Ten adults with hypertonic wrist flexors volunteered as subjects in an experiment comparing the effectiveness of dorsal and volar resting hand splints in the reduction of abnormal muscle tone. Subjects were randomly assigned to two groups of five each. Individuals in one group were fitted with dorsal splints, and individuals in a second group with volar splints. Measurements by spring-weighted scales were taken to assess the efficiency of each splint design in the reduction of hypertonus. Results demonstrated no significant differences between the volar and dorsal splints in reducing hypertonus. However, the age of the subjects was found to be an intervening variable: The older subjects of both groups demonstrated a gradual but not significant decline in hypertonus, whereas the younger adults demonstrated a significant decline in hypertonus over a 6-week period.

Opinions concerning the use of splints in the rehabilitation of hypertonic wrist flexors have been controversial, divergent, and based weakly upon systematic research (1-3). Chariat (1) described disagreements primarily among proponents and opponents of splinting the hemiplegic and, secondarily, among proponents concerning the optimum time splints should be worn and the design of the splint. Rosenada and Ellwood (3) believed splinting controversies resulted from a lack of research, inadequate definitions of muscle tone, and inadequate measurement devices.

The Research Literature

Brennan (4) conducted a study of 14 hemiplegic patients, for whom he constructed volar surface wrist, hand, elbow, and knee splints that were worn 24 hours a day for 1 year. He compared treated and untreated joints of all 14 patients and con-
cluded that, in all splinted joints, abnormal muscle tone had been abolished and that increased strength and range of motion were secondary effects. He suggested that splinting affected peripheral rather than central mechanisms, thereby altering the neuromuscular spindles' reaction to stretch.

Kaplan (2) attempted to apply neurophysiological principles to a splint design for hemiplegic clients. He theorized that tactile stimulation of antagonistic musculature through the use of textured surface dorsal splints would not only reduce hypertonus but would also stimulate functional return of the involved limb. Ten hemiplegic subjects were splinted in this manner and began a 24-hour-a-day wearing schedule. The schedule was reduced to 8 hours a day when some participants complained of pain. The study's conclusions were that dorsal textured wrist splints decreased hypertonus and led to increased functional strength of the impaired hand. Kaplan suggested that splinting be used as a supplementary approach to neurophysiologically designed exercise in rehabilitation (2).

In a comparison of dorsal and volar surface splinting techniques, Chariat's study (1) involved 20 subjects, 10 splinted with each splint design, and concluded that: 1. the pressure exerted by a volar splint resulted in increased muscle tone; 2. the use of dorsal splints reduced muscle tone; 3. constant splint wearing could have adverse effects; 4. exercise should supplement splint wearing; and 5. facilitation techniques used in conjunction with splint wearing would increase the functional return of the involved limb. Snook (5) presented three case histories to support her contention that a dorsal splint she had designed reduced spasticity. Snook's contention was confirmed recently in a study of five severely/profoundly handicapped children (6).

Several major problems exist with the studies cited above: 1. the research design and methodology used in one study were not used in following studies, making the findings of each study difficult to compare with the others; 2. because the findings of one study do not logically lead to the construction of the next, it is difficult to conceptualize how the different findings fit into an overall network; 3. some of the investigator's conclusions are only loosely based upon the data collected; and 4. the research designs create methodological concerns in general. For example, Brennan (4) studied a reduction of muscle tone generally related to volar surface splinting. Kaplan (2) did not compare his design to Brennan's nor measure muscle tone in the same manner. Neither author described how strength was measured nor submitted his range of motion data to statistical analysis; yet, both authors claimed that the splints they used reduced spasticity, increased strength, and increased range of motion.

The Splinting Controversy

Westcott (7), in an historical review of 12 major approaches used before 1955 for the rehabilitation of the hemiplegic hand, found that only 4 of the 12 approaches recommended splinting as an adjunctive therapeutic procedure. Wynn-Parry (8), in the classic book on hand rehabilitation, does not mention splinting as a prophylactic measure in reducing muscle tonus. Trombly and Scott (9) stated that the utility of splinting the hypertonic hand was debatable and made no suggestions concerning its use.

Bunnell (10) stated that static splinting of the hypertonic hand led to muscular atrophy and joint stiffening. Rood (11) and Farber and Huss (12) suggested that static splints could increase hypertonus. Bunnell (10) and Farber and Huss (12) suggested the usefulness of dynamic splinting techniques in reducing hypertonicity and increasing function. Gillette (13) noted two uses for static wrist splints in hemiplegia—for the release of the cortical thumb and as an aid in the evaluation of rehabilitation potential before surgical intervention.

The purpose of the present study was to compare the effectiveness of dorsal and volar resting hand splints in the reduction of hypertonicity. Hypertonus, for the purposes of this study, is defined as the plastic, viscous, and elastic properties of the muscle resistant to stretch and with a tendency to return a limb to a particular abnormal resting position (6, p. 190). This definition includes measurement of only the passive component of hypertonus as defined by Stolov (14) and is similar to the operational definition used by Long (15). It is a measurement of the tendency of the muscle toward contracture.

Method

Subjects. Ten adults (four from a nursing home, five from an adult handicapped developmental center, and one who was an outpatient at a hospital) volunteered for this experiment. All had medical conditions that led to hypertonus of their wrist flexors. Medical diagnoses of subjects were: six cerebrovascular accidents, one traumatic brain injury, and three with cerebral palsy. Ages ranged from 24 through 76, and the onset of disability was, in all cases,
at least 1 year before the beginning of the experiment. The subjects were randomly assigned to one of two groups who were then splinted with dorsal hand splints (GP-I, Figure 1) and volar hand splints (GP-2, Figure 2).

**Equipment.** The measurement technique for hypertonus required the use of a spring-weighted scale attached to a removable desk-top tray by a 'C' clamp (see Figure 3). A leather lace was attached to the hook end of the scale and a Velcro cuff that could be placed around the subject's hand was secured to the opposite end of the lace (6).

The dorsal splint used was similar to the one described by Snook (5). The volar splint was a resting hand splint with finger separators described by Malick (16).

**Procedure.** Participants were measured for hypertonus for the same 3 days of 1 week before the splint application to provide baseline data. Measurements to assess changes in muscle tone were taken the same 3 days a week for 5 subsequent weeks while subjects wore splints. Subjects did not wear splints for more than 2 hours per day and all measurements were taken within 3 hours after splints had been removed.

Measurements were taken in the following manner: Subjects sat in wheelchairs, and therapists ensured the lack of reflexive interference through proper positioning techniques (6). The arm was placed along the lateral surface of the trunk with the elbow at 90° of flexion and the forearm halfway between pronation and supination. The forearm was supported by the tray surface, and the wrist was extended over the tray surface to avoid friction when measurements were taken. The subject's hand was moved as close to the normal resting position as possible.
Table 1
Weekly Scores (age, groups, and total weekly scores) for the Dorsal and Volar Groups

<table>
<thead>
<tr>
<th>No. Subjects</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>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>2.0</td>
<td>2.0</td>
<td>2.5</td>
<td>2.0</td>
<td>.5</td>
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<tr>
<td>2</td>
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<td>1.5</td>
<td>1.25</td>
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<td>1.0</td>
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<td>OL</td>
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<td>8.25</td>
<td>8.25</td>
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<table>
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<th>No. Subjects</th>
<th>Week 1</th>
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<th>Week 4</th>
<th>Week 5</th>
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<tr>
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Table 2
t-Test Results for the Dorsal and Volar Groups

<table>
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<tr>
<th>Group</th>
<th>X₁, Week 1</th>
<th>X₂, Week 6</th>
<th>X₁ - X₂</th>
<th>t</th>
<th>p*</th>
<th>df</th>
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<td>Dorsal</td>
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<td>1.45</td>
<td>3.02</td>
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<td>6</td>
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<td>Volar</td>
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<td>1.75</td>
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<td>2.37</td>
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</table>

*All p = one-tail test values.

Table 3
t-Test Results Dorsal and Volar Comparison

<table>
<thead>
<tr>
<th>X₁ Reduction of Tone Dorsal</th>
<th>X₂ Reduction of Tone Volar</th>
<th>X₁ - X₂</th>
<th>t</th>
<th>p*</th>
<th>df</th>
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</thead>
<tbody>
<tr>
<td>1.45</td>
<td>1.40</td>
<td>.05</td>
<td>.08</td>
<td>not. sign.</td>
<td>8</td>
</tr>
</tbody>
</table>

*All p = one-tail test values.

Results

Analysis. Two questions were posed by this study: 1. Do dorsal and volar splints reduce muscle tone? and 2. Is there a differential reduction of muscle tone when either dorsal or volar surface splints are used? The t test was used to determine whether differences existed between the week 1 and week 6 scores of subjects assigned to both groups to answer the first question. It was also used to answer the second question by subtracting each individual's week 1 and week 6 scores and comparing the differences in the magnitude of the reduction of muscle tone among the dorsal and volar groups.

An individual's weekly score was derived by adding together the three daily scores of each subject in each week. Table 1 contains the individual weekly scores for each subject for each of the 6 weeks in the dorsal and volar group.

Question 1. Data demonstrated that a significant reduction in hypertonus occurred in the volar and dorsal conditions (Figure 4). The (30° extension), and a Velcro cuff was secured around the palmar surface of the hand. With the line taut and the scale reading 0, the therapist released the wrist while maintaining the position of the forearm so that the force of the wrist toward flexion registered on the scale. Therapists felt that practice using the techniques was needed before the study began (6). (An individual measurement of 1.75-2.25 lbs seemed to be correlated to severe hypertonus while a measurement of .25 to .75 lb seemed to represent mild hypertonus. No data were collected to confirm this observation. A yet unpublished study demonstrated inter-rater and test-re-test reliability of the measurement technique to .25 lb.)
range of the reduction of hypertonus over 6 weeks in the dorsal group was 7.25 lbs of pull ($t = 3.02, p < .01$), whereas the range of reduction of hypertonus in the volar group was 7.00 lbs of pull ($t = 2.42, p < .05$) (see Table 2).

Question 2. The data demonstrated that neither the volar nor dorsal condition resulted in a more significant reduction of hypertonus. The mean reduction of muscle tone for the dorsal group was 1.45 lbs of pull, whereas the mean for the volar group was 1.40 lbs of pull ($t = .08, p < .05$).

An Intervening Variable. Although the analysis demonstrated no significant group difference in the reduction of hypertonus between the dorsal and volar conditions, the probability level for error was higher in the volar condition ($p = .05$) than in the dorsal condition ($p = .01$). Further analysis indicated that the ages of subjects accounted for this. Even though subjects were randomly assigned to groups, as illustrated in Table 1, four persons 65 years or older (OL) were placed in the volar group, whereas only one person in this age category was placed in the dorsal group. The other five subjects were 35 years or younger (Y).

Figure 5 graphically illustrates the range of reduction of hypertonus for the OL (7.00 lb) and Y (11.25 lb) subjects. Table 3 illustrates the $t$-test results for the reductions in hypertonus for each condition and the reduction in hypertonus when the Y and OL groups are compared to each other. As illustrated in this table, there was a significant reduction of hypertonus in the Y group with a $t = 3.32$ and $p$ less than .005. There was no significant reduction of hypertonus in the OL group, although the $p = .10$ indicates a trend existed in this direction, and the reduction of muscle tone was significantly greater among the Y subjects, $p = .05$.

Discussion
The major findings of this study were that static splinting reduces hypertonicity, both dorsal splints and volar splints reduce hypertonus, and age has a significant effect upon tonal reduction. These findings are consistent with our previous reports and the replication of the research design and methodology further demonstrate the validity of the measurement techniques (6).

The primary limitation to the conclusions that can be drawn from this study are that the measurement technique does not measure the hyper-reflexive status of the neuromuscular spindle, and measurements were taken within 3 hours after splints had been removed. It is
Figure 5
A graphic comparison of the reduction of hypertonus for the older and younger adults in the study

Possible that both splint designs have different effects upon the tonal mechanism and that rebound could occur. If either splint design did in fact increase the dynamic component of muscle tone or rebound occurred, this would be reflected by an increased measurement of hypertonus over the 6-week period. The rate of firing of the neuromuscular spindle should have a direct effect upon the plastic, viscous-elastic properties of the muscle and tendons that the measurement device assesses.

The finding that both splint designs reduced hypertonus should help resolve the conflict between those proponents of static splinting who argue about the superiority of dorsal or volar surface designs. The most parsimonious explanation for tonal reduction is that prolonged stretch of the golgi tendon organs causes autogenic inhibition that results in decreased hypertonus (6, 17). Although it is logical to assume that sensory stimulation to the volar surface of the forearm would result in an increased rate of firing of the sensory receptors of the stimulated surface (1), adaptation to this stimulus could occur and neutralize this effect (17). The results do not rule out the possibility that some other factors act to reduce hypertonicity. Both splint designs maintain the hand in approximately the same position and release the cortical thumb; this may be the dependent factor in reducing hypertonus (11-13).

The unexpected finding was that age had an effect upon tonal reduction. Older subjects did not demonstrate a significant reduction in hypertonus, whereas younger ones did. The simplest explanation would be that the normal aging processes of the muscle, tendon, and cartilaginous tissue affected the potential for tonal reduction (18). Wright and Johns (19) found that normal muscle tone was higher in the aged. It cannot be concluded that a significant tonal reduction would not have occurred if the study had been continued or if the older population sample had been larger.

Implications for Treatment
The findings suggest two implications for treatment of the hypertonic hand. First, static splinting is a useful therapeutic procedure in the rehabilitation of the hand dominated by hypertonus. Wynn-Parry (8) describes three approaches to the rehabilitation of the hypertonic hand—the pharmacological approach, physical exercise, and surgical intervention. The initial goals of the physical exercise and pharmacological approaches are the same, relaxation of the hypertonic muscle (7, 8, 20). Matthews (21)
notes that a problem with the pharmacological approach is that a drug's action is not site-specific, therefore voluntary as well as involuntary muscular contraction is inhibited when it is used. Wynn-Parry (8) states that surgical intervention is only useful in a select number of cases. Splinting does not demonstrate the drawbacks of other approaches; it can be widely applied; it does not inhibit voluntary muscular contraction, and it can be used to supplement physical exercise.

Second, the amount of time an individual should be splinted needs to be re-examined. Bunnell's (10) major objection to splinting was immobilization of the joint. Volunteers for this study were splinted for only 2 hours a day. Snook's (5) subjects wore splints 4 hours a day. Kaplan (2) and Chariat (1) used 8-hour-a-day splint-wearing schedules, whereas Brennan's (4) subjects wore splints 24 hours per day. If tonal reduction can occur in 6 weeks after only 2 hours of splinting a day, is it necessary to immobilize joints for longer periods of time?

Suggestions for Future Research
Research often creates more questions than answers, which was true of this study. Further investigation and knowledge are needed in the following areas:

1. A better understanding of the operational features of splint design in the reduction of hypertonus.
2. A better understanding of possible intervening variables such as the extent of thought process disturbance, sensation, and other unidentified factors that might have an effect upon splinting in the reduction of hypertonus.
3. A more detailed explanation of how the age factor does influence treatment results.
4. A complete evaluation of the potential functional return of the limb caused by splinting.
5. A comparative analysis of splinting to other therapeutic techniques in the effectiveness of hypertonus reduction.
6. A more detailed analysis of the effects of the time-wearing variable, its effect upon rehabilitation, and its interaction with other variables.

Summary
Ten adults with hypertonic wrist flexors volunteered as participants in a study designed to determine whether dorsal or volar resting hand splints differentially affected hypertonus. Findings demonstrated that both types of splints reduced hypertonus. The age of the participants involved in the study was found to have a bearing upon the results, since those persons more than 65 years of age did not demonstrate a significant tonal reduction. Results demonstrated that splinting is a useful adjunctive therapeutic procedure. Implications for treatment were discussed, and suggestions for future research were made.

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