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PERONEUS LONGUS CAN NOT BE FULLY ACTIVATED DURING ANKLE COMPLEX EXERCISES BY UNINJURED SUBJECTS

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SYNOPSIS

This study characterized, for the first time, the extent to which the peroneus longus muscle can be voluntarily activated by uninjured subjects during common ankle rehabilitative exercises. Ten healthy subjects performed isometric maximum voluntary contractions (MVCs) of eversion and plantarflexion on a dynamometer and against manual resistance, and performed dynamic whole-body activities that place large loads on the ankle complex (vertical jumps and side-cuts). During these activities, surface EMG signals were collected from the peroneus longus and expressed as a percentage of the maximum motor responses elicited by electric stimulation. Voluntary activation levels of the peroneus longus during isometric MVCs performed on the dynamometer and performed against manual resistance were not significantly different. Side-cuts produced significantly larger activation levels than those maximum vertical jumps and the isometric exercises. Nevertheless, the activation levels were substantially lower than those reported for other lower extremity muscles. These results serve as the basis for further questions related to whether voluntary peroneus longus activation level can be affected by specific rehabilitative efforts, whether activation levels are influenced by acute and chronic ankle complex injuries and, if so, whether this effect influences the functional outcome of rehabilitation efforts following ankle injuries.

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INTRODUCTION

The lateral ankle ligaments are the most frequently injured ligaments of the lower extremity during activities of daily living and sports.[3] While most of these injuries have an excellent prognosis,[1, 2, 4, 14] an estimated 20 to 40 percent of ankle ligament injuries may develop residual symptoms that include recurrent injuries.[10] Aside from structural deficiencies associated with mechanical and functional instabilities, neuromuscular deficiencies have been historically suggested to contribute to recurrent injuries but this has not been sufficiently investigated.

One variable to which clinical importance has been attributed in the etiology of recurrent injuries is weakness of the peroneal muscles.[11] Although this cause-effect relationship has not been convincingly substantiated, it is not an unreasonable hypothesis that contemporary rehabilitation from ankle ligament injuries generally includes a component focused on strengthening the peroneal muscles.[9]

Strengthening the peroneal muscles poses considerable obstacles to rehabilitation efforts. For example, it is difficult, if not impractical, to simulate the dynamic conditions during which the ankle complex experiences inversion injuries occur and during which the peroneal muscles have been proposed to offer dynamic stabilization of the ankle complex. Furthermore, the functional range of ankle complex motion associated with typical, or expected peroneal muscle contraction is much smaller than the range of motion associated with ankle complex inversion injuries. Also, the ankle complex motion of inversion is more complex than can be effectively simulated clinically with presently available quantitative strength measurement devices.[6] These points underscore the difficulty of specifically training the strength of peroneus longus.

The maximum force with which a muscle can contract, its strength, is reliant on numerous architectural properties and the ability to deliver neural drive to activate the muscle. Our long-term objective is to determine if diminished ability to activate the peroneus longus muscle is a contributing factor to functional instability of the ankle complex. The purpose of this study was to characterize the extent to which the peroneus longus muscle can be voluntarily activated by uninjured subjects during rehabilitation exercises commonly associated with rehabilitation from ankle complex inversion injuries. We expected to find that uninjured subjects could activate peroneus longus to a similar extent demonstrated in other skeletal muscles.

MATERIALS AND METHODS

Ten healthy subjects (8 men and 2 women, age: 27.4±4.9 years, height: 172.9±6.8 cm, mass: 68.2±8.9kg) volunteered to participate in the study and provided informed consent. All subjects were right-leg dominant using the criteria of the preferred foot for kicking a ball, and had no recent lower extremity injuries or histories of chronic ankle injuries.

Branched surface electrodes[7] (recording diameter=8mm; center-to-center distance = 20 mm) were placed over the belly of right peroneus longus in the assumed direction of the underlying muscle fibers. A reference electrode was placed over the ipsilateral patella. Standard skin preparation procedures reduced the interelectrode resistance to less than 5 kΩ. The detected EMG signals were amplified using a Noraxon telemetered EMG system (CMRR = 130 dB, gain = 1000, bandpass = 15-500 Hz), digitized at 1 kHz , stored, and analyzed off-line.

Each stimulation was a supra-maximum rectangular stimuli (3 ms duration) applied to the common peroneal nerve through a bipolar bar electrode placed over the caput fibulae to elicit the maximum muscle response (Mmax, Figure 1). Each subject' s Mmax was established as the mean of five stimulations and the mean was used to normalize the voluntary activation levels.

Subjects were comfortably seated with right knee and ankle joint angles maintained at 60 degrees of flexion and at the neutral position, respectively. The right foot was secured to a foot plate of a Kin-Com dynamometer (Chattanooga Corp., Chattanooga, TN., USA). Five trials of maximum voluntary contraction (MVC) were performed for isometric eversion and five trials were performed for isometric plantarflexion. The subjects generated their MVC over a period of about three seconds and maintained the force for two seconds, during which EMG signals of the peroneus longus were measured (Figure 2a).

Five trials of MVC were performed for eversion and five trials were performed for plantarflexion against manual resistance provided by a trained orthopaedic surgeon. EMG signals of the peroneus longus were collected for two seconds while the subjects maintained their maximum efforts.

For the dynamic whole-body activities, the subjects stood upright with their arms relaxed at their sides, body weight distributed approximately equally on each foot, the feet parallel to one another and spaced approximately 20 cm apart. From this initial position, the subjects performed five trials of maximum effort side-cuts and five trials of maximum vertical jumps. Side-cuts were performed by first jumping to the right and immediately jumping back toward the original location, to the left, as soon as possible after the right foot contacted the floor. The distance through which the subjects were airborne was subjectively selected based on the subjects ability to perform the activity as quickly as possible. EMG signals were collected during the vertical propulsion phase of the vertical jumps and the propulsion phase of the return to original location during the side-cuts (Figure 2b).

The rectified baseline-to-peak amplitude (peak amplitude) and the averaged integrated amplitude (averaged amplitude) of the EMG, each divided by the analogous values of Mmax-waves, were the dependent variables. For the dynamic whole-body activities, the onsets and offsets of EMG were identified visually, rectified, and integrated, using custom interactive software. The evertor and plantarflexor roles of the peroneus longus were the rationales for the analyses of peroneus activation during the propulsion phase of side-cuts and vertical jumps. The experimental design for the isometric exercises was a 2 x 2 (dynamometer/manual resistance by eversion/plantarflexion) repeated measures ANOVA. Comparisons between isometric and dynamic exercises, and *a posteriori* multiple comparisons were made using paired t-tests. A significance level of $p \leq 0.05$ was used.

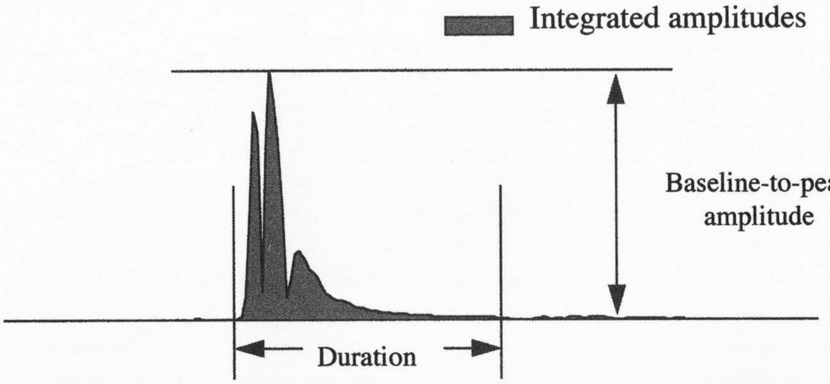

Figure 1. Representative rectified Mmax-wave. The baseline-to-peak amplitude and the averaged integrated amplitudes (area/duration) were calculated.

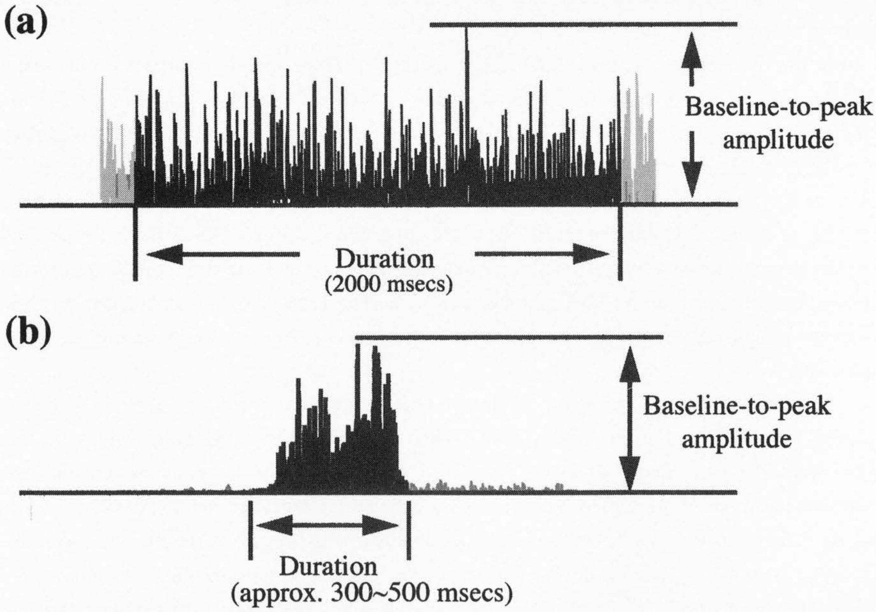

Figure 2. Representative rectified EMG signals recored during (a) eversion MVC against manual resistance and (b) the secondary propulsion phase of a side-cut. The baseline-to-peak and the averaged integrated amplitudes (area/ duration) were calculated.

Table I: Means±standard deviation for the normalized (a) peak and (b) averaged amplitudes (expressed in percent) of the peroneus longus during maximum voluntary eversion and plantarflexion performed on a dynamometer and against manual resistance.

(a)

	Dynamometer	Manual Resistance
eversion	17±7	16±10
plantarflexion	16±10	17±7

(b)

	Dynamometer	Manual Resistance
eversion	13±7	14±11
plantarflexion	15±11	14±10

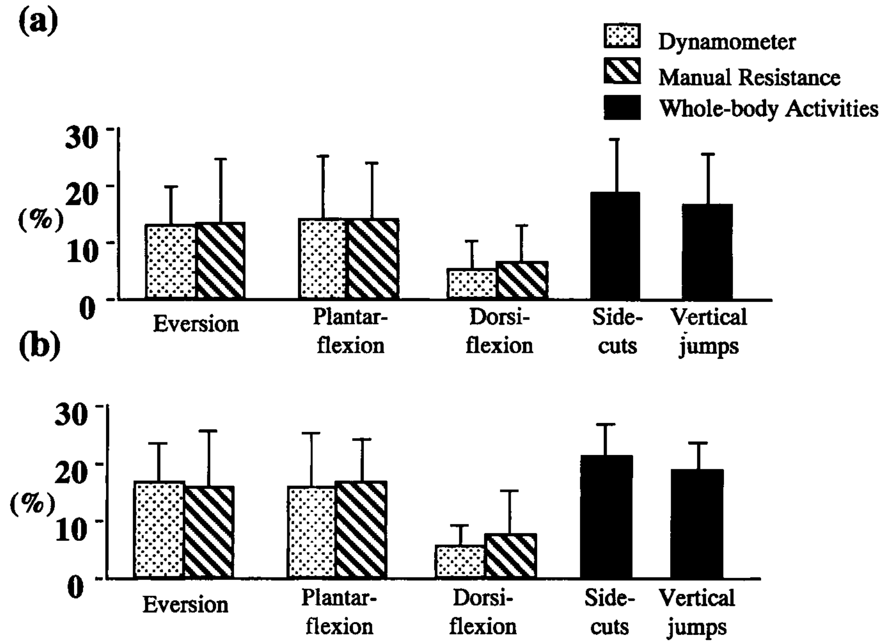

Figure 3. Activation levels of the peroneus longus expressed in percent Mmax, (a) in terms of the peak and (b) the averaged amplitudes. Bars illustrate standard deviation.

RESULTS

The differences between peroneus longus activation levels measured during isometric activities performed on the dynamometer and against manual resistance were not found ($p=0.743$). This was true for both the normalized peak and averaged amplitude values (Table I).

Activation of the peroneus longus during side-cuts (22±6 and 19±10 for normalized peak and averaged amplitude, respectively) was larger than that during isometric eversion against manual resistance ($p=0.0212$ and $p=0.0095$ in terms of the normalized peak and averaged amplitude, respectively) and that during isometric eversion performed on the dynamometer ($p=0.0754$ and $p=0.0379$). Activation of the peroneus longus during the vertical jumps (19±5 and 17±9 for normalized peak and averaged amplitude, respectively) was not different ($p>0.1$) from the activation levels during isometric plantarflexion against manual resistance and isometric plantarflexion performed on the dynamometer (Figure 3).

DISCUSSION

This is the first study to report on the extent to which uninjured subjects can voluntarily activate the peroneus longus muscle during rehabilitation activities used in conjunction with ankle inversion injuries. On average, the subjects were capable of activating the peroneus longus to approximately 20 % of its maximum during side-cuts. This was the largest voluntary activation level as a group average observed in this study. The normalized activation levels observed for peroneus longus activation are substantially lower than the activation levels, normalized to the Mmax, reported for other lower leg muscles. Sale et al.[8] reported that the soleus muscle can be activated voluntarily up to 150% of its Mmax during MVCs. However, the observed values for the peroneus longus are larger, on average, than those reported for some upper extremity and hand muscles.[5, 12, 13] Our results suggest that voluntary maximum activation of the peroneus longus may be a difficult or novel task for uninjured subjects. This raises questions about how specific training may influence the capability to deliver neural drive to this muscle. Average changes of about 20% in activation level were reported by Keen et al.[5] after a 4 week training period and average changes in excess of 50 percent were reported by Yue et al.[12] after a 5 week training period. In contrast, an average 40 percent and 26 percent decrease in the ability to deliver neural drive was reported as a result of a 5 and 4 week period of immobilization[12, 13]. Thus, a particularly relevant clinical question is whether the ability to voluntarily activate the peroneus longus muscle is diminished in subjects with ankle complex injuries and if, in a subgroup of these subjects, the diminished abilities are persistent. This would give credence to the hypothesis of this being a contributing factor to chronic functional instability.

The impetus for this work includes the lack of evidence in the literature of systematic study of the neuromuscular factors that contribute to recurrent ankle complex injuries. The specific rationale included the physiological relationship between the ability to voluntarily deliver neural drive to skeletal muscle and the ability of that muscle to generate force, and the relationship between the ability to deliver neural drive to a muscle and strength gains. We reasoned that a quantitative method by which the ability to voluntarily activate this potentially functionally important muscle can be determined would be useful clinically. Considering the primary evertor role of the peroneus longus, the highest activation level may have been expected during the sustained isometric eversion MVC tasks. However, activation levels during eversion MVC was not significantly different from those during plantarflexion MVC. Both activities reached approximately 15% maximum. This result suggests that the plantarflexion exercise is as effective as the eversion exercise for activating the peroneus longus voluntarily. In general, ankle rehabilitative programs are designed to provide increased stability of the ankle complex, and have focused on peroneal muscle strengthening, aiming to return patients to activities of daily living and to prevent recurrent sprains. However, at the early stage of rehabilitation, patients with ankle injuries frequently find it painful to perform eversion exercises. Our data suggest that relative to delivering a strengthening stimulus, and having the peroneus longus contract through a large portion of its functional excursion, plantarflexion exercises can very likely substitute for eversion exercises. The data also suggests, however, that the dynamic whole body exercises provide not only a significantly larger level of activation, and thus strengthening stimulus, but also provides an advantage of being functionally specific.

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