Improving Elbow and Wrist Range of Motion Using a Dynamic and Static Combination Orthosis

Audrey Yasukawa, MOT, OTR, Jerome Lulinski, CO, Lisa Thornton, MD, and Paula Jaudes, MD

ABSTRACT

This pilot study examined the efficacy of improving range of motion at both the elbow and wrist using a dynamic and static combination orthosis. The sample population included six children, two females and four males with a mean age of 12 years, 6 months with a primary diagnosis of cerebral palsy. Among the sample, five children received an orthotic device for one arm and one child received an orthotic device for each arm. None of the children demonstrated functional use of the involved limb, and all experienced moderate spasticity interfering with passive movements at elbow and wrist. Upper extremity range of motion was assessed using goniometric measurements of passive range of motion, and tone was evaluated using the Modified Ashworth Scale. One subject received a botulinum toxin (BTA) injection to both left and right upper limb, and another subject received to the right upper limb. All participants underwent serial casting of the wrist for 3 to 4 weeks, followed by application of an Ultraflex (Ultraflex Systems Inc., Pottstown, PA) orthosis. Caregivers were asked to increase daily Ultraflex wear time from 1 hour to 5 hours or more. Range of motion and tone assessments were taken at five different intervals throughout the study: preintervention, and at 2, 3, 6, and 10 months. Among the subjects who wore the Ultraflex brace according to the outlined protocol, improvements were seen at the 10-month assessment in passive range of motion at either the elbow or wrist or in both joints in five of the seven limbs examined. The results demonstrate a positive statistical correlation between brace wear and range of motion at the elbow and wrist as compared with those who did not wear the brace. Because of the small sample size, the effects of BTA in conjunction with Ultraflex orthosis wear on range of motion was limited. In addition, four of the six caregivers reported their children primarily wore the Ultraflex orthosis during school hours, and for a limited time after school hours. Two subjects did not comply with the protocol, and the range of motion declined from the original baseline. The long-term prognosis of maintaining range of motion will ultimately depend upon the family’s ability and willingness to comply with the prescribed treatment. Further studies investigating compliance at home and working with the school are needed. (J Prosthet Orthot. 2008;20:41–48.)

KEY INDEXING TERMS: cerebral palsy, dynamic bracing, elbow orthosis, wrist orthosis, muscle spasticity

Insult to the brain at birth or after a traumatic injury often results in central nervous system (CNS) damage, which may lead to muscle spasticity with resultant tightness or abnormal posturing of the upper extremity. Contractures are commonly seen in children with neurologic involvement, especially when there is no isolated movement or functional control of the arm. In children with cerebral palsy presenting with spasticity and muscle imbalance, the shortening of muscles crossing two or more joints form a major component of many contractures. The arm often remains in a fixed posture for prolonged periods of time.

The typical posture of the spastic upper extremity in a child with a CNS insult consists of internal rotation of the humerus, flexion of the elbow, pronation of the forearm, and flexion or extension of the wrist with flexion of the fingers and thumb. If the individual’s limb remains in a static position, they are at risk for developing contractures of the muscles, tendons, ligaments, joint capsule, tautness of the skin, and shortening of the nerves and blood vessels.

In a pilot study, Pandyan et al. described post acute stroke subjects with no functional return of the hand as showing changes associated with contracture formation at the wrist (i.e., a decrease in passive range of motion and posturing of the wrist). The subjects with no signs of functional recovery demonstrated increased resistance to passive movement, and an increase into wrist flexion with no active opposing muscle group into extension.

Children with severely involved tone and fixed contractures of both the wrist and elbow present a challenge to the occupational therapist. Caregivers report difficulty with daily dressing and hygiene care for the child with severe tightness and limited range of motion. To prevent potential skin and hygiene problems, conventional treatment includes splinting, positioning, serial casting, botulinum toxin type A (BTA), or medication to assist with relaxing the muscles. In an effort to prevent contractures, the use of daily muscle stretch alone to increase extensibility of soft tissues and joint mobil-
ity provides limited success and is not a recommended treatment approach to prevent contractures in a nonfunctional arm.3,4

BTA has been used in children with CNS dysfunction to treat focal spasticity or dystonia to produce local temporary weakness in an effort to decrease spasticity. The BTA injection may decrease muscle spasticity to a degree by which short tight muscles can be lengthened through a stretching program via serial casting. Several studies provide support for the use of BTA in the upper limb to reduce spasticity, reduce painful contractures, improve positioning for splinting and improve function for activities of daily living.5-8 Individuals who have not shown functional improvement and range of motion gains after BTA administration may have greater static contractures and poor active motor control, which may serve to limit the effectiveness of the BTA injection.9,10

From a clinical perspective, benefits of the BTA injection into spastic muscles assist with a temporary reduction in spasticity. After administration of BTA, an increase in passive range of motion of the tight and spastic muscle can be facilitated through the application of a series of casts or splints that gradually position the muscle in a lengthened position. The BTA injection may last 3 to 5 months before an increase in muscle tone returns. The occupational therapist should consider providing the child with a splint or bivalve cast to maintain passive range of motion after serial casting protocol.

Maintaining or improving range at both the elbow and wrist is difficult when both joints are affected. In an effort to maintain passive range of motion at both joints, therapists often used either a long arm bivalve cast or a resting hand splint in conjunction with an elbow bivalve or a dynamic elbow orthosis placed over the splint to optimize elbow and wrist positioning.

A case series5 compared a static bivalve cast with a low-load prolonged stretch orthotic device. The use of a static bivalve cast did not accommodate for the change in range of motion occurring over time at the elbow joint from an increase of spasticity or muscle tightness. A static bivalve cast was shown to be unsuccessful for long-term use in increasing range of motion. Additionally, decreased wearing tolerance of the bivalve cast made it difficult for the child to wear, and new bivalve casts needed to be fabricated to accommodate for changes in alignment and range of motion. The Ultraflex (Ultraflex Systems Inc., Pottstown, PA) orthotic, with the dynamic elbow tension, allowed the tension to be adjusted for comfort and fit.

Collins et al.6 described the use of a customized adjustable orthosis for reducing contracture in a patient with head injury who exhibited severe spasticity of the wrist. The wrist orthosis had a joint adjustment, which was changed at intervals to promote slow gradual stretch to the spastic wrist flexors. The results demonstrated gains in range of motion.

Contractures can be reduced through splinting by increasing tendon length and maintaining the elasticity of the connective tissue. Static splinting is used to hold a joint in a fixed position. A static progressive method is useful in the treatment of contractures using a turnbuckle splint, which is applied and adjusted incrementally by the patient to cause progressive stretch in an area of tightness.11-13 A dynamic orthosis stimulates continuous muscle lengthening by applying constant tension to the connective tissue. This allows for a slow gradual stretch to assist with lengthening.14,15 The Ultraflex orthosis provides a low-load prolonged stretch at the elbow and has a static wrist component with adjustability for accommodating changes in range of motion (Figure 1).

The purpose of this pilot investigation was to determine the efficacy of an Ultraflex orthosis with dynamic elbow and static wrist components in maintaining or improving passive range of motion of the elbow and wrist (in some cases after BTA injection).

**METHODOLOGY**

**SUBJECTS**

The sample population included six children between the ages of 7 and 16 years (mean age, 12 years) who had a primary diagnosis of cerebral palsy (Table 1). A total of seven braces were fabricated, one subject with both left and right arm braces. Informed consent was obtained from the guardians in accordance with the Institutional Review Board, which approved the study. Participants met the following inclusion criteria: decreased range of motion at both the elbow and wrist; abnormal muscle tone interfering with range of motion or functional movement, as measured by the Modified Ashworth Scale (MAS).16 Subjects excluded from the study were individuals with significant behavior problems, because of potential for interference with the prescribed orthotic device wearing program; significant upper extremity spasticity, with scores of 3 or 4 on the MAS (3 representing considerable increase in tone with passive movement difficult and 4 representing affected parts rigid in flexion); muscle tightness in only one joint of the arm. Participants involved in the study did not have functional or volitional control of the arm. Four
Table 1. Physical characteristic, initial and 10 months postpassive range of motion of the subjects

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Subject Impairment</th>
<th>Sex</th>
<th>Age</th>
<th>Medication</th>
<th>Elbow ROM Initial 0° to 150° Flexion</th>
<th>Elbow ROM 0° to 150° Flexion After 10 Months</th>
<th>Wrist ROM Initial 0° to 80° Flexion</th>
<th>Wrist ROM 0° to 80° Flexion After 10 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Right arm</td>
<td>M</td>
<td>7</td>
<td>Oral baclofen</td>
<td>80° to 140° flexion; lacks 80° extension</td>
<td>90° to 140°; lacks 90° extension</td>
<td>60° to 110° flexion</td>
<td>70° to 110° flexion</td>
</tr>
<tr>
<td>2</td>
<td>Right arm</td>
<td>M</td>
<td>11</td>
<td>Oral baclofen</td>
<td>60° to 150° flexion; lacks 60° extension</td>
<td>50° to 150°; lacks 50° extension</td>
<td>30 to 90° flexion</td>
<td>5° to 90° flexion</td>
</tr>
<tr>
<td>3</td>
<td>Right arm</td>
<td>M</td>
<td>11</td>
<td>Oral baclofen; BTA</td>
<td>90° to 150° flexion; lacks 90° extension</td>
<td>90° to 150° flexion; lacks 90° extension</td>
<td>50° to 125° flexion</td>
<td>20° to 125° flexion</td>
</tr>
<tr>
<td>4</td>
<td>Right arm</td>
<td>F</td>
<td>16</td>
<td>No medication</td>
<td>70 to 150° flexion; lacks 70° extension</td>
<td>90° to 150° flexion; lacks 90° extension</td>
<td>55° to 110° flexion</td>
<td>60° to 110° flexion</td>
</tr>
<tr>
<td>5</td>
<td>Right arm</td>
<td>F</td>
<td>16</td>
<td>Oral baclofen; BTA</td>
<td>40° to 150° flexion; lacks 40° extension</td>
<td>30° to 150° flexion; lacks 30° extension</td>
<td>50° to 140° flexion</td>
<td>20° to 140° flexion</td>
</tr>
<tr>
<td>6</td>
<td>Left arm</td>
<td>F</td>
<td>16</td>
<td>Oral baclofen; BTA</td>
<td>30° to 150° flexion; lacks 30° extension</td>
<td>30° to 150° flexion; lacks 30° extension</td>
<td>65° to 140° flexion</td>
<td>30° to 140° flexion</td>
</tr>
<tr>
<td>7</td>
<td>Left arm</td>
<td>M</td>
<td>16</td>
<td>No medication</td>
<td>50° to 150° flexion; lacks 50° extension</td>
<td>30° to 150° flexion; lacks 30° extension</td>
<td>50° to 140° flexion</td>
<td>20° to 140° flexion</td>
</tr>
</tbody>
</table>
of six subjects received medication for muscle relaxation (Table 1).

PROCEDURE

A physician evaluated all children before entry into this pilot study. Before a participant receives the orthotic brace, a baseline evaluation was completed, which included the MAS to assess tone and passive range of motion goniometric measurements. At the conclusion of the study a questionnaire including several open-ended questions regarding the orthotic brace were asked to the caregivers.

Evaluation of the arm occurred before intervention and at 2, 3, 6, and 10 months. The MAS is a clinical measurement of resistance to passive movement (Table 2) using a numerical scale (0–4) to grade resistance felt by the therapist during a quick stretch maneuver opposite to the muscle group being tested. This test was performed by an experienced occupational therapist while the child was seated in his/her wheelchair or on a plinth. Passive range of motion of the elbow and wrist was measured in degrees with a goniometer. A caregiver interview was completed at the end of the study to determine the following: degree of satisfaction with the orthosis, daily wearing tolerance and schedule (hours orthotic was worn per day), ease of donning/doffing orthotic, fit of the device, and ability of the orthotic to maintain range of motion.

BTA was administered by one injector into the biceps, brachioradialis, and wrist flexors in three of the upper extremities of two subjects. All of the subjects were casted at the wrist to gradually improve range of motion, to assist with the ease of wearing the Ultraflex orthosis (Figure 2). The wrist casts were left in place for 7 to 10 days and replaced with new casts to incorporate any gains in range of motion obtained from the application of the first cast. Once improvement in alignment for positioning of the wrist was attained through the casting protocol (15°–20° increase in passive range), all subjects were fitted by a certified orthotist with the Ultraflex brace containing dynamic elbow and static wrist components (Figure 3). Each orthosis was custom fitted to subject’s involved limb, and caregivers were asked to gradually build up wearing tolerance for subjects to wear the device as much as possible day and night. In addition, the caregiver was provided with instructions to gradually increase the tension control level of the elbow (ranging from tension 1 to 7) to improve the range of motion into elbow extension.

Table 2. Modified Ashworth Scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No increase in muscle tone</td>
</tr>
<tr>
<td>1</td>
<td>Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end range of motion when the affected parts moved in flexion or extension</td>
</tr>
<tr>
<td>1+</td>
<td>Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the range of motion</td>
</tr>
<tr>
<td>2</td>
<td>More marked increase in muscle tone through most of the range of motion, but the affected part is easily moved</td>
</tr>
<tr>
<td>3</td>
<td>Considerable increase in muscle tone, passive movement is difficult</td>
</tr>
<tr>
<td>4</td>
<td>Affected part is rigid in flexion or extension</td>
</tr>
</tbody>
</table>

RESULTS

In seven of the involved limbs three elbows showed gains in passive range of motion, two elbows maintained the baseline range, and two elbows lost range of motion from baseline. Five of seven wrists gained passive range of motion, and two lost range of motion from baseline.
The average MAS score at baseline was 2 for the wrist and/or elbow. The subjects who received a BtA injection showed a decrease in muscle tone by a half point (MAS 1+); however, the change was temporary, and tone increased to the baseline status.

SPSS 15.0 statistical software was used for data analyses. A correlation analysis was done using the small sample. Pearson product-moment coefficient was used to compare one continuous variable and one dichotomous variable. The relationship between available range at the elbow or wrist and compliance with the wearing schedule protocol was examined. All statistical analyses were calculated using a 0.01 and 0.05 significance level.

Two-tailed analysis was used to compare measurements of the elbow or wrist at baseline and at 2, 3, 6, and 10 months after intervention (Tables 3 to 6).

**DISCUSSION**

In children with CNS dysfunction, muscle weakness (or paralysis) and spasticity are the major factors leading to the development of contractures. Muscles immobilized in a lengthened position with slow gradual tension may show improvements in range of motion. The primary findings in this study demonstrated that increasing upper extremity passive range of motion was related to compliance with the prescribed orthotic wearing schedule. The BtA injection used to control persistent localized spasticity seemed to have a limited effect on range of motion in the subjects who were injected before initiation of study. However, because of the small sample size, the relationship between range of motion and the use of BtA in conjunction with Ultraflex bracing may be limited. Improvements in range of motion were noted in subjects who continued to wear the Ultraflex as outlined in the study protocol. Further studies should examine the effect of medication in combination with orthotic use on range of motion and tone.

Additional factors that influenced range of motion included the position of the subject while seated in the wheelchair. The arm posture, especially if in a reclined wheelchair position, contributed to flexed positioning of the child's elbow. The wrist position was influenced by the pull of gravity into wrist flexion or wrist extension depending on the position and angle of the flexed elbow. Changes in postural alignment as a result of postural instability or decreased...
control of the trunk, pelvis, and lower extremities influenced alignment of the upper extremity. While seated in the wheelchair a child with limited control may initiate movement by pulling his/her head forward, flexing the thoracic spine, and activating the pectoralis muscles, which in turn produces greater internal rotation of the humerus. This may cause skin breakdown around the forearm while wearing the Ultraflex with the constant pull of the forearm into pronation (Figure 4). By improving the position of the child in their wheelchair, the overall alignment of the arm may improve. Because the child becomes weaker more time is spent in sitting. Such positioning predisposes the arm to internal rotation, elbow flexion, and wrist contractures. It is important to evaluate not only the upper extremity alignment, but also the body positioning in the wheelchair.

In upright standing, the child with cerebral palsy hemiplegia may pull the trunk into lateral flexion on the involved side because of a poor base of support. The asymmetry of the body may affect the posture and alignment of the arm. When the child attempts to ambulate or uses stairs, the arm is often in a high guard position and used for postural control. This may affect the child's ability to maintain range of motion of the arm because of the poor base of support and its influence on the kinetic chain to the upper extremity.

For the subjects who wore the brace daily, caregivers reported that the brace was applied in the morning before school and also during the after-school hours. The caregivers reported that the brace was removed at home in the evening.

Figure 4. The abnormal pull into internal rotation and forward shoulder may cause problems with wear of the Ultraflex.

Caregivers were responsible for monitoring the Ultraflex wearing schedule and with gradually increasing the child's tolerance for overnight wear. The caregiver was to closely monitor their child's Ultraflex wearing tolerance at home.
before sending the child to school with the brace. All caregivers reported that the brace was not worn at night because their child was unable to sleep because of discomfort. However, all caregivers stated that their child did wear the brace at school and home during the day. The caregivers reported that they discussed the use of the Ultraflex with the school therapist, and asked the school to monitor the wear. Oftentimes, the demands of situations at home and work affected the caregiver's ability to follow through with the wearing schedule protocol. In such cases, caregivers reported that they depended on the school to monitor the child's wearing schedule.

In this study there was no communication between the school therapist and the clinic occupational therapist. Generally, the clinic therapist work directly with the caregiver, and the caregiver provides information to the school therapist. The tension control lever of the elbow was never adjusted higher than the number 2 out of 7 despite improvements in range of motion seen in four of seven limbs. The tension was originally set at 2 by the clinic therapist and left at that setting. The caregivers were responsible for adjusting tension as needed, to gradually improve range of motion.

Two of the subjects had difficulty complying with the wearing schedule, and consequently, range of motion did not improve. One of the subjects was 16 years of age, ambulated short distances, and was not interested in wearing the brace. Initially, the caregiver and subject wanted to improve range; however, the subject chose not to follow the guidelines of the wearing schedule. The caregiver of the other subject stated that it was difficult to manage the consistent monitoring and ongoing care. Both subjects gave up wearing the brace all together.

CONCLUSION

The results of this study indicate a positive statistical correlation between brace wear and range of motion. Subjects who wore the brace had increased range of motion at the elbow and wrist as compared with those who did not wear the brace. Children with increased tone of the upper extremity and joint contractures need to have range of motion consistently monitored to prevent skin breakdown, to improve hygiene, and to assist with ease of care. An orthotic program should become a permanent part of preventative care. The children in the study were asked to wear the brace at night during sleeping hours. Use of the orthotic as a night-time brace may not be indicated, as the interruption of sleep may render this inappropriate for some users.

Long-term prognosis in the maintenance and improvement of range of motion in a child's upper extremity through the use of an orthotic device depends on the family's ability and willingness to comply with the prescribed treatment. In the past 20 years less cohesiveness has occurred between school and hospital therapists, because school therapists have been obliged to focus strictly on facilitating the educational process. This study demonstrates that to truly serve children with disabilities, a partnership between hospital, school, and home is required. This pilot study demonstrated the importance of further inquiry into the relationship between the school therapists and staff with clinic therapists for a team-based approach. Given the important role of caregivers in terms of compliance with recommended treatment protocols, an integrated approach to service provision may have a key role in facilitating information sharing and supporting continuity of care. Working in partnership with the school and clinic and having an available school-based orthotist may help provide the ongoing family teaching and support that is needed to provide such continuity of care. Further studies are needed to examine influences that effect family compliance with long-term orthotic wear and how compliance is influenced by comprehensive collaboration between hospital, family, and school.

ACKNOWLEDGMENTS

We thank Dr. Ann Jackson for her statistical assistance, and Colleen Harper and Sarah Reppenhagen for their editorial assistance.

REFERENCES


