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Single measurement reliability and reproducibility of volitional and magnetically-evoked indices of neuromuscular performance in adults

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Abstract

This study documents intra-session and inter-day reproducibility (coefficient of variation [*V*%]) and single measurement reliability (intra-class correlations [R_I]; standard error of a single measurement [SEM%] [95% confidence limits]) of indices of neuromuscular performance elicited during peripheral nerve magnetic stimulation. Twelve adults (five men and seven women) completed 3 assessment sessions on 3 days, during which multiple assessments of knee flexor volitional and magnetically-evoked indices of electromechanical delay (EMD_V; EMD_E), rate of force development (RFD_V; RFD_E), peak force (PF_V; P_TF_E), and compound muscle action potential latency (LAT_E) and amplitude (AMP_E) were obtained. Results showed that magnetically-evoked indices of neuromuscular performance offered statistically equivalent levels of measurement reproducibility (*V*%: 4.3–31.2%) and reliability (R_I: 0.98–0.51) compared to volitional indices (*V*%: 3.7–25.2%; R_I: 0.98–0.64), which support the efficacy of both approaches to assessment and the indices PF_V, EMD_V, EMD_E and LAT_E offer the greatest practical utility for assessing neuromuscular performance.

Keywords: Magnetic stimulation; Reproducibility; Reliability; Neuromuscular performance

1. Introduction

Contemporary empirical research spans a continuum of demands that include the need for effective evaluation of ipsilateral and contralateral limb difference in performance capabilities within a single test session, and the evaluation of treatment interventions over time. Each research application (e.g. intra-session vs. inter-day) represents unique challenges in the selection of an appropriate test protocol to enable sufficient precision of measurement to facilitate confident discrimination between performances (Altman, 1991; Mercer and Gleeson, 2002). Neurological abnormality associated with peripheral magnetic stimulation of motor nerves may need to be diagnosed on the basis of contralateral transmission latency differences of only 1.5 ms, corresponding typically to an 11% deficit (Chokroverty et al., 1993). Discrimination of changes in the performance levels of the elite strength athlete may be similarly demanding of experimental design sensitivity, given that strength performance might be expected to vary by only ±5% over the competitive season (Gleeson and Mercer, 1992). While participant numbers can be manipulated to achieve a desired level of experimental power for inter-group treatment comparisons (Lipsey, 1990), contemporary clinical practice frequently dictates the necessity for a case-study approach. Appropriate protocol considerations include the number of required inter- and intra-session replicates; estimates of which are calculated on the basis of the reproducibility and reliability characteristics of the performance indices of interest. However, the variability of intra-session estimates of neuromuscular performance is frequently less

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than that associated with inter-day comparisons (Gleeson and Mercer, 1992; Polkey et al., 1996; Vivodtzev et al., 2005) and as such, calculation of reliability based principally on intra-session measures may overestimate the available precision of measurement and fail to account fully for the biological variability inherent in between-day neuromuscular performance assessments (Gleeson et al., 2002).

Indices of neuromuscular performance, such as peak force, the speed by which muscle force can be initiated (electromechanical delay) and the rapidity with which meaningful levels of force can be mustered (rate of force development), can provide markers of the dynamic capabilities available during mechanical loading of a particular joint system (Gleeson et al., 1997; 1998a,b; 2000; Johansson, 1991; Mercer et al., 1988; Rees, 1994). Optimal functioning of the knee flexors in particular is considered fundamental to the prevention of ACL injury (Gleeson and Mercer, 1996; Johansson, 1991; Rees, 1994). Methodologically diverse investigations have examined the reproducibility of peak force of the thigh musculature subsequent to volitional muscle activation and have reported intra-day coefficients of variation (V%) of 4.1% (Viitasalo et al., 1980) and inter-day V% scores of 6.6% (Gleeson et al., 2002) for the knee extensors and flexors, respectively. Other indices of neuromuscular performance such as electromechanical delay (EMD) have received less scrutiny. A wide range of absolute EMD values reported in the literature for the same muscle (38.0–106.0 ms for the rectus femoris (Vos et al., 1991; Zhou et al., 1996, respectively) has been interpreted by some researchers to represent an inherent variability of this index (Bochdansky et al., 2000). This is despite reports of good intra-day reliability ($r = 0.93$ (Viitasalo et al., 1980)) and reasonable measurement reproducibility (V%: 6.1% (Gleeson et al., 1998b); 8.2% (Viitasalo et al., 1980)) and the likelihood that diverse methodologies may have differentially influenced the magnitude of EMD scores. Further investigation is warranted to elucidate the levels of intra-day and inter-day reproducibility and reliability that might be expected of this index and, whether these measurement characteristics differ systematically between volitionally-derived and evoked indices of neuromuscular performance.

Several authors have utilised magnetic stimulation techniques in the estimation of the performance capacity of the neuromuscular system (e.g. Barker et al., 1987; Chokroverty et al., 1993; Evans et al., 1988; Polkey et al., 1996; Vivodtzev et al., 2005; Zhu et al., 1992) and in the diagnosis of neurological abnormality (Benecke, 1996; Murray, 1991). Magnetic stimulation of a peripheral motor nerve activates the fast motor units (Maertens de Noordhout, 1991) and has become popular as a painless alternative to electrical stimulation for assessing true maximal neuromuscular performance (Gleeson, 2001; Hopkins and Ingersoll, 2000; Zhou et al., 1995). Only limited information is available in the contemporary scientific literature regarding the reproducibility and reliability characteristics of indices of neuromuscular performance associated with magnetic stimulation. Polkey et al. (1996) reported intra-day and inter-day coefficient of variation (V%) scores of 3.6% and 8.5%, respectively, for maximum twitch tension of the knee extensors subsequent to magnetic stimulation of the femoral nerve. Hamnegard et al. (2004) reported an intra-day V% of 6.7% for knee extensor peak twitch force.

The aim of this study is to examine the intra-session and inter-day reproducibility and single measurement reliability of indices of voluntary and magnetically-evoked neuromuscular performance of the knee flexors in adults.

2. Methods

2.1. Participants

Twelve adults (5 men, 7 women; [mean ± SD], age 27.4 ± 7.9 years; height 1.73 ± 0.06 m; body mass 68.9 ± 8.3 kg) gave their informed consent and participated in this study. All participants were regularly involved in exercise (at least 3-times per week) and were asymptomatic at the time of assessment. Participants were instructed to refrain from strenuous physical activity for the 24 h prior to each test. Four participants of an original sample size of sixteen had been excluded from the study on the basis that they had not reached validity criteria for responses during magnetically-evoked muscle activation (described subsequently). Assessment protocols were approved by the Ethics Committee for Human Testing of the University of Wales, Bangor.

2.2. Participant and dynamometer orientation

Participants were secured in a prone position on a custom-built dynamometer (modified from Gleeson et al. (1995)). The bi-lateral lever-arms of the dynamometer were attached to the legs of the participant by means of padded ankle-cuffs and adjustable strapping just proximal to the lateral malleolus. The dynamometer and knee joint's axes of rotation were aligned as closely as possible. Adjustable strapping across the mid-thoracic spine, pelvis and posterior thigh proximal to the knee localised the action of the involved musculature. A functionally relevant knee flexion angle of 25° (0.44 rad) associated with the greatest mechanical strain on key ligaments (Beynnon and Johnson, 1996), was maintained throughout testing. This angle was identified for each participant during activation of the involved musculature using a goniometer system. Once secured into position and prior to testing, participants were required to perform a series of warm-up muscle activations, comprising of 2 × 50%, 75% and 100% of subjectively-judged maximal voluntary peak force. Each of the activations was sustained for 3 s and was separated from the next by 10 s. A period of approximately 2 min separated the cessation of the warm-up and the commencement of testing. The orientation of the participant and dynamometer is illustrated schematically in Fig. 1.