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# Daily muscle vibration amelioration of neural impairments of the soleus muscle during 2 weeks of immobilization

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ABSTRACT

V-wave, F wave and H-reflex responses of soleus were used to determine neural adaptations to 2-week immobilization and whether muscle vibration intervention during immobilization would attenuate the negative adaptations induced by immobilization. Thirty subjects were divided into the ankle immobilization group and the immobilization with muscle vibration group. Mechanical vibrations with constant low amplitude (0.3 mm) were applied (12 × 4 min daily) with a constant frequency of 100 Hz on the soleus muscle of the subjects in vibration group during the ankle immobilization period. Soleus maximal M-wave (Mmax) and H-reflex (Hmax) were evoked at rest. F-wave was recorded by supramaximal stimulation delivered at rest and V-wave during maximum voluntary contraction (MVC). The EMG during MVC was represented by its root-mean-square (RMS) value. Each subject was examined before and after 2 weeks of immobilization. Results showed that following 2 weeks of immobilization, Mmax, Hmax and F wave all did not change with immobilization in either group ($P > 0.05$). After 2 weeks of immobilization, significant reductions in V/Mmax (of 30.78%) ($P < 0.01$) and EMG RMS (24.82%) ($P < 0.001$) were found in the immobilization group. However, no significant changes occurred in the immobilization with muscle vibration group. Such findings suggested that 2 weeks of immobilization resulted in neural impairments as evidenced by the reduction in EMG and V wave, and that such decrease was prevented by the intervention of muscle vibration during the immobilization period.



## 1. Introduction

Immobilization is a frequently used treatment for musculoskeletal injuries and plays an important role in the rehabilitation of diseases. However, a number of problems, such as reductions in muscle mass, strength, and motor performance (Berg and Tesch, 1996; Duchateau, 1995; Kawakami et al., 2001; Seki et al., 2001) can emerge from this form of treatment. Although the mechanisms involved in the negative adaptations are caused by a variety of factors, reduced neural drive of the muscle from the central nervous system (Cruz-Martinez et al., 2000; Deschenes et al., 2002; Gondin et al., 2004; Hortobagyi et al., 2000; Lundbye-Jensen and Nielsen, 2008a; Miles et al., 1994; Seki et al., 2007) seems to play a determinant role in the early stages of immobilization. Some studies have also reported that neural changes also account for the majority of the recovery in muscle motor performance following immobilization (Pathare et al., 2006; Stevens et al., 2006; Vandenborne et al., 1998). Such findings suggest the possibility that improvements in neural function can delay or reduce the loss in muscular performance. Therefore, finding some effective measures is necessary to guard against the occurrence of neural function impairments.

Muscle vibration is a powerful tool for the stimulation of proprioceptors. Recently, numerous studies have investigated the use of vibration in improving motor control. Periods of vibration that markedly increase the excitability of neural circuits, which control the motor output to the stimulated muscles, are well documented (Binder et al., 2009; Claus et al., 1988; Forner-Cordero et al., 2008; Fourment et al., 1996; Siggelkow et al., 1999; Smith and Brouwer, 2005; Steyvers et al., 2003a). However, whether the acute effects of muscle vibration can be translated into long-term changes following repeated vibrations at regular intervals is not clear yet. If it is the case, then a designed muscle vibration to the immobilized limb can be hypothesized to attenuate the decline in muscle activation developed during immobilization.

The Hoffman reflex (H-reflex) is mainly a monosynaptic reflex caused by activation of group Ia afferent fibers from muscle spindles. Maximal H-wave amplitude (Hmax) compared with maximal muscle compound action potential (M-wave) has been generally used to assess the excitability of spinal motoneurones (Funase et al., 1996;

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Taborikova and Sax, 1968). Many investigations have examined H-reflex activity following unloading interventions in humans and have reported either significant increases (Clark et al., 2006a; Duchateau, 1995; Lundbye-Jensen and Nielsen, 2008a,b) or no changes (Kaneko et al., 2003; Lambertz et al., 2003). The lack of consistency in the results of these studies may be due to the conditions under which the H-reflexes were obtained.

An important characteristic of the H-reflex is that it declines as the stimulus to the nerve is increased beyond a certain level; at supramaximal stimulus, the H-wave disappears (Upton et al., 1971). This reduction in the H-reflex is due to the collision between the orthodromic and antidromic impulses (generated by $\alpha$-motor axon stimulation) in motor axons. When a supramaximal electrical stimulus is applied to the nerve during voluntary contraction, an increased number of voluntary motor impulses result in increased incidence of antidromic collision, which allows more motoneuron axons to be cleared for the passage of the evoked reflex response, and as a result the H-reflex volley is allowed to pass to the muscle, where it is recorded as a so-called V-wave (Aagaard et al., 2002; Upton et al., 1971). Such response has been used increasingly in recent years to study spinal and supraspinal adaptations to strength training (Del Balso and Cafarelli, 2007; Gondin et al., 2006; Racinais et al., 2007; Aagaard et al., 2002). However, to our knowledge, this response has never been used to study neural adaptations to muscle vibration despite its advantageous influences in spinal and cortex excitability.

As an electrophysiological variant of H-reflex, a change in V-wave amplitude may result from the changes occurring at both spinal and supraspinal levels. Modulations in H-reflex responses could be ascribed to spinal mechanisms, and thus a concomitant analysis of these types of evoked responses would help to better explore the mechanism involved in neural alterations. When it comes to the H-reflex and V-wave modulations, we have to take into account that the supramaximal level of nerve stimulation used during the recording of V-wave also causes massive excitation of all afferent axons in the peripheral nerve. As a result, the evoked V-wave response will recruit both large and small motoneurons, whereas H-reflex primarily relies on the pool of smaller motoneurons (Aagaard et al., 2002; Duclay and Martin, 2005; Gondin et al., 2006). In addition to the activation of large afferents fibers, stimulation of a mixed nerve (supra-maximal for motor fibers) results in activation of peripheral motor fibers. The impulse could propagate orthodromically to the corresponding muscle and antidromically to the spinal motoneurones. The orthodromic potential elicits an M wave, whereas the antidromic potential results in a recurrent discharge (‘backfiring’) of some motoneurones which finally lead to a late F-wave response in the test muscle. F wave is another typical tool to assess the excitability of the motor neuron pool (Dengler et al., 1992; Fox and Hitchcock, 1987). Therefore, this study intended to use V-wave, F wave and H-reflex to detect neural adaptations to 2-week immobilization and to assess the effectiveness of muscle vibration in attenuating the neural impairments induced by immobilization.

## 2. Materials and methods

### 2.1. Subjects

The experiments were performed on 30 neurologically intact human subjects (17 males and 13 females) aged 18–46 years old. These subjects were randomly assigned into two groups: immobilization group (IMM) and immobilization with muscle vibration group (IMM-MV). All subjects gave their informed written consent to the experimental procedure, as approved by the local ethics committee. Each subject was examined on the day the cast was applied, and the same test was repeated after 2 weeks of immobilization.

### 2.2. Immobilization

At the end of the pre-test, a plaster cast was placed by the orthopedic surgery department staff. The subject’s right ankle and foot were covered by two layers of cotton padding. The cast was positioned around the ankle, foot, and toes, maintaining the ankle joint in a neutral position. Subjects were instructed to elevate their immobilized legs most of the time and to limit their use as much as possible, especially avoiding foot plantar flexion. However, they were given crutches to allow mobility. After 2 weeks of immobilization, the cast was removed by the experimenter immediately before the beginning of the post-test. To make all subjects of both groups had similar levels of activity during the study, we visit them daily and monitor the overall level of activity.

### 2.3. Muscle vibration

Beginning the day following immobilization, subjects in the IM-MV group received muscle vibrations. Vibrations were delivered by a handheld vibrator with a 1.0-cm diameter probe driven by a sinusoidal signal generator coupled with a power amplifier. The vibrator was positioned and pressed lightly by the experimenter on the soleus muscle belly. The vibration amplitude was adjusted to 0.3 mm from peak to peak, and the frequency was fixed at 100 Hz. Four series of 1 min vibrations were applied with 1 min rest intervals in-between. This cycle was repeated thrice for a total of 30 min at 2 min intervals. This protocol was adopted four times a day and was applied at 8 AM, 12 PM, 4 PM, and 8 PM, respectively. This vibration intervention continued until the night before the post-test.

### 2.4. Electromyography (EMG)

All pre- and post-immobilization tests were performed by the same electromyographer, who was blinded to the subject group. Subjects were in a supine position with the thighs supported to flex the knees at 120°; the ankle joints were kept flexed at 90°. The position ensured that the muscle was relaxed. Testing the reflexes in the same joint positions in the pre- and post-immobilization experiments was also necessary.

After careful preparation of the skin (i.e., shaving, abrasion, and cleaning with alcohol), soleus muscle EMG activity was recorded using bipolar silver-chloride circular electrodes with a diameter of 10 mm and an interelectrode distance of 20 mm. The recording electrodes were placed along the mid-dorsal line of the leg, 5 cm distal from where the two heads of the gastrocnemius join the Achilles tendon for the soleus. The locations were carefully measured in each subject to ensure positioning consistency across testing sessions.

At the start of the experiment, subjects were instructed to contract the right plantar flexors as hard and fast as possible 4–6 times for 5 s at 120 s intervals. EMG corresponding to the maximum voluntary contraction (MVC) level in each subject was determined (EMGmvc), represented as a root-mean-square (RMS) value. The EMG signals were preamplified and band-pass filtered at 20 Hz–2 kHz (P511 Grass Instruments, AstroMed) and a common mode rejection ratio >100 dB.

### 2.5. H-reflex recordings

The H-reflex was evoked by percutaneous bipolar stimulation of the tibial nerve in the popliteal fossa. The anode was placed on the knee. The sensitivity was set at 1–2 mV/div and the sampling frequency at 10 kHz. By adjusting the position of the cathode, the optimal stimulation site with the weakest stimulus intensity for eliciting the H-wave was identified. Rectangular pulses with