The Effect of Therapeutic Massage on H-Reflex Amplitude in Persons With a Spinal Cord Injury
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Research Report

The Effect of Therapeutic Massage on H-Reflex Amplitude in Persons With a Spinal Cord Injury

Background and Purpose. The effect of therapeutic massage on the H-reflex amplitude in persons without neurological impairment has been established. To investigate its effects in a sample of persons with a spinal cord injury (SCI), two independent but interrelated studies were undertaken. Study 1 investigated whether the recorded response (H-reflex amplitude) to massage with the subjects in the supine testing position was similar to that recorded in previous studies in which the subjects were tested in the prone position. This study was undertaken because the prone testing position was considered inappropriate for persons with SCI. In study 2, the therapeutic effect of massage (petissage) on H-reflex amplitude in persons with SCI was examined. Subjects. Seven persons without neurological impairment volunteered to participate in study 1, and 10 individuals with a traumatic SCI volunteered to participate in study 2. Methods. The two studies shared many methodological features and involved the recording of 10 H-reflex and M-response peak-to-peak amplitudes from the triceps surae muscle during each of five sequential, 3-minute time periods. Massage treatment (MASS) was given during the third time period, and the premassage time periods (C1, C2) and postmassage time periods (C3, C4) served as control conditions. Study 2, in addition to recording the peak-to-peak amplitudes of the recorded responses, also included the recording of the H-reflex latencies. Results. The results of study 1 showed that massage applied with the subjects in the supine position decreased the H-reflex amplitude during the massage. A 56% decrease in the H-reflex amplitude was recorded. Study 2 demonstrated a 27% mean group decrease in the H-reflex peak-to-peak amplitude during the massage for all subjects, with variations in individual responses ranging from an increase in the H-reflex amplitude of 20% to a decrease of 84%. An analysis of variance revealed that the H-reflex means of the five conditions were significantly different. Newman-Keuls post hoc analyses revealed that the mean of the MASS condition (2.01 mV) was significantly different from the means of C1, C2, and C4 (2.79, 2.81, 2.58 mV). The mean of C3 (2.42 mV) was not found to be statistically different from the means of the other conditions. These changes were noted against a stable M-response. Conclusion and Discussion. The results recorded in study 1 are comparable to those obtained with the subjects in the prone position. Based on these results, the supine position was adopted as the testing position for study 2. Study 2 further showed a decrease in H-reflex amplitude concomitant with massage in persons with SCI, but no long-term effects were noted. [Goldberg J, Seabome DE, Sullivan SJ, Leduc BE. The effect of therapeutic massage on H-reflex amplitude in persons with a spinal cord injury. Phys Ther. 1994;74:728-737.]

Key Words: H-reflex, Massage, Motoneuron excitability, Rehabilitation, Spinal cord injury.
in the H-reflex amplitude (an indirect measure of spinal motoneuron excitability and a measure of changes along the spinal reflex pathway) during massage. This effect was specific to the muscle being massaged and lasted only for the duration of the massage, with a return to premassage H-reflex values immediately upon cessation of the massage. The decrease in the H-reflex amplitude was also found to vary directly with the amount of pressure applied. Furthermore, these studies have attempted to identify the mechanisms involved in the recorded response. The contribution of antagonist reciprocal inhibition, changes in nerve conduction velocity, and changes in skin temperature have all been excluded as possible mechanisms in the recorded decrease in the H-reflex. A recent study examining the neuromuscular response to effleurage (another massage technique) has demonstrated that this manipulation also produced a decrease in the H-reflex amplitude during massage.

Having established that massage is effective in reducing the H-reflex amplitude in subjects without neurological impairment, the logical research progression was to investigate the efficacy of massage in reducing the level of motoneuron excitability (H-reflex amplitude) in a neurologically impaired population. A systematic review of the literature located only one study that investigated the therapeutic effects of massage in a neurologically impaired population. Larue examined the effects of electromyographic (EMG) biofeedback, an audio-relaxation tape, and massage on the reduction of tendon reflex activity in a group of subjects with hemiplegia and reported that postmassage reflex activity was decreased. (Latency and amplitude of the tendon tap reflex were quantified from the EMG signal.) Larue's experimental protocol, however, was designed primarily to compare the effects of the EMG biofeedback and the audio-relaxation tape. Massage was not expected to play a role in the decrease in hyperreflexia, and the protocol was therefore not designed specifically to investigate the effects of massage. Furthermore, the subjects in the study were required to change positions (from a sitting position to a prone position) during the course of the data collection. These postural changes may have influenced the results. Due to these methodological constraints, the reported decrease in hyperreflexia following massage must be cautiously interpreted. Consequently, the confirmation of the therapeutic effects of massage in a neurologically impaired sample still awaits scientific investigation.

Among the many neurologically impaired populations requiring treatment by physical therapists, patients with a spinal cord injury (SCI) represent a substantial proportion and generally exhibit a heightened state of motoneuron excitability in comparison with neurologically healthy subjects. Furthermore, persons with SCI are usually young, and this factor is advantageous when conducting H-reflex studies, as it results in easily discernable H-reflexes. Thus, persons with SCI provide a useful group with which to examine the effects of massage using the H-reflex as the dependent variable. In addition, changes in the amplitude of the H-reflex following SCI have been well documented. Following an initial decrease in the H-reflex peak-to-peak amplitude during the phase of spinal shock, the H-reflex evolves to a heightened state of excitability within 3 to 6 months, which then persists. This increased amplitude in the evoked H-reflex may be indicative of an increased state of excitability of the spinal motoneuron pool. Although this state of motoneuron hyperexcitability also exists in the presence of hyperreflexia, no clear correlation between the H-reflex amplitude and the degree of hyperreflexia has yet been established.

Prior to the initiation of the study of the effects of massage in persons with SCI, one important methodological constraint needed to be addressed. In previous studies, the subjects were tested while lying in a prone position. The prone position, however, can cause respiratory difficulties in persons with SCI and is often difficult to assume on a narrow treatment table. These potential problems associated with the prone position rendered it inappropriate for data collection in our sample. The supine position, a variation of the standard semireclined sitting position recommended for H-reflex recordings, has been suggested in the literature as an adequate subject position for H-reflex recordings. However, as both neuromuscular status and the H-reflex amplitude can be influenced by such factors as body and limb position, temperature, and emotional stress, we considered it important to verify whether massage, applied to subjects

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**References**

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This study was approved by the Ethics Committee of the Institut de Réadaptation de Montréal.

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in the supine testing position, would produce effects similar to those recorded in the prone testing position.1–5

This research was thus divided into two separate, but interrelated, studies. The purpose of study 1 was to investigate whether the recorded response (H-reflex amplitude) to massage with the subjects positioned supine was similar to that recorded in previous studies in which the subjects were tested in the prone position. It was expected that the H-reflex measurements recorded during massage in the supine position would follow the same trend as those previously recorded in the prone position (ie, a decrease in H-reflex amplitude during the massage). Study 2 was designed to investigate the effect of therapeutic massage on the H-reflex in a sample of persons with SCI. Based on our information will be reported separately.

Subjects

Study 1. Seven neurologically healthy subjects (5 women, 2 men), with a mean age of 24.6 years (SD = 2.6, range = 20–28), volunteered to participate in this study. Subjects were recruited from the staff and student populations of both the Université de Montréal and the Montreal Rehabilitation Institute (MRI). All subjects signed an institutionally approved (MRI) informed consent form prior to participation in the study.

Study 2. Ten subjects with traumatic SCIs (9 men, 1 woman), with a mean age of 26.5 years (SD = 4.9, range = 21–33), volunteered to participate in this study. Descriptive characteristics of the subjects, as recorded from their medical charts, are presented in Table 1. Participants were recruited from the inpatient and outpatient populations of the MRI. Subjects were informed of the project by their physiatrist, and their participation was contingent on voluntary acceptance and physician approval. All participants signed an institutionally approved (MRI) informed consent form prior to participation in this study. Criteria for admission to this study were (1) the presence of a traumatic lesion of the spinal cord above the lumbar segments, (2) hyperreflexia in the triceps surae muscle group as recorded from the subject’s medical chart, (3) the ability to maintain a supine position for a period of at least 40 minutes, and (4) the absence of contractures or pressure sores that could prevent the subject from assuming the experimental position. Subjects with a history of metabolic problems (eg, diabetes), orthopedic problems (eg, hip dislocation), or neurological problems (eg, a previous peripheral nerve injury) that could have an effect on the H-reflex and subjects with any condition that could interfere with or impede adequate data collection (eg, urinary problems) were excluded from participation in the study.

Method

The two studies reported in this article shared many methodological features and therefore will be presented together. When there are obvious differences between the two studies, the information will be reported separately.

Table 1. Descriptive Characteristics of Subjects (n = 10) (Study 2)

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Neurological Level of Injury*</th>
<th>Completeness of Injury (C/I) ²</th>
<th>Gender</th>
<th>Age (y)</th>
<th>Time Since Injury (mo)</th>
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<tr>
<td>1</td>
<td>C-5</td>
<td>C</td>
<td>M</td>
<td>33</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>C-5</td>
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<td>M</td>
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<td>6</td>
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<tr>
<td>3</td>
<td>C-6</td>
<td>I</td>
<td>M</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>C-6</td>
<td>C</td>
<td>M</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>C-4</td>
<td>I</td>
<td>M</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>C-5</td>
<td>C</td>
<td>M</td>
<td>26</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>T-5</td>
<td>I</td>
<td>F</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>T-10</td>
<td>I</td>
<td>M</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>C-4</td>
<td>I</td>
<td>M</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>T-6</td>
<td>C</td>
<td>M</td>
<td>33</td>
<td>3</td>
</tr>
</tbody>
</table>

*Most caudal neurological segment that tests as normal or intact for both sensory and motor function (American Spinal Injury Association, 1989). ²C = complete injury; I = incomplete injury, as recorded from the subject’s medical chart.

The massage technique used in these studies was one-handed petrissage applied to the belly of the triceps surae muscle group. The petrissage was performed in a standardized fashion in accordance with previously described guidelines23,24 and as used in our earlier studies.3,4 One-handed petrissage consists of alternately grasping and lifting the muscle away from the bone in a circular motion, releasing the tissues on the downward part of the motion.3,3 The same therapist (JG) applied the massage to all the subjects to avoid intertherapist variation. The massage was applied at a standardized rate of 30 manipulations per minute and at a pressure of 1.75 kPa (7 in H2O). The rate and pressure were based on the results of an earlier study conducted in our laboratory.4 The therapist was trained using a pressure quantification system (PQS).
that has been described in detail elsewhere\(^4\) and is reviewed only briefly here. The system consists of an air pump, an inflated Jobst upper-extremity sleeve,\(^5\) and a calibrated pressure gauge.\(^6\) The PQS provided quantitative feedback to the therapist regarding the amount of pressure applied to the sleeve. The therapist trained on the PQS until she could reproduce 10 petrissage manipulations at the preestablished pressure and rate without feedback (verbal or visual) within an accepted error margin of ±5%. The rate and pressure were monitored by an assistant using a stopwatch and the pressure gauge. The therapist retrained to these criteria prior to each data collection session to ensure accurate replication of the standardized rate and pressure.

**H-Reflex and M-Response**

**Instrumentation**. To ensure the standardization and reliability of the H-reflex during the data collection period, the stimulating and recording electrodes were positioned as shown in Figure 1. The anode, a 20-cm\(^2\) pad, was positioned on the left quadriceps femoris muscle just proximal to the superior pole of the patella. The cathode, a 1-cm\(^2\) Meditrace silver-silver chloride disposable electrocardiographic (ECG) surface electrode,\(^7\) was positioned in the popliteal fossa over the tibial nerve following localization of the nerve using a hand-held electrode probe.

H-reflex recordings were taken from a distal recording site of the left triceps surae muscle group using a pair of pregelled surface electrodes (Meditrace silver-silver chloride disposable ECG surface electrodes). The placement of the recording electrodes was standardized, according to the procedure adapted by Morelli et al.,\(^8\) at \(\frac{1}{2}\) of the distance between the left lateral malleolus and the distal crease of the popliteal fossa, with an interelectrode distance of 15 mm. The electrodes were positioned in parallel to the direction of the muscle fibers. The ground electrode (Meditrace silver-silver chloride disposable ECG surface electrode) was positioned over the left medial malleolus.

H-reflexes and M-responses were elicited from the tibial nerve every 10 seconds by a 1-millisecond square-wave impulse sent by a computer-driven Grass S88 stimulator\(^9\) and related stimulation isolation (Grass SIU\(^5\)) and constant current (Grass CCU\(^1\)) units. Electromyographic recordings were amplified (TECA model \(\text{A6MK}^3\)) and band-pass filtered (3 dB down at 8 and 1,600 Hz) prior to being digitized at 5,000 Hz. H-reflex and M-response peak-to-peak amplitudes and latencies (defined as the time from the application of the stimulus to the first positive deflection point that exceeds two standard deviations from the resting EMG baseline) were measured and recorded for analysis (for study 1, only H-reflex amplitudes were recorded). The M-response was monitored to ensure than any changes in H-reflex amplitude during or after the massage were not artifactual secondary to changes in the recording or stimulating conditions.

**Experimental procedure**. In study 1, the subjects independently adopted a supine position on a padded treatment table. Their left lower extremity was positioned in a foam block designed to maintain the limb in a stan-
Data were collected every 10 seconds during the first 2 minutes of five sequential, 3-minute time periods (Fig. 2). The massage treatment (MASS) was given during the third time period, and the first two time periods (C1, C2) and the last two time periods (C3, C4) served as control conditions. A **condition**, for the purposes of our study, was defined as a series of 10 H-reflexes and M-responses elicited from the triceps surae muscle group at 10-second intervals at the intensity established during the recruitment profile. Although theoretically the 10 stimuli require only 100 seconds, a fixed (3-minute) time interval was chosen for each condition to permit the rejection of any signals containing an artifact and to permit the collection of replacement data. This situation accounted for approximately 1% of the trials. In addition, some time was also required to reinitialize the software to allow the following condition to begin at the designated time. The premassage control conditions (C1, C2) served to establish baseline values against which comparisons could be made with changes occurring during the massage condition. In addition, these premassage conditions assured the stability of the reflexes over time by providing H-reflex and M-response values for a 6-minute period. The postmassage control conditions (C3, C4) were initiated in order to verify whether any sustained H-reflex decrease existed due to the position change or the sample group. In the 3-minute massage condition, data were collected only during the first 2 minutes. The remaining time (1 minute) was used to prepare the system so that C3 could begin immediately on cessation of the massage. Thus, recordings were obtained from the triceps surae muscle group during the massage.

**Data Analysis**

**Study 1.** Descriptive statistics (means, standard deviations, standard errors of the mean, and coefficients of variation) were calculated for both the H-reflex and M-response peak-to-peak amplitudes for the 10 trials in each condition. The means of the H-reflex

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*Velcro USA Inc, 406 Brown Ave, Manchester, NH 03108.*
Table 2. Descriptive Statistics for H-reflex Peak-to-Peak Amplitudes (in Millivolts) (Study 1)

<table>
<thead>
<tr>
<th>Condition</th>
<th>C1</th>
<th>C2</th>
<th>MASS</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>3.58</td>
<td>3.62</td>
<td>1.59</td>
<td>3.48</td>
<td>3.70</td>
</tr>
<tr>
<td>SD</td>
<td>1.89</td>
<td>1.97</td>
<td>1.23</td>
<td>1.88</td>
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<tr>
<td>SEM</td>
<td>0.71</td>
<td>0.74</td>
<td>0.46</td>
<td>0.71</td>
<td>0.76</td>
</tr>
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<td>CV</td>
<td>0.53</td>
<td>0.54</td>
<td>0.77</td>
<td>0.54</td>
<td>0.54</td>
</tr>
</tbody>
</table>

*Data were collected every 10 seconds during the first 2 minutes of five sequential, 3-minute time periods. The massage treatment (MASS) was given during the third time period; the first two (C1, C2) and last two (C3, C4) time periods served as control conditions.

Study 2. The same statistical analyses described for study 1 were also performed with the data obtained from study 2. Two slight differences, however, existed: (1) In study 2, the H-reflex latencies were also analyzed (in the same manner as the H-reflex amplitudes in study 1), and (2) the probability level for significance for study 2 was set at P<.05. The reduced value for study 2 reflects the explorative nature of the study.

Results

Study 1

The results of this preliminary study were similar to the results of earlier studies in that there was a decrease in the amplitude of the H-reflex during the massage. The values for the H-reflex peak-to-peak amplitudes recorded during the control conditions ranged from 3.48 to 3.70 mV, whereas the mean H-reflex amplitude recorded during the massage condition was 1.59 mV. Values for the mean M-responses ranged from 0.42 to 0.44 mV. The descriptive statistics for the H-reflex and M-response peak-to-peak amplitudes for each condition are presented in Tables 2 and 3. The ANOVA for the H-reflex amplitudes detected a significant difference between the resulting means (F=21.54; df=4,24; P=.000). The ANOVA table for the H-reflex amplitudes is presented in Table 4. No significant difference was found between the mean M-responses over the period of data collection (F=2.28; df=4,24; P=.09). The stability of the M-response throughout the period of data collection indicated that no change occurred in the recording conditions during this time interval.

Subsequent post hoc analysis of the H-reflex means, using the Newman-Keuls procedure, determined that the H-reflex amplitude recorded during the massage condition was significantly different from the values recorded during the four control conditions. No other comparisons were found to be significant.

Study 2

M-response. The mean group peak-to-peak amplitudes for the M-responses elicited during each condition varied between 0.16 and 0.19 mV (Tab. 5). The ANOVA detected no significant difference (F=1.92; df=4,36; P=.13) between these means (Tab. 6). This finding is indicative of the stability of the recording and stimulating conditions throughout the period of data collection.

H-reflex. Descriptive statistics for the H-reflex peak-to-peak amplitudes and latencies are presented in Table 5. The means of the peak-to-peak amplitudes varied from 2.01 to 2.81 mV. The latencies for all conditions

**SYSTAT Inc, 1800 Sherman Ave, Evanston, IL 60201.

Table 3. Descriptive Statistics for M-response Peak-to-Peak Amplitudes (in Millivolts) (Study 1)*

<table>
<thead>
<tr>
<th>Condition*</th>
<th>C1</th>
<th>C2</th>
<th>MASS</th>
<th>C3</th>
<th>C4</th>
</tr>
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<tr>
<td>X</td>
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<td>0.42</td>
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<tr>
<td>SD</td>
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<tr>
<td>SEM</td>
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<td>0.25</td>
</tr>
<tr>
<td>CV</td>
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<td>1.52</td>
<td>1.51</td>
<td>1.50</td>
</tr>
</tbody>
</table>

*See Table 2 footnote for explanation of conditions.

**SEM=standard error of the mean.

*CV=coefficient of variation.
ranged from 32.36 to 33.77 milliseconds. The resulting ANOVAs (Tabs. 7, 8) revealed a significant conditions effect for the mean H-reflex peak-to-peak amplitudes ($F=4.06; df=4.36; P=.008$) but not for the corresponding H-reflex latencies ($F=1.52; df=4.36; P=.22$). Post hoc analyses determined that the mean H-reflex amplitude during the massage condition was significantly reduced compared with the means of C1, C2, and C4. No statistically significant difference was found between the mean of the massage condition and the mean of C3. The mean of C3 was increased compared with the mean of the massage condition but was decreased compared with the means of the other control conditions, although this difference was not statistically significant.

Eight of the 10 subjects showed a decrease in H-reflex amplitude (range=3%–84%). The other 2 subjects (subjects 3 and 6) showed increases of 20% and 4%, respectively. Inspection of the data revealed no obvious association between the descriptive characteristics of those subjects who responded with a decrease in H-reflex amplitude (“inhibition”) due to the massage and those who did not (Tabs. 1, 9).

A continued reduction (albeit not statistically significant) in the H-reflex amplitude was seen in subsequent conditions following the cessation of the massage. This carryover effect was noted to be present in 6 of the 8 subjects who showed a decrease in the H-reflex amplitude during the massage (Tab. 9).

**Discussion**

**Study 1**

The postural change brought about by adapting to the supine position did not affect the pattern of the H-reflex recordings during massage because there was the expected decrease in the H-reflex peak-to-peak amplitude during the massage condition. The decrease in the H-reflex amplitude recorded was of a magnitude of 56%, which is similar to that recorded in earlier studies.14 As a result, the supine position was determined to be appropriate and of potential usefulness for data collection involving a subject group for which the prone position would be contraindicated. Based on the findings of this study, the supine position was chosen as the experimental position for subjects participating in study 2.

**Study 2**

Our investigation studied the effect of one-handed petrissage on the H-reflex peak-to-peak amplitude in a sample of persons with SCI. There was a 27% mean group decrease in the H-reflex peak-to-peak amplitude during the massage. This decrease was less than that seen in earlier studies involving neurologically healthy subjects.1–4 As a result, the supine position was determined to be appropriate and of potential usefulness for data collection involving a subject group for which the prone position would be contraindicated. Based on the findings of this study, the supine position was chosen as the experimental position for subjects participating in study 2.
the hypothesis that massage is effective in reducing the excitability of the spinal motoneuron pool in individuals with SCI, as measured by changes in the H-reflex amplitude.

The effect produced by massage in persons with SCI was not as uniform as the effects seen in our earlier studies involving subjects without neurological impairment.1-4 In those studies, all participants responded to the massage with a significant decrease in the H-reflex amplitude. Although this was not the case in study 2, the degree of "inhibition" (reduction in H-reflex amplitude) produced in those subjects who responded to the massage was of a sufficient magnitude to result in an overall average decrease (±SD) in the H-reflex amplitude of 27%±35% during the massage, compared with premassage control conditions 1 and 2.

The variability, as well as the decreased magnitude, of the response seen in our study compared with that of our earlier work3-4 was not unforeseen. Levin and Chapman26 investigated the effect of stimulation of the common and superficial peroneal nerves on the H-reflex in both subjects without neurological impairment and subjects with SCI. They found that the response to common peroneal nerve stimulation in subjects with SCI was not uniform and that the magnitude of the response was greatly reduced compared with that of subjects without neurological impairment. More importantly, they related the variability in the response to the severity of the hyperreflexia in their subjects. Although the severity of the hyperreflexia was not measured in our study, this factor could explain the variability in the recorded response.

Although for the group there was no decrease in amplitude during C3 compared with the other control conditions (C1, C2, C4), there was a tendency toward a carryover effect (a sustained decrease in the H-reflex amplitude following cessation of the massage). This lack of significance was marginal and can probably be attributed to the lack of statistical power due to the small sample size used in this study and to the large variability in the response to massage recorded in these subjects.

A carryover effect was observed in 6 of the 8 subjects who responded to the massage with a decrease in H-reflex amplitude. This is the first time such a carryover effect has been observed with the application of massage3-4 and is a very encouraging development, which may have clinical implications. A similar tendency has been demonstrated in relation to circumferential pressure applied to the leg.27 Robichaud et al27 found no persistence of the decreased H-reflex (recorded from the triceps surae muscle) in a control group (a facilitation was noted following the cessation of pressure), but a 1-minute carryover was seen in a group of subjects with hemiplegia. It is difficult at this time, however, to hypothesize as to the mechanism involved in this carryover effect.

We have previously demonstrated4 that the "inhibitory" effect produced by massage is directly related to the degree of pressure applied during the massage. The pressures used in that study corresponded to 2.50 kPa and 1.25 kPa as measured on the PQS developed for the study. Both pressures were shown to have an "inhibitory" effect on the H-reflex amplitude, with the greater pressure resulting in the greater decrease in the H-reflex amplitude. With the deeper pressure (2.50 kPa), however, some participants complained of discomfort. Therefore, as a precautionary measure in testing subjects with decreased sensation and a fragile muscle mass, a mean pressure of 1.75-kPa was selected as the criterion pressure. It is impossible at this point to state whether a greater pressure would have resulted in a greater response in the group of subjects with SCI. This issue awaits further investigation.

**Clinical Implications**

The effectiveness of massage in decreasing motoneuron excitability in a sample of persons with SCI is comparable to that seen with similar modalities commonly used in the clinical setting. The effects of tendon pressure, circumferential pressure, and stretching on the H-reflex have been investigated in both subjects without neurological impairment27-31 and subjects with neurological impairment13,27,32,53 Tendon pressure has been shown to produce a decrease in the H-reflex amplitude of 29% in 7 out of 8 subjects with hemiplegia.32

### Table 6. Analysis of Variance Results for M-response Peak-to-Peak Amplitudes (Study 2)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
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<td>0.007</td>
<td>0.002</td>
<td>1.92</td>
<td>.13</td>
</tr>
<tr>
<td>Error</td>
<td>36</td>
<td>0.034</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 7. Analysis of Variance Results for H-reflex Peak-to-Peak Amplitudes (Study 2)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
<td>4</td>
<td>4.27</td>
<td>1.07</td>
<td>4.06</td>
<td>.008</td>
</tr>
<tr>
<td>Error</td>
<td>36</td>
<td>9.46</td>
<td>0.26</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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which is similar to the average decrease in the H-reflex noted in our study. In contrast to massage, the effect of intermittent tendon pressure in subjects without neurological impairment is not uniform. Kukulka et al. reported that 28 of the 32 control group subjects they tested responded to intermittent tendon pressure with a decrease in H-reflex amplitude. Recently, Robichaud et al. investigated the effect of circumferential pressure (using an air splint) on the H-reflex in both subjects with and without hemiplegia. The pressure application resulted in a decrease in the H-reflex in both groups (40% in the nonhemiplegic group and 52% in the hemiplegic group) for recordings taken at 5 minutes into the pressure application. The inhibitory effect of stretching on the H-reflex in individuals without neurological impairment also appears to be consistent. The percentage of decrease in H-reflex amplitude noted with stretching, however, falls between 21% and 47%. As was observed with massage, the effect of stretching in a neurologically impaired sample is also inconsistent. Although all these associated H-reflex studies were oriented toward the clinical setting, only one study demonstrated a carryover effect following the application of the modality. Thus, it is not possible to compare the carryover effectiveness of massage to these other physical modalities.

The fact that no currently used physical modality appears to be consistently effective in reducing motoneuron excitability (as evidenced by changes in the H-reflex) in a neurologically impaired sample makes the option of a massage application interesting, particularly in a population of persons with SCI. In our study, the application of massage resulted in an increase in motoneuron excitability in only two subjects; all other subjects showed a decrease in the H-reflex amplitude. The application of massage in an SCI population offers a unique advantage that the other modalities do not, in that massage is known to increase local circulation in subjects without neurological impairment. Thus, in the event that the massage is ineffective in reducing the hyperexcitable state of the motoneuron pool in a particular subject, it may increase the local circulation in a region where circulation is often deficient secondary to muscle paralysis or loss of vasomotor adjustment resulting from the injury. Thus, based on the findings of these H-reflex studies, the application of massage in a population of persons with SCI is a potentially viable alternative to modalities that are currently used in the clinical setting to control conditions associated with increased motoneuron excitability. The efficacy of massage in reducing the hyperexcitable state of the motoneuron pool in other neurologically impaired populations is still unknown. This question awaits further investigation.

**Conclusion**

The results of this study indicate that massage produces a reduction in H-reflex amplitude during massage in 8 out of 10 persons with SCI. This reduction is comparable to that seen in earlier studies with neurologically healthy subjects. The reduced level of motoneuron excitability is seen to carry over in some individuals for periods that may be of clinical usefulness. In the grouped data of the subjects with SCI, however, no significant sustained decrease in the H-reflex amplitude was observed. The use of massage is therefore not supported if a long-term carryover effect is the main treatment goal.

### Table 8. Analysis of Variance Results for H-reflex Latencies (Study 2)

<table>
<thead>
<tr>
<th>Source</th>
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<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
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<td>11.37</td>
<td>2.84</td>
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<tr>
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<td>36</td>
<td>67.30</td>
<td>1.87</td>
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</tbody>
</table>

### Table 9. Percentage of Change in H-reflex Peak-to-Peak Amplitudes for Conditions MASS, C3, and C4 (Study 2)

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>$\text{Mean}_{C1-C2}$ (mV) (100%)</th>
<th>Condition*</th>
<th>MASS</th>
<th>C3</th>
<th>C4</th>
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<tbody>
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<td>22</td>
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<td>2</td>
<td>2.53</td>
<td>91</td>
<td>109</td>
<td>109</td>
<td></td>
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<tr>
<td>3</td>
<td>1.70</td>
<td>120</td>
<td>107</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.78</td>
<td>97</td>
<td>95</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3.76</td>
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<td>65</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.42</td>
<td>104</td>
<td>104</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3.53</td>
<td>90</td>
<td>93</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>3.47</td>
<td>42</td>
<td>82</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>2.16</td>
<td>16</td>
<td>85</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>6.20</td>
<td>97</td>
<td>107</td>
<td>110</td>
<td></td>
</tr>
</tbody>
</table>

*See Table 2 footnote for explanation of conditions. Results represent the percentage of the value for each condition compared with the baseline values calculated from the mean of C1 and C2, which represents 100%. Therefore, 22% represents a decrease in H-reflex amplitude of 78%, whereas 120% represents an increase in H-reflex amplitude of 20%.
Acknowledgments

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Joanne Goldberg, Derek E Seaborne, S John Sullivan and Bernard E Leduc

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