Follow-Up Study On Usage of Externally-Powered Orthoses

by Joan E. Beard, O.T.R.* and Charles Long II, M.D.**

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Over the past decade, externally-powered orthotic devices, some of which have been developed here and in conjunction with the Engineering Design Center of Case Western Reserve University, have been provided for severely paralyzed patients at Highland View, a chronic disease hospital of 340 beds.

Control systems for the flexor hinge hand splint, enabling prehension, have included those utilizing the McKibben carbon dioxide muscle (1), electrical muscle stimulation (4), and electric motor drives with three-level myoelectric control (6, 9) and with electric switch actuators (mechanical) operated by the shoulder (2), forearm, and chin (5) (Fig. 1). External powering for the Balanced Forearm Orthosis (B.F.O.), consisting of a mercury switch-activated elbow cable-drive system (8) for hand-to-mouth positioning (Fig. 2), and a special touch-plate control (7) for an electric

Figure 1

Flexor hinge hand splint, activated either by myoelectric control or by a manually-operated switch, on C5 quadriplegic patient.

*Occupational Therapist in Research, Ampersand Research Group, Department of Physical Medicine and Rehabilitation, Highland View Hospital, Cleveland, Ohio.

**Director, Ampersand Research Group, Department of Physical Medicine and Rehabilitation, Highland View Hospital, Cleveland, Ohio.

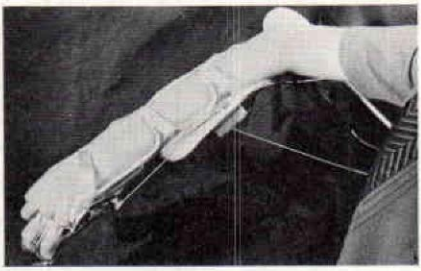

Figure 2

B.F.O. with mercury switch-controlled elbow cable and externally-powered hand splint on C4 quadripligic patient.

wheelchair, have additionally provided increased function potential for patients with C4 level quadriplegia.

Functional levels of quadriplegia used indicate the lowest level of residual motor function present (3). C4 quadriplegics, most of whom have a medical diagnosis of C4-5, have functional shoulder elevation and essentially complete paralysis of the arms. C5 quadriplegics, whose medical diagnosis is often C5-6, have shoulder and elbow muscles of fair to good strength but no wrist motion. Some C5 quadriplegics rely on B.F.O.'s but need no external powering other than for prehension.

A follow-up study was conducted primarily to determine to what extent our externally-powered orthotic devices are used by patients with C4 and C5 level quadriplegia following discharge from the hospital. The patients included in the study were all quadriplegics *without functional wrist extension* to whom orthotic devices of any type had been issued and who were first discharged from Highland View between June 1957 and November 1969, a period covering 12½ years. Information was obtained from medical records and questionnaires were completed by interview whenever possible.

Only results on usage of externally-powered devices, and educational pursuit, vocation, and living situation of those who have them, will be presented here. Other information collected, which will be correlated and reported later, includes that pertaining to usage of all orthoses and adapted equipment issued, orthotic system problems and suggestions for improvement, incidence of medical complications, special interests, evaluation of capabilities and actual level of independence in daily activities, and enumeration of causes of injury.

Number of quadriplegic patients in the study:		41
Subtract:	Expired:	8
	Could not be located:	2
	Failed to respond:	1
Number for whom questionaires have been completed:		30
Subtract:	Had some return of wrist extension:	4
	Were not issued externally-powered devices:	5
Number of C4 and C5 quadriplegics with externally-powered devices:		21

Figure 3

The number of patients participating in the study is shown in Fig. 3. The 21 patients with externally-powered orthoses, ranging in age from 17 to 57, included seven with C4 functional level quadriplegia and 14 with C5. All had traumatic spinal cord injuries. In this group, 19 questionnaires were completed by telephone or in person and two, by mail. The reliability of the findings would be expected to be greater than had more been completed by mail.

It was found that nine of these people, or 43%, are being formally educated. Two are in high school, three attend college, and four take correspondence courses. All except one person's tuition is paid by the Bureau of Vocational Rehabilitation. Eight of the nine are living at home as opposed to nursing home or extended care facilities while 76% of all 21 patients live at home. None of the 21 are working.

Usage of Orthoses

The chart (Fig. 4) shows the percentage of patients who, of those that have the special devices given, are actually using them. Thirty-one percent of the 29 devices listed are being used. A third of the patients who have any externally-powered orthotic devices are actually using them. Half of the few who have touch-plate wheelchair drive controls use them. All patients with electric-switch controlled hand splints use them; the McKibben muscle is the next popular; and no one is using his myoelectric control, electrical stimulation control, or externally-powered B.F.O. In some cases, the sample size is particularly small. It is really too soon to tell the frequency of usage of the electric switch control due to the small number issued to date and the short time-lapse since issuance (eight months for last of series). However, for many reasons, it appears to be the most functional prehension system of those used here. Most of the 21 people felt that the functional performance of the externally-powered hand splints themselves was adequate and any limitations in system design, with the exception of slow speed of application, were rarely severe enough to warrant disuse.

Three times as great a percentage of C5 quadriplegics are using their externally powered devices as are the C5's. The externally-powered B.F.O. does not possess adequate functional potential for the most severely involved patients. Both the poor quality of performance and the small number of activities which can be accomplished, due to limited range of motion and lack of forceful movement, lead to disuse. Without good proximal

Special device:	No. of C4 quadriplegics:			No. of C5 quadriplegics:			No. of C4 and C5 quads:		
	Use device:	Have device:	Percentage:	Use device:	Have device:	Percentage:	Use device:	Have device:	Percentage:
Externally-powered hand splints:									
McKibben muscle:	1	2	50%	2	9	22%	3	11	27%
Electrical stimulation:	0	1	0%	-	-	-	0	1	0%
Myoelectric:	0	4	0%	0	1	0%	0	5	0%
Electric switch:	-	-	-	4	4	100%	4	4	100%
Totals and percentages:	1	7	14%	6	14	43%	7	21	33%
External-powering for B.F.O.:	0	4	0%	-	-	-	0	4	0%
Touch-plate wheelchair drive:	2	4	50%	-	-	-	2	4	50%

Figure 4

Reasons for Disuse:	No. of times mentioned by different patients:
Slow speed of application	8
Poor quality of performance of activities	7
Slow speed of performance of activities	5
Hindrance in other activities	5
No interest or desire to do activities	3
Time limitation due to school	1
Architectural barriers	1
	30

Figure 5

arm function, the externally-powered hand splint is apparently of little value to these patients. The additional time required for application of the entire system is not justified. Poor quality of performance of activities was the reason most frequently cited by patients with C4 level quadriplegia for disuse of externally-powered orthoses.

Reasons for Disuse

Reasons given by the 14 people who do not use their externally-powered orthotic devices are shown in Fig. 5. All but two of those presently not using them had used them for a short period of time following discharge from the hospital. Although the desire to accomplish activities independently usually seems to be present, it is often more efficient and more practical for someone else to do daily activities for the patient, particularly in the home environment where many other factors are involved. Both time required for application of the device and for independent performance become too lengthy. Because the patient already depends heavily upon his family for essential daily care, he, in some instances, wants to avoid increasing demands upon them out of consideration for them and to avoid increased feelings of dependency within himself. His own time may be limited due to school. The relatively few activities which can be done independently are often interspersed in the daily routine with those in which he is not independent. It is often not worth putting on the orthosis to permit independent accomplishment of tasks requiring prehension, many of which are short-term in nature. Some things which require a longer period of time for completion and are related to interests, such as typing and page-turning, do not require prehension and can be done with simpler devices, applied with greater ease and sometimes independently. These most common activities, often required in pursuing educational goals, are frequently accomplished with B.F.O.'s without external powering, simple hand splints, or mouthsticks. Occasionally special interests are pursued which require prehension and increased usage of externally-powered hand splints.

The standard flexor hinge hand splint used here interferes with pro-

Live away	Live home	Multiplicative factor*
1/5	8/16	2.5
Not use	Use	Multiplicative factor
5/14	4/7	1.6

Proportion of patients pursuing educational goals and multiplicative factor

Live home	Live away	Multiplicative factor
4/16	3/5	2.4
Not being educated	Being educated	Multiplicative factor
3/12	4/9	1.8

Proportion of patients using externally-powered orthoses and multiplicative factor

*Quotient of two ratios.

Figure 6

pelling a regular wheelchair and can rarely be put on independently by these people. It is often not worth having it periodically applied to do an activity. Elimination of the need for removal of the splint practically necessitates the purchase of an electric wheelchair. Redesigning the splint so that it could be put on independently with ease by less severely involved C5 quadriplegics would probably be a worthwhile endeavor.

Ensuring high quality and speed of performance of an increased number of activities may not be sufficient in many cases to justify the longer application time, the most frequently cited reason for disuse. Perhaps, additionally, decreasing application time, and enabling independent application by some, would eliminate competition from simpler devices and increase usage among those presently not using externally-powered orthoses. If, in addition, performance of activities were extremely efficient, approaching the normal speed, any continued avoidance of independent accomplishment with orthoses would probably be due to the basic nature of daily activities, to the degree of acceptance of the severe disability on the part of the family and the patient himself, to association of the equipment itself with disability, to level of support and encouragement from the family, to desire for attention, communication, or dependence, and to the level of desire to pursue interests. Assistance, even when it is not necessary, is usually easy to obtain in the home environment when it is desired.

Factors contributing to disuse, as expressed by the participants in this study, are interrelated and, of

	Live away	Live home	Multiplicative factor
Not use	0/2	5/12	undefined
Use	1/3	3/4	2.3
Multiplicative factor	undefined	1.8	1.3

Proportion of patients pursuing educational goals and multiplicative factor

	Live home	Live away	Multiplicative factor
Not being educated	1/8	2/4	4.0
Being educated	3/8	1/1	2.7
Multiplicative factor	3.0	2.0	1.3

Proportion of patients using externally-powered orthoses and multiplicative factor

Figure 7

course, vary among individuals. This discussion may help to formulate a more realistic picture, although further evaluation remains highly subjective.

Correlation with Living Situation and Education

Relationships appear to be present between living situation and pursuance of educational goals, as well as between each of these and usage of externally-powered orthoses. The sample sizes are too small to make a statistical evaluation, or even the expression of percentage increase between groups, meaningful. Nevertheless, some interesting, and reasonable, trends are revealed.

The numbers of people pursuing educational goals and using externally-powered orthoses, of those groups specified, are shown in Figs. 6 and 7. In the second chart of Fig. 7, the lower number in the first box, for example, signifies the number of people who live at home and are not pursuing educational goals. The upper figure, or numerator, is the number, of this group, who are using their orthoses. In Fig. 7, in comparing groups, the alternate variable is controlled.

The numerical comparison of groups is employed for convenience. However, it must be kept in mind that the multiplicative factors (quotients of two fractions) are very approximate due to the small sample size. The figures in the lower right-hand box of each chart of Fig. 7 are also approximate and relate the magnitude of increase, in education and in usage, resulting from a change in each of the two variables affecting them.

The greatest proportion of patients doing educational work involved the group living at home and using their orthoses. Those using their devices tended to be living away from home and pursuing educational goals.

Two and a half times as great a percentage of those living at home (eight out of 16) as of those living away (one out of five) are pursuing educational goals. In the first chart of Fig. 7, eliminating the effect of using upon education by including only those who are not using their orthoses, we see that no one living away from home is pursuing educational goals while five of the twelve at home are. This trend may be partly to the increased physical help and psychological support often available at home for this type of pursuit.

While living at home strongly increased the likelihood of pursuing educational goals, living away increased usage of orthoses with similar intensity. Three out of five people living away from home and only four of the 16 at home use their externally-powered orthoses. Those who can and desire to do routine tasks independently are often encouraged to do them in living situations away from home where time is available and fewer intimate relationships exist. As stated previously, it is often more efficient simply to be assisted in the home situation.

Usage of orthoses also increased, but to a lesser extent, with ongoing education. Almost twice as great a percentage of those pursuing educational goals (four out of nine) as

of those not pursuing them (three out of 12) use their devices, Eliminating the living situation influence resulted in three times as great a percentage. A math course, for example, ocasionally creates a need to use the externally-powered hand splint even though the activities most related to education do not require its use. It is possible that those living at home who are able to do some routine activities quite efficiently are more likely to be enthused about doing so if they are also enthused about their educational or leisure-time pursuits. Support from the family is then available for both desired endeavors. Yet, schooling imposes increased limitations on time upon the family and patient, making performance of routine tasks by the family more expedient in other cases.

In this study, the relative influences appear to differ little in intensity. Fig. 7 shows that a change in living situation results in only 1.3 times as great a proportion of patients, either pursuing educational goals or using orthoses, as does a change in the alternate variable. The effect of living at home, as compared with usage, upon education is about the same as, or slightly less than, the relative effects of living away and pursuing educational goals upon usage of orthoses.

The factors contributing to disuse, discussed in the previous section, tie in nicely and, along with additional knowledge of the patient and his situation and types of activities for which the orthoses are used, provided some explanation for the trends exhibited here.

Conclusion

In spite of the fact that most reasons for disuse are not exclusively related to the system's functional capabilities, design and provision of useful orthoses, especially for C4 quadriplegics, remains an important challenge in the field of rehabilitation. Only one of the seven C4 quadriplegics in this study uses his externally-powered hand splint. No one uses the external powering for the B.F.O., which does not possess adequate functional potential for the most severely involved patients of this group. The 43% of the C5 quadriplegics, who do use their externally-powered hand splints, find the added functional potential useful to them. A majority of these people have good proximal musculature, wish to be as independent as possible, have electric wheelchairs, use the orthosis regularly for a variety of common activities, and do not feel application of the device takes too long. Half of them live away from home and half are pursuing educational goals, both of which appear, in this study, coincident with increase in usage of externally-powered orthoses.

As many of us realize, the presently available systems, which have been tested here and elsewhere in the past, are of very limited value to the most severely involved C4 quadriplegics. Their design, both from the structural and the control aspects, challenges the ingenuity of the engineers. Systems in the research and theoretical stages include those utilizing logic circuitry for pattern recognition and preprogrammed motion and those in-

corporating a more natural positional-proportional control actuator. In proceeding with these multi-axes-control devices, the importance of the basic requirements of volitional control, ease and automatism of operation, natural output motion, efficient response to error and change of intention, and short training period must never be overlooked or minimized in the design of functional orthoses.

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References

1. Barber, Louis M. and Nickel, Vernon L.: (An Historical Review) Carbon Dioxide-Powered Arm and Hand Devices. Amer. J. Occup. Ther 23: 215-225, 1969.
2. Lehneis, Hans Richard: Application of External Power in Orthotics. Orth. and Pros. J. 22: 34-45, 1968.
3. Long, Charles: Congenital and Traumatic Lesions of the Spinal Cord, in Krusen, J.T.: Handbook of Physical Medicine and Rehabilitation. Philadelphia and London, W. B. Saunders Company, pp. 559-571, 1965.
4. Long, Charles and Masciarelli, Vince: An Electrophysiologic Splint for the Hand. Arch. Phys. Med. 44: 499-503, 1963.
5. Prentke, Edwin M.: A Chin Switch for Control of Orthoses. Arch. Phys. Med. Submitted Sept., 1969 for publication in Ach. Phys. Med.
6. Prentke, Edwin M. and Beard, Joan E.: A Surface Electrode Design for Myo-electric Control. Orth and Pros. J. 23: 63-67, 1969.
7. Prentke, Edwin M. and Romich, Barry: Wheelchair Acceleration Limiter. Orth. and Pros. J. 22: 1-3, 1968.
8. Prentke, Edwin M., Romich, Barry and Derda, Harry: A Rack and Pinion Cable Drive for Orthoses. Orth. and Pros. 23: 139-141, 1969.
9. Trombly, Catherine A., Prentke, Edwin M. and Long, Charles, II: Myo-Electrically Controlled Electric Torque Motor for the Flexor Hinge Hand Splint. Orth. and Pros. Appl. J. 21: 39-43, 1967.