The Effects of a Short Thumb Opponens Splint on Hand Function in Cerebral Palsy: A Single-Subject Study

Glenn Goodman, Susan Bazyk

Key Words: cerebral palsy • child development disorders • hand functions • muscle spasticity

An AB single-subject research design was used to assess the effectiveness of a short thumb opponens splint on hand function in a 4-year-old girl with cerebral palsy. Baseline data for active range of motion, grip, and pinch strength, grasp patterns, the Box and Block Test of manual dexterity (Maubiovez, Voland, Kashman, & Weber, 1985), and 1-in. cube stacking were collected twice a week for 4 weeks. The child was fitted with a short thumb opponens splint, which was worn 6 hr during the day and all night for 4 weeks. The weekly measures of the dependent variables continued during the treatment phase. Visual and statistical analysis of the data indicate that the child showed a clinically significant improvement in palmar and radial abduction, thumb opposition, grip strength, performance on the Box and Block Test scores, cube stacking, and lateral pinch. These results suggest that for this child with cerebral palsy, the use of a short thumb opponens splint improved underlying aspects of hand function as well as hand function itself. Replication of this study with a more complex single-subject design involving more subjects is recommended to confirm these results.

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Thumb adduction at the carpometacarpal joint is an abnormal pattern typically noted in children with spastic cerebral palsy (Pratt & Allen, 1989). This abnormal pattern can limit hand function, specifically in the type and quality of prehension patterns used and in the coordination of release. If unattended, the web space may eventually shorten and a contracture may develop, causing significant limitations in hand function and potential problems in hygiene and skin integrity.

For the child displaying tightness in thumb adduction, early treatment to inhibit this pattern and facilitate thumb abduction, extension, and opposition is critical for improvement in hand function in play and self-care. Occupational therapists may use different treatment approaches to address this goal. A neurophysiological approach involves movement and handling techniques to reduce hypertonicity (Boehme, 1988). The pattern of thumb abduction and extension has been used as a key point of control during handling to inhibit abnormal tone in the hand and arm (Boehme, 1988). A biomechanical approach involves the use of splinting the thumb in extension with abduction or in opposition to prevent or correct deformity, reduce spasticity, and improve hand function (Boehme, 1988). In the present study, we investigated the use of splinting to reduce tightness in thumb adduction.

Different kinds of splints have been designed and used by occupational therapists to minimize tightness in thumb adduction. The short thumb opponens splint is intended for those children with moderate to severe hypertonicity, whereas both the sof-splint and thumb-loop splint are intended for those displaying minimal to moderate hypertonicity (Boehme, 1988).

Although occupational therapists commonly use splinting in treating children with spasticity, this practice continues to be controversial (Neuhaus et al., 1981). Although several research studies have measured the effects of splinting on spasticity, most of these have looked at adults (Brennan, 1959; Kaplan, 1962; McPherson, 1981; Mills, 1984). The results of these studies suggest that splinting decreases spasticity (Brennan, 1959; Charait, 1968; Kaplan, 1962; McPherson, 1981), increases strength (Brennan, 1959; Kaplan, 1962), and increases range of motion (Brennan, 1959; Charait, 1968; Mills, 1984). Although all of these studies identified changes in underlying aspects of hand function, many of them used subjective measures to note change (Brennan, 1959; Charait, 1968; Kaplan, 1962). The exceptions are McPherson and Mills, who objectively measured changes in spasticity. None of these studies objectively measured changes in actual hand function.

Specific information on the benefits of the thumb opponens splint is minimal. Most documentation has been descriptive, except for a pilot study by Exner and Bonder (1983), who used a counterbalanced experimental design to compare the effects of three types of
splints—the MacKinnon splint, the orthokinetic cuff, and the short opponens thumb splint—on the hand function of 12 children with spastic hemiplegia. The dependent variables measured changes in spontaneous bilateral activity, grasp skills, and arm-hand posture. The subjects wore the splints for 8 hr per day for 6 weeks, with a 2-week interval between splint types. Although the results indicated a significant difference in grasp data with all of the splints, no significant interaction effect was found between splint type and change in hand function. An analysis of scores for clusters of subjects did, however, indicate a significant difference in response to the splints. The MacKinnon splint was most often associated with improved grasp skill, bilateral hand use, or both, whereas the orthokinetic cuff was most strongly associated with changes in bilateral hand use. The short opponens thumb splint was less frequently associated with changes in grasp or bilateral hand use. Furthermore, more changes in hand function seemed to occur in children with moderate or severe impairment than in those with milder impairment (Exner & Bonder, 1983).

In summary, few studies have objectively measured the effectiveness of splinting in children with spasticity. Because splinting is often viewed as an inexpensive method to extend the benefits of therapy outside the treatment session (Exner & Bonder, 1983), it is important that occupational therapists continue to objectively measure their effectiveness. Only Exner and Bonder specifically studied the effectiveness of the short thumb opponens splint. Although the short thumb opponens splint was found to be less effective in improving grasp skills when compared with the MacKinnon splint and orthokinetic cuff, it is sometimes a more attractive and feasible option when considering the needs of the individual child. It provides direct thenar contact to more effectively oppose and abduct the thumb than do the MacKinnon splint and orthokinetic cuff.

Our aim in the present study was to objectively measure the effects of a short thumb opponens splint on hand function and on the underlying aspects of hand function in a child with moderate spastic quadriparesis. We hypothesized that there would be a significant (p ≤ .05) increase in the underlying aspects of hand function (active range of motion and grip and pinch strength) and in hand function (speed and quality of grasp and release) itself after the application and wearing of a short thumb opponens splint. Further, we hypothesized that there would be qualitative changes in grasp patterns, as observed in photographs taken before and after splinting.

Method

Design

An AB single-subject design was chosen because it allows systematic comparison of baseline and intervention data (Ottenbacher, 1986). A more complex single-subject design could not be used due to time constraints. The subject was available only for 8 weeks because of an impending surgery. The baseline phase occurred during the first 4 weeks of the study and was followed by a 4-week treatment phase.

Subject

The subject was a 4-year-old girl with cerebral palsy. She demonstrated moderate spastic quadriparesis, with greater hypertonicity on the left side of her body. Evaluation indicated near-normal use of the right hand for grasp and release and use of the left hand primarily for gross assistance with bilateral activities. Left hand function was significantly limited due to hypertonicity in the elbow, wrist, and finger flexors. Tightness in thumb adduction limited active range of motion of the thumb, strength of grasp and pinch, and coordination of grasp and release during cube stacking (see Table 1). Additionally, the development and quality of prehension was limited. For example, the subject used a lateral pinch rather than a fine pincer grasp to prehend small objects, due to a lack of thumb opposition. Palmar and radial digital grasps were used with significant thumb adduction. The subject was able to use an assisted release pattern by crudely releasing objects against a surface.

Table 1

Visual Analysis of Dependent Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Change in Slope</th>
<th>Change in Trend</th>
<th>Change in Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cube stacking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>-0.50</td>
<td>ns</td>
<td>3.08</td>
</tr>
<tr>
<td>Treatment</td>
<td>+1.50*</td>
<td>*</td>
<td>5.54*</td>
</tr>
<tr>
<td>Box and blocks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>+1.00</td>
<td>ns</td>
<td>8.62</td>
</tr>
<tr>
<td>Treatment</td>
<td>+5.50*</td>
<td>ns</td>
<td>10.37*</td>
</tr>
<tr>
<td>Radial abduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>+6.00</td>
<td>ns</td>
<td>42.50</td>
</tr>
<tr>
<td>Treatment</td>
<td>+10.00*</td>
<td>ns</td>
<td>48.25*</td>
</tr>
<tr>
<td>Palmar abduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>+3.00</td>
<td>ns</td>
<td>37.87</td>
</tr>
<tr>
<td>Treatment</td>
<td>+9.00*</td>
<td>ns</td>
<td>47.25*</td>
</tr>
<tr>
<td>Opposition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>0.00</td>
<td>ns</td>
<td>2.00</td>
</tr>
<tr>
<td>Treatment</td>
<td>+0.90*</td>
<td>*</td>
<td>2.40*</td>
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<tr>
<td>Grip strength</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Baseline</td>
<td>-1.55</td>
<td>ns</td>
<td>1.19</td>
</tr>
<tr>
<td>Treatment</td>
<td>+4.30*</td>
<td>*</td>
<td>2.34*</td>
</tr>
<tr>
<td>Lateral pinch</td>
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<td></td>
<td></td>
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<tr>
<td>Baseline</td>
<td>-1.25</td>
<td>ns</td>
<td>2.29</td>
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<tr>
<td>Treatment</td>
<td>+0.85*</td>
<td>*</td>
<td>2.80*</td>
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<tr>
<td>Palmar pinch</td>
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<td></td>
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<td>Baseline</td>
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<td>ns</td>
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</tr>
<tr>
<td>Treatment</td>
<td>+0.50</td>
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<td>2.12</td>
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<td>Tip pinch</td>
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<td></td>
<td></td>
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<td>Baseline</td>
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<tr>
<td>Treatment</td>
<td>+0.03</td>
<td>*</td>
<td>1.46</td>
</tr>
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</table>

Note: ns = not significant.

*Clinically significant with the visual techniques for single-subject analyses.
**The Splint**

The short thumb opponens splint was chosen as the independent variable, or treatment method, because it is designed to biomechanically increase the opportunity for the thumb to be used in prehension of objects. By serving as a distal point of control, it positions the thumb in opposition and may reduce spasticity proximally. Because the splint was to be worn during the day, we wanted one that would promote and not interfere with hand function. Although the subject may have benefited from a larger splint for positioning the wrist in extension, such a splint would have limited hand function and mobility, especially because the subject used creeping to move within her environment. The short thumb opponens splint was chosen over the sof-splint and thumb-loop splints because the latter splints, which are made with soft materials, did not offer the stability necessary for the subject’s moderate degree of spasticity.

We made a volar-type short thumb opponens splint from polycaprolactone-based low-temperature thermoplastic material (see Figure 1). We positioned the thumb in opposition by supporting it at the thenar eminence and the metacarpophalangeal joint with only a partial covering of the proximal phalanx of the thumb. The volar portion of the splint helped maintain the palmar arch and wrapped around the hypothenar eminence, ending over the dorsum of the hand. A small touch-fastener strap rotated the thumb so that the pads of the thumb and index finger met during activities requiring pinch.

**Evaluation**

The dependent variables measured underlying aspects of hand function (active range of motion of the thumb and grip and pinch strength) and hand function (speed and quality of grasp and release) in the left extremity. The following measures were used to evaluate changes in the dependent variables, as follows:

1. Active range of motion of the carpometacarpal joint in radial abduction, palmar abduction, and opposition (Trombly, 1983).
2. Assessment of grip (spherical grasp) strength with the Martin Vigorimeter1 (Robertson & Deitz, 1988).
5. The average number of 1-in. cubes stacked in three trials.
6. Observation of qualitative aspects of prehension with the Erhardt Developmental Prehension Assessment (Erhardt, 1982) and photographs.

The first four evaluations were chosen because they were found to be the most objective and standardized tests available for the variables being studied. These tests were administered according to standardized protocols for each. Stacking 1-in. cubes was used because it objectively measures coordination of prehension and release. The Erhardt Developmental Prehension Assessment and photographs were used to objectively note changes in wrist and thumb position during prehension of a pellet, a 1-in. cube, and a 1-in. dowel.

**Procedure**

The child was seen for two preliminary sessions before the beginning of the study, which allowed us to practice the evaluations, establish rapport with the child, and finalize the evaluation protocol. Evaluations were given in the following order: active range of motion, prehension assessment, cube stacking, the Box and Block Test, and grip and pinch strength. Testing was administered by the second author each session, while the first author recorded the data and took the photographs. The entire evaluation battery took approximately 30 min. Testing occurred in the child’s home while she was positioned in an appropriate-sized chair with the table surface at elbow height.

Baseline data were collected twice a week for 4 weeks. Although none of the dependent variables

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1Available from Elmed, Inc., 60 West Fay Avenue, Addison, IL 60101.
2Available from B&L Engineering, Santa Fe Springs, CA 90670.
showed stable baseline data (stability was defined as 80% of the scores within 15% of the mean), the decision was made to begin treatment after the fourth week due to the subject's limited availability.

During the treatment phase, the child wore the splint for 3 hr in the morning, 3 hr in the evening, and all night. Biweekly evaluation of the dependent variables continued during the 4 weeks of treatment with the same methods employed for the baseline phase. The child did not wear the splint during evaluation.

Data Analysis

Two procedures were used to determine if the data were fit for statistical analysis. The variability of scores from the mean (stability) was assessed for the baseline data, for the treatment data, and for the data as a whole. Additionally, autocorrelation coefficients were computed for each variable to establish whether there was serial dependency in the baseline data (Ottenbacher, 1986).

The primary hypothesis, that there would be a significant increase in underlying aspects of hand function and in hand function itself following the application and wearing of a thumb oppositions splint, was tested with visual inspection of the data for changes in slope, trend, and level. Celeration lines were also computed to quantitatively analyze the data and to augment visual analysis. Examples of how the data were graphed for analysis are shown in Figures 2 and 3.

Results

The tests for stability of the data indicate that none of the variables contained 80% of the scores within 15% of the mean for any of the groupings used, thus showing that the child's performance was inconsistent in both phases of the study. The test for serial dependency of the baseline data, however, indicated that only the Box and Block Test scores displayed a significant autocorrelation coefficient, thus suggesting that it would be appropriate to use visual inspection and to compute the celeration lines for the data (Ottenbacher, 1986). Additionally, visual inspection of the data and the autocorrelation coefficients led us to conclude that there was not a practice effect in the baseline phase for any of the dependent variables. The data were analyzed to identify changes in slope, trend, and level from baseline to treatment phase (see Table 1).

Slope is defined as the difference between the first and last data points of a trend line computed for each phase of the study. The baseline phase data showed negative slopes for cube stacking, grip strength, lateral pinch, and tip pinch. All of the treatment phase data demonstrated positive slopes, thereby indicating an improvement in test scores during the treatment phase. Only the palmar pinch data had similar slopes in the baseline and treatment phases. A clinically significant change in slope was defined when the slope changed in a positive direction from the baseline phase to the treatment phase. We used clinical judgment in this analysis in considering the variable being measured, the units of change across phases, and the significance of the changes in relation to normative data, or how the change affects hand function. All of the dependent variables except palmar pinch and tip pinch were judged as being clinically significant for change in slope.

Trend was analyzed through the assessment of the direction of the trend lines in the baseline and treatment phases. If the trend line changed from negative or neutral in the baseline phase to positive in the treatment phase, the variable was considered significant for change in trend. Cube stacking, opposition, grip strength, lateral pinch, and tip pinch demonstrated a change in trend.

Level was defined as the difference between the baseline and treatment phase means. Variables were considered clinically significant if the treatment mean was at least one standard deviation above the baseline mean. With this method of analysis for level, all of the variables were significant except for palmar pinch and tip pinch.

Celeration lines, computed with the use of the mean scores of the first and second phases of the baseline data, were used to draw a line that would predict the future.
performance of each variable. The number of treatment phase scores above the celeration line was counted. Statistical significance was determined through the use of Bloom's probability table (Ottenbacher, 1986). Cube stacking, palmar abduction, grip strength, and lateral pinch were shown to be statistically significant with the use of the celeration line approach.

In addition to visual analysis and statistical evidence of change during the treatment phase, inspection of the before-and-after-treatment photographs indicated positive changes in the quality of prehension (see Figure 4). After treatment, the child displayed an improved ability to prehend the dowel with increased thumb abduction and opposition as well as wrist extension.

Discussion

The results of this study support the primary hypothesis that there would be a significant increase in underlying aspects of hand function and in hand function following the application and wearing of a short thumb opponens splint. All of the dependent measures except tip and palmar pinch strength displayed a clinically significant improvement based on visual and statistical analysis.

Active palmar abduction, radial abduction, and opposition of the thumb increased significantly following splinting. It appears that this added range of motion allowed for an improved use of the thumb in the prehension of objects, as noted in the before-and-after photographs (see Figure 4). Whereas before splinting the subject used a lateral pinch to prehend objects, after splinting she used palmar abduction of the thumb when opening her hand to prehend an object. Although she continued to demonstrate thumb adduction at the carpometacarpal joint after splitting, she could use her thumb in ways that more closely resembled opposition during prehension. Additionally, the child displayed increased wrist extension during prehension, which supports the concept of distal splinting affecting more proximal muscle tone.

Grasp strength scores also improved significantly following splint wear. Possibly, with improved thumb opposition, the thumb is biomechanically in a better position for use in a spherical grasp.

Significant changes in the Box and Block Test scores and in cube stacking suggest positive changes in hand function, specifically in the speed and accuracy of release. This improvement may be due to the added range of motion and reduction in thumb adduction tightness.

Palmar and tip pinch strength did not significantly improve, perhaps because pinch is a more difficult prehension pattern to perform than the more primitive grasp pattern. Overflow, which occurred with this resistive activity, caused the child to move into an abnormal pattern of thumb adduction and wrist flexion, thus making it difficult for her to maintain the appropriate prehension pattern on the pinch meter to obtain the maximum strength reading. The use of pinch meters or dynamometers may not always give an accurate representation of strength in persons with spasticity.

The evaluations used in this study were generally found to be effective. Standardized instructions and norms for children help to remove experimenter bias and to accurately measure changes. The following difficulties, however, were encountered:

1. Lack of sensitivity in the bulb vigorimeter and pinch meter was noted in the measuring of strength in a child with significant weakness and spasticity. Although the small bulb was used in this study, as recommended by Robertson and Deitz (1988), the large bulb recorded higher readings. Optimal bulb size for the measurement of grip strength in children with physical disabilities should be examined further.

2. Lack of stability in the range of motion scores leads one to be cautious regarding these findings. The negative effect of spasticity on accuracy of
range of motion measurements has been documented (Bobath, 1970).

3. Lack of norms for 4-year-olds for the Box and Block Test of manual dexterity presented some difficulty. In addition, it was hard to convey the concept of speed to the subject, suggesting that this may be an unrealistic measure for this age group.

Study Limitations

The primary limitation of this study is related to the AB single-subject design. Although this design allows for systematic evaluation of the treatment, it does not rule out the possibility that other factors may have affected the child’s performance during the intervention phase (Ottenbacher, 1986). Because of this, the design lacks power and limits the ability to make causal inferences from the results. In addition, although the baseline data indicate that there was not a practice effect with the repeated evaluations, we do not know whether the evaluation procedures might have interacted with the treatment to cause improvement. An ABAB design would have controlled for the possibility of practice effect.

The AB design also limits one’s ability to measure the long-term effects of splinting. The results of this study do not indicate whether the positive changes in hand function following splinting would continue with or without continued wearing of the splint. An ABAB single-subject design would have helped answer this question.

Another limitation of the study is that the baseline data did not reach a level of stability before the treatment phase. Due to time constraints, we could not extend the baseline phase beyond eight sessions, which is generally considered adequate for this type of study (Ottenbacher, 1986). Variation in the baseline measures may have been due to a number of factors, including variation in the child’s interest, energy level, and muscle tone. Ideally, treatment should not begin until baseline measures stabilize.

Conclusion

The results suggest that for this child with cerebral palsy, the use of a thumb opponens splint improved underlying aspects of hand function and hand function itself. Active range of motion of the thumb, grip strength, cube stacking, and performance on the Box and Block Test improved significantly after 4 weeks of splint wear. Palmar and tip pinch strength did not improve significantly. Because of limitations associated with a small sample size, further study is needed to generalize these findings to other children with cerebral palsy. We recommend replication of this study with the use of more complex single-subject designs that use more than 1 subject.

Acknowledgments

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References