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EMG normalization method based on grade 3 of manual muscle testing: Within- and between-day reliability of normalization tasks and application to gait analysis

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ABSTRACT

Electromyography (EMG) is an important parameter in Clinical Gait Analysis (CGA), and is generally interpreted with timing of activation. EMG amplitude comparisons between individuals, muscles or days need normalization. There is no consensus on existing methods. The gold standard, maximum voluntary isometric contraction (MVIC), is not adapted to pathological populations because patients are often unable to perform an MVIC. The normalization method inspired by the isometric grade 3 of manual muscle testing (isoMMT3), which is the ability of a muscle to maintain a position against gravity, could be an interesting alternative. The aim of this study was to evaluate the within- and between-day reliability of the isoMMT3 EMG normalizing method during gait compared with the conventional MVIC method. Lower limb muscles EMG (gluteus medius, rectus femoris, tibialis anterior, semitendinosus) were recorded bilaterally in nine healthy participants (five males, aged 29.7 ± 6.2 years, BMI 22.7 ± 3.3 kg m^{-2}) giving a total of 18 independent legs. Three repeated measurements of the isoMMT3 and MVIC exercises were performed with an EMG recording. EMG amplitude of the muscles during gait was normalized by these two methods. This protocol was repeated one week later. Within- and between-day reliability of normalization tasks were similar for isoMMT3 and MVIC methods. Within- and between-day reliability of gait EMG normalized by isoMMT3 was higher than with MVIC normalization. These results indicate that EMG normalization using isoMMT3 is a reliable method with no special equipment needed and will support CGA interpretation. The next step will be to evaluate this method in pathological populations.

1. Introduction

Clinical gait analysis (CGA) is a medical examination that quantifies gait deviations in patients with complex gait disorders [1]. Measurement tools used for CGA usually comprise a three-dimensional motion system, with force plates, videos and electromyography (EMG) sensors. Taken together, these measurements are used to quantify gait kinematics, kinetics of the lower and upper body, and the EMG pattern of lower-limb muscles. Among these tools, EMG plays an important role in CGA [2] by quantifying muscle recruitment patterns and supporting the understanding of neuromuscular gait control. EMG analysis can provide information about the level and distribution of dynamic muscle activity. Furthermore, EMG analysis coupled with kinematics and kinetics can help us to better understand whether and how musculoskeletal system impairment contributes to abnormal movement [3].

The interpretation of EMG in CGA is usually limited to raw signal inspection and timing of activation, based on normal electromyographic patterns [4]. It enables identification of left/right asymmetry, and out-of-phase or absence of contraction, such as co-contraction and spasticity [5–7]. The EMG profile during gait must consider both the timing and relative amplitude of the EMG signal representation [8]. Indeed, EMG signal amplitude could improve CGA interpretation by adding to the timing of activation an additional dimension related to muscle strength [9].

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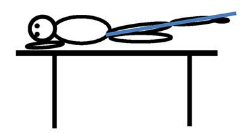
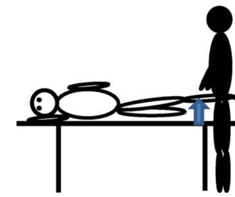
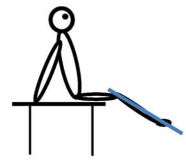
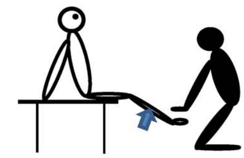
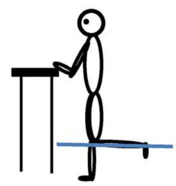
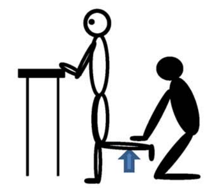
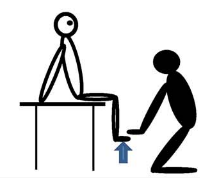
Muscle	Position	IsoMMT3	MVIC
Gluteus medius	Side-lying with uppermost limb hip and knee flexed to 0° and lies across the lowermost limb with foot resting on the table and hip and knee flexed to 45°; uppermost hip abducted at 0°.		
Rectus femoris	Short sits with pad under the distal thigh to maintain the femur in horizontal position; hands rest on the table on either side of the body for stability and may grasp the table edge; knee extended through available range of motion not beyond 0°.		
Semi-tendinosus	Stand in orthostatic position with hands on a table for stability; knee flexed at 90° and the other leg is straight and the pelvis is horizontal.		
Tibialis anterior	Short sits with pad under the distal thigh to maintain the femur in the horizontal position; hands rest on the table on either side of the body for stability and may grasp the table edge; tibia aligned with the vertical and ankle flexed at 0°.		

Fig. 1. Participant positions for each muscle tested (gluteus medius, rectus femoris, semitendinosus and tibialis anterior) in the isoMMT3 and MVIC exercises adapted from Hislop et al., 2014 [18].

To compare EMG amplitude between individuals, between muscles and/or between days, normalization is needed [10,11] because of anatomical and physiological factors that are recognised to significantly influence EMG amplitude [12]. Normalization of EMG signals is achieved by dividing the EMG envelope from the task under investigation by a discrete value (mean or maximum) from a reference contraction of the same muscle. Instead of being presented in μV or mV, the normalized EMG amplitude is hence expressed as a percentage of the reference value.

The International Society of Electrophysiology and Kinesiology (ISEK), adopting the recommendations of Merletti [13] on the *Standards for Reporting EMG Data* [13], specifies that it is common to normalize force/the moment of force and the respective EMG relative to a maximum voluntary isometric contraction (MVIC) [13].

This method is not suitable for some pathological populations [11,14,15], however, as MVIC cannot be reached because of the difficulty of recruiting muscles (due to selectivity problems in central lesions) and pain level [14,16]. MVIC is also dependent on training [13,17] and may be affected by psychological factors, such as motivation [17].

To solve this issue, various alternative normalization methods have been proposed, but there is no clear consensus. A systematic review concluded that sub-maximal voluntary isometric contraction (subMVIC) methods provide outputs with good reliability, whereas MVIC methods provide poor reliability [11]. Methods using the EMG directly from the task under investigation to normalize EMGs from that task (i.e., the mean or maximum value of EMG envelope during the investigated task) reduce within-day inter-individual variability, but intra-individual variability with these methods is similar to un-normalized EMG [11]. Even if these methods yield the most homogeneous pattern of muscle activity during gait, they are not relevant for understanding the amplitude aspect of EMG signal because they remove the true variation of EMG amplitude and do not provide information about the degree of muscle activation required during gait [11].

Indeed, a potential subMVIC method could be used to normalize EMG using the ability of the patient to maintain an anatomical segment against the force of gravity. This alternative method is an isometric normalization task inspired by grade 3 of manual muscle testing (isoMMT3). The corresponding MVIC method inspired by grade 5 of manual muscle testing (isoMMT5) [18] will be considered the reference method during the current study. Interestingly, the isoMMT3 method seems promising from a practical perspective as there is no need for any specific equipment, and it is faster and easier to perform than MVIC, particularly in pathological populations. However, the feasibility and reliability of this method must be established before it can be used in clinical practice.

Therefore, the aim of the present study was two-fold:

(1) to evaluate the within- and between-day reliability of isoMMT3 normalization tasks compared with an MVIC method; and
(2) to assess between-day reliability of the gait EMG linear envelope (EMG_LE) normalized by isoMMT3 and MVIC methods.

2. Methods

2.1. Participants

Nine healthy volunteers (five male, four female; age: 29.7 ± 6.2 years; height: 1.73 ± 0.94 m; body mass: 68.6 ± 12.9 kg; body mass index [BMI]: 22.7 ± 3.3 kg m^{-2}) were