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DEVELOPMENT OF A MULTIFUNCTIONAL HAND PROSTHESIS

Fig. 1: 3D CAD drawing of our new multifunctional hand mechanism. Drawing shows how middle, ring and little fingers move together as a unit.

By Richard F. ff. Weir, Ph.D

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We are developing a new multifunctional hand prosthesis and controller based on multiple (3-4) surface EMG (sEMG) signals with funding from the Department of Veterans Affairs (Weir 2002) [See Fig. 1]. For any prosthesis to be clinically successful it must be mechanically robust which means the prosthesis should be as mechanically simple as possible. Consequently, the digits of our multifunctional hand will be solid non-articulated designs to improve robustness. In this new hand the index finger is to be able to move independently of the middle, ring and little (MRL) fingers. The middle, ring, & little fingers (MRL finger block) move as a single unit. The thumb is limited to a single degree-of-freedom and is oriented such that it will operate along its preferred plane – 45° (Lozac'h, 1984) [as opposed to two DOF in the physiological thumb]. These functions were chosen to maximize overall hand function for the number of degrees-of-freedom to be controlled versus the number of sites available.

The hand mechanism we are building is based on a three motor hand and a two motor wrist. During grasping once the hand has grasped it becomes a rigid extension of the wrist, which is then used to position the hand further, as such active control of the wrist becomes very important to overall hand function.

One motor will drive a single DOF thumb that will operate along the preferred 45° plane; one motor will drive the index finger; one motor will drive the middle, ring and little fingers as a unit; one motor will provide wrist extension/flexion and one motor will provide wrist rotation. The drive trains for these motors will be based on the drive train developed for our partial hand mechanism [Weir et al., 2001, 2002]. The multifunctional mechanism is currently to be controlled using a fuzzy logic based myoelectric controller we are also in the process of developing [Ajiboye et al. 2002].

Designing the mechanism with these particular degrees-of-freedom will allow it to generate tip, palmar, lateral

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and cylindrical grasp patterns (Keller, et al., 1947) [See Fig. 2]. Keller, et al. found that palmar prehension (or tri-digital pinch) was the most frequently used prehensile pattern for static grasping while lateral prehension is used most often for dynamic grasping. This finding combined with the reduction of most prosthetic terminal devices to a single DOF has meant that most prosthetic hands incorporate palmar prehension as the dominant grasp pattern. The persistence of this pattern, combined with a wide width-of-opening in prosthetic hand designs and its general acceptance over the years tends to support this compromise (Heckathorne, 1992). Having control of the thumb independent of the fingers enables the implementation of lateral prehension as well.

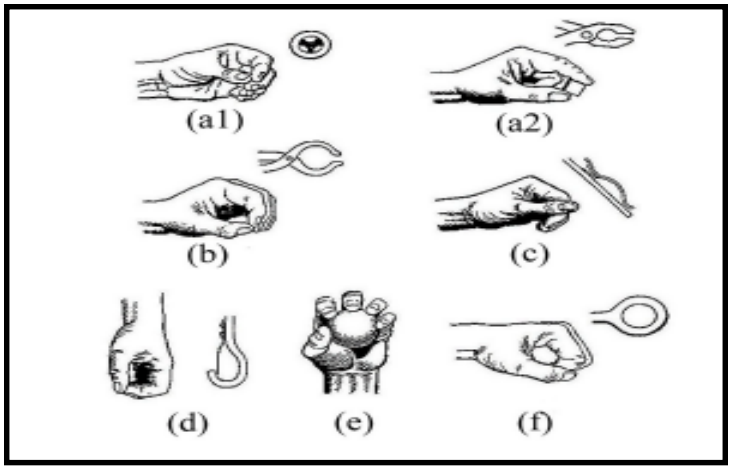

Fig. 2: The prehension patterns of the hand as defined by of Keller et al. (1947) a1) palmar Prehension (3 jaw chuck); a2) palmar Prehension (2 finger); b) tip Prehension; c) lateral Prehension; d) hook Prehension e) spherical Prehension; f) cylindrical Prehension

To control this hand, a four site EMG multifunction controller based on fuzzy-logic is under development. We believe that our new hand can be controlled with three surface sites, or one and half degrees-of-freedom, so long as the thumb can be controlled. Position of the thumb with respect to the position of the fingers determines the grasp pattern taken by the hand during prehension. This hand will use two "close" signals, one for the index and MRL finger drives together and a second for the thumb drive. The timing, or speed, of thumb closure with respect to finger closure determines whether tip, palmar of lateral prehension results. A single "open" signal drives all digits (fingers & thumb) back to "start" positions. This implies a one and half DOF control system. These machinations to reduce independently controlled degrees-of-freedoms would not be necessary if sufficient control sites could be located, as such, the current application would enable all degrees-of-freedom of this mechanism to controlled in parallel.

This project demonstrates that the current application is not occurring in the absence of any other work, but is, in fact, part of a grander vision in which devices with multiple degrees-of-freedom will be available by the end of the proposed grant period. It is planned that these mechanisms will be able to take advantages of the increased degrees-of-freedom offered by implanted EMG sensors. ❖

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REFERENCES:

Ajiboye, A. B., Weir, R. F. ff., Heckathorne, C. W., and Childress, D. S., (2002): Neurofuzzy Logic as a Control Algorithm for an Externally Powered Multifunctional Hand Prosthesis. Proceedings of the Myoelectric Controls Conference (MEC2002), Fredericton, New Brunswick, Canada, August 19th - 23rd, University of New Brunswick, New Brunswick, Canada.

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Development and Measurement Properties of the Orthotics and Prosthetics Users' Survey (OPUS):

A Comprehensive Set of Clinical Outcome Instruments

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Abstract

The objectives of this project were to develop a set of self-report instruments that assess functional status, quality of life, and satisfaction with devices and services that can be used within an orthotics and prosthetics clinic. Selecting items from a variety of existing instruments, we developed and revised four instruments that differentiate patients with varying levels of lower extremity function, quality of life, and satisfaction. Evidence of construct validity is provided by a hierarchy of item difficulty that is consistent with clinical experience. The internal consistency of the responses provides evidence of reliability. The usefulness of the Orthotics and Prosthetics Users' Survey (*OPUS*) should be manifest as orthotic and prosthetic practitioners evaluate the quality and effectiveness of their services or as programs fulfill accreditation requirements that mandate outcomes assessment.

Introduction

People seeking orthotic and prosthetic services present with a variety of impairments. Those receiving orthotic services include people with brain injuries, spinal cord injuries, cerebral palsy, stroke and burns, among others. After assessing the patient, an orthotist designs and fabricates an orthosis (brace) to lend support or protection to a limb, the spine, or the head. Prosthetic services are provided to people with congenital limb deficiencies or amputations. In these cases, a prosthetist designs and fabricates an artificial hand, arm, foot or leg (American Academy of Orthotists and Prosthetists, 1990). The rehabilitation goals in providing orthotic and prosthetic devices are to improve physical functioning and quality of life - goals that require instruments specifically designed to quantify these goals.

The need to measure and evaluate rehabilitation practice in general and orthotics and prosthetics (O&P) practice specifically has received growing recognition in the past several years (Fuhrer, 1995; Hoxie, 1995, 1996; Polliack & Moser, 1997). Fuhrer (1995) outlined recommendations for medical rehabilitation outcomes research generated at a 1994 conference organized by the National Center for Medical Rehabilitation Research (NCMRR). Critical to NCMRR's agenda, and reiterated throughout the report, is the need for valid, reliable and change-sensitive outcome measures to evaluate the efficacy and effectiveness of rehabilitation practices. The American Board for Certification in Orthotics and Prosthetics (ABC) echoes this call for certification by encouraging outcomes measurement and clinical pathways within the context of a continuous quality improvement process (Hoxie, 1995, 1996). Specifically, the quality assessment and improvement standard states "There is an ongoing quality assessment and improvement program designed to objectively and systematically monitor and evaluate the quality and appropriateness of patient care, pursue opportunities to improve orthotic and/or prosthetic care and resolve identified problems" (ABC Standards of Profession Manual, 2002).

Much of the O&P research over the past 40 years has focused on biomechanics and engineering. Examples of pioneering innovations include myoelectric prosthetic hands and the use of stronger yet lighter materials in the fabrication of prosthetics and orthotics. These innovations have greatly improved the function and appearance of these devices (Bowker, 1981), though users' satisfaction and functional benefits have not been assessed in a comprehensive manner. Industry sales figures are evidence of an innovation's impact on patients, though even this information does not reflect users' continued device use, benefit and satisfaction. What is missing are patients' perspectives of the impact a device

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and services have on their physical functioning and quality of life. Patient perspectives on devices and services as well as satisfaction with services are widely recognized as important in other areas of rehabilitation and in health care generally. Donabedian stated "patient satisfaction may be considered to be one of the desired outcomes of care, even an element in health status itself...It is futile to argue about the validity of patient satisfaction as a measure of quality. Whatever its strengths and limitations as an indicator of quality, information about patient satisfaction should be as indispensable to assessments of quality as to the design and management of health care systems" (1988). Ware, Phillips, Yody and Adamczyk (1996) stated that health status and patient satisfaction are the primary outcomes of interest for rehabilitation care. The greatest challenge, they argue, is the lack of standardization in measures that would allow outcomes to be compared across programs.

Outcome measurement has been the subject of several articles in O&P trade publications (American Orthotics and Prosthetics Association, 1998; Otto, 1999, 2000). A recurring concern is the industry's need to quantify outcomes as a means of justifying the cost of services to payers and of responding to growing pressure from consumer groups. The industry would benefit from a set of instruments that can accurately and conveniently measure important and relevant outcomes. Such an assessment could provide many benefits: assist the field develop evidence-based practice and clinical pathways, assure client satisfaction, supplement earnings reports, enhance payer relations, and provide a means of implementing program accreditation.

Clinicians who provide services to O&P users have made progress in assessing the benefits of services from patients' perspectives. Grise and Gautier-Gagnon (1993, 1994) developed the Prosthetic Profile of the Amputee (PPA), a questionnaire designed to evaluate factors associated with continued use of a lower extremity prosthesis after discharge. Imbedded in the PPA is the Locomotor Capabilities Index (LCI), a lower extremity functional status measure. The authors report a high level of internal consistency (Cronbach a coefficient of .95) for the 14 items of the LCI. To date, the instrument has been validated primarily with a sample of older patients with unilateral, lower extremity amputations. Its sensitivity to change, and therefore its effectiveness as an outcome measure, has yet to be established.

Legro and associates (1998) developed the Prosthesis Evaluation Questionnaire (PEQ), a condition-specific measure of not only quality of life but also functional status and patient satisfaction. The PEQ consists of 10 separate scales and addresses several important components of prosthesis use - appearance, function, quality, and cost. The PEQ's developers reported good reliability for each of the subscales (Cronbach a coefficients ranging from .73 to .89, with the exception of the scale assessing transfers that had a coefficient of .47). Limitations that may detract from its clinical use are the length of the instrument (137 items) and the arduous scoring of visual analog responses.

Focus on Therapeutic Outcomes (FOTO) also developed a tool to assess multiple outcomes. They were engaged by the Orthotics and Prosthetics National Office in collaboration with ABC to develop an outcome tool to assess health status, client satisfaction, and prosthetists' perception of function for lower extremity amputees (Hart, 1999). The Orthotics and Prosthetics National Office Outcomes Tool (OPOT) was built around the Medical Outcome Study - Short Form 36 (MOS SF-36; Ware, 1993), a generic health-related quality of life instrument. The tool also included 13 satisfaction questions and prosthetists' report of clients' ambulation. While psychometric analyses were conducted as part of its development, the cross-sectional nature of the study did not allow assessment of the instrument's sensitivity to change nor its ability to detect subtle changes in lower extremity function.

Instruments have also been developed to assess functional status in pediatric patients with limb loss. Pruitt, Varni and Setoguchi (1996) developed the Child Amputee Prosthetics Project - Functional Status Inventory (CAPP-FSI) to assess prosthetic use and function with patients 8 to 17 years of age with upper or lower extremity limb loss. This group developed a parallel instrument called the Child Amputee Prosthetics Project - Functional Status Inventory for Pre-school Children (CAPP-FSIP; Pruitt, et al., 1998). Both instruments use parents as proxies for children and record both the frequency of performing an activity and whether the child used the prosthesis when performing the activity. While quite promising, these instruments require additional development before they can be used routinely as clinical outcome measures.

Researchers at Bloorview MacMillian Centre developed their own functional index for children with congenital unilateral upper extremity limb loss (Wright, et al., 2001). The Prosthetic Upper-Extremity Functional Index (PUFI) is used to evaluate a child's ability to perform a variety of unilateral upper extremity activities using and not using their myoelectric prosthesis. The PUFI is in its early stages of development with psychometric data based on a small sample of 24 children. The researchers report a software program currently in development that may facilitate further testing of the instrument.

Efforts to assess user satisfaction have been reported by Polliack and Moser (1997) and by Dillingham, Pezzin, MacKenzie and Burgess (2001). Polliack and Moser described

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a simple approach of measuring and evaluating outcomes in an individual O&P practice using an instrument they developed themselves. While they described some of the patient satisfaction items, they did not report evidence of the instrument's validity and reliability. Such evidence would be essential if this instrument was to be used to compare the quality of services across facilities. Dillingham's team conducted follow-up interviews with a retrospective cohort of trauma-related lower extremity amputees. Although the information gleaned from these interviews is valuable, the methodology employed is not easily transferred to an O&P clinic as a means for ongoing quality assessment of clinical interventions.

These initial efforts to develop outcome measures and to evaluate O&P clinical outcomes are important steps, but there are still significant gaps in this body of work. Most work focuses on prosthetic users with little attention given to orthotic users, even though orthotics make up a larger proportion of devices fabricated. Physical and occupational therapists, physicians, and epidemiologists have conducted much of their research using generic instruments that have not been developed specifically for of O&P services. Needed is a comprehensive set of valid and reliable measures that assess relevant aspects of O&P patients' perspectives of function, quality of life and satisfaction. Such a set of measures would support the systematic evaluation of various interventions, help establish clinical pathways and standards of care, and serve as the basis for research-based, quality improvement initiatives.

This report summarizes work supported by the National Institute on Disability and Rehabilitation Research through a Rehabilitation Engineering and Research Center on Prosthetics and Orthotics to develop an outcomes database. The objective was to develop instruments for evaluating the outcomes of prosthetics and orthotics services that are clinically useful and possess good measurement properties. This paper describes the initial development of a lower extremity functional status instrument, a health-related quality of life instrument, and separate instruments assessing client satisfaction with services and their device.

Methods

Initial Instrument Development

We completed a comprehensive literature search using MEDLINE, CINAHL, and Recal to identify generic and O&P-specific outcome instruments. This search yielded several dozen instruments. After input from an advisory committee that included clients, orthotists, prosthetists, physical therapists, occupational therapists, physiatrists, psychologists and social workers we decided to focus the instruments on the following constructs: upper extremity and lower extremity functional status, health-related quality of life, and client satisfaction. Initially, we developed age-specific measures, one for adults and one for children, for each of the constructs.

First Field Test Sample

The first field test of the instruments consisted of telephone interviews with a sample of past recipients of O&P services at the Rehabilitation Institute of Chicago (RIC). The sample of 66 respondents consisted of 52 adults and 14 parents answering on behalf of their child. There were 35 orthotics users and 17 prosthetics users in the adult group, and nine orthotics users and six prosthetics users in the child group.

Measure Construction

Rating scale (or Rasch) analysis (RSA; Rasch, 1960/1980; Wright & Stone, 1979; Wright & Masters, 1982) provides a sophisticated means of evaluating each instrument's effectiveness in measuring a specific construct - functional status, quality of life, and satisfaction. RSA is a probability-based method for converting ordinal level ratings into equal-interval measures and can also be used to evaluate an instrument's reliability. Two estimates are produced by this analysis: a *person ability* measure and an *item difficulty* value. A person ability measure is an estimate of each individual's overall performance on the set of items while an item difficulty value is an estimate of the difficulty of performing each task, relative to the other items in the set. Information from RSA allows one to identify items that misfit the construct or are redundant (are of similar difficulty levels as other items in the set) and can be removed. Evidence of construct validity is provided by a hierarchy of item difficulty that is consistent with clinical experience. A Windows-based program called WINSTEPS (Wright & Linacre, 2002) provides a convenient means of implementing RSA.

A number of psychometric criteria are used to describe the quality of the instrument. These include *person separation*, which indicates how well the set of items distinguishes different levels of ability within the sample. Values greater than 2.0, corresponding to a Cronbach's a of .80, are desirable. *Item separation* indicates the range of item difficulty covered by the measure. Again, values greater than 2.0 are desirable. The *average person measure* indicates how well targeted the item set is to the sample. An average person measure of zero indicates an item set perfectly targeted to the sample since the average item difficulty is by default set at zero. *Item misfit* reflects the extent to which a significant portion of the sample responds anomalously to a specific item; desirable values are between .7 and 1.4. Like a c^2 statistic, fit statistics summarize the residuals between expected and observed responses. Large values (greater than 1.4) indicate excessive "noise" due

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to unexpected responses; small values (less than .7) indicate observed values that are too similar to the expected values.

Evaluation of First Field Test Results

The first set of outcome measures consisted of separate modules - function, quality of life, and satisfaction. Each module contained age-specific measures for young children (ages 2-5 years), older children (ages 6-15 years), and adults aged 16 years and older. Feedback from both respondents and clinicians indicated that age-specific measures were cumbersome and impractical. This impression was borne out during our initial rating scale analyses. Therefore, we combined the adult and child responses for each of the items that were the same and calibrated the items for the combined sample. In general, this approach revealed a sensible hierarchy of item difficulty for each of the measures; it also revealed that a number of items were redundant. The limited number of respondents with upper extremity impairment led us to defer development of this functional status measure.

Instrument Revisions

Lower Extremity Functional Measure. In addition to combining the items into a single instrument for all age groups, we dropped 12 of the original 25 items due to misfit, redundancy, or because they were age-specific tasks. Next, we developed seven new items using input from clinicians and consumers with the intent of expanding the range of item difficulty. In addition, we added a sixth rating scale category to distinguish the inability to perform a task from never doing a task. The revised instrument consists of 20 items and has six response categories: 0 - not applicable; 1 - very easy/perform independently; 2 - easy/need very little or no assistance; 3 - slightly difficult/need some assistance; 4 - very difficult/need a lot of assistance; 5 - cannot perform the activity.

Health-Related Quality of Life. As with the lower extremity functional measure, we combined the items into a single instrument for all age groups. We dropped many age-specific items and revised the multiple rating scales to two rating scales. The revised health-related quality of life instrument consists of 23 items and uses two, five-level response categories: a frequency scale and an extent of agreement scale.

Follow-up Evaluation of Satisfaction with Device. The initial satisfaction measure consisted of 27 items addressing both device and service issues and used a variety of rating scales. As with the other measures, we dropped redundant items and revised the multiple rating scales into a single rating scale. The revised follow-up evaluation of client satisfaction with devices consists of 11 items and uses one rating scale with four "extent of agreement" response categories. Initial analysis showed that two items dealing with the cost of the device ("I can afford the out-of-pocket expenses to purchase and maintain my prosthesis/orthosis" and "I can afford to repair or replace my prosthesis/orthosis as soon as needed") misfit the construct indicating that cost issues are distinct from the overall construct of device satisfaction. Although we did not combine these items with other satisfaction items to obtain a total measure, we retained them in the database because they are relevant to client compliance and health care policy issues.

Follow-up Evaluation of Satisfaction with Services. Redundant and misfitting items were dropped while three new items were added. Feedback from consumers guided our development of new items. The revised follow-up evaluation of client satisfaction with services consists of 10 items and uses the same four "extent of agreement" response categories as the satisfaction with device measure.

Second Field Test Sample

Pediatric clients receiving outpatient services at Shriners Hospital for Children in Chicago, adult clients receiving O&P services at RIC, and past recipients of RIC O&P services formed the second field test sample. The combined sample consisted of 164 subjects, including 80 adults and 84 children. In the adult group, 43 were orthotics users and 37 were prosthetics users; in the child group, 36 were orthotics users and 48 were prosthetics users.

Second Field Test Calibration Results

Results of the item calibrations for each of the instruments in terms of average person measure, person and item separation, and item misfit are presented in Table 1.The criteria for acceptable psychometric characteristics are presented above.

Lower Extremity Functional Measure. Calibration of the lower extremity functional status responses yields desirable person and item separation statistics. The item map for this scale (Figure 1) depicts the item hierarchy in equal-interval log-odd units ("logits"). By default, the average item difficulty is zero with easier items in the negative range and more difficult items in the positive range. The map shows that the easiest items are "get on and off toilet," "get up from a chair," and "walk in-doors." Items of average difficulty include "pick up an object from the floor while standing," "get on and off an escalator," and "walk out-doors on uneven ground." The most difficult items are "walk up to two hours" and "run one block." Three items misfit slightly: two are relatively easy items ("dress lower body," "put on and take off prosthesis or orthosis"), and the third is the most difficult item ("run one block"). In spite of these slight misfits, all of the items are retained because they are both clinically relevant and constitute a measure spanning a wide range of ability. The items are well-

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targeted to the sample as indicated by an average person measure of 0.58.

likely that the paid work and school items misfit because they were completed by only part of the sample. The items are reasonably targeted to the sample as indicated by an average person measure of 1.06.

Follow-up Evaluation of Satisfaction with Device. Calibration of the satisfaction with device responses yields acceptable person and item separation statistics. The item map for this scale depicts the item hierarchy. The map shows that the easiest items to endorse are "the weight of my prosthesis (or orthosis) is

Table 1. Calibration Summaries

	Average person measure	Person separation index (reliability	Item separation index (reliability)	Misfitting items (item misfit)
Lower extremity function	0.58	3.95 (.94)	7.26 (.98)	Run one block (1.51) Dress lower body (1.43) Put on and take off device(1.50)
Health-related quality of life	1.06	2.74 (.88)	4.79 (.96)	Physical condition restricts ability to do paid work (1.54) Physical condition restricts ability to attend school (1.62) Keep to self to avoid others' reactions to your device (1.66)
Satisfaction with device	1.01	1.70 (.74)	2.47 (.86)	Clothes are free of wear and tear from my device (1.44) Easy to put on my device (1.64)
Satisfaction with services	2.91	1.89 (.78)	2.10 (.82)	None

Health-Related Quality of Life. Calibration of the health-related quality of life responses also yields desirable person and item separation statistics. The item map for this scale depicts the item hierarchy. The map shows that the easiest items are "how often during the past week have you been happy," "how often during the past week have you felt calm and peaceful," and "how often during the past week did you have a lot of energy." Items of average difficulty include "how often during the past week have you felt downhearted and depressed," "how much does pain interfere with your activities (including both work outside the home and household duties)," and "how much does your physical condition restrict your ability to do chores." The most difficult items are "how often during the past week did you feel worn out" and "how often during the past week did you feel tired." Three items misfit slightly: "how much does your physical condition restrict your ability to do paid work," "how much does your physical condition restrict your ability to go to school," and "how much do you keep to yourself to avoid the reaction of others to your use of a prosthesis or orthosis." It is

manageable" and "my prosthesis (or orthosis) is durable." Items of average difficulty were "it is easy to put on my prosthesis (or orthosis)" and "my clothes are free of wear and tear from my prosthesis (or orthosis)." These two items also misfit slightly. The most difficult items to endorse are "my skin is free of abrasions and irritations" and "my prosthesis (or orthosis) is pain free to wear." The items are reasonably targeted to the sample as indicated by an average person measure of 1.01.

Follow-up Evaluation of Satisfaction with Services. Calibration of the satisfaction with services responses also yields acceptable person and item separation statistics. The item map for this scale (Figure 4) depicts the item hierarchy. The map shows that the items easiest to endorse are "I was shown the proper level of courtesy and respect by the staff" and "I received an appointment with a prosthetist/orthotist within a reasonable amount of time." Items of average difficulty are "I am satisfied

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with the training I received in the use and maintenance of my prosthesis/orthosis" and "the prosthetist/orthotist gave me the opportunity to express my concerns regarding my equipment." The items most difficult to endorse are "I was a partner in decision-making with clinic staff regarding my care and equipment" and "The prosthetist/orthotist discussed problems I might encounter with my equipment." None of the items misfit the construct. Not unlike other satisfaction instruments, the items are mistargeted to the sample as indicated by an average person measure of 2.91. This mistargeting reveals a high level of satisfaction with services.

Discussion of Results

The study objectives, to develop self-report instruments for evaluating the outcomes of prosthetics and orthotics services that are both clinically useful and possess good measurement properties, were achieved. We started with a large set of potentially useful items and honed them to a small enough set that can be used without undue patient burden. The instruments contain a sufficient number of items to provide reliable estimates. Consumer and clinician input assured clinical relevance. We used contemporary measurement technology to evaluate individual items as well as the entire item set for use with prosthetic and orthotic clients.

Several clinical applications are immediately apparent. *OPUS* should be useful for prosthetic and orthotic programs in undertaking quality assessment and improvement activities, evaluating change in patients' functional status and quality of life, and assessing satisfaction with devices and services. *OPUS* assesses clinically relevant domains of patient experience that should help clinicians provide high quality care. Patients with unusual response patterns (e.g., difficulty performing easy items and little difficulty performing harder items) can be easily identified and questioned in greater detail during follow-up evaluations about their unique needs or the environment that makes their experience unique. Patients with minimal change in function can be identified easily with the *OPUS* lower extremity items. Finally, clinicians can follow-up with patients who are not satisfied with one or more aspects of their services for further evaluation.

We realize that this study has some limitations: We selected clients from only two rehabilitation programs and the sample size is not large to discern differences in subgroups of clients (adults and children, prosthetic and orthotic users). Moreover, it is possible that clients referred for O&P services in other settings might show a narrower or broader range of responses. Future work will ameliorate this shortcoming.

Future research activities also include developing a measure of upper extremity functional status, evaluating instruments' sensitivity to change, and discerning differences between patient groups with different types of impairment. Work is underway to evaluate a set of upper extremity items. The relatively small population of patients using upper extremity prostheses and orthoses requires greater time and resources. We have secured the participation of several clinics in the United States and Canada that have diverse patient populations in order to evaluate subgroup differences in function, quality of life and satisfaction, as well as different ways these groups might define these constructs.

In summary, the four components of *OPUS*—lower extremity functional status, quality of life, satisfaction with devices and satisfaction with services - provide clinicians with a useful tools to evaluate individual client and program outcomes. The psychometric properties are promising as the instrument demonstrates the ability to detect a wide range of function, quality of life and satisfaction, and possesses good internal consistency and construct validity. The next steps are to evaluate the instruments' sensitivity to change over time and differences across patient groups defined by impairment and prescribed device. ❖

Acknowledgments

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References

THE AMERICAN BOARD FOR CERTIFICATION IN ORTHOTICS AND PROSTHETICS (2002). ABC Standards of Profession Manual available at http://www.abcop.org/Facility_Standards_of_Performance_Manual.asp#14

AMERICAN ACADEMY OF ORTHOTISTS AND PROSTHETISTS (1990). The orthotics and prosthetics profession. Journal of Prosthetics and Orthotics 2, 101-111.

AMERICAN ORTHOTIC AND PROSTHETIC ASSOCIATION (1998). Outcomes in the prosthetics and orthotics profession. O & P Almanac Dec., 1998.

BOWKER JH (1981). Amputee rehabilitation: critical factors in outcome. Journal of the Arkansas Medical Society 78, 181-183.

DILLINGHAM TR, PEZZIN LE, MACKENZIE EJ, BURGESS AR (2001). Use and satisfaction with prosthetic devices among persons with trauma-related amputations: a long-term study. American Journal of Physical Medicine and Rehabilitation 80, 563-571.

DONABEDIAN, A. The Quality of Care: How Can It Be Assessed? JAMA 260, (1988):1743-1748.
FUHRER MJ (1995). Conference report: an agenda for medical rehabilitation outcomes research. American Journal of Physical Medicine & Rehabilitation 74, 243-248.

GRISÉ MCL, GAUTIER-GAGNON C, MARTINEAU GG (1993). Profile of people with lower extremity amputation: Conception and design of a follow-up questionnaire. Archives of Physical Medicine and Rehabilitation 74, 862-870.

GAUTIER-GAGNON C, GRISÉ MCL (1994). Prosthetic profile of the amputee questionnaire: validity and reliability. Archives of Physical Medicine and Rehabilitation 75, 1309-1314.
HART DL (1999). Orthotics and Prosthetics National Office Outcomes Tool (OPOT): Initial reliability and validity assessment for lower extremity prosthetics. Journal of Prosthetics and Orthotics 11, 101-111.

HOXIE LO (1995). Outcome measurement: a primer for orthotic and prosthetic care. Journal of Prosthetics and Orthotics 7, 132-136.

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NORTHWESTERN UNIVERSITY

Northwestern University PRL&RERP&NUPOC NEWS

NOTE: The Capabilities date designation has been changed from "January, April, July and October" to "Winter, Spring, Summer and Autumn" to more accurately reflect our quarterly nature. Volume and number designations remain the same.

Childress Addresses Conference on Physical Disabilities Through the Lifespan

Dudley S. Childress, PhD, presented an overview of Prosthetics and Orthotics Lifespan Issues at the Conference on Physical Disabilities Through the Lifespan, held July 21-22, 2003 in Bethesda, Maryland. The conference was sponsored by the National Center for Medical Rehabilitation Research, National Institute of Child Health and Human Development, National Institutes of Health. Cosponsors included the National Institute of Disability and Rehabilitation Research and the Rehabilitation Research and Development Service, U.S. Department of Veterans Affairs.

Abstract of Dr. Childress' Presentation

Elderly people in the last years of their lives often lose limbs below the knee (transtibial amputations). Although these people may not be very active physically, a prosthesis is considered of value if it merely helps people get to the toilet and back independently or with minimal assistance. For many years it has been thought that very lightweight, low cost, durable, attractive and functional transtibial prostheses of uni-body construction would be of much use to elderly people and possibly to others. *Engineering research associated with fast prototyping methods and automated foot alignment could make such prostheses feasible*. The object is to use high-tech methods to produce simple, low-tech prostheses of high quality.

Partial foot prostheses/orthoses have not received the research attention needed to develop quality aids in this largely forgotten or ignored field of prosthetics and orthotics practice. New biomechanical ideas that center around providing effective "roll-over shapes" for partial foot prosthetic systems appear to provide a way to improve walking function. Roll-over shape is defined as the effective geometry (rocker) that the foot/ankle complex conforms to from heel contact to opposite heel contact.

Ankle-foot-orthoses are one of the most widely used orthotic devises, yet little research has been directed toward improving their function. New results suggest that improvement my be possible if we can make the foot-ankle-orthosis system behave so that the roll-over shape of the system mimics an ideal shape (e.g. a shape that is biomimetic). Engineering research has shown this possible for foot prostheses with rigid ankles and more research can likely demonstrate how this can be accomplished in ankle-foot-orthosis systems.

Surgical techniques that provide supplementary control sites for upper-limb prostheses have been investigated for almost a century, often with considerable success. *Expanded research is needed on an approach called "neuromuscular reorganization" which currently is being investigated for use in prosthesis control* whereby nerves that originally went to body parts that have been amputated are routed in muscles that have been surgically prepared to serve as myoelectric control sites. In this way, redundant nerves can be used in ways that are easily understood by the body.

Lisette Ruberte and Lexyne McNealy Organize G-SALSA

The Graduate Student Association for Latino and Spanish Activities (G-SALSA) on the Northwestern University campus became a reality through the efforts of two NUPRL&RERP graduate students. Lissette Ruberte and Lexyne McNealy, both candidates for doctoral degrees in Biomedical Engineering, were instrumental in founding the organization.

The primary purpose of G-SALSA is to promote academic and social networking among graduate students of Latin and Spanish-speaking heritage and to increase the number of

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News from the Department of Veterans Affairs

VA Makes Transition to Reduce Processing Time for Veterans Applying for an Annual Clothing Allowance

By Robert M. Baum

Coordinated by Robert M. Baum
Prosthetic Program Manager, P&SAS SHG,
VA Central Office, Washington D.C.

Veterans, who because of a service-connected dis ability, wear or use a prosthetic or orthopedic appliance which tends to wear out or tear clothing, and veterans, who because of a service-connected skin condition use a medication that causes irreparable damage to outer garments, are eligible for payment of an annual clothing allowance. To qualify for annual payment, veterans must apply and their eligibility must be established as of August 1 of the year for which payment is claimed.

Historically, The Veterans Health Administration (VHA) and the Veterans Benefits Administration (VBA) shared responsibilities for VA's Clothing Allowance Program. This shared responsibility required duplication of efforts and processes. In order to develop better ways to conduct business and ensure efficiency in utilizing resources, VA developed a team to look at cross-cutting efficiencies that would benefit the VA as well as the veterans served by this program.

The intra-agency workgroup developed a plan to conduct a cross-cutting test to determine the extent to which processing time and hand-off occurrences between VBA and VBA can be reduced and service delivery improved by having VHA process and finalize annual clothing allowance payments; in essence, taking VBA out of the process. Furthermore, this would also allow veterans to apply and have their claim processed where they are being seen, saving veterans a lot of time and follow-up between VHA and VBA. This was tested at several VHA and VBA facilities during Fiscal Years 2001 and 2002. The data and feedback received from the results of the test indicate that transferring responsibility for the award action on the annual re-certification portion of the Clothing Allowance benefit to VHA's Prosthetic and Sensory Aids Service would significantly reduce processing time, by at least 67% (test-site data). Local Veterans Service Organizations received positive feedback from veterans and veterans expressed appreciation for the reduced waiting times for benefit payments.

Due to this successful cross-cutting effort, the Under Secretary for Benefits and the Under Secretary for Health established a transition team to ensure a successful transfer of responsibility for this program to VHA's Prosthetic and Sensory Aids Service in Fiscal Year 2003, Nationwide. The transition team was successful in meeting this goal as the entire process moved to VHA's Prosthetic and Sensory Aids Service on July 1, 2003, and medical centers are now solely responsible for processing all claims for clothing allowance.

The only major change that will effect veterans is the need to send applications for annual clothing allowance to the Prosthetics Department at their nearest VA Medical Center in lieu of their Regional Office. Veterans who are already receiving a recurring payment will not be affected by this change. Applications can be obtained from their nearest VA Medical Center, their local Veterans Service Organization, or on VA's website.

VA is excited about this change and their efforts in simplifying the process for both VA and the veterans served. ❖

Please send us your articles, success stories, comments or suggestions for future issues in the VA Presents. E-mail: *Robert.Baum@hq.med.va.gov* ***Address: PSAS SHG (113), 810 Vermont Ave., NW, Washington, DC 20420. Phone (202) 273-8515. Fax: (202) 273-9110.***

NUPRL&RERP News

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Latino/a students on campus the awareness of their presence and value to Northwestern University. Lisette Ruberte is Vice President of G-SALSA.

In a workshop held July 10 for graduate students who are members of minorities and who attend Northwestern, Lisette Ruberte talked about seeking employment and covered topics including letters of recommendation and the interview. Lexyne McNealy addressed choosing the right program versus the right school, campus visits and follow-up.

Visiting Fellows from Germany and Austria Present Topics

On April 11, physicians visiting the United States as fellows gave presentations an several topics of interest to the staff of Northwestern University and the Rehabilitation Institute of Chicago. Dr. med Jan Matussek from Berlin, Germany discussed two and three-dimensional posture control in idiopathic scoliosis. He also spoke about a new orthosis and about "Dynamic ankle brace testing". Dr. med Ernst Bernhard Zwick of Graz, Austria presented two topics, “Hamstrings and Cerebral Palsy" and "Tamarack Joints in inner shoes”. Dr. med Bernd Koester of Regensberg, Germany presented “Diabetic Foot Syndrome, Therapeutic Concepts Yesterday and Today”, and “Therapeutic Footwear for the Diabetic Foot”.

NUPRL Receives Grant for Technology Transfer of Powered Hand

The Department of Veterans Affairs Research and Development Service has awarded a grant for technology transfer of an Externally-Powered Trans-Metacarpal Hand Prosthesis. Principle Investigator for the project is Richard F.. *ff.*Weir, PhD.

Margrit Meier has Abstract Accepted to International Conference

Margrit Meier, PhD has had an abstract accepted to Salford's 2nd “International Conference on Biomechanics of the Lower Limb in Health, Disease, and Rehabilitation”, to be held in Manchester, England, UK, September 1-3, 2003. The abstract is entitled “A Comparison of the “C-Leg and the 3R60 Prosthetic Knee Joint.”

Comprehensive Set of Clinical Outcome Instruments

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HOXIE LO (1996). Outcome measurement and clinical pathways. Journal of Prosthetics and Orthotics 8, 93-95.

LEGRO MW, REIBER GD, SMITH DG, DELAGUILA, M, LARSEN J, BOONE D (1998). Prosthesis evaluation questionnaire for persons with lower limb amputations: assessing prosthesis-related quality of life. Archives of Physical Medicine and Rehabilitation 79, 931-938.

LINACRE JM, WRIGHT BD (2002). WINSTEPS: A Rasch program for rating scale analysis. Chicago: MESA Press.

OTTO J (1999). Outcomes insights: a current perspective Parts 1 and 2. O & P Business News Dec. 15, 1999 and Jan. 1, 2000.

POLLIAK AA, MOSER S (1997). Outcomes forum: facing the future of orthotics and prosthetics proactively: theory and practice of outcomes measures as a method for determining quality of services. Journal of Prosthetics and Orthotics 9, 127-134.

PRUITT SD, VARNI JW, SETOGUCHI Y (1996). Functional status in children with limb deficiency: development and initial validation of an outcome measure. Archives of Physical Medicine and Rehabilitation 77, 1233-1238.

PRUITT SD, VARNI JW, SAID M, SETOGUCHI Y (1998). Functional status in limb deficiency: development of an outcome measure for preschool children. Archives of Physical Medicine and Rehabilitation 79, 405-411.

RASCH G (1960). Probabilistic models for some intelligence and attainment tests. Copenhagen: Danmarks Paedogogiske Institut 1960 (Chicago: University of Chicago Press 1980).
WARE JE (1993). SF-36 Health Survey: manual and interpretation guide. Boston, MA: The Health Institute, New England Medical Center.

WARE PJ, PHILLIPS J, YODY BB, ADAMCZYK J (1996). Assessment Tools: Functional Health Status and Patient Satisfaction. American Journal of Medical Quality 11, S50-S53.
WRIGHT BD, MASTERS G (1982). Rating scale analysis: Rasch measurement. Chicago: MESA Press.

WRIGHT BD, STONE MH (1979). Best test design. Chicago: MESA Press.
WRIGHT FV, HUBBARD S, JUTAI J, NAUMANN S (2001). The prosthetic upper extremity functional index: Development and reliability testing of a new functional status questionnaire for children who use upper extremity prostheses. Journal of Hand Therapy 14, 91-104.

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Copies of *OPUS* instruments are available from the corresponding author.

Development of a Multifunctional Hand Prosthesis

Continued from page 2

Heckathorne, C. W., (1992): Components for Adult Externally Powered Systems, Chapter 6C. In: Atlas of Limb Prosthetics, Surgical, Prosthetic, and Rehabilitation Principles, 2nd Edition, Bowker, J. H., and Michael, J. W., (Editors), Mosby-Year Book, Inc., St. Louis, Missouri, pp. 151-175.

Keller, A. D., Taylor, C. L., and Zahn, V., (1947): Studies to Determine the Functional Requirements for Hand and Arm Prostheses, Department of Engineering, University of California at Los Angeles.

Lozac'h, Y., (1984): The Preferred Working Plane for an Active Thumb. Proceedings of the 2nd International Conference on Rehabilitation Engineering (RESNA 84), Ottawa, Canada, June 17-22.

Weir, R. F. ff., Grahn, E. C., and Duff, S. J., (2001): A New Externally-Powered, Myoelectrically Controlled Prosthesis for Persons with Partial Hand Amputations at the Metacarpals. Journal of Prosthetics and Orthotics. Vol. 12, No. 2, pp. 26 - 31, June 2001.

Weir, R. F. ff., and Grahn, E. G., (2002): A Myoelectrically Controlled Prosthetic Hand for Transmetacarpal Amputations. Proceedings of the Myoelectric Controls Conference (MEC2002), Fredericton, New Brunswick, Canada, August 19th - 23rd, University of New Brunswick, New Brunswick, Canada.

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- ❒ Computer Aided Engineering/Design/Manufacturing
- ❒ Pediatric Prosthetics
- ❒ Prosthetic Feet
- ❒ Prosthetics & Orthotics: General
- ❒ Upper Limb Prosthetics & Orthotics

Other Sources for Prosthetic & Orthotic Information:

Consumer Information:
National Limb Loss Information Center
900 East Hill Avenue - Suite 285
Knoxville, TN 37915
Toll Free: (888)AMP-KNOW

Prosthetic-Orthotic Education:
National Commission on Orthotic and Prosthetic Education
330 John Carlyle Street - Suite 200
Alexandria, VA 22314
e-mail: info@ncope.org

General Information about Prosthetics & Orthotics:
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