College of Public Health and Human Sciences

DEVELOPMENT OF A METHOD TO QUANTITATIVELY MEASURE ARTHROGENIC MUSCLE INHIBITION IN THE PERONEALS

Whitley F Nelson, Yu-lun Huang, Samuel T Johnson, Marc F Norcross

BACKGROUND

After a joint injury, arthrogenic muscle inhibition (AMI) leads to decreased neuromuscular control and strength, as neural inhibition prevents volitional activation of the entire motor neuron pool. This results in an inability to fully activate the muscle and can lead to increased muscle atrophy and joint instability due to a lack of proper neuromuscular control. AMI is suggested to occur following joint injury due to inflammation and alterations in afferent information from mechanoreceptors surrounding the joint, causing pre-synaptic inhibition which results in AMI (Rice & McNair, 2010; Hopkins & Ingersoll, 2000).

Traditional rehabilitation techniques such as strength training are unable to effectively reduce AMI and it has been demonstrated that AMI persists following rehabilitation (Palmieri-Smith, Hopkins, & Brown, 2009). Given this and the prolonged muscular weakness and instability associated with AMI, there is a need to identify interventions that can improve neuromuscular function in those with AMI.

Clinically, Kinesio Tape® is commonly used by sports medicine practitioners to attempt to achieve this neuromuscular improvement. Kinesio Tape® provides sensory stimulation through the activation of cutaneous mechanoreceptors and this is thought to facilitate efferent neuromuscular control and activation through the increased activation of sensory afferent stimuli (Akbaş, Atay, & Yüksel, 2011; Yoshida & Kahanov, 2007). However, whether Kinesio Tape® can reduce AMI has not been established in past research. This may be due in part to previous studies utilizing healthy study subjects who did not demonstrate a neuromuscular deficit.

PURPOSE

Research has demonstrated that those with functional ankle instability (FAI) exhibit AMI (Palmieri-Smith et al. 2009; McVey, Palmieri, Docherty, Zinder, & Ingersoll, 2005), and thus the overarching purpose of the present project is to determine whether Kinesio Tape® can reduce AMI in those with FAI. However, the completion of this aim requires that AMI can be accurately measured in the peroneal muscles of individuals with FAI. While previous research described the use of the H_{max}:M_{max} ratio as a measure of inhibition (Palmieri-Smith et al. 2009), pilot testing in our laboratory identified a limitation to this method and required the development of an alternative method to quantitatively measure AMI consistently.

CHALLENGES WITH H:M RATIO

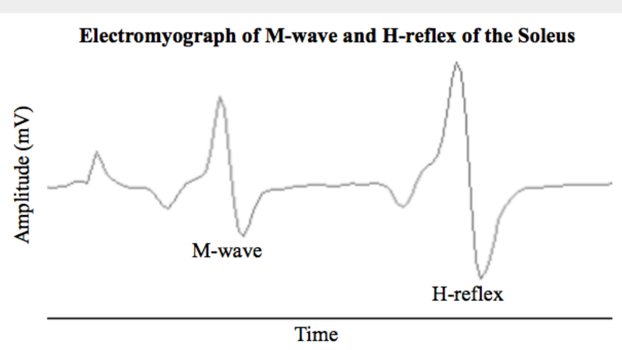

Figure 1: Typical M-wave and H-reflex in the Soleus muscle following stimulation

Using the H_{max}:M_{max} ratio as a means to assess neuromuscular inhibition requires using a short, low intensity electrical stimulus to elicit a monosynaptic reflex, known as the H-reflex (Palmieri-Smith et al. 2009). As this stimulus intensity is sequentially increased, the magnitude of the H-reflex diminishes while the magnitude of the M-wave, which is reflective of the degree of motor unit pool activation, increases. The changes in H-reflex and M-wave magnitudes, in response to different stimulus intensities can be graphed on a recruitment curve as seen in Figure 2. As stimulus intensity is increased, the M-response should eventually plateau, illustrating M_{max} or the maximal motor unit activation. However, when we applied this method to the peroneals in the laboratory during pilot testing, we were unable to achieve a consistent H-reflex, or a plateau of the M-wave before we reached maximal stimulus intensity as seen in Figure 3.

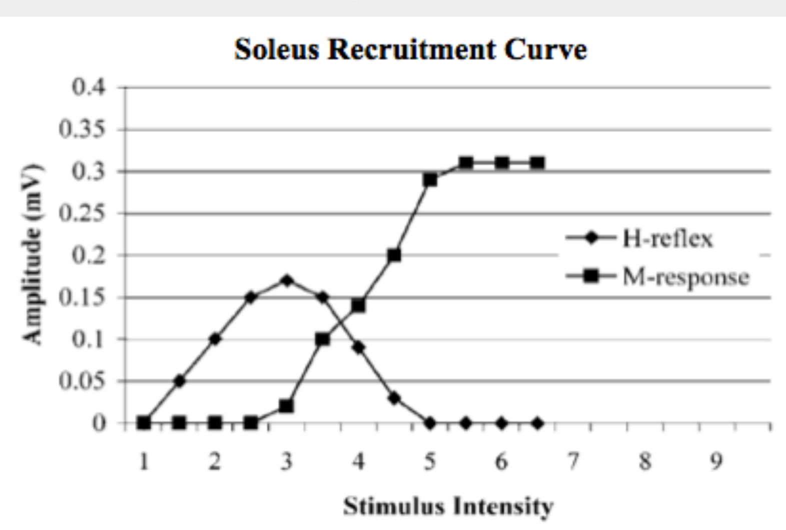

Figure 2: Soleus Recruitment Curve which illustrates the expected plateau in M_{max} (Adapted from Palmieri-Smith et al. 2009).

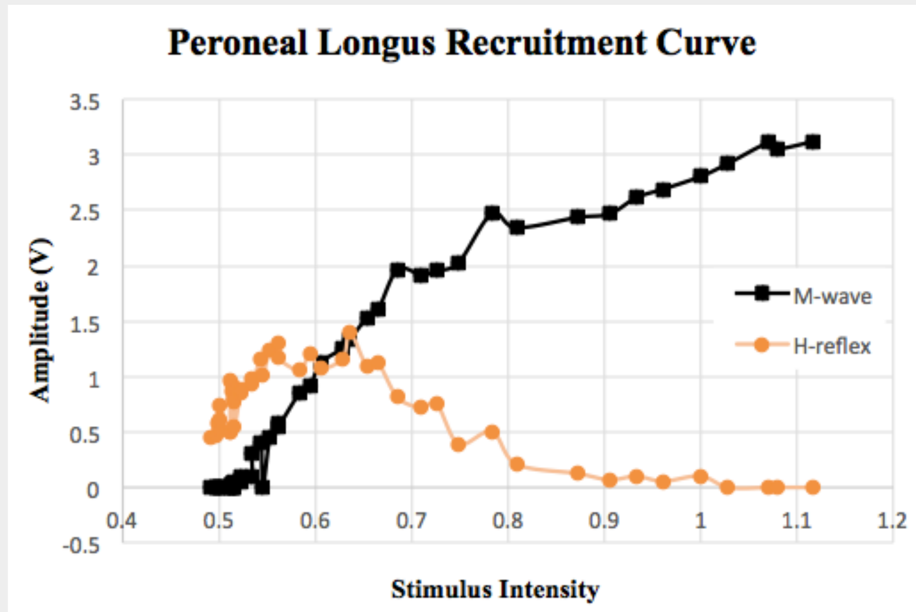

Figure 3: Exemplar Peroneal Longus Recruitement Curve from pilot testing. Note that in contrast to Figure 2, the M-wave steadily increases and fails to reach a plateau.

Given this, we were not confident that M_{max} was actually obtained and concluded that using the H_{max}:M_{max} ratio technique would not be an appropriate method to evaluate AMI.

ADAPTATION OF CAR

After the H-reflex was unable to consistently measure AMI, the central activation ratio (CAR) of the muscle was then identified as an alternate method for quantifying AMI. This method has been successfully used for the quadriceps muscles, but it has not previously been applied to the peroneal muscles.

The peak torque produced by a maximal voluntary isometric muscle contraction (MVIC) can be measured using a Biodex dynamometer. This value reflects the portion of the motor neuron pool that can be volitionally activated. When a superimposed burst of electrical stimulation is applied to the muscle or nerve as a person is performing an MVIC, any inhibited motor units will be activated, resulting in an increase in torque production (Pietrosome, Park, Gribble, Pfile & Tevald, 2012). As shown in Figure 4, the ratio between the torque produced by the voluntary contraction to the torque produced with the superimposed burst can be calculated and is termed the central activation ratio (CAR). This value represents the percentage of motor units that are uninhibited and can be used to quantify the extent of AMI. If a clinical intervention improves neuromuscular function and decreases AMI, then CAR will increase representing an increase in the number of uninhibited motor units.

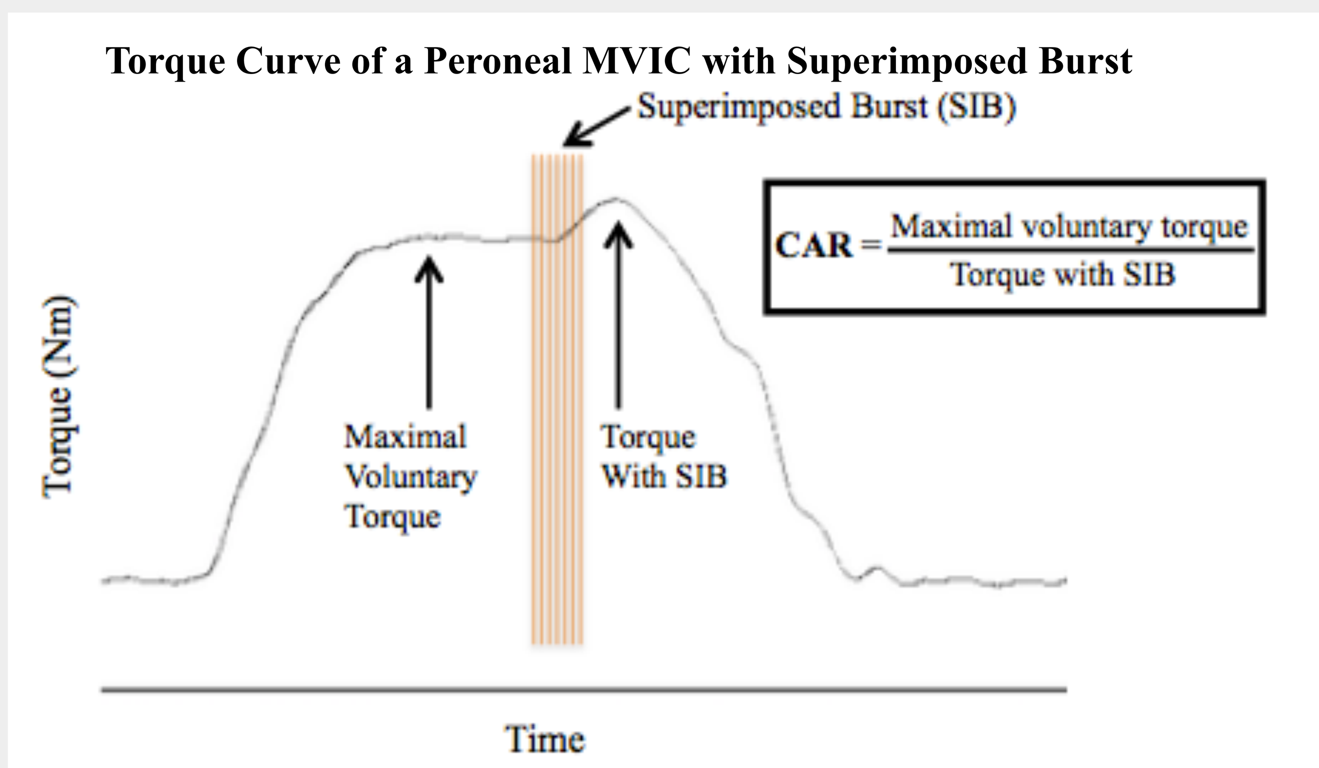

Figure 4: Typical torque-time curve showing torque produced by maximal voluntary isometric contraction (MVIC) alone and with a superimposed burst of electrical stimulation (SIB). The difference in the maximal torque produced by the subject during MVIC and the torque produced by the addition of the SIB illustrates AMI. Using these torque values, we can then calculate the central activation ratio (CAR) in order to quantify AMI.

Applying this methodology to the peroneal muscles required multiple adaptations and trials to ensure that AMI was consistently and reliably measured. Several of these challenges are outlined below:

- Appropriate electrode placement to consistently activate the peroneals
- Accounting for placement of Kinesio Tape® for the study design
- Pilot testing illustrated that full knee extension during the MVIC trials could be too uncomfortable for participants and we realized there needed to be timed breaks scheduled into the testing procedure
- Using multiple trials to calculate an average MVIC torque, to create a threshold for ensuring subjects plateau during the voluntary contraction prior to receiving the SIB

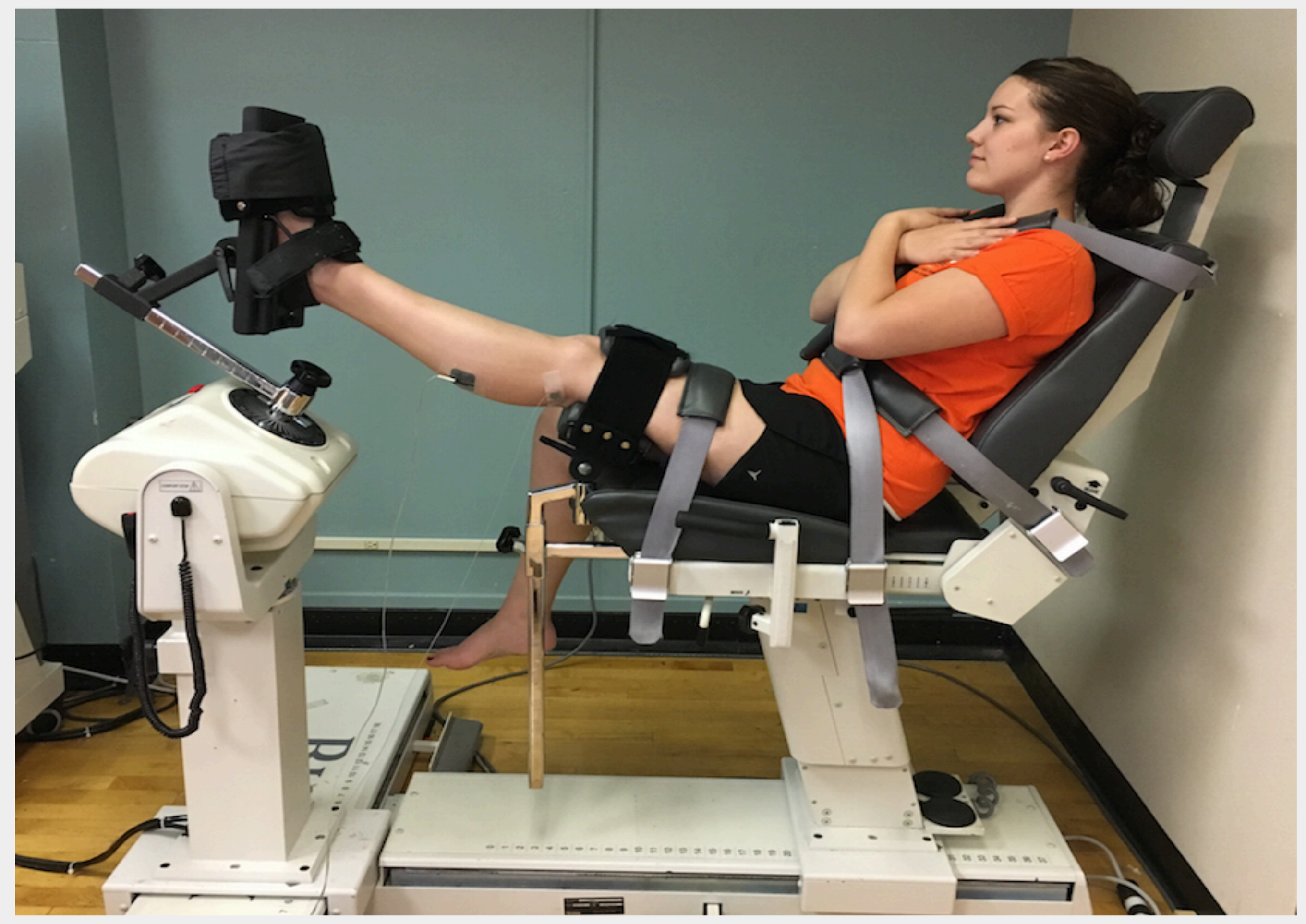

Figure 5: Final testing position and electrode placement for subjects on the Biodex dynamometer. Positioning allows for evaluation of ankle eversion torque during a MVIC with a SIB.

CONCLUSION

In summary, the central activation ratio method of measuring AMI was successfully adapted to the peroneal muscles. This adaptation now makes it possible to quantify the amount of inhibition of this muscle group. As such, we can now evaluate the efficacy of a clinical intervention consisting of an extended application of Kinesio Tape® and rehabilitation exercises for decreasing AMI and facilitating improved neuromuscular function in individuals with FAI.

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Oregon State University