Orthotic Intervention for Development of Hand Function With C-6 Quadriplegia

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Key Words: hand functions • orthotics and prosthetics evaluation • spinal cord injury

Objectives. Much has been written about the use of static orthoses to maintain proper position and prevent deformity, but there are few empirical data to determine whether static orthoses improve function, maintain range of motion, or prevent deformity in the hand.

Method. This study measured gains in hand function during a 3-month rehabilitation period in 15 persons with sixth cervical (C-6) level complete quadriplegia, 7 of whom wore a static orthosis at night (experimental group) and 6 who did not wear the orthosis (control group). Hand function, range of motion and strength were measured in all subjects 4 weeks and 8 weeks after the study commenced, and again after 12 weeks in only 69% of the subjects.

Results. No significant differences were found in hand function between control and experimental groups; hand function had improved significantly in all 13 subjects.

Conclusion. As the effects of deformity have been clinically observed, future studies should examine the effects of static orthoses with increased daily wear or wear over a longer period of time.

Hand function is important to the quadriplegic person. A survey of 74 persons with various levels of quadriplegia, ranging in age from 18 to 67 years, showed that normal arm and hand function were rated more important (75.19%) than bowel and bladder function (13.8%), leg function (8.1%), or sexual function (2.7%) (Hansen & Franklin, 1976).

Orthotic fabrication or management is a typical treatment element in occupational therapy. However, there are no empirical data on the effectiveness of this intervention. In a 1982 survey of 50 centers offering physical dysfunction affiliations in the U.S., occupational therapists and orthotists identified themselves as primarily responsible for fabrication and fit of orthoses. Fifty percent of the occupational therapists who responded were responsible for 75% of the orthoses required (Lohman, 1982). Neuhaus et al. (1981) found that therapists with more clinical experience had a greater tendency to use orthotics. The authors acknowledged inconsistency and conflicting practices in splinting, as the same rationales were offered for opposite approaches. In Krajnik and Bridle's (1992) survey of 101 therapists working with spinal cord injury, respondents chose 5 most important reasons from a list of 11 for use of static splints, with the most frequently given rationale (28.7%) to “prevent contractures of the wrist and hand.” With patients with C-6 spinal cord injury, respondents provided resting hand splints the most often (67.3%), but together a long opponens (25.7%) or a short opponens (46.5%) were issued equally often. Of seven listed clinical reasoning criteria for using the orthosis, the two highest ranked were muscle strength (48%) and level of injury (32%).

The fabrication of orthoses is a major cost to the consumer with quadriplegia. According to 1993 cost estimates from an informal survey of vendors, a bilateral opponens orthoses, depending on the material used, may cost from $100 to $700. This does not include the labor costs of 2 to 3 hr, based on the experience of this therapist.

Objective measurement of the efficacy of positioning or static orthoses is essential for cost-effective and ethical occupational therapy practice in spinal cord injury treatment. This study examined the effect of static orthoses on the development of tenodesis hand function of subjects with C-6 quadriplegia.

Literature Review

Orthoses are not the only aspect of treatment for achieving functional hand use in persons who are quadriplegic. Of equal importance is maintenance of range of motion (Trombly, 1983), hand surgery (Ainsley, Voorhees, & Drake, 1985; Moberg, 1978), participation in meaningful activity while using hands (Bedbrook, 1981), and control of edema (Cheshire & Rowe, 1970; Curtis, 1978), and long-term effects (Whiteneck et al., 1993).

The literature contains no studies on the efficacy of
static or positioning orthoses for the prevention of deformity or promotion of function in spinal cord injury but does contain numerous anecdotal descriptions of orthotic devices and rationales for orthotic intervention.

Descriptions have focused on the value of using certain static orthoses to promote a functional hand position (Freehafer, 1969; Pierce & Nickel, 1977; Zejdlik, 1983). Other means of maintaining a functional position, especially during the initial period of recovery, have been palmar rolls, pads, or hand rolls (Rozin, 1978); platform orthoses with thumb positioners (Newsom, Keenan, Maddry, & Aguilar, 1969); or rolls of cotton batting (Bedbrook, 1981; Bromley, 1985).

Sargant and Braun (1986) gave guidelines for specific orthoses within 48 hr of the injury, depending on the strength of the wrist and finger muscles. Nickel, Perry, and Garrett (1963) advocated the use of orthoses with paralyzed hands during periods of idleness that occur when the patient is not involved in treatment sessions. Yarkony, Bass, Kennan, and Meyer (1985) stated that splinting was indicated to prevent contracture that would interfere with full recovery. Several authors indicated that the force of gravity pulls the hand into a cadaverlike position of wrist flexion, metacarpalphalangeal (MCP) extension, and proximal interphalangeal/distal interphalangeal (PIP/DIP) flexion, or claw hand (Bloch & Basbaum, 1986; Bunch & Keagy, 1976; Eisenberg & Falconer, 1978; Ford & Duckworth, 1987) (see Figure 1).

Fishwick and Sellers (1977) discussed three “philosophies of splinting”: the “splint to the hilt” approach, which prepares the hand for use of functional splints and results in a better cosmetic appearance; the “splint to maintain position” approach, which advocates use of a static splint at night to promote a weak mechanical pinch; and “no splinting” which results in a claw-hand deformity that may be considered an inevitable alternative.

Bedbrook (1981) described the four types of hands that develop in the C-6-7 quadriplegic as “1) the well-rehabilitated hands in which the natural tenodesis is encouraged and enhanced through systematic and well-planned therapy; 2) the hand with moderately severe tightness of the flexors which results in an inability to extend the fingers despite full wrist flexion and further progress is not possible unless the muscles and the joints are relaxed; 3) the hand with joint stiffness which is a secondary consequence of a shoulder-hand pain syndrome (e.g., reflex sympathetic dystrophy) aggravated by inactivity in the early stage of recovery and stems from indifferent treatment; and 4) the hand with overstretched finger flexors from poor treatment and which no orthosis can correct” (no page number available). In this fourth category, the person is unable to obtain a pinch with the wrist in extension and the MCP joints are biomechanically pulled into extension.

Orthoses have been recommended by authors to enhance the hand’s tenodesis effect and to reinforce its habitual use by stabilizing the thumb in a functional position. The person with quadriplegia is able to obtain a palmar or lateral prehension through the passive tenodesis effect (see Figure 2), which permits the person who has no hand strength to produce grasp and release with wrist motion and allows for a few grams of prehension (Bunch & Keagy, 1976). Tenodesis orthoses typically position the fingers in MCP flexion of 60° to 90°, with slight PIP and DIP flexion and thumb abduction and opposition (Lehneis, 1977). Various aspects of tenodesis orthoses have been emphasized by writers. For example, Malick and Meyer (1978) specified that the optimum thumb position consists of abduction, flexion, and rotation. McKenzie (1970) recommended the use of a removable thumb post to maintain the thumb in opposition, abduction, and with a slight IP flexion. Zejdlick (1983) specified stability of the thumb in opposition, as well as guided flexion and extension of the MCP joints of the index and middle fingers, as requirements for tenodesis orthoses use. Hill (1986) advocated use of a short opponens insert that may be easily removed because thumb stabilization in opposition hinders the equally functional need for adduction and MCP/CMC (carpalmetacarpalphalangeal) extension to permit transfers and independent pushing of the wheelchair.
In summary, the literature provides the rationales for the use of orthoses in spinal cord injury as being idleness, change in the hand structures, effects of gravity, immobilization, and promotion of tenodesis function. The literature also gives an overview of current orthotic practices. The literature, however, lacks efficacy data on orthotic use in spinal cord injury. Therefore, this study was attempted to determine whether night wear of static opponens orthoses improved hand function, range of motion, and tenodesis prehension in persons with C-6 quadriplegia.

Method

Subjects

Seventeen persons with C-6 spinal cord injury who had been admitted to Craig Hospital in Denver were referred to the study by their occupational therapist. Thirteen subjects (1 woman and 12 men), ranging in age from 18 to 42 years with a mean age of 26 years, agreed to participate in the study. Time since injury ranged from 6 to 8 weeks. Subjects were randomly assigned to either a control group \((n = 6)\) or an experimental group \((n = 7)\). Both groups received the same rehabilitation treatment, but only the subjects in the experimental group were issued positional orthoses.

Intervention: Opponens Orthosis

The 7 subjects in the experimental group were issued a short opponens or long opponens orthosis, depending on the strength of their wrist extensors (Bloch & Basbaum, 1986). Wrist strength was measured by the same evaluator adhering to the strength index recommended by Kroemer and Howard (1970) and with standard muscle testing techniques (Daniels & Worthingham, 1972). Two trials were used and the greater strength was recorded (Schrenck & Forward, 1965). Subjects with muscle strength below a 3 or Fair grade warranted the long opponens \((n = 1)\). The long opponens fabricated for the study was similar to the cock-up and C-bar type, which includes a thumb post and maintains the wrist in 30° through a volar forearm trough (Hill, 1986; Malick & Meyer, 1978) (see Figure 3). Subjects with wrist extensor strength above the Fair grade were given the short opponens \((n = 6)\) (Malick & Meyer, 1978; Sargant & Braun, 1986). The short opponens made for this study was of the Rehabilitation Institute of Chicago type, which includes a dorsal and palmar support, a C-bar, and a thumb post (Bunch & Keagy, 1976; Hill, 1986) (see Figure 4). Both the long and short opponens orthoses maintained the distal transverse arch and the thumb web space in 35° of CMC abduction, the metacarpophalangeal joint in full extension, and the interphalangeal joint in slight flexion. They were made from low temperature thermoplastic material and secured with self-gripping straps.

Procedure

Orthoses were worn at night for 8 hr, as soon as a wearing tolerance of 1 to 3 days was achieved. To build wearing tolerance, the following schedule was implemented: Day 1 – 1 hr on, 1 hr off; Day 2 – 2 hr on, 2 hr off; Day 3 – 8 hr on at night with periodic skin checks by the nursing staff members. A diagram of the orthosis that displayed how the orthosis was worn, contraindications, wearing schedule, and the standard technique for passive range of motion were posted over the subject’s bed for the nursing staff members. A handout regarding the care of the orthosis was given to the subject.

Measures

The Jebsen Test of Hand Function, which consists of seven subtests (writing, cards, small common objects, simulated feeding, checkers, large light objects, and large heavy objects) (Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969), was used to measure hand function. Although the Jebsen Test cannot measure all functional uses of the hand in activities of daily living, it does allow documentation of a continuum of ability within each of the seven subtest categories (Lynch & Bridle, 1989).
In a previous report of use of the Jebsen Test with 11 subjects with C-6-C-7 quadriplegia, Jebsen et al. (1969) reported that at least one of the 11 subjects was unable to do each subtest and that the most difficult subtests for the subjects were writing, simulated feeding, and lifting small common objects. A subject was determined to be unable to perform on the subtest if he or she took longer than 80 seconds. Time post injury and age range were not reported. Test–retest reliability coefficients range from .60 to .90 across subtests and across both hands for a significance level of $p < .01$.

Due to the inability of most persons who are quadriplegic to perform all of the subtests, and because the injuries of subjects in the present study were relatively recent and therefore they had undeveloped tenodesis effects, the Jebsen Test was modified. A maximum of 5 min, instead of 80 seconds, was given to complete each subtest; in the writing subtest, a black ballpoint pen was replaced with a felt tip pen with a 1-in. diameter built-up handle and the directions “write, do not print” were omitted; in the card subtest, subjects were allowed to turn the cards over by pushing them to the edge of the table, then flipping them or using a pinch; in the small common objects and checkers subtests, subjects were allowed to slide the objects off the table with their thumbs into their palms or use a pinch; in the simulated feeding subtest, a built-up handle 1 in. in diameter was added to the teaspoon; and in the large light objects and large heavy objects subtest, subjects were permitted to use the opposite extremity to stabilize the can at its top. Lastly, the subjects were seated uniformly, 17 in. from the edge of a pneumatic table to the front of the wheelchair armrest with the table locked at 32 in. high to allow for the wheelchair.

Standard goniometric technique (Askew, Becket, An, & Chao, 1983; Norkin & White, 1985) was used to measure active range of motion. A gram pinch meter\(^1\) (Fred Sammons, Inc.) was used to measure passive lateral prehension.

**Data Collection**

Initial evaluations of muscle strength, sensation, and range of motion of the upper extremities that had been performed by the subject’s primary occupational therapist, as well as demographic data, were collected from the medical record. Measurements of hand function, range of motion, and wrist strength were performed at 4 weeks, 8 weeks, and 12 weeks of the study.

Range of motion data at the MCP, PIP, and DIP joints of the fingers were gathered as the subjects moved within the tenodesis pattern, as the wrist was extended, the fingers were measured for finger flexion; as the wrist was passively assisted by gravity, fingers were measured for extension. Opposition was measured by the distance from the thumbnail to the nearest opposing surface of the index finger during the tenodesis effect. This measurement of opposition was used to gain an idea of the opening and closing of the hand. Palmar abduction of the thumb was measured while the subject moved in the tenodesis release pattern (Swanson, Hagert, & Swanson, 1983).

Passive lateral prehension data were collected in three steps: (a) subjects passively flexed their wrists while their elbows were supported on the table with the forearm in pronation, (b) the pinch meter was positioned between the thumb IP joint and the nearest opposing surface of the index finger, and (c) subjects extended their wrists to obtain a measurement. The mean of three trials was calculated as the subjects’ average (Swanson, Goran-Hager, & Swanson, 1978).

**Data Analysis**

Four of the 13 subjects (2 from each group) were discharged before the third measurement at 12 weeks, therefore two separate analyses were performed. For the 9 subjects (4 control, 5 experimental) tested three times, a $2 \times 3$ mixed analysis of variance (ANOVA) (treatment $\times$ time) with repeated measures on the second factor was performed. For the 13 subjects (6 control, 7 experimental) tested two times, a $2 \times 2$ mixed ANOVA (treatment $\times$ time) with repeated measures on the second factor was performed. The interpretation of significant main effects or interaction effects was simplified by the use of the Tukey HSD post-hoc test.

**Results**

No significant differences between control (non-orthoses) and experimental (orthoses) groups on any of the dependent measures of hand function were found at the 4-week, 8-week, or 12-week measurement periods. Dependent measures were gram pinch, opening of the hand in release, closing the hand in grasp, strength of wrist extension, total passive motion of each digit, passive range of motion of the thumb web space and the scores on the Jebsen Test. Table 1 displays the means on the Jebsen Test scores taken at 8 and 12 weeks of the study. There were differences found in 4-, 8-, and 12-week measurements. Table 2 shows the effect of time on performance with the Jebsen Test. There was a significant improvement in hand function over time regardless of whether the subject wore an orthosis. For the 13 subjects tested at 8 weeks, there was a significant improvement in performance on the checkers subtest ($F = 10.32; df = 1, 11; p < .01$), the simulated feeding subtest ($F = 7.58; df = 1, 11; p < .01$), and the large light object subtest ($F = \ldots$)

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Table 1
Jebsen Test of Hand Function: Means of Dominant Hand in Experimental and Control Groups

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Time for Control Group (sec)</th>
<th>Time for Experimental Group (sec)</th>
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<tbody>
<tr>
<td></td>
<td>8 Weeks (n = 6) 12 Weeks (n = 4)</td>
<td>8 Weeks (n = 7) 12 Weeks (n = 5)</td>
</tr>
<tr>
<td>Writing</td>
<td>80.1 69.3</td>
<td>64.5 68.8</td>
</tr>
<tr>
<td>Turning cards</td>
<td>35.9 20.9</td>
<td>23.4 30.1</td>
</tr>
<tr>
<td>Small common objects</td>
<td>117.7 98.8</td>
<td>100.6 92.4</td>
</tr>
<tr>
<td>Simulated feeding</td>
<td>54.7 29.3</td>
<td>25.8 30.1</td>
</tr>
<tr>
<td>Picking up checkers</td>
<td>120.8 129.9</td>
<td>143.8 115.6</td>
</tr>
<tr>
<td>Lifting large light objects</td>
<td>104.2 66.7</td>
<td>111.5 104.8</td>
</tr>
<tr>
<td>Lifting large heavy objects</td>
<td>184.4 130.3</td>
<td>152.1 149.0</td>
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5.49; df = 1, 11; p < .05). For the subjects tested at 12 weeks, there was a significant improvement on the cards subtest (F = 3.94; df = 2, 14; p < .05) with the significant gain occurring between 4 and 8 weeks, a similar effect for performance on the large light objects subtest (F = 4.30; df = 2, 14; p < .05), and a significant improvement in performance on the small common objects (F = 4.92; df = 2, 14; p < .05) with equally significantly additional improvement seen between the 8 and 12 weeks of orthosis wear.

A significant increase was found in pinch strength for all 13 subjects. This increase was seen both at 8 weeks (F = 4.41; df = 1, 11; p < .05) and in the 9 subjects tested at 12 weeks (F = 4.46; df = 2, 14; p < .05). However, in the latter group, the significant gain was only made between the 4- and 8-week measurement periods, calling into question any further effect of orthosis wear over time.

The size of the opening of the hand in a release motion was not significantly different between 4-, 8-, and 12-week groups as measured by passive range of motion. There was no significant difference between groups in closing the hand during the tenodesis effect. Similarly, when the means of the dominant and nondominant hand are compared over time, they show no significant differences except for the checkers subtest at 8 weeks (F = 4.76, df = 1,11; p < .05).

Discussion
The finding of no significant differences in hand function between the 7 subjects with an orthosis and the 6 subjects without an orthosis on any of the measurements was unexpected, yet both the experimental and control groups demonstrated similar improvement of hand function and prehension strength over time on certain dependent measures. Improvement was noted on some tests of the Jebsen and on pinch strength. That both groups demonstrated improvement in ability to use their hands for small and large objects supports clinical observations that manipulation abilities in activities of daily living tasks such as feeding, drinking from a cup, and picking up objects become increasingly easier for persons with C-6 quadriplegia over time. Such improvement ultimately frees the person from dependence on adaptive equipment for completion of a daily regimen. The finding of a significant improvement in strength of tenodesis prehension over time in both control and experimental subjects can be translated as an increased stability to hold objects during typing and writing tasks and improved ability to use keys, dress, pick up heavier objects, and manage urinary equipment.

Although surgery has given persons with C-6 quadriplegia the opportunity for a stronger lateral pinch, not all of these persons can financially afford this option. If reimbursement becomes more restricted, more of these persons will have difficulty obtaining insurance approval for hand surgery. Development of a strong tenodesis pinch through use of a static orthosis may be an acceptable option to surgery. The functional orthosis can be used for tasks requiring strong and prolonged prehension, such as drawing, desk work, and use of tools. Continuous wear of a hand orthosis, however, is hindered by the need to manipulate a wheelchair and perform transfers. Development of an adequate tenodesis was the second most often cited reason for discontinuing the use of a static or functional orthosis (Krajnik & Bridle, 1992; Shepherd & Ruzicka, 1991).

This study has several limitations that may account for the results. First, the length of time the orthosis was worn may not have been sufficient to produce any effect. Second, the daily activities of pushing a wheelchair and practicing transfers could have counteracted any stabilization of the thumb produced by the orthoses, as it was worn only during the night. Third, orthosis application within the first 4 months of rehabilitation after injury might not have been as effective as application later when deformities seen with quadriplegic hands and reduced

Table 2
Jebsen Test of Hand Function: The Effect of Time on Performance for 13 Subjects Tested at 8 Weeks and 9 Subjects Tested at 12 Weeks

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Time (sec)</th>
<th>Time (sec)</th>
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<tbody>
<tr>
<td></td>
<td>4 Weeks (n = 13)</td>
<td>8 Weeks</td>
</tr>
<tr>
<td>Writing</td>
<td>76.1 79.3</td>
<td>74.5 90.6</td>
</tr>
<tr>
<td>Turning cards</td>
<td>35.1 22.9</td>
<td>39.6 21.9</td>
</tr>
<tr>
<td>Small common objects</td>
<td>121.9 97.7</td>
<td>124.7 92.4</td>
</tr>
<tr>
<td>Simulated feeding</td>
<td>54.7 30.3</td>
<td>42.1 25.2</td>
</tr>
<tr>
<td>Picking up checkers</td>
<td>120.8 129.9</td>
<td>143.8 115.6</td>
</tr>
<tr>
<td>Lifting large light objects</td>
<td>104.2 66.7</td>
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<td>184.4 130.3</td>
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<tr>
<th>Subtest</th>
<th>Time (sec)</th>
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<tbody>
<tr>
<td></td>
<td>4 Weeks (n = 9)</td>
</tr>
<tr>
<td>Writing</td>
<td>131.3 83.8**</td>
</tr>
<tr>
<td>Turning cards</td>
<td>177.6 161.4</td>
</tr>
<tr>
<td>Small common objects</td>
<td>131.3 107.7*</td>
</tr>
<tr>
<td>Simulated feeding</td>
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</tbody>
</table>

*p < .05
**p < .01
joint mobility are more apparent. Perhaps the effects of immobilization do not occur during the early period after injury. Last, the small sample accounted for a high variability of measurements. Because of these limitations, the study should be repeated with a larger sample and collecting data through 1 year after injury.

The subjects in this study employed whatever grip was possible to hold onto the objects in the Jebesen Test. They used such grips as weaving the objects through or between the fingers. Often the object was simply laid in the palm of the hand. However, the thumb web grip, which occurs when the object is held and in contact with the web of the thumb (Sperling & Jacobson-Sollerman, 1977), was observed to be the most stable. It was also used more frequently in the experimental group (68%) than in the control group (54%). Finger grips were used less frequently, probably because the subjects were allowed to place the object in the palms of their hands by sliding it off the table. The results of the study might have been different if the subjects were required to use either web of thumb or finger grips. Thus, the quality of prehension may be an important variable to examine to determine the effects of orthotic devices.

Without further investigation of the long term effect of orthoses, the occupational therapist will not know whether or not such devices help prevent deformity and thus improve hand function. Clinical observations suggest that orthotic intervention is necessary in long-term management of spinal cord injury, even though this study provided no evidence that short-term intervention made a significant difference. Long-term effects, the influence of wearing the orthosis for longer periods of time, larger sample populations, and evaluation of the quality of prehension employed by the quadriplegic person are all worthy of investigation.

Conclusion

This study found no significant improvement in hand function as it relates to passive range of motion, strength of prehension, or coordination in subjects with C-6 spinal cord injury wearing thumb opponens orthoses during sleep as compared to those subjects with C-6 spinal cord injury who did not wear such an orthosis. The study did show significant improvement of hand function over time, especially in pinch strength, turning cards, picking up small objects, simulated feeding, and holding onto light cans in all subjects.

Further study of the application of orthoses is necessary to determine the long-term effects of orthotic positioning versus nonpositioning, to determine the amount of time the orthoses should be worn to counteract the deforming forces of gravity or hand use in activity, and to distinguish the differences in the effectiveness of various types of positional orthoses. Until orthotic efficacy studies are conducted, orthoses will be fabricated according to the therapist's philosophy or the institutional demands rather than according to proven intervention. As health care reform begins to affect the health care practitioner, practices that are not based on solid evidence will be denied.

Acknowledgment

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References


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