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Clinical Evaluation of UNB 3-State Myoelectric Control for Arm Prostheses[a]

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ABSTRACT

This report describes an attempt to conduct (in 1978 during a period of one week) an intensive, thorough, and objective evaluation of a prosthetic control system in such a manner that the evaluation avoids what are seen as shortcomings common among evaluation procedures described in the literature. The evaluation, in terms of benefits to patients, involved consideration on an interdisciplinary basis among an engineering team, prosthetics team, and therapy team. Nine below-elbow and two forequarter amputees participated. The device evaluated was the University of New Brunswick 3-state myoelectric control system, in the 12-volt version designed in 1975. This system is intended for use where there are not enough control sites to permit use of an Otto Bock or similar control system, and permits on/off control of a powered hand or other device in two directions from a single muscle. Observations on each patient by the 14-person evaluation team are summarized, and an Appendix presents questionnaires with summarized responses of the subjects and their families.

INTRODUCTION

With the increasing interest in myoelectric control of prostheses, it is important to evaluate carefully the functional capacity of such systems and to determine whether or not they are of benefit to the patient. Numerous evaluations have been reported but few of them are complete, objective evaluations involving a substantial number of patients. (An annotated bibliography of some evaluations of myoelectric control systems is available from UNB or from the Bulletin of Prosthetics Research.)

Much of the literature involves a comparison of myoelectric control with other types of control. In general, the rating of the myoelectric control system is then dependent on the system with which it was compared, as well as the type of amputee. In Schmeisser and Seamone's report (1), on a 5-year evaluation, externally powered prostheses were rated more favourably than otherwise-similar body-powered prostheses in a high proportion of upper-limb amputees. They reported an increase in functional capabilities enabling bimanual task performance, especially for short above-elbow or shoulder disarticulation amputees. In particular, myoelectrically controlled prostheses were the units of choice for wrist disarticulation, below-elbow, elbow disarticulation and short above-elbow amputees. But for

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the bilateral amputee whose limb remnants are long enough to provide function (with speed and dexterity) with a bilateral body-powered prosthesis, the externally-powered systems were considered unsuitable.

In a study by Peizer et al. (2), below-elbow and above-elbow amputees who normally wore conventional prostheses were tested for differences in performance when controlling terminal devices and elbows by means of pull-switches versus myoelectric signals. Indications were that myoelectric control was superior, resulting in performance which was more natural and less fatiguing. Carlson (3) and Ross (4) also reported studies supporting the superiority of myoelectric control over switch control, citing faster performance and more precise manipulations as two major benefits. With respect to the UNB myoelectric control system, a report by Friesen (5) using below-elbow amputees as subjects indicated a preference for myoelectric control relative to cable control.

In many cases, the evaluation of a particular myoelectrically controlled prosthesis is done by the designer of the unit or by his associates (6, 7, 8) and therefore cannot be considered totally objective. Another shortcoming is the fact that emphasis in most cases is on circuit or device design (5, 7, 9, 10), with only a brief section devoted to fitting and patient response.

The small number of patients fitted with any given unit is also a factor in many evaluations. Other than the evaluation reported by Soerjanto (11) of 57 patients over a 3-year period, there are very few involving a definite and substantial number of patients. (Even Schmidl (8) refers only to "extensive" experience and "large"—but unspecified—numbers of subjects.)

The report presented here describes an intensive evaluation of the UNB 3-state myoelectric control system as worn by nine below-elbow amputees and two forequarter amputees. (This is the 12-volt system, designed in 1975). The patients had been fitted in three different centres, some recently, and others several years earlier.

To ensure competent assessment, the evaluation was carried out by an experienced clinic team consisting of orthopaedic surgeons, prosthetists, engineers, an electronics technologist and occupational therapists. To foster objectivity, a number of persons who had no prior experience with the UNB system were included. (Team members were all experienced with other types of prostheses, and those without direct experience with the UNB system had been familiarized with it through courses or seminars.)

DESCRIPTION OF THE UNB SYSTEM

The UNB 3-state control system is intended for use where there are not enough control sites to permit the use of an Otto Bock or similar system. It provides on-off control of a powered hand (or other device) in two directions from a single muscle. The system is designed so that, with no voluntary myoelectric signal, the hand is stopped (off). With a small signal the hand closes, and with a large signal the hand opens. (System time-constants permit transitions between "off" and "opening" without activating the "closing" state.)

The two switching levels which define the boundaries of the active states are adjustable to permit optimum settings for each patient. Settings reflect the level of electrical noise when the control muscle is relaxed, and the level of the strongest contraction which can be maintained comfortably. The theoretical basis for this adjustment has been developed by Parker (12, 13) and the instrument used for adjusting the control system is described by Brittain and Baird (14). Sensitivity is such that the system can be used when a maximum comfortable sustained contraction elicits as little as 20μV (microvolt) rms myoelectric signal.

The control unit is housed with rechargeable 12-V, 225-mAh (milliampere hour) NiCad batteries in a cylindrical package 5 cm in diameter by 7.5 cm long, with a mass of 160 g. For operating an electric elbow, a 450-mAh battery is usually substituted, increasing the length to 10 cm and the mass to 250 g. One unit mounts readily within the prosthesis of a short below-elbow amputee, and for a forequarter amputee two units may be mounted within the humeral section of the prosthesis. A more detailed description of this control system is given by Brittain and Caldwell (15).

One of the patients evaluated was wearing a UNB sensory feedback system. This unit makes use of strain gages mounted on the forefinger of the hand to provide an indication of pinch force via electrocutaneous stimulation (16).

It is necessary to test each patient individually to determine which muscle will give the best control, as this will vary from one person to another. Below-elbow amputees are then fitted with Münster sockets which have the electrodes mounted in the socket over the control muscle. Flexible silicone rubber sockets as described by Sauter (17) are used most commonly. Forequarter amputees require two control muscles, one to operate the hand and the other to operate the elbow. Remnants of either chest or back muscles, (pectoralis major, trapezius, latissimus dorsi, etc.) can be used

as long as the person can learn to contract the two muscles independently. (This has been achieved by all forequarter amputees seen by the authors.) Both forequarter patients who took part in this evaluation were using the trapezius and latissimus dorsi muscles to control their prostheses. The electrodes are mounted on the prosthesis frame.

EVALUATION PROTOCOL

The evaluation was carried out at the Ontario Crippled Children's Centre in Toronto over a period of 1 week. Each patient was reviewed independently by an engineering team, a prosthetics team and a therapy team. Following this, each patient was seen at one of two special amputee clinics held for this evaluation program. Here the three review teams were joined by one or more orthopaedic surgeons and other interested hospital staff as available, and all aspects of the fitting were considered on an interdisciplinary basis. Participants are listed in Table 1.

The prosthetics review was the least formal of the three pre-clinic sessions. Its primary purpose was to determine whether modification or repair of the prosthesis was indicated as a consequence of patient growth or weight change, normal deterioration of the prosthesis in daily use, or accidental breakage. If repair or modification was needed and schedules permitted, the work was done immediately. While this resulted in some patients going through the therapy evaluation wearing a recently modified prosthesis to which they were not fully accustomed, on balance it seemed to permit the most reasonable overall assessment.

During the engineering review, emphasis was placed on finding and correcting any malfunctions, and on making sure that the switching levels were appropriate for the patient's present signal level range.

The review by the occupational therapists consisted of the following:

1. Questionnaires completed by the patient concerning the comfort, reliability, utilization, and cosmesis of the prosthesis;
2. A questionnaire completed by a parent or close relative concerning the patient's use and acceptance of the prosthesis;
3. An assessment by the therapy team of the patient's performance in each of seven controlled tasks; and
4. A general evaluation by the therapy team of any aspects of the patient's use of the prosthesis and attitude toward it.

TABLE 1—The Evaluation Team

Orthopaedic Surgeons:	Dr. D. Gibson, OCCC Dr. R. Gillespie, OCCC Dr. G. Hunter, WCB
Prosthetists:	W. Burt, WCB R. Dakpa, OCCC W. Sauter, OCCC Z. Wedderburn, OCCC
Occupational Therapists:	M. Grosse, WCB H. Hager, WCB M. Marshall, OCCC B. O'Shea, Queen's
Engineers:	V. Dunfield, UNB G. Iles, OCCC R. Scott, UNB
Electronics Technologist:	R. Caldwell, UNB

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Sample questionnaires and a summary of patients' responses are given in Appendices 1–5.

In addition to written notes and completed questionnaires from each team, and notes from the two clinics, both black-and-white photographs and colour slides were taken of each patient, and the therapists' functional-assessment sessions were recorded on videotape. It is from this material that the following results have been extracted.

NOTES ON INDIVIDUAL PATIENTS

Below-Elbow Amputees

Case No. 1.—age 16, female, left terminal transverse hemimelia, below-elbow. She was fitted with a myoelectric prosthesis (Fig. 1) at age 14 after rejecting her conventional prosthesis (hook TD) because of cosmesis. She is considered to be an excellent user, wearing the myoelectric prosthesis all day and even for sports such as skiing, tennis, volleyball and basketball. She likes the hand, although it is slow compared with her normal hand and requires more concentration than a cable-controlled hook. She finds the wrist difficult to position (because of the glove), and this makes some activities awkward. She has trouble judging the grip strength of

FIGURE 1.
This 16-year-old subject was fitted with a myoelectric prosthesis at age 14 after rejecting her conventional prosthesis (hook TD) because of cosmesis. She is considered an excellent user. (Case No. 1: left terminal transverse hemimelia, below-elbow.)

the hand, making her slightly less confident than she was with her hook.

Interference from an electric refrigerator somtimes causes her hand to open inadvertently.

This subject is generally pleased with the cosmesis of the myoelectric prosthesis, although she likes to wear long sleeves to cover the "bumpy" wrist.

Case No. 2.—age 20, female, left terminal transverse hemimelia, below-elbow. She was fitted with her first myoelectric prosthesis when she was 14 and is presently wearing a system with sensory feedback. She is a good user—although she tends not to use it for many activities due to the slow speed and her fear of staining the glove. She wears the prosthesis all day and occasionally gets inadvertent activity when she forgets to pay attention to the feedback. She would like to be able to adjust the gain herself, and also to have fingers which would bend for a better grip.

Case No. 3.—age 16, male, right below-elbow traumatic amputation at age 8. He has been wearing a myoelectric prosthesis for 4 months and is presently a poor/fair user. He does not pre-position the hand, and consequently looks awkward when doing activities. However, he says he uses this arm for more activities, and is more adept with it, than he was with his conventional prosthesis. He wears the arm all day, switching it off when walking so that the hand will not close inadvertently.

Case No. 4.—age 19, male, right terminal transverse hemimelia, below-elbow. This subject has been wearing a myoelectric prosthesis for 8 years and is a good/excellent user. He uses it for most of his activities, including sports—the only exception being cross-country skiing. Although he found it difficult to use at first, he is now more confident with it than he was with his conventional system, and finds it more comfortable and more cosmetic.

His only criticism concerned the wrist, which he would like to be able to flex and lock in position. (Subsequent to the evaluation he was provided with an Otto Bock ball wrist unit, and his response to that has been highly favourable.)

Case No. 5.—age 20, female, right terminal transverse hemimelia, below-elbow. She had been an excellent user of her conventional prosthesis, and when she was fitted with a myoelectric system at age 16, she adjusted very quickly. She uses it in a spontaneous and natural way and although it is heavier than her conventional prosthesis, she finds it comfortable. She is pleased with the cosmesis of the arm, especially since she does not have to worry about a harness showing.

She sometimes will not send the arm for repairs because she does not want to be without it.

Case No. 6.—age 13, female, right terminal transverse hemimelia, below-elbow. She began wearing her myoelectric prosthesis about 10 months prior to the evaluation, and finds it more comfortable and more cosmetic than her conventional prosthesis. Learning to operate the hand was difficult, but once she had learned, she found control easier. She prefers not to wear it for sports, and also takes it off at home. When not using the hand she turns it off to avoid inadvertent activity.

This subject has had only 3 days of functional training

and although she is considered to be a good user, she would benefit from more training.

Case No. 7.—age 18, female, right terminal transverse hemimelia, below-elbow. She had been wearing a myoelectric prosthesis since she was 15, but had some trouble with sores caused by the electrode paste. She was fitted with a pasteless system and a new socket immediately prior to the evaluation.

This subject wears her myoelectric prosthesis all day and is a good user. She is learning to play the violin but finds it difficult.

Case No. 8.—age 45, female, left terminal transverse hemimelia, below-elbow. This woman received her first prosthesis when she was 13. That was a conventional unit with a functional hand, but because she never had any functional training she eventually removed the harness and wore the unit as a cosmetic prosthesis.

She was fitted with a myoelectric prosthesis at the age of 42 and prefers it to the conventional unit. She found it difficult to learn to operate and attributes that to her age. She can perform fewer tasks with it but is more adept at the things she can do. She plays the piano, using the prosthesis to play the bass notes. She usually wears the hand about 10 hours a day and finds the grip good, but complains that the hand is too slow to keep up with her normal hand.

The only feature of the prosthesis that she really does not like is the ease with which the glove discolours.

Case No. 9.—age 16, male, left terminal transverse hemimelia, below-elbow. He had been wearing a conventional prosthesis with a hook until he was fitted with a myoelectric system 3 months prior to the evaluation. He is a good user and wears it for many activities including most sports (the exceptions are badminton and tennis, for which it seems too heavy). He turns the hand off for sports. He prefers the prosthesis to his hook—although he finds it heavier, hotter, slower, noisier, and more difficult to use than a hook. Because he has a very short residual limb (ulna length by X-ray is only 4.5 cm), his elbow flexion is limited to 90 degrees, and this bothers him, but he likes the cosmesis and the grip-strength of the arm.

Forequarter Amputees

Case No. 10.—age 18, male, left forequarter amputation at age 15 due to a tumour. He was fitted with a myoelectric hand and elbow prosthesis (Fig. 2) at age 16. He wears the arm at home and when around other people, but does not wear it at work (he is a groundskeeper at a golf club) or for sports. He is presently a poor user, primarily because of lack of training. During the evaluaton, he tried many new tasks and was surprised at what he could do. He seemed to learn quickly; with more training he would probably become a good user.

This forequarter amputee sometimes has difficulty operating the hand and elbow independently, and he has trouble with the passive-friction shoulder joint—which slips. He finds the elbow noisy. The lifting capacity is not enough. He needs a larger capacity elbow battery as his 225-mAh battery discharges too quickly.

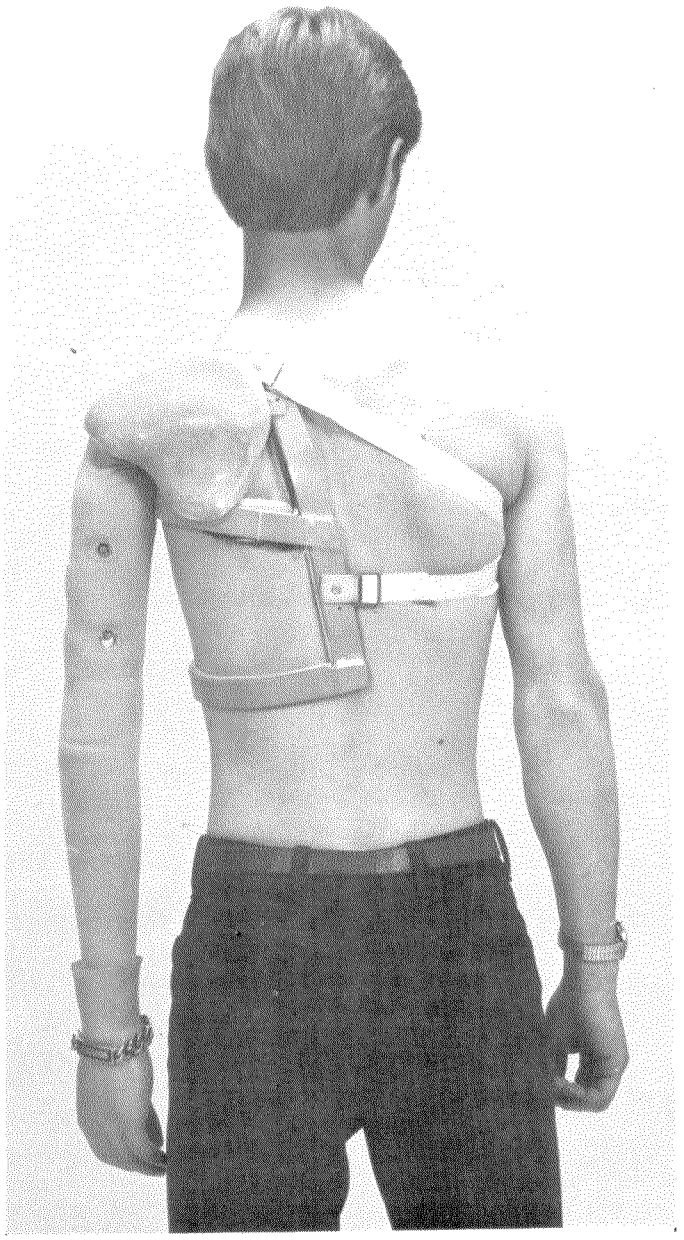

FIGURE 2.
This 18-year-old subject was fitted with a myoelectric hand and elbow prosthesis at age 16. He tried many new tasks during the evaluation and was "surprised" to discover how many things he could do with it. With more training he would probably become a good user. (Case No. 10: left forequarter amputation at age 15 due to a tumour.)

Case No. 11.—age 20, male, right forequarter amputation following an industrial accident at age 19.

This traumatic amputee had been wearing a myoelectric hand and elbow for 3 months before the clinic. At first he had trouble controlling the units independently, but that skill improved with practice. He likes the prosthesis but is a very poor user at present, due partly to the lack of control and functional training, and partly to an apparent lack of motivation on his part. He wears the unit all day, turning it off after each use.

SUMMARY AND RECOMMENDATIONS

Below-Elbow Amputees

This group consisted of 9 patients, ranging in age from 13 to 20 but with one 45-year-old subject, all with short below-elbow residual limbs. At the time of fitting of these patients, it was considered impractical (because of the short residual limbs) to seek two forearm control sites free of interference, as would have been required for an Otto Bock control system. The following observations are made:

1. For these patients the UNB 3-state myoelectric control system, with an Otto Bock hand (fitted with a Münster socket containing the electrodes) is clearly superior to a conventional prosthesis.
2. The most important advantages cited by these patients relative to a conventional prosthesis are improved cosmesis and freedom from a harness.
3. The most important control system deficiency noted by the patients is lack of feedback concerning pinch force. The patients feel less confident than with their conventional prosthesis, particularly in sustained use.
4. The one patient in this group wearing an early version of the UNB feedback system is very enthusiastic about it. However, conscious attention is necessary to utilize the feedback, and if she is distracted she may drop or crush objects. Thus her overall performance at this time is not significantly better than that of comparable patients without feedback.
5. The above observations indicate a need for continued development and extended clinical evaluation of a force feedback system.
6. The 100% patient acceptance rate among all below-elbow amputees fitted with the 1975 UNB system indicates that a broader range of patients probably would benefit. It is suggested that younger patients be fitted, requiring development of a smaller control system and acquisition of suitably sized terminal devices. Two hands for children are currently available—the Systemteknik hand and the Variety Village hand. (Development of a 6-volt control system, in a package considerably smaller than that required for the 12-volt system, has already been initiated at UNB. More than two dozen subjects have been fitted satisfactorily in clinical trials which began in the fall of 1979. Further details are available from UNB—*Communication from Scott, October 14, 1980.*)

Forequarter Amputees

This group consisted of two patients, one amputated due to carcinoma and one due to trauma. Since there were few control sites available, the UNB control system was used in conjunction with an Otto Bock hand and a Variety Village electric elbow. The following observations were recorded:

1. A conventional body-powered functional prosthesis is generally not feasible for a forequarter amputee.
2. Because few patients have been fitted with the system, meaningful evaluation is difficult. (Four patients have been fitted but one could not attend the evaluation because of illness, and one had recently died.)
3. The 10-cell, 225-mAh battery is not adequate to operate an electric elbow. All future fittings should use a 450-mAh battery for the elbow.[b]

General Observations

1. There is a need to provide more convenient, prompt repair when breakdowns occur. For patients remote from service centres it may be appropriate to have a standby prosthesis, perhaps cosmetic only, to be worn while the primary prosthesis is being repaired.
2. Regular followup, preferably through an interdisciplinary amputee clinic, is desirable. The suggested interval is every 6 months for younger patients, every year for adults.

[b]Battery power rarely if ever fulfills theoretical performance levels. In a recent paper (18) by R. R. Caldwell and one of the authors, data on the performance of an Otto Bock 12-volt hand were shown. Where a fully charged 225-mAh battery with a nominal voltage of 12 V "should" provide approximately 1500 cycles of operation, the amputee's normal use of additional energy to build up pinch force after the hand has closed on an object brought the battery capacity down to 1140 hand cycles—at room temperature. Various power losses in the control system, standby power use, and less-than-complete charging brought the "reasonable expectation" to about 900 cycles. This fell to about 500 cycles at 0 deg. Celsius, and less than 100 cycles at minus 20 deg.

Among the revealing graphs with that brief paper is one which strongly conveys the extent to which the inner cover and glove tend to degrade hand performance, and tend to amplify the effect of cold.

3. Most patients would benefit significantly from more occupational therapy at the time of fitting, especially in relation to functional use training.
4. There is a need for better documentation of fitting, training, and subsequent management of patients as an aid to future research and development.
5. Most patients keep their myoelectric control system switched off when not in use. This may indicate a problem with adjustment or training, such that inadvertant activation of the prosthesis occurs unless conscious attention is given to maintaining relaxation of the control muscle.
6. The control system developers must provide greater assistance concerning control system adjustment, either through revised adjustment procedures and instructions, or by providing better training for prosthetists and therapists on this topic. (Since this evaluation, the UNB trainer has been redesigned to simplify the controls and make the adjustment procedure less complicated. The new equipment and procedures were introduced at a workshop attended by 12 prosthetists and therapists.)
7. Successful fitting of myoelectricaly controlled prostheses is a specialty which requires careful attention by a skilled prosthetist/therapist team with engineering support. To maintain competence, such a team must fit myoelectric prostheses frequently.

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Finally we acknowledge the assistance of the patients—the most important part of any clinical evaluation team—who re-arranged their schedules to participate in this evaluation. ■

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NOTE: Appendix 1—Appendix 4 (on the following pages) presents questionnaires with summarized responses of the subjects and their families

APPENDIX 1

Subject Questionnaire, Part One (summary of 11 responses)

PURPOSE: This questionnaire is designed to obtain information about your myoelectric prosthesis. The first two parts deal with the performance of the prosthesis in terms of comfort, reliability, ease of use, and function, as well as its appearance and your acceptance of the prosthesis. In the third part, you are asked to indicate the specific tasks for which you use your prosthesis.

INSTRUCTIONS: Please respond to each question as accurately and completely as possible, giving explanations where requested. There may be some questions which do not apply to you, for example, you may not have a powered elbow. Simply mark such questions *NA*.

1. Have there been any malfunctions in your prosthesis in the past two months? If so, please explain.

   7 — No
   1 — loose screw
   1 — broken wire
   1 — broken charger connector
   1 — hand sometimes won't work

2. Have there been any changes in the operation or function of your prosthesis during the past two months? If so, please explain.

   10 — No
   1 — needs gain adjusted. Hand becomes too easy to open.

3. In the week prior to completing this questionnaire, what was your wearing time to the closest hour?

Sunday	_____ hours	Thursday	_____ hours
Monday	_____ hours	Friday	_____ hours
Tuesday	_____ hours	Saturday	_____ hours
Wednesday	_____ hours		

   10 hours / day — below-elbow average
   15 hours / day — 1 forequarter
   4 hours / day — 1 forequarter

4. (a) When do you usually first put on the prosthesis each day?

   7 — after getting dressed
   2 — before getting dressed
   1 — afternoon
   1 — before breakfast

   (b) When do you usually finally take off the prosthesis each day?

   7 — just before going to bed
   1 — 5:00
   2 — 8:00-9:00
   1 — after school, but puts it on again if going out later

   (c) Do you ever remove and reapply the prosthesis during the day for any reason? If so, please explain the reason and how often this occurs.

   6 — No
   1 — Yes in order to rest arm
   1 — Yes when going swimming
   1 — Yes when it gets too warm
   1 — Yes for about 1 hour after work
   1 — Yes after supper, if going out later

5. Do you have any difficulty taking off or putting on the prosthesis? If so, please explain.

   No.

6. Have you had any skin reactions from the socket or the electrodes? If so, please give details.

   1 — rash at first but OK now
   1 — itchy and scaly skin within last 4 months
   1 — pimple on stump
   1 — allergy from electrodes and paste
   7 — No

7. When you remove the prosthesis, can you see a mark where the electrodes have been?

   Clearly __10__
   Faintly _____
   Not al all __1__ (forequarter)

8. Is the prosthesis comfortable? If not, please explain.

   8 — Yes
   1 — slips when sweaty
   1 — heavy, electrodes uncomfortable on back
   1 — have to flex arm to keep it on

9. Has the fit of the socket changed in any way over the past two months? If so, please explain.

   5 — No
   2 — gained weight, socket small
   2 — lost weight, socket big
   1 — socket a little too big
   1 — weight fluctuates

10. Does the socket ever become loose during any particular activity? If so, please explain.

    4 — No
    5 — Yes, when sweating or during sports
    1 — shoulder slips when getting up from sitting position

11. (a) Do the batteries ever run down during a day's use? If so, please explain (frequently, only after prolonged use, etc.).

    5 — No
    6 — Yes after a lot of use

    (b) Do you ever use batteries more than one day before recharging? If so, please explain the circumstances and the length of use between charges.

    7 — No
    3 — Yes, if hand is not used much (1-36 hrs)
    1 — Yes when staying out all night unexpectedly

12. Do you have any difficulty connecting or disconnecting the charger? If so, please explain.

    10 — No
    1 — Yes because of bent pins

13. Does the prosthesis make any noise? If so, does it cause a problem?

    1 — No
    1 — very little
    7 — Yes, but no problem
    1 — Yes, especially the elbow
    1 — Yes, when leaning on it air comes out and makes a noise

14. Is there ever any hand movement which you have not consciously initiated? If so, please explain the circumstances.

    6 — No
    2 — Yes, because of interference from refrigerator, amplifiers etc.
    1 — Yes, hand closes when walking
    1 — Yes, unconsciously activates hand when nervous or tense
    1 — Yes, when not paying attention to feedback

15. Do you ever switch off the control unit or the hand when you are wearing the prosthesis? If so, please explain the circumstances.

4 — Yes to keep it in one position
3 — Yes to save batteries
2 — Yes for sports
1 — Yes to avoid opening before electrodes set in
1 — No

16. Is the grip of the hand sufficient for most activities? If not, please explain and give examples.

10 — Yes

17. For most activities, is the speed of the hand. . .

_____ **too fast**
__7__ **about right**
__4__ **too slow**

If too fast or too slow, please explain and give examples.
Prosthesis cannot keep up with other hand
Faster to use one hand for some things

18. Does the hand ever become more difficult to operate as the day progresses? If so, please explain.

5 — No
3 — Yes when tired
1 — Yes, bothered by weight
1 — Yes when batteries are low, hand is slow and won't grip tightly.

19. When you remove the prosthesis, is there moisture from perspiration inside the socket? If so, does this cause any problem?

1 — No
8 — Yes but no problem
1 — Yes, apt to slip
1 — only after strenuous exercise

20. Is there any feature of the hand which you do not like? If so, please explain.

6 — No
Glove loose around elbow
Too big around wrist and thumb
Wrist is bumpy — wears sleeves to cover it
Glove absorbs dye and newsprint
Hand small, glove orange and shiny

NOTE: QUESTIONS 21–25 DO NOT APPLY TO BELOW-ELBOW PROSTHESES

21. For most activities, the speed of the elbow is:

__2__ **about right**
_____ **too slow**
_____ **too fast**

If too slow or too fast, please explain and give examples.

22. (a) Is there ever any elbow movement which you have not consciously initiated? If so, please explain.

1 — No
1 — Yes, when trying to use the elbow without the hand

(b) Does it ever prevent you from using the prosthesis? If so, please explain.

2 — No

23. (a) When you operate the elbow, is there ever any undesired activity of the hand which you cannot control? If so, please explain.

2 — No

(b) Does it ever prevent you from using the prosthesis? If so, please explain.

2 — No

24. Is there any feature of the elbow which you do not like? If so, please explain.

1 — No
1 — Noisy, not much lifting ability

25. (a) Does the shoulder unit ever need tightening? If so, approximately how often?

1 — Yes every 6 months
1 — No (has been wearing prosthesis only 2-3 months)

(b) If the shoulder unit does loosen, does it interfere with any activities? If so, please explain.

1 — Can bend over but cannot straighten up without shoulder slipping.

APPENDIX 2

Subject Questionnaire, Part 2 (summary of 9 below-elbow amputees)

INSTRUCTIONS: This part of the questionnaire is designed to obtain your opinion about your myoelectric prosthesis IN COMPARISON WITH THE PROSTHESIS YOU WORE BEFORE. There are five possible choices for each question. Please check one answer that best describes the difference between your myoelectric prosthesis and your previous prosthesis. Please use the space at the right of each question for any comments you might have. Your comments will be appreciated.

1. My myoelectric (M-E) arm is generally:

_____ **much less comfortable**
__1__ **somewhat less comfortable**
__1__ **about as comfortable**
__4__ **much more comfortable**
__3__ **somewhat more comfortable**

2. When I use my M-E arm, my stump:

_____ **hurts more**
__8__ **does not hurt**
__1__ **hurts somewhat more**
_____ **hurts somewhat less**
_____ **hurts about the same**

3. When wearing my M-E arm, it feels:

__6__ **somewhat heavier**
__1__ **much heavier**
_____ **much lighter**
__2__ **about the same**
_____ **somewhat lighter**

4. When wearing my M-E arm, my stump feels:

__3__ **somewhat cooler**
__2__ **somewhat hotter**
_____ **much hotter**
__4__ **about the same**
_____ **much cooler**

continued

5. When wearing my M-E arm, my stump perspires:

__5__ **about the same**
__1__ **much more**
__2__ **somewhat less**
__1__ **somewhat more**
____ **much less**

6. The amount of effort it takes me to use my M-E arm is:

__3__ **much less**
__1__ **about the same**
__1__ **much more**
__2__ **somewhat more**
__2__ **somewhat less**

7. The equipment used to keep my M-E arm on (socket, harness) is:

__2__ **about as comfortable**
__5__ **much more comfortable**
__1__ **somewhat more comfortable**
____ **much less comfortable**
__1__ **somewhat less comfortable**

8. The amount of care I have to give my M-E arm is:

__3__ **somewhat more**
__1__ **much less**
____ **about the same**
__1__ **somewhat less**
__4__ **much more**

9. The way I use my M-E arm looks:

__2__ **somewhat better**
__6__ **much better**
____ **somewhat worse**
__1__ **about the same**
____ **much worse**

10. The amount of control I have in using my M-E arm is:

__2__ **about the same**
__4__ **somewhat better**
____ **much worse**
__1__ **somewhat worse**
__2__ **much better**

11. My M-E arm is:

____ **about the same**
__2__ **much noisier**
____ **much less noisy**
____ **somewhat less noisy**
__7__ **somewhat noisier**

12. When I'm dressed in street clothes, I think my M-E arm is:

__2__ **somewhat more obvious**
____ **about the same**
____ **somewhat less obvious**
__7__ **much less obvious**
____ **much more obvious**

13. The number of activities that I can perform with my M-E arm is:

__1__ **somewhat decreased**
__2__ **greatly decreased**
__1__ **somewhat increased**
____ **greatly increased**
__5__ **about the same**

14. Learning to operate and control my M-E arm was:

__1__ **much easier**
__1__ **about the same**
__1__ **much more difficult**
____ **somewhat easier**
__6__ **somewhat more difficult**

15. When using my M-E arm, I feel:

__2__ **somewhat more confident**
__3__ **somewhat less confident**
__3__ **much more confident**
____ **much less confident**
__1__ **about the same**

16. For doing activities, my M-E arm is:

__1__ **somewhat less satisfactory**
__1__ **much less satisfactory**
__3__ **much more satisfactory**
____ **somewhat more satisfactory**
__4__ **about the same**

17. Before successfully learning a new activity with my M-E arm, I must practice:

__4__ **about the same**
__1__ **much more**
__1__ **much less**
__1__ **somewhat less**
__2__ **somewhat more**

18. In using my M-E arm, I think I am:

__3__ **somewhat more adept**
____ **much less adept**
__2__ **much more adept**
__2__ **somewhat less adept**
__2__ **about the same**

19. When wearing my M-E arm, I feel:

__2__ **somewhat more self-conscious**
____ **much more self-conscious**
____ **much less self-conscious**
__3__ **about the same**
__4__ **much less self-conscious**

20. Please add any additional comments or suggestions you have about your myoelectric arm. Your comments will be valuable during ongoing development of the myoelectric system:

It should be — quieter (2)
— faster
— lighter
It should have — larger hand
— more wrist movement
— more realistic glove
The battery outlet and switch should be hidden (2)
Would like to be able to judge grip strength
Would prefer switch in hand rather than arm
Would like a flatter wrist — not round
Would like passive fingers to be active
Hand doesn't open wide enough
Grip would be improved if hand could make a fist (for holding purse, bowl)

APPENDIX 3

Subject Questionnaire, Part 3. (Summary of all except Denyse)

BILATERAL UPPER-EXTREMITY FUNCTIONAL ACTIVITIES	Regularly		Sometimes		Prosthesis Not Satisfactory		Prosthesis Not Needed	
	B-E	FQ	B-E	FQ	B-E	FQ	B-E	FQ
Dressing Activities:								
1. Grasp shoe lace and tie	6			1			2	
2. Unbutton cuff on sound side	2		3		2		3	
3. Grasp toothbrush and apply paste	6		1	1			1	
4. Grasp and pull coat on and off hanger	5		2				2	
5. Grasp washcloth and wash sound hand	2		6					
6. Grasp nail file and file nails	1		4				4	
7. Grasp necktie and tie	1		4				3	
8. Take off and put on watch	3		4	1			1	
9. Grasp clothing while zipping zipper	5		3					
10. Grasp shirt sleeve and remove from good arm	3		4		1		1	
11. Grasp trousers and pull belt through loops			6				1	
12. Grasp belt to buckle			3		1		3	
13. Grasp and pull up socks	2		1				4	
14. Grasp and pull up trousers or skirt	4		2		1		1	
15. Grasp and pull on glove	2		6	1				
16. Grasp and pull on rubbers	2		2				3	
Eating Activities:								
1. Cut meat with knife and fork	5		3	1	1			
2. Hold glass and fill from faucet	3		3	1				
3. Grasp dishes and serve self	4		2		2		2	
4. Grasp milk container and open	3		3	2			1	
5. Hold Dixie cup and eat ice cream	2		4	1	2			
6. Grasp and eat ear of corn	1		3	1			4	
7. Grasp bread and butter it			3		1		3	
8. Grasp orange and peel it	1		5		1		1	
9. Grasp egg and shell it	1		4		1		2	
10. Support tray and carry it	4		3	2			1	
11. Other (unwrapping chocolate bar, opening pop can, etc.)	6	1		1			2	
Tasks about the Home:								
1. Dry dish with dishtowel	5		2				1	
2. Use a dust pan and brush	1		6	1			1	
3. Make a bed	2		3				3	
4. Thread a needle	3		5		1			
5. Grasp a telephone and dial	1		3	1			3	
6. Carry a pail with a terminal device			3	1	2		2	
7. Use a rolling pin			5	1			2	
8. Support a mixing bowl	3	1	3				2	
9. Hold material and sew	3		3	1	1		2	
10. Sweep with broom	6		1	1		1	1	
11. Shovel snow	2		4	1		1	1	
12. Rake leaves	2		4			1	1	
13. Push a lawn mower	2		4			1	1	
14. Grasp a hose and water lawn	2		2				3	
15. Support and carry grocery bag	5		1		1		1	1
16. Use a safety pin	1		4	1			3	
17. Wrap a parcel	6		2					
18. Hang clothes on a clothes line	4		2				2	
19. Use a wallet	1		3	1			4	
20. Handshake	2		3	1	1		2	

	Regularly		Sometimes		Prosthesis Not Satisfactory		Prosthesis Not Needed	
	B-E	FQ	B-E	FQ	B-E	FQ	B-E	FQ
School Activities:								
1. Sharpen a pencil	7				1			
2. Draw a line using a ruler	7				1			
3. Use a paper clip	2		3				2	
4. Hold paper while using scissors	5		2		1			
5. Weight paper and write	5		2				1	
6. Grasp & carry paper(s) with terminal device	4		3		1			
7. Hold paste jar, open and glue	2		6					
8. Hold book while writing on blackboard	4		4				1	
9. Carry lunch box by handle with T.D.	1		3				4	
Play Activities:								
1. Grasp put-together toys	4		1				3	
2. Grasp swing chains			5		1			
3. Grasp bicycle handles	5		1	1	1			
4. Grasp rungs of a jungle gym	1		1				2	
5. Grasp skipping rope handles	2		2		1		1	
6. Grasp drum sticks and play drums			2		1		1	
7. Catch a ball (2 handed)	2		3		2		1	
8. Throw a ball (2 handed)	2		2		3		1	
9. Grasp playing cards	3		3	1	1		2	
10. Fishing	2	1	4	1			2	
11. Grasp a baseball bat and swing	2		2		2	1	1	
12. Badminton	2		3				2	1
13. Golf			2			1	2	
14. Croquet			3				2	1
15. Hockey	1		4				3	1
16. Grasp oars and row			4		1		1	
17. Grasp an archery bow and shoot			3		2		1	
18. Support camera and take photographs	2		2		2		3	
19. Grasp musical instrument and play	1		1		3		1	
20. Put records on phonograph	2		4				3	1
21. Grasp nail while hammering	1		3	1			1	
22. Assistance using a plane			3				1	
23. Grasp wood while sawing	1	1	3				1	
One-Handed Items:								
1. Break an egg	1		2				5	1
2. Slice Bread	3	1	5				1	
3. Peel Potatoes	2		4		2			

APPENDIX 4

Family Questionnaire (summary of 11)

PURPOSE: This short questionnaire, designed to be completed by someone close to the subject, requests your impressions of the subject's acceptance and use of the myoelectric prosthesis. Each question has five possible answers. Please check the ONE answer which, in your opinion, best describes the subject. Any additional comments will be valuable and appreciated.

1. When using the myoelectric arm, the subject appears frustrated:

   _____ **frequently when trying a new activity**
   6 B-E **never**
   1 B-E, 1 FQ **sometimes when the arm is first put on**
   _____ **frequently**
   2 B-E, 1 FQ **seldom**

2. When compared with the previous prosthesis, the myoelectric arm looks:

   2 B-E **somewhat more attractive (except with short sleeves)**
   _____ **much less attractive**
   6 B-E **much more attractive**
   _____ **somewhat less attractive**
   1 B-E **about the same**
   2 FQ **not applicable**

3. The myoelectric arm seems to be:

   1 FQ **somewhat inconsistent**
   2 B-E **very reliable**
   1 B-E **very unreliable (often needs gain adjusted)**
   2 B-E, 1 FQ **acceptable**
   4 B-E **reasonably reliable**

4. The subject complains about wearing the myoelectric arm:
   - 1 B-E, 1 FQ for some activities (sports)
   - 2 B-E, 1 FQ sometimes, especially in the summer
   - 5 B-E never
   - 1 B-E seldom
   - _____ frequently

5. The subject uses the myoelectric arm for new activities:
   - 6 B-E usually spontaneously
   - 2 B-E, 1 FQ sometimes spontaneously
   - 1 FQ only with persuasion
   - 1 B-E seldom
   - _____ only when reminded

6. Using the myoelectric arm, the subject learns new activities:
   - 2 B-E after a few attempts
   - _____ only with great difficulty
   - 1 FQ after lots of practice
   - 4 B-E very quickly
   - 3 B-E, 1 FQ with some practice

7. The subject seems to accept the myoelectric arm:
   - _____ not at all
   - 8 B-E, 2 FQ exceptionally well
   - _____ about average
   - _____ not very well
   - 1 B-E better than I expected

8. The subject uses the myoelectric arm:
   - _____ somewhat awkwardly
   - 7 B-E exceptionally well
   - 1 B-E, 1 FQ about average
   - 1 FQ better than I expected
   - _____ very poorly

   (One patient had the prosthesis too short a time to comment

9. Any additional impressions or comments you can give will be most valuable:

   Will wear short sleeves now, where she wouldn't with conventional prosthesis.

   Would like a way of cleaning the glove.

APPENDIX 5

Functional Evaluation (summary of 10—all except Maxine)

	Excellent		Good		Fair		Poor	
	BE	FQ	BE	FQ	BE	FQ	BE	FQ
Fold towel	3		4		1	1		1
Scrape food off plate	2		6			1		1
Tie shoes	6		1	1	1			1
Feed paper into typewriter*	1		4	1	1			1
Shuffle and deal cards	1		2		1	1	4	1
Put bandaid on sound side	3		3		1	1	1	1
Use safety pin	1		6	1	1	1		

*2 B-E patients normally do this with their sound hand because carbon paper would stain glove.

Overall impression:

- 1 B-E — excellent
- 3 B-E — good/excellent
- 3 B-E — good
- 1 B-E — poor/fair
- 1 FQ — poor but with good potential (no functional training)
- 1 FQ — very poor (prosthesis worn 2–3 months)