Effect of Air-Splint Application on Soleus Muscle Motoneuron Reflex Excitability in Nondisabled Subjects and Subjects with Cerebrovascular Accidents

We investigated the effect of air-splint pressure on soleus muscle motoneuron reflex excitability in 18 nondisabled subjects with no history of neurological disease and 8 subjects with cerebrovascular accidents (CVAs). Motoneuron reflex excitability was assessed by measuring the percentage of amplitude change in the Hoffman reflex (H-reflex). Pressure was applied for 5 minutes, after which the air-splint was deflated. Ten H-reflexes were recorded and averaged for each subject before pressure application to obtain a baseline value. H-reflexes were also recorded at set intervals during and after pressure application. Two-way analyses of variance for repeated measures were used to compare each group's pressure and postpressure measurements with the baseline value. Significant F tests were followed by post hoc t tests. Analyses of variance were used to compare the nondisabled subjects' H-reflex recordings with those obtained for the subjects with CVAs. The nondisabled subjects demonstrated reductions of 55% at 1 minute, 52% at 3 minutes, and 40% at the fifth minute of pressure application. The postpressure measurements showed increases in the reflex amplitude at 1 and 3 minutes postpressure, however, by the fifth minute, the amplitude was not different from the baseline value. The subjects with CVAs demonstrated reductions of 41% at 1 minute, 48% at 3 minutes, and 52% at 5 minutes of pressure application. None of the postpressure measurements, however, were statistically different from the baseline value. A statistically significant difference was demonstrated between the nondisabled subjects and the subjects with CVAs at the first minute of pressure release. Air-splint pressure may be useful when a temporary decrease in muscle reflex activity is a therapeutic goal. [Robichaud JA, Agostinucci J, Vander Linden DW. Effect of air-splint application on soleus muscle motoneuron reflex excitability in nondisabled subjects and subjects with cerebrovascular accidents. Phys Ther. 1992;72:176–185.]

Key Words: Alpha motoneuron reflex excitability, Cerebrovascular accident, H-reflex, Physical therapy, Pressure, Rehabilitation.
unopposed by antagonists, may lead to contracture. Permanent muscle shortening from loss of sarcomeres has been shown to occur very rapidly when unopposed muscle contractions are induced experimentally. Therapeutic techniques to reduce motoneuron excitability, therefore, may have potential for maintaining muscle length and preventing contractures in those muscles that are most susceptible to length changes in the patient with neurological disease. Clinicians and researchers have attempted to alter motoneuron excitability through a variety of measures including cooling, vibration, and pressure.

### Table 1. Description of Subjects with Cerebrovascular Accidents (CVAs)

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Sex</th>
<th>Side of CVA</th>
<th>Age (y)</th>
<th>Time Since CVA (mo)</th>
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<td>7</td>
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<tr>
<td>2</td>
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<td>4</td>
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<td>5</td>
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<td>6</td>
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<tr>
<td>8</td>
<td>F</td>
<td>Right</td>
<td>54</td>
<td>6</td>
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</table>

### Figure 1. Diagram of experimental setup for stimulation and recording of H-reflexes. The subject is positioned prone on a plinth.

Numerous investigators have studied the effects of pressure on the amplitude of the H-reflex. Kukulka and colleagues studied the application of continuous pressure over the Achilles tendon. A decrease in the soleus muscle H-reflex amplitude was demonstrated, but this decrease was short lasting and independent of the amount of pressure applied. The duration of H-reflex reduction by tendon pressure, however, has been correlated with the type of pressure applied, with intermittent pressure providing longer-lasting decreases than continuous pressure. These results have been reported for both subjects with no history of neurological disease and subjects with cerebrovascular accidents (CVAs). The effects of pressure applied to muscle bellies are less consistent than the effects of tendon pressure on changing the amplitude of the H-reflex. Muscle tapping has been shown to result in both decreases and increases of the H-reflex response. An increase in the H-reflex amplitude was noted when continuous pressure was applied over the soleus muscle belly in neurologically normal subjects; however, there were limitations in the results of this study. In addition, Morelli and colleagues have demonstrated that massage over the belly of the triceps surae muscle produced a decrease in the H-reflex. None of these studies, however, reported long-lasting effects.
The component of muscle tone that results from reflex contraction is hard to quantify, and the effectiveness of various treatments is difficult to assess. An indirect measurement of muscle tone is the measurement of motoneuron reflex excitability. Soleus muscle motoneuron reflex excitability can be assessed by evaluating changes in the Hoffman reflex (H-reflex). The H-reflex is an electrically stimulated monosynaptic reflex that excites the muscle spindle's Ia afferents. Action potentials are transmitted to the spinal cord where monosynaptic connections cause motoneurons to reach threshold, thereby causing the extrafusal muscle fibers to contract. Changes in this reflex excitability can be evaluated by measuring amplitude changes of the H-reflex. A finding of decreased motoneuron reflex excitability after use of a procedure would suggest a condition that may be conducive to reducing muscle tone.

An air-splint is a pneumatic sleeve that is applied around an extremity and inflated to various pressures. It provides circumferential pressure to peripheral receptors and to agonist and antagonist muscles. Therapists have postulated that air-splints can decrease muscle tone; however, this postulate has never been systematically evaluated. The purpose of this study was to investigate the effect of circumferential pressure provided by an air-splint on the soleus muscle motoneuron reflex excitability in nondisabled subjects with no history of neurological disease and in subjects with CVAs.

**Method**

**Subjects**

Eighteen nondisabled, neurologically normal subjects (6 men, 12 women) and 8 subjects with CVAs (4 men, 4 women) participated in the study. The nondisabled subjects had no history of neurological disease or lower-extremity muscular disorders and ranged in age from 20 to 54 years (X̄=29.4, SD=8.7). The subjects with CVAs had had strokes at least 3 months prior to the study (X̄=16.25).
Figure 3. Mean and standard deviation for H-reflexes for pooled data of neurologically normal subjects (n=18) (P=.008). (0=baseline level)

In the popliteal fossa, a 1-millisecond stimulation was applied to the skin over the tibial nerve, and proper cathode positioning was determined when (1) the direct motor reflex (M-wave) and H-reflex (H-wave) displayed similar wave configurations, (2) the H-wave was evoked before the M-wave, and (3) the least amount of current was required to elicit an H-reflex. The stimulating intensity was increased until a maximal H-reflex was observed, after which the on-line average of 10 H-reflexes was recorded. While observing the on-line average of the maximal H-reflex, the intensity was decreased until 50% of the maximal H-reflex was obtained. At this stimulating intensity, a subject’s baseline H-reflex was established by averaging 10 stimulations of the tibial nerve. With continued tibial nerve stimulation at 5-second intervals, the air-splint was manually inflated with an air pump and a hand-held bulb and maintained within a range of 36.7 to 40.8 mm Hg for 5 minutes. The air-splint was then deflated. H-reflex recordings were made for an additional 5 minutes. During the experiment, the M-wave from each stimulus was monitored to ensure stimulating and recording electrodes were not displaced. If the...
Figure 4. Each trace represents the ensemble average of 10 H-reflexes for a representative subject with cerebrovascular accident. The initial wave represents the direct M-wave that is followed by the H-reflex. The traces, from top to bottom, correspond to baseline (prepressure) reflex (A); 1-, 3-, and 5-minute pressure H-reflexes (B–D); and 1-, 3-, and 5-minute postpressure H-reflexes (E–G).

M-wave amplitude or shape changed, the data were not used in the analysis.

Ten H-reflexes were recorded and averaged for each subject before inflation of the air-splint to obtain a baseline value (test 1). H-reflexes were also recorded at 1, 3, and 5 minutes after inflation of the air-splint (tests 2–4) and at 1, 3, and 5 minutes after deflation of the air-splint (tests 5–7). The first two pressure measurements were taken during air-splint inflation and pressure stabilization. The third pressure measurement was recorded after the pressure had stabilized. If the air-splint pressure had not stabilized by the fourth minute, the data from that subject were not used in the analysis.

Data Analysis

A Statview II statistical program was used for all data analyses. Ten H-reflex amplitudes (peak-to-peak measurement) were averaged for the baseline condition and for each of the six test conditions. Separate one-way analyses of variance (ANOVAs) for repeated measures were used to evaluate changes in the H-reflex amplitude across test conditions for each group. A two-way ANOVA was used to make comparisons between the two groups of subjects and across the test conditions. Post hoc t tests (with Bonferroni's correction for multiple comparisons) were used when significant F values were demonstrated. All post hoc tests' level of significance was designated at .008.

Results

Significant differences in H-reflex amplitude were demonstrated between the nondisabled subjects and the subjects with CVAs (Tabs. 2, 3). Post hoc tests revealed a significant (P < .008) decrease in the nondisabled subjects' H-reflex amplitudes at 1, 3, and 5 minutes of pressure application when the measurements were compared with the baseline value. The H-reflex amplitude was decreased by 55% at minute 1, 52% at minute 3, and 40% at minute 5 of pressure application when compared with the baseline value. The first two postpressure measurements were increased by 24% and 26%, respectively (P < .008) (Figs. 2, 3). By the fifth minute postpressure, the H-reflex was not significantly different from the baseline value.

The subjects with CVAs demonstrated a significant decrease in the amplitude of the H-reflex for the 1-, 3-, and 5-minute pressure measurements. During pressure application, the H-reflex was decreased by 41% at
minute 1, 48% at minute 3, and 52% at minute 5 (P≤.008) (Figs. 4, 5). Postpressure measurements at 1, 3, and 5 minutes were not significantly different from the baseline value.

Comparisons of H-reflex amplitudes between the nondisabled subjects and the subjects with CVAs revealed a significant group X test interaction (Tab. 4, Fig. 6). An independent t test revealed a significant difference between the groups at the 1-minute postpressure measurement.

**Discussion**

This study showed that circumferential pressure applied by an air-splint around the lower leg reduced soleus muscle motoneuron reflex excitability in both neurologically normal subjects and subjects with CVAs. This reduction in reflex excitability lasted throughout the 5 minutes of pressure application. These findings differed from those of previous pressure studies in that the H-reflex amplitudes demonstrated by our subjects remained depressed for a longer time. A possible explanation for the increase in duration of inhibition may be the method of pressure application. In the previous studies, the investigators either massaged the muscle or applied pressure by slowly pressing a small, blunt object into a tendon or muscle belly. Pressure applied in this way slowly stretches the muscle with minimal cutaneous stimulation. Mark and colleagues showed that tonic stretching of calf extensor muscles briefly inhibits the H-reflex through a postsynaptic inhibitory mechanism mediated by group II spindle afferents.

In this study, we applied pressure by inflating an air-splint circumferentially around the limb. Circumferential pressure compresses the limb with minimal muscle stretching. We believe the effect on motoneuron excitability from muscle stretch receptors would therefore be negligible. Assuming this to be true, we believe the H-reflex inhibition observed in this study is more likely related to the cutaneous effects that occur when an air-splint is inflated around the skin. This hypothesis also would explain the sustained inhibition that resulted after air-splint inflation. Cutaneous stimulation has been demonstrated to have long-lasting effects on motoneuronal reflex excitability. The cutaneous origin of the observed inhibition, however, remains speculative and requires further investigation.

The increase in the H-reflex amplitude shown by both groups with pressure release may be a response of thermoreceptors. Air leaving the splint may cause a cooling effect, which would increase the H-reflex amplitude. Additionally, pressure re-

**Table 4. Analysis-of-Variance Results for Mean H-Reflexes Comparing Subjects with Cerebrovascular Accidents (n=8) and Neurologically Normal Subjects (n=18)**

<table>
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<th>Source</th>
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<td>6505.41</td>
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*aP≤.05.*
lease could facilitate the cutaneous mechanoreceptors. These mechanisms, therefore, could further increase soleus muscle motoneuron reflex excitability. Although both groups showed increases in H-reflex amplitude, the nondisabled subjects demonstrated significant increases above the baseline measurement for the 1- and 3-minute postpressure measurements. Only two of the subjects with CVAs demonstrated similar increases in H-reflex amplitudes with pressure release (Fig. 7).

The apparent difference in the degree of facilitation with the release of pressure for the subjects with CVAs may be explained by the presence of increased tone. These subjects may initially have had a higher level of motoneuron reflex excitability than that of the subjects with no neurological deficits; thus, increases of the H-reflex above baseline may not have been as apparent.

**Clinical Implications**

These results support the clinical use of air-splint pressure in reducing motoneuron reflex excitability in patients with CVAs. This decrease in motoneuron reflex excitability may suggest a condition that may be conducive to reducing muscle tone. Clinicians who use air-splints to promote joint stability should be aware that they may actually be inhibiting the activity of muscles encompassed by the air-splint.

**Conclusion**

Circumferential pressure applied by an air-splint around the lower leg reduced soleus muscle motoneuron reflex excitability in neurologically normal subjects and subjects with CVAs in this study. This reduction lasted throughout 5 minutes of pressure application. Further research on varied patient populations is needed to understand the clinical and physiological effects of circumferential pressure by air-splint application on the central nervous system.
Acknowledgments

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References


Commentary

Spasticity is a highly overrated symptom of upper motor neuron syndrome that has occupied the center of attention and efforts of neurological physical therapists and occupational therapists since the 1950s.1 Despite reports in the literature that spasticity does not cause the primary movement dysfunctions that occur following central nervous system damage,2,3 therapists are still linking abnormal movement patterns and spasticity and proclaiming that we must provide the patient with inhibition of abnormal patterns and tone in order to restore normal voluntary movement.4 It is refreshing to see in this article that the authors have been precise in their definition of spasticity and thus realistic in the clinical implications of their results.

Spasticity is an increase in resistance to passive stretch that is proportional to the velocity of the stretch.5,6 It is no longer thought to be due to hyperactivity of gamma motoneurons resulting from loss of inhibition from higher centers, but rather to a disturbance of reflex circuits within the spinal cord that is manifested by an increased excitability of alpha motoneurons.5,7 The authors of this article have measured alpha motoneuron excitability, by using the Hoffman reflex (H-reflex), in order to evaluate the effects of the application of air-splints in nondisabled individuals and individuals who have had a cerebrovascular accident (CVA). They infer from the literature that by reducing motoneuron excitability, contractures may be prevented. Although contractures that develop following neurological damage are probably due mainly to lack of active muscle contraction and to lack of joint motion and muscle stretching, the hyperexcitability of the stretch reflex may indeed contribute...