Objective Evaluation of a Splint Designed to Reduce Hypertonicity

(Spasticity, muscle tone, rehabilitation, brain damage, severely profoundly handicapped)

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Snook's spasticity reduction splint was evaluated objectively with five severely and profoundly handicapped subjects. The force of spastic wrist flexors in pounds of pull was measured on a spring-weighted scale. Findings demonstrated that the device designed for this study was useful in measuring hypertonus; splint wearing resulted in a reduction of the passive component of muscle tone and that this reduction was related to the length of time the subjects wore splints; the effects of splint wearing were not necessarily permanent. Components that contribute to the condition of hypertonicity are discussed, as well as the implications of the study findings for occupational therapists.

Occupational therapists increasingly need to document the effectiveness of treatment measures. The development of a tool suited for the clinic that would measure hypertonus would benefit therapists working with brain-damaged clients. It would be useful for documentation purposes in dealing with third-party payers, and would be useful in further clinical research by monitoring a patient's response to treatment. This article introduces a measurement tool that was used in a study to evaluate the effectiveness of a "spasticity reduction" hand splint.

The splint evaluated was designed by Snook (1) and based upon Bobath's theories that the therapeutic use of reflex inhibiting movement patterns led to a reduction of abnormal muscle tone (2). Snook contended that flexor spasticity of the hand is reduced in brain-damaged individuals who wear this splint and supported this idea with clinical observations and case histories (1).

Over the last 20 years, pharmacologists, physicians, therapists, and scientists developed inventive methods for measuring abnormal muscle tone. Their research is useful in identifying the properties of muscle tone.

The Properties of Muscle Tone

Classical neurophysiological theory holds that spasticity is the result of exaggerated stretch reflexes (3, 4). Various experimenters have attempted to delineate the properties of spasticity for research purposes.

Herman found that three factors contributed to the tension of the spastic muscle: the behavior of the stretch receptors, the level of motor-neuron activity in the muscle, the inherent visco-elastic, plastic, and contractile properties of the muscle (5).

Jansen (3) theorized that components of spasticity could be separated into two factors based upon the reaction of the muscle spindle to stretch. The first factor, the active tension or "dynamic response," is the response of the muscle while being stretched. This factor includes the velocity and force of the movement. The second factor, the "static...
response," is the spindle's reaction to maintained extension.

Stolov (6) discussed the measurement of muscle tone as separate from the measurement of spasticity. He believed spasticity is not synonymous with hypertonicity; rather, spasticity refers only to the state of hyperactive stretch reflexes, whereas hypertonicity could exist without the presence of hyperactive stretch reflexes. He explained that muscles exhibit elastic, plastic, and viscous nonreflexive properties that contribute to muscle tension. Stolov defined muscle tone as the resistance to passive elongation. He thought muscle tone was mediated by the interaction of the dynamic factor or the tension of the muscle during stretch, and static tension or the tension of the muscle at a new length after stretch had been completed. The dynamic factor was caused by the interaction of reflexive and nonreflexive forces; the static tension was composed of nonreflexive forces or the physical composition of the muscle (6).

Herman and Stolov agreed that the contribution of the physical composition of the muscle to hypertonicity is the factor most often ignored in research (5, 6).

Quantitative Measurements of Spasticity
In a review of the literature, three types of attempts to produce quantifiable measurements of spasticity were discerned: studies that used electromyographic techniques (4, 7); studies that used equipment designed to record physical responses of the muscle when it was stimulated (8-11); and studies that combined both methodologies (6, 12-14).

In electromyographic studies, a specific muscle was stimulated either by a mechanical tendon tap or by an electrode. Measurement of the neural response was then recorded on an oscilloscope or on a specifically designed recording device. These techniques measured the increase or decrease in the rate of firing of specific neuronal pathways of specific muscles.

The second type of study depended upon the creation of elaborate equipment to measure the force, velocity, pressure, or torque of muscles in response to either mechanical stimulation or controlled mechanical movement. Long developed a machine that measured the index finger's passive resistance to stretch when stimulated by an oscillating motion (12). Webster designed a system that recorded in torques the increased reflex properties of the lower leg when moved at different rates of speed (11). Erdman and Heather used a light reflection technique to photographically record the foot's response to a mechanical tap of the Achilles tendon (8).

Although agreeing to the importance of adequate assessment of muscle tone, these investigators used complex or expensive methods (8, 9) that could be criticized as unsuitable for daily clinical use. Too, inconsistencies among the investigators' definitions of the properties of muscle tone measured (4) have made comparisons difficult. Long, who said investigators who quantify muscle tone face complex problems, avoided some confusion by operationally defining the components of muscle tone (12).

For the present study, the author defined hypertonus as the viscoelastic and plastic properties of a muscle resistant to stretch and with a tendency to return to a particular abnormal resting position. This definition is related to Long's concept of postural contraction (12) and to Stolov's concept of the passive component of hypertonicity (6). However, Long's and Stolov's definitions of hypertonus excluded the reflexive contribution of muscle tone.

Using this definition, then, measurement of the passive component of hypertonicity could be accomplished by assessing the force of the limb to return to an abnormal resting position from the normal resting position. Since the normal resting position of the hand is midway between pronation and supination with 12 to 20 degrees of extension (15), the passive force exerted by the wrist toward flexion beyond this point would indicate hypertonus. For this study, zero degrees of flexion or extension using the 180-degree measurement method was considered the normal resting position of the hand.

This study investigated three specific questions. Does splint wearing reduce hypertonicity? Is there any relationship between the amount of time splints are worn and their effectiveness? Are the effects of splint wearing permanent?

Method
Subjects. Five students, one female and four males, ranging in age from 10 to 18, were chosen for this study from the population of 20 handicapped students mainstreamed in an Iowa public school. They were chosen because they exhibited hypertonus of wrist flexors. Three students exhibited spastic hemiparesis and two exhibited spastic quadriparesis. All had been labeled as severely profoundly handicapped, using the Iowa school system classification (IQ < 30) and had medical diagnoses of hypertonicity. Tonal assessments made prior to the study classified three students as having severe abnormal tone and two as having mild abnormal tone. None
Table 1 Data Configuration, Weekly Measurements of Hypertonus and Information for Subjects.

<table>
<thead>
<tr>
<th>SS</th>
<th>Hand</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Tone</th>
<th>t Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hemi, TBI, L</td>
<td>9.25</td>
<td>6.75</td>
<td>4.00</td>
<td>3.25</td>
<td>2.00</td>
<td>3.25</td>
<td>Severe</td>
<td>Week 1-5</td>
<td>t = 3.77*</td>
</tr>
<tr>
<td>2. Quadraplegic, unidentifying etiology, R</td>
<td>5.00</td>
<td>3.75</td>
<td>3.00</td>
<td>3.50</td>
<td>2.75</td>
<td>5.00</td>
<td>Severe</td>
<td>Week 1-6</td>
<td>t = 2.38†</td>
</tr>
<tr>
<td>3. Hemi, Sturge-Weber, R</td>
<td>6.75</td>
<td>5.50</td>
<td>5.00</td>
<td>3.00</td>
<td>3.50</td>
<td>4.75</td>
<td>Severe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Hemi, TBI, L</td>
<td>3.25</td>
<td>2.75</td>
<td>1.50</td>
<td>1.25</td>
<td>1.1</td>
<td>.75</td>
<td>Mild</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Quad, unidentifying etiology, R</td>
<td>2.25</td>
<td>2.00</td>
<td>1.25</td>
<td>.25</td>
<td>.1</td>
<td>.1</td>
<td>Mild</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>2.00</td>
<td>1.50</td>
<td>25</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ X = \frac{4.71}{1/20} \]
\[ T = \frac{3.86}{2/30} \]
\[ \frac{2.61}{3/4.75} \]
\[ \frac{2.11}{4/5.50} \]
\[ \frac{1.68}{5/6.0} \]

N = 7
* Significance, .01
† Significance, .05

of the five students had range of motion limitations beyond the normal resting position of the hand.

One student's diagnosis was Sturge-Weber syndrome, two students had brain damage due to traumatic injury, and two had brain damage of undetermined origin. Brain damage in all cases occurred at least 8 years before the study.

**Instrument.** The instrument developed to measure hypertonus consisted of a spring-weighted fishing scale anchored by a 'C' clamp to a table top at the height of the subject's forearm when the subject was in the testing position. A 20-pound test fishing line was attached to the weighing hook of the scale and an adjustable loop was made with the other end of the line.

**Experimental Design.** For six weeks, measurements were taken Monday through Friday, mornings and afternoons. Splints were not worn the first week. Splints were worn for 15 minutes the second week, and each week thereafter wearing time was increased in 15-minute intervals. During the fifth week the splints were worn for 1 hour, twice daily, for 5 days.

Data collected during the first week were used as a baseline. Data collected during the mornings and afternoons were used to determine whether the time of day affected the measurement. Data collected from weeks 2 through 5 were used to analyze how length of time affected splint wearing. Data from the sixth week were used to assess the effects of hypertonus once the splints had been removed.

**Procedure.** Splints were made before the beginning of the experiment. Each subject's teacher scheduled splint wearing and measurement taking. Each teacher was responsible for applying and removing the splints. Teachers, fully trained by the investigators in the test procedure, were not aware of the variables involved nor of the hypotheses being tested.

One scale was used for each classroom. (The five students came from four different classrooms.) The four scales were calibrated before the beginning of the experiment.

Measurements were taken in the following manner. Subjects sat either in their adapted wheelchairs or in chairs with adequate positioning ensured. The head was positioned to counteract the effects of the ATNR reflex. (Influence of flexor tone at the wrist could result from the ATNR.) The arm was placed in the position recommended by Esch and Lepley for the measurement of range of motion for pronation and supination (16). The forearm rested on the table midway between pronation and supination, with the radiocarpal joint extended approximately 2.5 cm over the table surface. The fishing line loop was positioned around the hand just below the metacarpal phalangeal joint and under the thumb. The scale was adjusted to read zero degrees when the wrist was held in a zero extension position. Then the wrist was released, allowing the hand to be pulled toward the abnormal resting position. Measurement was taken when the pointer of the scale stopped fluctuating, which occurred after 1 to 5 seconds. It was taken just after the splints had been removed.

**Results.**

**Analysis.** The t test was used to analyze the variance of the morning and afternoon measurements and the measurements of weeks 1 and 5, and weeks 1 and 6. Since the sample size was small, the t test could have...
overemphasized the differences necessary to obtain significance, when trends in the data strongly suggested these differences; therefore, the Wilcoxon matched-pairs signed rank test was also used. These scores were reported in terms of $T$ (17).

Since no significant differences were found between data collected in the morning or afternoon, scores for each day were averaged. Each subject's daily scores were added to produce a weekly score, which was then used for all further statistical analysis.

Subjects' background information, weekly scores, mean scores for each week, subjective tone assessment, t and $T$ score results are given in Table 1. An $N$ of 7 was used for all statistical analyses because, for quadraparetic subjects requiring two splints, independent data were collected for each hand.

In relation to the three study questions posed, the following results are reported.

**Reduction in Hypertonicity.** Data demonstrated a significant reduction in hypertonicity after 4 weeks of splint wearing. The average pounds of pull recorded for all subjects for the first week (the no-splint-wearing condition) was 4.71 pounds. The average for the fifth week (the fourth week of splint wearing) was 1.68 pounds ($t = 3.77; p < .01$).

**Time.** Tone decreased as splint wearing time increased. The graph in Figure 2 illustrates that tone reduction appears almost linear. The Wilcoxon matched-pairs signed rank test was used to analyze this trend. Differences in weekly scores for each subject were in a positive direction except for the two scores of Subject 2 (week 4 subtracted from week 3) and the one score of Subject 3 (week 5 subtracted from week 4) (Figure 1). The reduction of tone in this linear fashion was due to one of three factors: the amount of time the patient wore a splint daily; the amount of time the patient wore a splint over a number of weeks (a cumulative effect); both the amount of time a splint was worn daily, interacting with the cumulative effect of wearing the splint for several weeks. Within the confines of the data collected no determination could be made as to which factor caused the tone reduction.

**Permanence.** After the splints were removed, hypertonicity increased. When the Wilcoxon matched-pairs signed rank test was used by subtracting week 6 from week 5 scores (Table 1), all differences were negative for each subject ($T = 0, p < .01$). Further analysis compared scores of weeks 1 to 5 ($t = 3.77, p = .007$) and 1 to 6 ($t = 2.38, p = .05$). Even though the data indicated that hypertonicity at week 6 was less than at week 1, the reduced statistical probability indicated increased muscle tone, suggesting that the effects of splint wearing were not permanent (Figure 2).

**Discussion**

There were five limitations to this study that could be corrected in future investigations. One, because the sample size was small and homogeneous, statistical tests that contained more power could not be used; therefore, inferences to populations beyond severely profoundly handicapped students must be guarded. Two, data collected from quadraparetic subjects who wore two splints were treated as independent. Bishop and others demonstrated that a stimulus to a foot in normal subjects would affect contralateral hand grasping abilities (7). Therefore, splint usage with one hand may affect hypertonicity
in the other. Three, the time variable could not be completely explained by the data collected. But I suggest that the third factor—amount of time a splint was worn daily, interacting with the cumulative effect of splint wearing weekly—is the most acceptable to explain the reduction in muscle tone. Four, interrater reliability tests were not conducted. But, since each teacher measured the same subject(s) daily, this was not considered an issue for this study. Five, the internal validity of the measurement tool was not tested. The weekly weight totals (pounds of pull for each student), when compared with the subjective assessment of tone by other therapists, were indicative of the validity of the instrument developed for the study. Further testing is needed. Also, future investigations would have more inferential power if scores could be correlated with already tested devices.

The population chosen for the study was ideal in other respects. Four of the five subjects were incapable of voluntary hand movement and could not have influenced the results because their hand movements were either totally reflexive or dominated by tone. The study demonstrated that the use of Snook's "spasticity reduction splint" reduced hypertonicity in five subjects. The obvious explanation for this reduction was that prolonged stretch of wrist flexors and stimulation of the Golgi tendon organs led to the inhibition of the flexors and stimulation of the extensors (18). This caused relaxation. The study neither supported nor refuted Snook's contention that wearing this splint led to a reduction in the dynamic components of muscle tone (1). Neither did it support nor refute Snook's interpretation of Bobath's theory upon which
the splint design was based. In a circular fashion, the study may lend credence to Snook’s contention and interpretation since the results were predicted from them.

Snook noted a normalization of tone in her subjects at the shoulders and elbows during splint wearing and, through clinical observation, I confirm this. Leavitt and Beasley remarked that relaxation of hypertonus was the goal of pharmacological therapy (13)—it is a prerequisite for therapeutic intervention. Gillette (19), Harris (20), and Bobath (2) agree. From this viewpoint, the splint should be useful in the rehabilitation of the brain-damaged individual. This study did not collect data about the rehabilitation of the hand dominated by abnormal muscle tone because the sample, being severely profoundly handicapped, did not represent an appropriate rehabilitation to intelligence (21). Further study would definitely be suggested.

Snook used a more rigorous and demanding splinting schedule than that used in this study. Since our schedule was chosen arbitrarily, it would be beneficial to investigate whether the length of time a patient wore splints in any single time period or whether the cumulative effect of splint wearing over time was a more important variable to the reduction of hypertonus. Also, it would be important to know whether the linear relationship that emerged from this study was mathematically computable, and further, whether there is an ideal splint wearing schedule that would maximize tonal reduction.

Summary
The effectiveness of a specific orthosis in tonal reduction was tested. Hypertonicity was found to decrease as splint wearing increased and to increase when splint wearing stopped. This suggests that the effects of splint wearing are not permanent. Inferences to larger populations were limited by the small sample size, sample homogeneity, and lack of inter-rater and internal validity tests of the measurement tool designed for use in this study.

The measurement tool, after further testing, can be useful to therapists in two ways. First, it can be used clinically to document the effectiveness of treatment—aiding in ensuring quality care, accountability, and credibility of the use of orthoses in tone reduction. Second, the tool can aid future clinical research by providing a sound basis for clinical practice procedures.

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REFERENCES