EFFECTS OF A SINGLE SESSION OF PROLONGED PLANTARFLEXOR STRETCH ON MUSCLE ACTIVATIONS DURING GAIT IN SPASTIC CEREBRAL PALSY

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ABSTRACT. Activations of the tibialis anterior (TA) muscles during gait were studied in children with spastic cerebral palsy (CP) immediately before and after 30 min of standing on a tilt-table with the ankle dorsiflexed to stretch the TA in the experimental group (n = 8) as compared to a control group (n = 11). The EMG activity from the TA and TA was recorded concomitantly with electronic footswitch signals by a computer. Video records were made of the sagittal gait movements. Effects of PMS were determined by comparing change scores for selected spatiotemporal and muscle activation parameters between the groups. The change scores defined for the muscle activation were: a post-test/pre-test ratio of the EMG activity in specific segments of the gait cycle and a locomotor spasticity index. PMS did not significantly affect any of the spatiotemporal parameters nor did it alter any of the TA and most of the TA activation parameters or the SI indexes for the TA and TA. Only the TA post/pre activation ratio for the 0–16% segment of the gait cycle was smaller (p < 0.04), indicating a decrease in TA activation post-PMS.

Key words: cerebral palsy, spasticity, gait, muscle stretch.

Prolonged muscle stretch (PMS) denotes a maintained stretching of spastic muscles by manual or mechanical means. Therapists make extensive use of inhibiting postures and manual stretching of hyper-tonic muscles to reduce muscle tone and subsequently encourage active movements (5). The term “inhibitive stretch” has been applied to specialized costs of various materials used to maintain the foot, ankle and toes in a position thought to inhibit abnormal spastic reactions when the child is standing or walking. In one of the few quantitative studies, Tardieu et al. (30) reported an increased range of passive ankle movements after three weeks in a cast. As a whole, however, the literature on the effects of such “inhibitive casts” consists of short anecdotal reports (1, 11, 13, 29) or case studies (8, 15, 16, 36) without control groups, in which semi-quantitative evaluation procedures are used.

More recently, Watt et al. (32) on the basis of subjective scores of gait changes from video records reported that 3 weeks of inhibitive casting led to a significant improvement in foot-floor contacts that was maintained up to 2 weeks after cast removal but was lost in retests 5 months later. In another study, Bertoti (4), found stride length measured from foot-plant records to be significantly longer in a group of CP children after 10 weeks of wearing a short leg cast as compared to a control group. Lastly, in a detailed biomechanical analysis of the use of an ankle-foot orthosis to control knee hyperextension, Simon et al. (27) reported that such braces corrected the knee hyperextension in all but one of 15 children and that in 3 the correction was maintained even after the brace was removed. Semi-quantitative analysis of the muscle activations failed to discern changes in the triceps surae activation with and without the brace although compensatory changes were noted in the quadriceps and gluteus maximus muscles. It could be that the semi-quantitative analysis procedures failed to reveal the amplitude modulations necessary to characterize the changes in EMG.

Oden & Knutson (23) showed how prolonged muscle stretch of spastic plantarflexor muscles of adult paraplegic patients could diminish passive restraint. Furthermore, by comparing the effects of plantarflexor stretch in the lying and standing positions with the aid of a tilt table they demonstrated the superiority of stretch when combined to the standing position over stretch alone. These results strongly supported the well known beneficial clinical effects on spasticity in paraplegic patients obtained by standing on a tilt table or with the aid of a special
METHODS

Subjects
Nineteen (19) children with spastic cerebral palsy were re-
cruited from the population of children treated at the Cardi-
nal Villeneuve Rehabilitation Center in Quebec City. The
children (12 diplegics and 7 hemiplegics), aged 3 to 13
years old, met the following inclusion criteria: absence of surgery
to the legs, clinical evidence of spasticity in the plantarflexors,
capable of walking 10 m unassisted and mentally capable of
capable of participating in the tests. They were divided into an experi-
mental (EXP) and a control (CT) group. These groups are
substantially, however, because random allocation of the sub-
jects, made for a parallel study (3) that included non-walkers
was not made in predetermined blocks stratified for disabili-
ity. The effects of the unequal number of diplegics and hemi-
plegics on the results were statistically evaluated. Prior
acceptance into the study, the children were evaluated by a neu-
ropathologist to confirm the diagnosis and then parental
or guardian informed consent was obtained. Subject charac-
teristics are given in Table I.

Procedures
1. Recording of gait movements and muscle activations. To
record muscle activations, surface electrodes were placed on the
triceps surae (TS) and tibialis anterior (TA) muscles of one
leg. Movement artifacts were reduced by connecting
short electrode leads to miniature preamplifiers which were
connected to a battery and an electrode box carried at the
waist, and then by means of a 10 m shielded cable to the
electrode selector unit of a Grass (Grass Corporation, Quin-
cy, Mass., USA) polygraph. The myoelectric signals were
amplified and recorded via constant time constant of 20 ms and
fused to a POP 112-25 Plus (Digital Equipment Corporation, Maynard, MA 01754, USA) computer for recording (ample frequency = 100 Hz) and analysis. The EMG activity was
synchronized to the gait cycle by electronic switches asso-
ciated with the heel, midfoot and toe of each shoe. The children
were requested to walk along an 8 m walkway at free speed.
Sampling of EMG and footswitch signals was automatically
started and stopped as the child began stepping from
photocell arrays placed 4 m apart. Concomitant video rec-
ords were made of the sagittal gait movements. Gait records
were taken twice: a pre-test just prior to the treatment and a
post-test made about 30 min after the treatment. At least
gait cycles were recorded for each test.

2. Experimental and control treatments. Following com-
pletion of the gait pre-tests, the EMG electrodes and foot-
switches were left in place as the children received either the
EXP or CTL treatment for 30 min. Children in the EXP
group stood up with the help of a modified tiltable platform
and knee positions were controlled by special supports and
stretch of the plantarflexors was maintained at a comfortable
level by keeping the ankle in maximal dorsiflexion by means
of an adjustable footplate. While standing, the children in the
EXP group were engaged in educational activities. Between
sessions, children in the CTL group were seated and also engaged
in educational activities.

3. Analysis. Temporal parameters were derived from the
footswitch signals and computed by the computer program as the
average gait velocity. For each subject, mean muscle
activation profiles obtained during the pre- and post-tests
were graphically represented as the threemplitude of the EMG
in each cycle of the gait cycle. Mean activation profiles were
then calculated for each group. The gait movement patterns
were selectively analyzed by visual appraisal of the video
records by experienced evaluators. Movement changes were
used to help interpret the data but were not considered pri-
mary outcome variables.

Treatment effects between the groups were defined by com-
paring change scores for selected gait parameters. Selected
spatiotemporal parameters were: cycle duration, % stance
phase, average velocity and cadence. The muscle activation
profiles were statistically analyzed in two ways. First the
activation profiles were divided into 6 segments: 0-16%, 16-35%,
16-40%, 40-50%, 50-60% and 60-100% of the gait cycle (Fig. 1A).
The area under the activation profile for each of these segments became a specific EMG parameter for

Table I. Subject characteristics

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Mean ± SD: 7.2 ± 2.2

Control group (n = 11)

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Mean ± SD: 7.3 ± 2.6

to illustrate: A) analysis of specific segments of the activation profile and B) subdivision of the activation profile for cal-
culation of the locomotor spasticity index.

the statistical analysis. EMG change scores were defined by
post/pre EMG ratios for each segment.

Secondly, the spastic locomotor disorder index (SI) pro-
posed by Fung & Babcock (12) was calculated for the TS and
TA area (Fig. 1B). The gait cycle is divided into two equal
time periods representing periods when the muscle is activated
(“on”) and relatively non-activated (“off”) and as such for the
TS and TA the gait cycle is subdivided into periods B1 (0-20%),
B2 (20-70%) and B3 (70-100%). The area (a) under the mus-
cle activation profile for each of these periods is calculated to
give a1, a2 and a3. The SI is defined as the ratio of the EMG
area in the “off” periods to that in the “on” periods. Thus for
the TS the SI = (a1 + a2)/a3 and for the TA the
SI = a1(a1+a3). Fung & Babcock (12) reported SI values of
0.12 ± 0.04 (n = 5) and 0.20 ± 0.07 (n = 5) for the medial
gastrocnemius and TA, respectively, in adult normal subjects.
The SI index for the activation profiles illustrated in Fig. 1 are
0.99 (spastic) and 0.23 (normal) for the TS and 0.87
(spastic) and 0.57 (normal) for the TA. For the sta-

tistical analysis the SI change score was equal to the difference in
SI between pre- and post-tests.

Differences between the groups for the spatiotemporal and
EMG change scores were statistically evaluated by the Mann-
Whitney U test with the significance level set at p = 0.05.

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Studied apparatus (for a review see Oden 21, 22).
One can question whether such inhibitory effects could be
expected to occur on muscle activations during gait fol-
lowing PMS. Involvement of the different central
mechanisms involved in the genesis of the semiauto-
matic gait activations as compared to reflex or volun-
tary activations performed in the sitting or lying posi-
tion (18).

In the present study the short-term effects of a single session
of PMS for the plantarflexors were evalu-
ated on activations of these same plantarflexors and the
antagonist dorsiflexors during gait in children with
spastic cerebral palsy using a control group de-
ign. The spastic plantarflexors were stretched by
standing on a tilt table for 30 min with the foot dor-
sioflexed by an adjustable footplate as described by
Knutsson & Oden (23). In a parallel study these
same children were shown to have significantly de-
creased spastic restraint in both the stretched and
shortened muscles by this procedure and increased
capacity to voluntarily activate the plantarflexors fol-
lowing this stretching procedure (19, 20, 31). Prelimi-
nary findings were reported at the Xth World Confed-
eration for Physical Therapy Congress in Sydney (26).

Fig. 1. Comparison of mean activation profiles of the triceps surae (TS) and tibialis anterior (TA) muscles during gait in a 5-year-old diplegic child and a normal child of the same age.
standing apparatus (for a review see Odén 21, 22). One can question whether such inhibitory effects may be expected to occur on muscle activations during gait following PMS given the different central mechanisms involved in the genesis of the semiautomatic gait activations as compared to reflex or voluntary activations performed in the sitting or lying position (18).

In the present study the short-term effects of a single session of PMS of the plantarflexors were evaluated on activations of these same plantarflexors and the antagonist dorsiflexors during gait in children with spinal cerebral palsy using a control group design. The spinal plantarflexors were stretched by standing on a stool for 30 min with the foot dorsiflexed by an adjustable footplate as described by Knutsson & Odén (23). In a parallel study these same children were shown to have significantly decreased spastic restraint in both the stretched and shortened muscles by this procedure and increased capacity to voluntarily activate the plantarflexors following this stretching procedure (19, 20, 31). Preliminary findings were reported at the Xth World Confederation for Physical Therapy Congress in Sydney (26).

**METHODS**

**Subjects**

Nineteen (19) children with spinal cerebral palsy were recruited from the population of children treated at the Cardi- nal Villenborn Rehabilitation Center in Quebec City. The children (12 diplegics and 7 hemiplegics), aged 3 to 13 years old, met the following inclusion criteria: absence of surgery to the legs, clinical evidence of spasticity in the plantarflexors, capable of walking 10 M unassisted and mentally capable of participating in the test. They were divided into an experimental (EXP) and a control group (CTG). These groups are subsumed, however, because random allocation of the subjects, made for a parallel study (31) that included non-walkers was not made in predetermined blocks stratified for disability. The effects of the unequal number of diplegics and hemiplegics on the results were statistically evaluated. Prior to acceptance into the study, the children were evaluated by a neurophysiologist to confirm the diagnosis and then parental or guardian informed consent was obtained. Subject characteristics are given in Table I.

**Procedures**

1. Recording of gait movements and muscle activations: To record muscle activations, surface electrodes were placed on the triceps surae (TS) and tibialis anterior (TA) muscles of one leg. Motion artifacts were reduced by controlling short electrode leads to minimize preamplifiers which were connected to a battery and an electrode box carried at the waist, and then by means of a 10 m shielded cable to the electrode collector unit of a Grass (Grass Corporation, Quin-

**Table I. Subject characteristics**

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Mean ± SD: 7.3 ± 1.0, 114 ± 12, 120.5 ± 20.5

**Gait control group**

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Mean ± SD: 7.3 ± 1.0, 114 ± 16, 122 ± 6

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**Fig. 1.** Comparison of mean activation profiles of the triceps surae (TS) and tibialis anterior (TA) muscles during gait in a five-year-old diplegic child and a normal child of the same age.

---

**Subjects**

Nineteen (19) children with spinal cerebral palsy were rec- though the analysis. EMG change scores were defined by post/pre EMG ratios for each segment. Secondly, the spastic locomotor disorder index (SI) proposed by Fung & Barkess (12) was calculated for the TS and TA (see Fig. 1B). The gait cycle is divided into two equal parts representing periods when the muscle is activated ("on") and relatively non-activated ("off"); thus for the TS and TA the gait cycle is subdivided into periods B1 (0-20%), 82 (20-70%) and B3 (70-100%). The area (a) under the muscle activation profile for each of these periods is calculated to give a1, a2 and a3. The SI is defined as the ratio of the EMG area in the "off" periods to that in the "on" periods. Thus for the TS the SI = (a1 + a2)/a3 and for the TA the SI = a2/a1 + a3. Fung & Barkess (12) proposed SI values of 0.12 ± 0.04 (a1 + a3) and 0.20 ± 0.07 (a2/a3) for the normal gait patterns and TA, respectively, in adult normal subjects. The SI index for the activation profiles illustrated in Fig. 1A are 0.99 (spastic) and 0.32 (normal) for the TS and 0.87 (spastic) and 0.37 (normal) for the TA. For the statistical analysis the SI change score was equal to the difference in SI between pre- and post-tests.

Differences between the groups for the spatiotemporal and EMG change scores were statistically evaluated by the Main- Whizley U test with the significance level set at p<0.05.

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**Fig. 2.** Comparison of EMG activation profiles of the TS and TA muscles during gait in a five-year-old diplegic child and a normal child of the same age.
RESULTS

1. Spatiotemporal parameters

Table II gives the spatiotemporal parameters for the pre- and post-tests as well as the change scores. Comparison of the change scores for the different parameters failed to reveal statistically significant (p > 0.05) differences.

2. Gait movements

Eight of the 12 diplegic children initiated the stance phase with foot placement in the mid-foot and toe placement contact. Of these, 8 had foot equinus throughout the stance phase accompanied by knee hyperextension in 3 cases and by excessive knee flexion in 3 other cases. Those with knee hyperextension had foot drag in the swing phase. In 3 of the diplegic children the gait dysfunction was less severe; the stance phase was initiated with heel contact and relatively minor abnormalities occurred in the ankle and knee movements throughout the gait cycle. Six of the 7 hemiplegic children initiated the stance phase with foot placement while only 1 had heel contact. In the stance phase, knee hyperextension was observed in 3 (accompanied by foot equinus throughout stance in 1 child) and excessive knee flexion during stance in 1, while toe drag during swing occurred in 6 of the hemiplegic children.

Visual inspection of the video records did not reveal systematic changes between the tests although minor changes were noted in some children. Furthermore, it was not possible to define systematic differences between the tests from analysis of the computer printouts of the footswitch contacts.

Table II. Spatiotemporal gait parameters obtained in pre- and post-tests for both groups of CP children

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<td>Velocity (m/s)</td>
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* Change score: difference between pre- and post-test scores.

* Values given as mean ± 1 SD.

Fig. 2. Comparison of muscle activation profiles during the gait cycle of a child with CP and normal gait. The shaded area indicates mean and vertical bars ± 1 SD. EMG amplitudes are shown relative to the gait cycle. The EMG activity was higher during the stance phase in the CP child than in the normal child.

3. Muscle activations

To illustrate the individual results, the activation profiles of the EMG signals for one of the children in the EXP group are illustrated in Fig. 2. This diplegic child walked with flexed knees and initiated the gait cycle with foot contact. As can be seen in the figure, the mean activation profiles of the TS and TA post-PMs generally fall within the dispersion of pre-test values and in this case, the variability of the EMG measures was higher in the TS during swing and in the TA during stance post-PMs. The SI for the TS was 0.99 in the pre-test and 0.95 in the post-test while for the TA it was 0.87 and 0.67 in the pre-test and post-test, respectively.

Fig. 3. Comparison of muscle activation profiles during gait in the 2 groups of subjects in pre- and post-tests. EMG amplitudes are shown relative to the gait cycle. The EMG activity was higher during the stance phase in the CP child than in the normal child.

Examination of individual values revealed that 7 of the 8 children in the EXP group had a post/pre EMG ratio < 1.0 for the TA in this segment of the gait cycle.

4. Spastic locomotor disorder index (SLDI)

Table IV gives the mean values and dispersions of the spasticity locomotor disorder index (SLDI) calculated in early stance and lower in late stance in the post-test but these changes were within the dispersion of the pre-test values. In the TA, the mean stance and swing phase activation level is lower in the post-tests but again within the dispersion of pre-test values. To verify the statistical significance of these small changes, EMG post/pre ratios for specific segments under the activation curves were compared (see Methods). These EMG post/pre ratios are given in Table III. The only significant difference between the respective post/pre ratios (change scores) between the EXP and CTL groups was the smaller ratio (p < 0.01) for the TA from 0–16% of the gait cycle, indicating a decrease in EMG activity in this part of the gait cycle post-PMs.

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RESULTS

1. Spatiotemporal parameters

Table II gives the spatiotemporal parameters for the pre- and post-tests as well as the change scores. Comparison of the change scores for the different parameters failed to reveal statistically significant (p > 0.05) differences.

2. Gait movements

Eight of the 12 diplegic children initiated the stance phase with forefoot (midsid and toe footswitch) contact. Of these, 8 had foot equinus throughout the stance phase accompanied by knee hyperextension in 3 cases and by excessive knee flexion in 3 other cases. These with knee hyperextension had foot drag in the swing phase. In 3 of the diplegic children the gait dysfunction was less severe; the stance phase was initiated with heel contact and relatively minor abnormalities occurred in the ankle and knee movements throughout the gait cycle. Six of the 7 hemiplegic children initiated the stance phase with forefoot contact while only 1 had heel contact. In the stance phase, knee hyperextension was observed in 3 (accompanied by foot equinus throughout stance in 1 child) and excessive knee flexion during stance in 1, while toe drag during swing occurred in 6 of the hemiplegic children.

Visual inspection of the video record did not reveal systematic changes between the tests although minor changes were noted in some children. Furthermore, it was not possible to define systematic differences between the tests from analysis of the computer printouts of the footswitch contacts.

Table II. Spatiotemporal gait parameters obtained in pre- and post-tests for both groups of CP children

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Experimental group (n=8)</th>
<th>Control group (n=11)</th>
<th>Change score ( \text{Pre-test} - \text{Post-test} )</th>
<th>Change score ( \text{Pre-test} - \text{Post-test} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stride length</td>
<td>66 (12)</td>
<td>67 (13)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(cm)</td>
<td></td>
<td></td>
<td>(1)</td>
<td>(1)</td>
</tr>
<tr>
<td>Cycle duration</td>
<td>1033 (123)</td>
<td>99 (131)</td>
<td>−39</td>
<td>1053 (121)</td>
</tr>
<tr>
<td>(ms)</td>
<td>(113)</td>
<td>(111)</td>
<td>(39)</td>
<td>(113)</td>
</tr>
<tr>
<td>Cadence</td>
<td>187 (263)</td>
<td>263 (113)</td>
<td>39</td>
<td>141 (145)</td>
</tr>
<tr>
<td>(steps/min)</td>
<td>(128)</td>
<td>(111)</td>
<td>(39)</td>
<td>(141)</td>
</tr>
<tr>
<td>Velocity</td>
<td>65 (12)</td>
<td>72 (12)</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>(%)</td>
<td>(13)</td>
<td>(16)</td>
<td>(3)</td>
<td>(3)</td>
</tr>
</tbody>
</table>

Change score: difference between pre- and post-test scores.

Values give mean ± 1 SD.

Fig. 2. Comparison of the muscle activation profiles pre- and post-tests (shaded area = ± 1 SD, n=30 gait cycles) and post-squares indicate mean and vertical bars ± 1 SD, n=20 gait cycles) in a gait cycle of a 4-year-old diplegic child. The amplitude (in mV) of the muscle activities in the tibialis anterior (TA) and tibialis anterior (TA) on the Y-axis is given relative to the gait cycle on the X-axis. Cadence = 163 and 178 steps/min in pre- and post-tests, respectively. Arrows indicate end of stance phase.

4. Spastic locomotor disorder index (SI)

Table IV gives the mean values and dispersions of the spasticity locomotor disorder index (SI) calculated in...

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pre- and post-tests as well as the change scores for each group. In the EXP group the SI for the TS in the pre-test ranged from 0.50 to 1.05 while in the CTL group it ranged from 0.38 to 1.66. Although not statistically different (p = 0.05), the SI index was higher and more variable in the CTL group in the pre-tests. Only small changes occurred in the SI index in post-tests and the change scores were similar in both groups (p = 0.05). The mean SI index for the TS was remarkably similar in both groups (range in EXP group = 0.59-1.00 and in CTL group = 0.62-1.65) although its variability was larger in the CTL group. The SI change scores between pre- and post-tests for both groups were similar (p = 0.05).

5. Effect of disability

Because the groups were not evenly matched for disability (hemiplegia or diplegia), the effect of disability on the different parameters was examined. This analysis revealed that the area under the EMG segment from 26-70% of the gait cycle was greater (p < 0.01) in the group of diplegic children in pre-tests. No other spatiotemporal or EMG pattern differed with disability in pre-tests. Analysis of the effect of disability on change scores again pointed to the 50-70% segment, revealing lower (p < 0.02) post/pre EMG ratios for the diplegic group thus suggesting that the prolonged latency of TS activation is reduced after PMS.

DISCUSSION

In this study the effects of a single session of prolonged stretch of the plantarflexors on activations of these same muscles and their antagonists during gait were studied in children with spastic CP. Despite in-depth analysis of the EMG activation profiles, the only significant finding was a lower TA activation from 0-16% of the gait cycle post-stretch. This lower early stance TA activation post-stretch did not, however, alter the SI index (12), possibly reflecting its lack of sensitivity. Since prolonged stretch of the TS results in reduced spastic restraint during passive ankle movements in the same children (31), it was also expected to reduce spasticity during walking. Indeed, on the basis of gait analysis from 0.50 to 1.05 while in the CTL group it ranged from 0.38 to 1.66. Although not statistically different (p = 0.05), the SI index was higher and more variable in the CTL group in the pre-tests. Only small changes occurred in the SI index in post-tests and the change scores were similar in both groups (p = 0.05). The mean SI index for the TS was remarkably similar in both groups (range in EXP group = 0.59-1.00 and in CTL group = 0.62-1.65) although its variability was larger in the CTL group. The SI change scores between pre- and post-tests for both groups were similar (p = 0.05).

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Table III. Mean post/pre EMG ratios calculated for different segments of the activation profiles during gait for the tibiceps surae (TS) and tibialis anterior (TA) muscles of both groups of CP children.

<table>
<thead>
<tr>
<th>Segment of gait cycle</th>
<th>0-16%</th>
<th>16-50%</th>
<th>50-70%</th>
<th>60-80%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXP (n=8)</td>
<td>1.14</td>
<td>1.07</td>
<td>0.91</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td>CTL (n=11)</td>
<td>1.12</td>
<td>1.16</td>
<td>1.12</td>
<td></td>
<td>1.11</td>
</tr>
<tr>
<td>TA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXP (n=8)</td>
<td>0.79</td>
<td>0.83</td>
<td>1.02</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>CTL (n=11)</td>
<td>1.04</td>
<td>0.97</td>
<td>1.10</td>
<td>1.01</td>
<td></td>
</tr>
</tbody>
</table>

* Values give mean post/pre EMG ratio for each segment.
*p < 0.05 (Mann-Whitney U-test).

Table IV. Comparison of the mean locomotor spasticity index calculated for the tibiceps surae and tibialis anterior muscles in pre- and post-tests for both groups of CP children.

<table>
<thead>
<tr>
<th>Experimental group (n=8)</th>
<th>Control group (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistical comparison</td>
</tr>
<tr>
<td></td>
<td>Pre-test</td>
</tr>
<tr>
<td>Triceps</td>
<td>0.74</td>
</tr>
<tr>
<td>surae</td>
<td>0.20</td>
</tr>
<tr>
<td>Tibialis</td>
<td>0.78</td>
</tr>
<tr>
<td>anterior</td>
<td>0.13</td>
</tr>
</tbody>
</table>

* Values give mean ± 1 SD for spasticity index calculated as defined by Fung & Barbeau (1989).
| Change score: difference between pre- and post-tests. | Differences between change scores were not significant; p > 0.05 (Mann-Whitney U-test). | 109 |

Prolonged muscle stretch and gait activations

The predicted beneficial effect on the TA, shortened by the procedure, was increased early stance and late swing phase activations. Not only did this not occur but in fact the only significant finding post-stretch was a decreased TA early stance phase activation. It is known that the TA activation burst in early stance becomes more prominent with maturation as normal infants acquire a definite heel-strike (24). It is thus not surprising to see an even lower TA activation burst in spastic CP who lack dorsiflexion at the end of the swing phase and initiate the gait cycle with full foot or toe contact (34). On the other hand, it is more difficult to explain the further decrease in this activation burst post-stretch. Could the lower activation level be a response of the usually elevated TA by the action of the spastic plantarflexors to the uncustomed shortened position held for 30 min while the TS is being stretched? This change in muscle length may affect the sensitivity of the muscle receptors so that the excitability of the TA is much reduced, resulting in a still lower activation level in early stance.

Since the control group had proportionally more hemiplegic cases than the experimental group, one can argue that the disability level may have skewed the response to the inhibitory procedure. This may have been the case for the 50-70% segment of the TS activation profile and it is possible that a larger proportion of diplegics may have led to significant changes for this EMG segment. In general, however, statistical evaluation of the effects of disability level on the changes in the parameters chosen to represent the effects of the stretching procedure showed that disability per se was not the determining factor in the differences in group results.

In summary, the results of the present study clearly indicate that a single session of TS stretching in the upright position does not produce a functional improvement in the gait pattern. These findings do not mean that long-term muscle stretch cannot affect muscle activations during gait but only that 30 min is not enough. Further studies are needed to determine the intensity and duration of the minimal effective stretching stimulus since casts and ankle orthoses which apply a stretch over longer periods can induce change. The results also demonstrate the instability and reproducibility of the gait activations in spastic CP when the recording electrodes are left in place. Finally, the present study emphasizes the importance of a
The group of diplegic children in pre-tests. No other spontaneous or EMG parameter differed with disability in pre-tests. Analysis of the effect of disability on change scores again pointed to the 50-70% segment, revealing lower (p < 0.02) post/pre EMG ratios for the diplegic group thus suggesting that the prolonged latency of TS activation is reduced after PMS.

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5. Effect of disability

Because the groups were not evenly matched for disability (hemiplegia or diplegia), the effect of disability on the different parameters was examined. This analysis revealed that the area under the EMG segment from 50-70% of the gait cycle was greater (p < 0.01) in the group of diplegic children in pre-tests. No other spontaneous or EMG parameter differed with disability in pre-tests. Analysis of the effect of disability on change scores again pointed to the 50-70% segment, revealing lower (p < 0.02) post/pre EMG ratios for the diplegic group thus suggesting that the prolonged latency of TS activation is reduced after PMS.

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<th>50-70%</th>
<th>50-70%</th>
<th>63-80%</th>
<th>84-100%</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
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<td>1.11</td>
<td>1.12</td>
<td>1.11</td>
<td></td>
</tr>
<tr>
<td>TA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>0.90</td>
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<td>0.97</td>
<td>1.01</td>
<td>1.10</td>
<td>1.01</td>
<td></td>
</tr>
</tbody>
</table>

Values give mean post/pre EMG ratio for each segment. EXP = experimental; CTL = control.

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<table>
<thead>
<tr>
<th>Experimental group (n=8)</th>
<th>Control group (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>Triceps</td>
<td>0.74</td>
</tr>
<tr>
<td>surae</td>
<td>(0.20)</td>
</tr>
<tr>
<td>Tibialis</td>
<td>0.78</td>
</tr>
<tr>
<td>anterior</td>
<td>(0.13)</td>
</tr>
</tbody>
</table>

Values give mean ± SD for spasticity index calculated as defined by Fung & Barbisis (1989).

[a] Change score: difference between pre- and post-tests.
[b] Differences between change scores were not significant; p > 0.05 (Mann-Whitney U-test).

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control group and the use of "change" scores in the statistical analysis. The interpretation of the effects of the strengthening procedure can be quite different when comparing pre- and post-test results within groups or when looking only at the experimental group.

ACKNOWLEDGEMENTS
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