elbow flexion. Despite generally good reliability, a mean change (upper 95% confidence interval) of 2.8 (7.8) kg, 1.9 (5.2) kg, and 2.6(7.1) kg may be required from a patient's baseline force measurement of right grip, elbow flexion, and knee extension to reflect real force changes. There was also a delay in the time for critically ill patients to generate peak muscle forces, compared with healthy controls ($P \leq .001$).

Conclusions: Dynamometry can provide reliable measurements in alert critically ill patients, but moderate changes in strength may be required to overcome measurement error, during the acute recovery period. Deficits in force timing may reflect impaired neuromuscular control.

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1. Introduction

Muscle weakness may contribute to both short- and long-term morbidity in survivors of a critical illness, but the clinical estimation of strength with manual muscle tests can be challenging. Intensive care unit–acquired weakness (ICUAW) [1] may be present at awakening in 25% of patients who have required mechanical ventilation for at least 5 days [2] and has been associated with both increased hospital mortality [2] and delayed successful extubation [3]. Although tests of volitional muscle strength are used at the bedside in clinical practice and in both observational studies and randomized controlled trials of early exercise in patients from the time of awakening to the post intensive care unit (ICU) period [2-9], they may be affected by patients' effort, alertness, and motivation. Thus, during the initial stages of the recovery spectrum where these confounders can be particularly pronounced, the reliability, measurement error, and sensitivity of strength tests are key to objective quantification and reevaluation of ICUAW [10].

The Medical Research Council (MRC) 0-to-5 scale [11] and summated score [1,12] may afford reliable grading of manual muscle tests in patients with Guillain-Barre syndrome [12] and several other populations who have required intensive care [2,4,5]. However, the MRC scale is an ordinal measure limited by its sensitivity at the higher grades [13]. It was originally designed for the examination of peripheral nerve lesions [11], and as polyneuropathy can be a component of ICUAW, the 0-to-3 MRC scale grades may provide adequate scoring options for strength assessment in patients with profound weakness. However, as demonstrated in a sample of critically ill patients, the higher MRC grades of average muscle strength encompass a large range of hand grip forces when measured with dynamometry [2], indicating a lack of differentiation between grades that may undersell strength graduations. Moreover, the difficulty of differentiating between MRC scale grades 4 and 5 has been suggested [14] as a reason for variable MRC score interrater reliability, in patients recovering from a critical illness [4]. While there is a paucity of data linking muscle strength to objective measures of physical function in the critically ill, it is possible that people with mild or no weakness according to the MRC scale could still have either weakness relative to their baseline or limited function because of impairments in associated elements of neuromuscular control. This may include the timing of force generation, which has not been previously investigated in the critically ill.

Dynamometry is the standard method of volitional muscle force measurement and may overcome some limitations of the MRC scale. While dynamometry is often regarded to have inadequate dynamic range for use in patients with very weak muscles [10,15,16], handheld devices are most applicable in the strength range of MRC grades 4 and 5. Nonetheless, with the exception of hand grip gauges, strength assessment with portable devices may be limited by examiners' ability to provide sufficient resistive force to stronger subjects or weaker subjects' inability to stabilize nontested joints within the same limb. Still, portable/handheld force gauges have been successfully used to measure both hand grip and knee extension in studies of critically ill patients [2,6-9]. However, both the change in strength required to overcome the measurement error associated with dynamometry and the test-retest reliability to ensure adequate consistency remain unknown. Indeed, the study of the reliability of dynamometry in the ICU has been limited to 1 interrater investigation [17].

Therefore, we aimed to investigate both the test-retest and interrater reliability of a muscle strength assessment with portable dynamometry in survivors of a critical illness. We also aimed to examine the minimal detectable difference (MDD) in force required to mitigate measurement error. To ascertain if the pattern of force production, as measured by the time of peak force generation, was altered in critically ill patients, healthy controls were additionally sampled. Finally, to enable a comparison with existing literature, we sought to depict forces according to MRC scale.

2. Materials and methods

This research conformed to the principles of the Declaration of Helsinki and was approved by the Southern Adelaide Health Service/Flinders University Human Research Ethics Committee (no. 277/09), including procedures for informed consent. A repeated-measures methodology was applied to assess both the interrater and test-retest reliability of peripheral muscle strength. Interrater reliability was assessed using 2 physiotherapists (examiner A and B), who completed the protocol 2 to 4 hours apart on the same day and were blinded to each other's results. The protocol was then repeated by examiner A 2 days later, so test-retest reliability could be investigated against the initial measurements made by examiner A. On each test day, the alertness and attention of critically ill subjects was assessed with the Richmond Agitation And Sedation Scale (RASS) [18] and Attention Screening Examination (ASE) [19].

2.1. Subjects

Critically ill patients were systematically screened from a single tertiary ICU from November 2009 to March 2010 inclusive. All consecutive patients who were 18 years or older with an ICU length of stay of 5 days or more and anticipated hospital admission of a further 3 days in the opinion of the treating physician were identified. Patients were excluded if they had an absolute contraindication that prevented peripheral muscle strength testing, a limitation to assessing the strength of more than 2 limbs, a preexisting confounder of hand grip function, an acute or preexisting neurologic condition, a cognitive/intellectual/psychiatric