

VIII. Functional Assessment

Portable Motorized Standing Aid

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Sponsor: VA Rehabilitation Research and Development Service

Purpose—It has been observed that there are a substantial number of disabled individuals who have great difficulty initiating movement from a seated to a standing position: once standing, they are able to ambulate with or without a walking aid. The purpose of this study was to develop a device which would allow the disabled to achieve a standing position without physical aid from another person.

Progress—To be effective, the device had to be portable, low cost, and applicable to various types of chairs. A search of the literature was made without finding a device that met our criteria. A variety of mechanical devices was considered, but due to the high torque load and the small space in which the mechanism must fit, many designs were rejected.

The first prototype was made; however, the physical size was over the required dimensions. Nevertheless, it was used to test the theory and practicality of the device.

Preliminary Results—Individuals with a variety of disabilities were tested (e.g., stroke, bilateral below-knee amputation, generalized weakness, rheumatoid arthritis). The results of the testing at this time have been positive.

Future Plans—A second generation standing aid is now at the fabricators. This device will be smaller than the first prototype. More extensive testing will be done.

Development of a Life Satisfaction Scale Applicable for People with Severe Disabilities

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Purpose—This study has developed a clinically useful structure interview that provides insight into the adjustment process of people with various disabilities. This was a longitudinal study of individuals enrolled in several inpatient rehabilitation programs of the Palo Alto VAMC (Western Blind Rehabilitation Center (WBRC), Spinal Cord Injury (SCI) Center, and Rehabilitation Medicine Services). A matched comparison sample of nondisabled veterans was also examined.

Progress—To date, the ACCESS questionnaire (Assessment of Current Community, Emotional, and Social Satisfaction) has been administered to over 1,200 patients and control subjects. The complete

series of interviews includes intake, discharge, and 6-month follow-up. In both the WBRC and SCI samples, 100 patients were interviewed who had actually received treatment 5 years ago. Data collection is complete in the WBRC sample, the 5-year SCI sample, and the control group. The current count on the SCI sample is: 66 intakes, 60 discharges, and 43 six-month follow-ups.

There are now 44 individuals in the Rehabilitation Medicine group. The original goal was to obtain at least 100 study participants in each group. We now project achievement of this goal in all but the Rehabilitation Medicine sample, where the final sample size will be 50.

Results—Preliminary results reveal a general high level of satisfaction with rehabilitation services provided within the VA, and a significant amount of psychosocial change during rehabilitation. This positive change appears consistent and stable over 6 months, and is comparable with matched control populations of people without disabilities as well as people that had rehabilitation over 5 years previously. The general quality of life of people with disabilities appears higher after rehabilitation, although many of the measures are still lower than the general nondisabled population.

Future Plans—Future plans consist of continued data collection and further analysis of existing data. In addition, dissemination of ACCESS in other research and clinical settings continues to be undertaken.

Publications Resulting from This Research

Determining Psychological Change During Rehabilitation Using the Standardized Interview ACCESS. Shindell S, Dunn M, Goodrich G, and Overbury O. Paper presented at the *American Psychological Association*, New York, NY, 1987.

Life Satisfaction Assessment. Shindell S. Paper presented at the *National Association for the Education and Rehabilitation of the Blind and Visually Impaired*, Chicago, IL, 1986.

An Investigation Into the Benefits of Upright Stance and Ambulation in the Severely Disabled

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Purpose—The benefits of upright stance are: improved bladder, bowel, pulmonary and cardiovascular function, a decrease in osteoporosis, and psychological advantages, as quoted by Rose (1972) and Carroll (1974). But neither gave any indication of the scientific basis of their statements. A similar beneficial tendency has been noted by members of the Orthotic Unit during their association with patients in the swivel walker. Griffiths (1977) published work showing the improvement in pulmonary function that occurred going from wheelchair to swivel walker.

Progress—This project involves fitting patients, who are either congenital or traumatic paraplegics, with the Reciprocating Gait Orthosis (RGO). Most patients had previously been chair-bound, but in the case of some young children, this was their initial walking orthosis allowing upright stance and mobility. All patients have an initial clinical assessment by a surgeon and physiotherapist to check general fitness and to identify any deformities that may preclude the fitting of the orthosis. If present, these would be surgically corrected if possible, to allow the patient to be accepted for the pre-training program. All the patients enter a pre-training program of frame-standing and physiotherapy to achieve

balance and maximize their upper-limb strength.

The physiological tests performed are pulmonary function, that is, vital capacity, F.E.V. 1 and peak expiratory flow rate. The older patients have an EKG and chest X-ray as necessary. Blood investigations are full blood count, urea and electrolytes, and a bone profile. An ultrasound assessment of the urological tract is also performed and a mid-stream urine specimen cultured. These investigations are performed, initially, at the commencement of the pre-training program and are repeated at regular intervals. Psychological testing, using the Revised Weschler Intelligence Scale for both adults and children and Locus of Control tests (adults—Rotter; children—Nowicki and Strickland) are also performed at this time. These tests are repeated when the patient has been ambulant in the RGO for six weeks and will then be repeated again, after approximately six months' use of the RGO.

Preliminary Results—We have so far recruited eight patients for this study, six adult (over 16 years) and two children and baseline tests have been performed. More patients are being assessed for the RGO and recruiting will continue. The patients will also, when trained and adept in the use of the RGO, have energy costings performed, using the Physiological Cost

Index (PCI) method. This method has been chosen as there is no cumbersome apparatus to hamper the patient in the use of the RGO, only a small radio telemetry system.

Future Plans/Implications—It is hoped that it will be possible to monitor changes in the bone density of

patients in the future, using CAT-scanning techniques. The project is long-term in nature, but it is hoped to be able to give some preliminary physiological and psychological results in the short term. Hopefully, some prescription guidelines will be produced.

New Motor Control Assessment Techniques for Evaluating Individuals with Severe Handicaps

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Purpose—In 1985 we embarked upon a complex evaluation program with a severely handicapped nonvocal cerebral palsy patient, with the goal of developing a specialized interface for use with an assistive communication device. In order to accomplish this, a motor control assessment procedure (MCAP), combining clinical observation methods with computer-aided motion analysis, was developed. MCAP examines two types of information which may be used for device control: myoelectric activity at various muscle sites, and the displacement of body parts in space. Special assessment tasks are used to evaluate systematically the patient's motor abilities in quantitative terms that lend themselves to the design and construction of assistive devices.

Progress—The myoelectric assessment was completed in late 1985. Myoelectric activity proved not to be a practical device-control method for the current subject. For the past year, the focus has been on the evaluation of spatial displacement; specifically, rotation of the head, which appears to be the most practical control site for this particular patient. A motion transducer was constructed to

measure head rotation in the horizontal plane. Using the transducer, the patient and several normal subjects were asked to perform a series of head movement tasks, including tracking periodic patterns of movement and pointing to various targets on a computer screen. Software was written to identify and analyze typical patterns of head movement for normal subjects, including slopes, velocities, and ranges of motion, and to compare them to the patient's performance. The results indicate that the patient possesses sufficient proportional control of head rotation to operate a communication device.

Future Plans—We will continue our efforts by performing a final in-depth assessment of the patient's head movement using WATSMART. The data from WATSMART will be used as guidelines for the design and fabrication of a practical head interface tailored precisely to our subject's needs and abilities.

Publication Resulting from This Research

New Motor Control Assessment Techniques for Evaluating Individuals with Severe Handicaps. Rudin NJ, Gilmore LD, Roy SH, De Luca CJ, *Journal of Rehabilitation Research and Development* 24(3):57-74, 1987.

Comparative Evaluation of Body Support Systems for Tissue Pressure Distribution

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Sponsor: Cleveland Clinic Research Foundation

Purpose—Four commonly used hospital mattresses were evaluated by 10 normal subjects for their ability

to change the interface pressures in the recumbent position.

Progress—The subjects were classified according to sex, body weight, and height. Pressure measurements were made in the supine position and the side-lying position, using the Gaymar, Scimedica, and the TIRR pressure transducers.

The four supports studied were the Geomat, the Akros, the Sof-care 402, and the standard hospital mattresses (as the control). A hospital bed, adjusted horizontally, was used to support all mattresses during measurements. Three pressure measurements were taken at each anatomical location with the transducer repositioned between each measurement and the highest of the three measurements reported as the maximum local pressure. When averaged over the 10 subjects, the mean and its

standard deviation is given as the mean maximum local pressure.

Preliminary Results—Data analysis is in progress to describe the relation between mattress types, transducers and anatomic sites using analysis of variance, F-test, and the Duncan multiple-range test for comparisons of means.

Using additional mattresses, further work is continuing at the request of the Nursing Service at CCF. The results will be utilized by the Enterostomal Therapy and the Cardiovascular Nursing Services for the development of improved care toward the prevention of decubitus ulcers.

Validation of a Gross Motor Function Measure (GMFM) for Assessment of Outcome in the Treatment of Cerebral Palsy

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Purpose—The objectives of this study are: 1) to evaluate the responsiveness to change of a gross motor function assessment measure (GMFM) for children with chronic neuromotor disabilities; and, 2) to compare several methods of quantifying motor function in order to compile a meaningful score which reflects actual performance in this population.

Progress—During the past 2 years, this study has evaluated the motor function of 140 children with neuromotor disabilities, and 30 normal children, at two points in time separated by three to six months. At the same time, judgments of change in motor function have been obtained from parents and therapists. The purpose of these judgments is to compare them with change scores on the GMFM in order to validate the responsiveness of the measure to change. In addition, 30 children have been videotaped on two occasions, for evaluation by trained physiotherapists “blind” to the “before-after” status of the children. This latter evaluation will add further validity to the results of the study.

This project has involved approximately 12 physiotherapists at the two centers, and represents a major collaborative effort in measurement development. The instrument is designed to capture

quantity of change in function, but has not attempted to assess quality of movement (performance).

Preliminary Results—Preliminary analysis of data from the GMFM study of 170 children indicates that the measure has good inter-rater reliability (values at or above 0.85 on several dimensions). The validity of the measure, with respect to its responsiveness to change, appears very strong. The correlations of change scores on the GMFM with therapist and parent judgments of change are consistently high (0.5 to 0.65), and are in fact much stronger than initially predicted when the study was being developed. It is therefore clear that we have created a measure of gross motor function which will be valuable in assessing change in the abilities of children with cerebral palsy.

Future Plans/Implications—The results of the study will be presented at an international scientific meeting and published in a major medical journal during the forthcoming year. In addition, a request for funding will be submitted to develop a measure of motor performance assessing quality of movement for use with children with neuromotor disabilities along with the GMFM which was not designed to capture the qualitative aspects of movement.

Pre-Clinical Research in Neuromuscular Diseases and Muscle/Nerve Biology

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Purpose—The goal of this project was to quantitatively evaluate neuromuscular function and its use in assessment of physical and pharmacological intervention modalities. To reach this goal, the objectives were to: 1) characterize and classify functional, contractile, morphological, histochemical, and biochemical characteristics of skeletal muscle and other organ systems in animals with naturally occurring and induced neuromuscular disorders; 2) evaluate various physical and pharmacological interventions for possible beneficial effects on these disorders; and, 3) determine, through close interaction with clinical projects, the potential for application to rehabilitation of patients with neuromuscular disorders.

Progress—Quantitative procedures were developed to objectively measure functional, contractile, and histochemical properties in chickens and mice with neuromuscular disorders. An extensive database system was developed to manage, access, and analyze all data. Work on development of a computerized, quantitative EMG analysis system continued, and a system to induce hypokinesia in hind limbs of mice was completed.

Results—Computer-generated plots of muscle fiber areas verified the subjective impression that high variability of fiber size is a major characteristic of inherited neuromuscular disorders in chickens and mice. The first study of older (18-month) dystrophic chickens revealed that: 1) the histopathological changes in avian dystrophy are clearly progressive; 2) those changes closely resemble those seen in human Duchenne dystrophy; and, 3) a high degree of fiber splitting occurs in late stages of avian dystrophy. One form of exercise (high-repetitive,

sub-maximal) was found to partially alleviate signs of murine dystrophy. The first contractile and electrophysiological studies of the recently-discovered “myotonic” mouse showed that this hereditary condition faithfully reproduces the major features of human myotonia congenita. Studies of the newly-discovered *mdx* (sex-linked) mutant in mice suggest that this may be a useful model of muscle fiber regeneration, but that it is dissimilar to the major sex-linked human dystrophy (Duchenne). A drug evaluation program that utilizes the dystrophic chicken consistently identified one class of compounds (glucocorticoids) as highly effective against major signs of the avian dystrophy. As a result of that finding, a corticosteroid was recently evaluated in a multi-clinic trial involving patients with Duchenne dystrophy. As predicted from the chicken studies, the compound was effective, but its clinical utility is limited due to dose-limiting adverse effects.

Publications Resulting from This Research

Effects of Passive Stretch on Muscle Contractility of Normal and Dystrophic Chickens. Abresch RT, Sharman RB, Enrikin RK, Larson DB, Fowler WM, Jr., *Muscle and Nerve* 9(5S):249, 1986. (Presented at VI International Congress on Neuromuscular Diseases, Los Angeles, CA, July, 1986.)

Therapeutic Trials in Muscular Dystrophy of the Chicken: Phase-II Effects on Plasma CK Activity and Muscle Histology. Enrikin RK, Larson DB, De La Vega D, Abresch RT, *Muscle and Nerve* 9(5S):271, 1986. (Presented at VI International Congress on Neuromuscular Diseases, Los Angeles, CA, July, 1986.)

Therapeutic Trials in Muscular Dystrophy of the Chicken: Phase-I Effects on Muscle Function. Enrikin RK, Levine NA, Atwal B, De LaVega D, Robles M, *Muscle and Nerve* 9(5S):271, 1986. (Presented at VI International Congress on Neuromuscular Diseases, Los Angeles, CA, July, 1986.)

Contractile and EMG Studies of Murine Myotonia (mto) and Muscular Dystrophy (dy/dy). Enrikin RK, Abresch RT, Sharman RB, Larson DB, Levine NA, *Muscle and Nerve* 10:293-298, 1987.

Clinical Research in Neuromuscular Diseases

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Purpose—The purpose of this research is to describe the natural course of neuromuscular diseases (NMD) with quantitative measurements of selected major characteristics, and evaluate effects of various therapeutic interventions on these characteristics and the natural course of the diseases.

Progress—Procedures were designed to measure the complications of weakness, limb contractures, spinal deformity, restrictive lung disease, cardiac function, neuropsychological function, and functional ability. A comprehensive and objective battery of measurements has been developed to describe the natural course of each NMD and to serve as the criteria against which the effectiveness of therapeutic interventions can be determined.

Results—About 400 individuals with various NMD's have been evaluated.

Weakness: In boys with Duchenne dystrophy (DMD), manual muscle test (MMT) scores were related to age in a logarithmic fashion. Using quantitative measurements, isokinetic testing yielded the most information on dynamic functional strength. Patients had about 50 percent of the isometric strength of normal controls, and, with the exception of those with myotonic dystrophy (MMD), demonstrated greater fatigability. When compared to MMT's, muscle groups demonstrating normal strength exhibited widely variant objective strength scores, but compared favorably for weak muscles. There was no correlation between MMT scores and measurements of endurance. Contractile measurements showed that MMD patients had a marked impaired relaxation, reduced tetanic tension development, and a significant post-tetanic potentiation of the twitch when compared to normal age-matched subjects.

Limb contractures: Contractures were severe and rapidly progressive in DMD and spinal muscular atrophy (SMA), but insignificant in other neuromuscular diseases.

Spinal deformity: 56 percent of DMD patients,

67 percent of those with Friedreich's ataxia (FA), and 55 percent of those with SMA had significant scoliosis. Only 15 percent of other patients had spinal deformity.

Restrictive Lung Disease: Patients with DMD and amyotrophic lateral sclerosis (ALS) showed diminishing pulmonary function with increasing disease duration. In DMD, VC dropped to levels of severe impairment between the ages of 12 and 14. In patients with slowly progressive neuromuscular diseases, there was no relationship between disease duration and pulmonary function.

Cardiac function: Abnormal EKG's occurred in 92 percent of DMD and MMD patients, 83 percent in Becker's dystrophy (BMD), 67 percent in Limb girdle dystrophy (LGD), and 53 percent in facioscapulohumeral dystrophy (FSH). In spite of the high incidence of abnormal EKG's, only about 15 percent had clinical findings of cardiac disease, and there was no correlation with age, disease duration, or severity of the disease.

Neuropsychological function: Significant cognitive defects were found in MMD and DMD patients but not in any of the other NMD's. Personality testing indicated that depression, while common, was not indigenous to a particular disease.

Functional ability: While there was a significant non-random relationship between UE/LE functional grade and strength, measurements were not entirely equivalent when evaluating an individual's clinical status. Upper extremity functional scales correlated better with strength measurements than did lower extremity scales.

Publications Resulting from This Research

Intellectual and Cognitive Function in Adults with Myotonic Muscular Dystrophy. Portwood MM, et al., *Archives of Physical Medicine and Rehabilitation* 67:299-303, 1986.

Upper Extremity Functional Ratings for Patients with Duchenne Muscular Dystrophy. Lord JP, et al., *Archives of Physical Medicine and Rehabilitation* 68:151-154, 1987.

Upper Versus Lower Extremity Functional Loss in Neuromuscular Disease. Lord JP, et al., *Archives of Physical Medicine and Rehabilitation* 68:8-9, 1987.

Functional Ability and Equipment Use Among Neuromuscular Disease Patients. Lord JP, et al., *Archives of Physical Medicine and Rehabilitation* 68:348-352, 1987.

Differential Diagnosis of Muscle Diseases. Fowler WM, Taylor RG, *Musculoskeletal Disorders*, 2nd Ed., R. D'Ambrosia

(Ed.), Lippincott, 1986.

Depression in Myotonic Muscular Dystrophy. Duveneck MJ, et al., *Archives of Physical Medicine and Rehabilitation* 67:875-877, 1986.

Rehabilitation Management of Neuromuscular Diseases Research and Training Center, UC Davis

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Purpose—The overall mission of this RT Center is to conduct a broadly-based, multidisciplinary program of research in the area of comprehensive rehabilitation management of neuromuscular diseases, and to initiate training that transposes the findings of this research into tangible products that rehabilitation practitioners and educators can use in service delivery and teaching programs. The purpose

of all research projects in the Center is to identify factors that prevent or limit successful rehabilitation, and develop intervention strategies to overcome those limiting factors. Specific research activities have been designed to function as a sequential series of clinical and pre-clinical projects grouped into two interrelated and correlated study sections.

Mobile Assessment Laboratory

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Purpose—The goal of developing a Mobile Assessment Laboratory (MAL) is to provide a mobile facility for pre-assessment of a disabled person's capabilities for driving. The ability to deliver this service at sites convenient to potential drivers makes evaluation for driving more readily available to a group who may not be able to come to an evaluation center because of financial or scheduling reasons.

Progress—The MAL is a Collins Omni Baron window van on a Ford 350 chassis with a 138-inch wheel base. It is equipped with power steering, power brakes, air conditioning, automatic transmission, roof mounted 110-volt air conditioning and heating unit, and a Collins rear-mounted hydraulic wheelchair lift. Behind the driver's seat there is a space of 160 inch × 75 inch × 74 inch high for pre-assessment procedures. The space contains a complete second-generation Computer-Assisted Driver Assessment System with motion analyzer, functional strength analyzer, and tracking simulator. There is also an adjustable-height table to support

equipment and supplies for hearing, vision, and psychometric testing. Space limitations of the mobile unit have required only minor modifications in equipment layout and testing procedures used in the service-delivery area of the Center.

The MAL can be taken to areas far from rehabilitation centers to perform driver pre-assessments of disabled persons. The unit can be powered by a gasoline-powered portable generator at sites without adequate power connections. The entire MAL evaluation can be carried out by two professionals: a driver evaluator and an assistant. One to five clients can be served per day depending on extent of evaluation procedures necessary and distance traveled that day. In addition to its providing greater client accessibility to driver evaluation, it is anticipated that the MAL will offer substantial savings to driving candidates and their funding sources. By facilitating the overall assessment process, it has the potential to restore or to initiate independent driving in a cost-effective manner.

Results—The MAL has expanded the capabilities of the Center in several ways. The unit has traveled to ten different states throughout the country for purposes related to driver assessment/evaluation. Over 50 pre-assessments have been performed in the MAL using first- and second-generation assessment systems. The MAL has also been exhibited at several in-state and out-of-state conferences and used to teach rehabilitation professionals about driving by disabled persons.

Future Plans/Implications—MAL equipment and procedures will continue to be improved when user feedback indicates. The cost effectiveness of the mobile approach to pre-assessment of a disabled person's capabilities to drive will be evaluated in detail. Rehabilitation professionals in various states will be interviewed to determine the most appropriate use of the MAL in different state systems. It is anticipated that other types of assessments will also be feasible in the MAL.

Computer-Assisted Driver Assessment System

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Purpose—The overall objective of the Computer-Assisted Driver Assessment System (CADAS) project is to provide an objective quantitative assessment of a disabled person's physiological capabilities for driving. Quantitative data are gathered on range of motion, functional strength, and tracking simulator performance. By providing this information, the CADAS aids a driving evaluator in determining whether a disabled person can drive a vehicle, if there is sufficient potential driving capability, and determine what vehicle modifications are necessary.

Progress—The Computer-Assisted Driver Assessment System comprises three major subsystems and a controlling computer. Two fully integrated second-generation systems using the IBM PC/XT micro-computer have been built and are operational. One system is located in the service-delivery area of the Center. The second system is part of a Mobile Assessment Laboratory equipped to perform pre-assessments of driving capabilities. Software in the C programming language records client personal information and controls and takes data from the three subsystems: the motion analyzer, the functional strength analyzer, and the tracking simulator. The modular menu-driven program also calibrates devices, guides assessment, manipulates and records data, and prints reports.

The motion analyzer has an extendable wand which is articulated in two planes. Wand length and angles in these two planes are detected by digital encoders. The system computer determines the

spherical coordinates of the wand tip by counting digital pulses from the three encoders. The computer presents a menu of up to 49 predefined points for characterization of client and wheelchair. The CADAS software produces a set of data and graphs that can be used by driver evaluator, drive educator, and vehicle modifier.

The functional strength analyzer is a steering wheel mounted rigidly on a shaft instrumented with strain gauges. The functional strength analyzer can assume a variety of configurations to measure forces on the steering wheel and on simulated hand controls. The static strength test, using the analyzer, measures the force applied to a steering wheel at various angles of tilt. The associated software provides menus to record data in a standard format.

The tracking simulator is a device developed at the Center to evaluate ability to track a target visually while using an assistive driving device. It can be configured to use several types of brake/accelerator and steering controls. The system computer, which also generates the target on a video monitor, displays the client's response according to the position of the controls the client is using. The result of the test is a set of measures of how well the client can track a target with different controls.

Future Plans/Implications—Refinements to design and operation of the three major CADAS subsystems, as well as the associated software, are based on user feedback. Ongoing efforts will result in a comprehensive technical report and a user's manual

covering CADAS. Ultimately, quantitative assessment information obtained from the CASAS will be used for comparison with a resident database of

assistive driving devices. From this comparison the computer will recommend devices to fit a client's needs.

Psychometric and Performance Predictors of Driving Ability

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Purpose—The purpose of studying psychometric and performance predictors is to develop an accurate but efficient battery of assessment/evaluation tests for driving ability of the disabled person.

Progress—An initial study compared Visual React and Visual Search scores from the Cognitive Rehabilitation Test with scores of performing the seven maneuvers on the Center's tracking simulator. There were promising correlations between performance on two left-turn maneuvers and Visual React scores. Based upon these results, a larger study was designed to investigate the relationships between various cognitive tests and driving abilities.

A second study tested the predictive capability of eight standard cognitive tests and two Center-developed performance tests. The cognitive tests were Wechsler's Adult Intelligence Scale (WAIS), WPS Symbol-Digit, Halstead-Reitan Trail Making, Diller-Yishay Cancellation, Cognitive Rehabilitation Test (Visual React and Visual Search), Driver Performance Test (DPT), Baylor Adult Visual Perception Test, and Motor-Free Visual Perception Test (MVPT). The Center's two-dimensional tracking simulator, with its pursuit tracking tasks and Small-Scale Vehicle (SSV), were also included in the expanded battery of tests administered to subjects. Error scores from the tracking tasks and driving

performance scores on the SSV were considered as potential predictors of driving ability. The criterion measure in the study was the subject's ability to drive a full-size vehicle on a closed driving course. Efforts required to control the tracking simulator, the SSV, and the full-size vehicle were similar.

Volunteer subjects in the second study were assigned to three groups. There were ten traumatic-brain-injured, seven spinal cord injured, and eight nondisabled subjects in the study. With few exceptions, all tests were given to all subjects.

Preliminary Results—Results of the various statistical analyses indicated that an accurate prediction of driving ability can be made from a small number of tests of the disabled person. In fact, most results generalize across spinal cord injured, traumatic-brain-injured, and non-disabled persons. Preliminary results show the strongest predictors to be the Driver Performance Test, the oral WPS Symbol-Digit Test, and SSV performance. It also appears that the oral WPS Symbol-Digit, the Driver Performance Test, and the Visual React task of the Cognitive Rehabilitation Test were good discriminators of cognitive abilities among the groups tested. The findings support the feasibility of using a simple test battery to indicate which driver candidates are ready for in-vehicle assessment.

Small-Scale Vehicle for Driver Assessment/Evaluation and Training

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Purpose—The goal of the Small-Scale Vehicle (SSV) project is to provide a cost-effective alternative to assessment/evaluation and training of disabled po-

tential drivers. By providing a low-threat, but realistic driving environment, the SSV facilitates evaluation of driving capabilities, familiarization with

assistive devices, and training on device use, vehicle operation, and driving behavior.

Progress—A second-generation SSV has been built and is currently being evaluated by current and potential users. The SSV is an electric golf car which has been extensively modified to incorporate a variety of control, safety, and instrumentation features. Although much smaller than a full-size vehicle, it offers a high degree of realism in terms of methods of steering and control, four-wheel design, and seating position. Its design permits the assessment and training of clients with a wide range of disabilities.

The steering system includes an adjustable steering column that allows the steering wheel to be positioned to meet the needs of the client. The system will accept any standard adaptive steering device. The adjustable reduced effort is a major feature.

The brake/accelerator functions are performed with the use of electronic modules or commercially available controls. Modules have been built to simulate the motions and efforts required to operate push-pull hand controls, push-right angle hand controls and servo-assisted push-pull and side-to-side controls. In addition, a floor-mounted push-pull quad control, a push-right angle hand control, and a left-foot accelerator can be installed. Standard brake and accelerator pedals are also operative. The brake system requires reduced effort to engage the brakes. An independent auxiliary braking system has been

added for the evaluator.

The seating system consists of automotive high-back bucket seats complete with restraining systems for the client and instructor. Overall safety features include a roll bar, warning lights and buzzers, fire extinguisher, circuit breakers, and drive motor cut-off switches.

A small-scale driving course is used for operation of the SSV. By driving the course under driver evaluator supervision, the operator experiences dynamic maneuvering challenges. The driver evaluator is able to determine effects of vehicle dynamics on driver performance in a controlled environment. The small-scale course requires about one-fourth the area of an equivalent full-scale course.

Results—The SSV Vehicle has proven to be a reliable, cost-effective, and meaningful approach to assessment/evaluation of the disabled driver.

Future Plans/Implications—The SSV will continue to be modified to meet the needs of users. Technological improvements will be made when higher efficiency, improved performance, or lower cost will result. It costs much less to purchase, operate, and maintain than full-size vehicles having the same assistive device capabilities. Space to house and to operate the SSV is much less than to operate a full-size vehicle. In some cases, on-the-road assessment/evaluation is completely eliminated, further reducing the need for a full-size vehicle.

Development of a Uniform National Data System for Medical Rehabilitation

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Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—The uniform data system for medical rehabilitation (UDSMR) was developed to meet a long-standing need to document severity of patient disability and the outcomes of medical rehabilitation. Previously there has been no uniform way to describe and communicate about disability. This effort was jointly sponsored by the American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation and endorsed or participated in by eleven other national

rehabilitation professional organizations.

The uniform data set is intended to be an appropriate, quickly administered, valid, and reliable measure which is discipline-free and acceptable to clinicians in the field. Data collected on key patient functional attributes (using the 7-level Functional Independence Measure or FIM) in a consistent manner allows clinicians and researchers to track patients from the initiation of hospital care through discharge and follow-up. With periodic reassess-

ment, changes in patient performance over time can be measured and rehabilitation outcomes determined. The uniform data set is a useful tool to facilitate treatment management and monitoring, quality assurance, program evaluation, determination of cost effectiveness of processes and resources used, and care policy decision-making.

Progress—The development of the data system has been carried out in three phases: pilot, trial, and implementation. The purpose of the pilot was to field test the instrument to determine its face validity and ease of administration. Upon completion of the pilot in the Spring of 1985, modifications were made in the instrument. The intent of the trial phase, completed in Spring 1986, and the implementation phase, begun in mid-1986 and continuing, was to assess interrater reliability, validity, precision, and time to administer the data set. Data were obtained at admission, discharge, and when feasible, follow-up 3-6 months after discharge.

Preliminary Results—Two hundred fifty patients from 25 inpatient facilities were assessed and 891 clinician assessments were performed during the trial phase. The clinicians were physicians (17 percent), occupational and physical therapists (28 percent each), and registered nurses (27 percent). Interrater reliability of the FIM was evaluated by comparing the results of multiple pairs of clinicians of differing disciplines, each pair assessing the same patient. The trial total score FIM intraclass correlation (ANOVA) was 0.88 on discharge (based on 184 observer pairs). Implementation phase preliminary intraclass correlation was 0.92 (based on 108 observer pairs). These reflect good interrater agreement.

Face validity was evaluated by means of specific

questions regarding difficulty (88 percent did not have difficulty), unnecessary items (97 percent felt there were no unnecessary items), items which should be added (83 percent felt no need for more items), and open-ended comments. The average score on an evaluation item regarding adequacy of the FIM as a measure of severity of disability was 3.4 (trial) and 3.5 (implementation) on a 5-point scale, which is in the better than average range.

Determination of the precision of the instrument (that is, how small a change is detectable from admission to discharge) revealed significant differences in trial FIM scores (10.7 ± 0.9 [standard error] FIM units). This finding suggests that the FIM has adequate precision. The time required to learn to use the FIM (60 minutes) and to routinely administer the FIM (26 minutes) seems acceptable.

Future Plans—Facilities wishing to participate in the use of the Uniform Data System will receive a GUIDE and an IBM compatible floppy diskette suitable for inputting data. Data may be forwarded to the Data Management Service (DMS) at the Buffalo General Hospital for entry into the data system, for analysis, and report back to participants.

Publications Resulting from This Research

- A **Uniform National Data System for Medical Rehabilitation.** Hamilton BB, Granger CV, Sherwin FS, Zielezny M, Tashman JS, *Rehabilitation Outcomes: Analysis and Measurement*, M.J. Fuhrer (Ed.), Brookes, Baltimore, MD, 1987.
- The **Functional Independence Measure: A New Tool for Rehabilitation.** Keith RA, Granger CV, Hamilton BB, Sherwin FS, *Advances in Clinical Rehabilitation* 1:6-18, M.G. Eisenberg and R.C. Grzesiak (Eds.), New York, NY, Springer, 1987.
- Advances in Functional Assessment for Medical Rehabilitation.** Granger CV, Hamilton BB, Keith RA, Zielezny M, Sherwin FS, *Topics in Geriatric Rehabilitation* 1(3):59-74, 1986.

Predictive Assessment in Prescription of Functional Aids for the Motor Disabled

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Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—The goal of this project continues to be the development of data, methods, and theory on which to base prediction of functional gain from therapies and technological intervention. It was

originally proposed that this concept be applied to three handicapping conditions: 1) disabling tremor of the upper limbs; 2) "equinus" and other spastic gait abnormalities; and, 3) loss of vocal communi-

cation due to impaired articulatory motor control.

Progress—During the past year, the second area has been inactive while considerable progress has been made in the first. In addition, supplementary support has been provided via this project for completing the development of the Tufts-MIT Prescription Guide, a computer-based system for optimal selection of nonvocal communication devices, funded primarily by a contract awarded to New England Medical Center Hospitals by the National Institute of Neurological and Communicative Disorders and Stroke (NINCDS). A summary of that work may be found elsewhere in this volume.

The primary focus in the area of tremor during the past year has been the completion of a two-degrees-of-freedom manipulandum, designed and built by doctoral candidate Bernard Adelstein. This apparatus has the configuration of a joystick coupled in each of its degrees of freedom to a pancake armature DC motor. The coupling is accomplished via a novel gimbal mechanism, in effect a direct drive “two-roll wrist.” This gives the manipulandum its essential back-drivable characteristic and minimizes friction and eliminates backlash. A digitally supervised analog control scheme allows the perceived impedance of the manipulandum to be varied over a broad range of experimentally interesting and/or hypothetically tremor-suppressing functions.

The motors are capable of producing 27 N force at the grip end of the handle, whose travel is about ± 10 cm in any direction and whose mechanical bandwidth is 65 Hz. Feedback of angular position, velocity, and acceleration for each degree of freedom is provided by optical encoders, tachometers, and accelerometers, respectively. The load presented to

the subject’s hand at the handle grip is a function of the gains of the feedback paths that are set via multiplying D/A converters by the host computer. A two-axis force transducer mounted in the grip senses hand force. A high forward path gain between the sensor and motor output torque tends to make the undesirable torques become imperceptibly small due to friction and the small cross-coupling between degrees of freedom.

At this writing, power-on testing of the manipulandum has been under way for several months. Elastic, viscous, and inertial loads have been successfully simulated. Near elimination of friction by torque feed-forward has been demonstrated by observing that the handle will fall to the limit of its travel from any off-center position under its own weight—a characteristic very different from its power-off behavior.

Future Plans/Implications—The experiments planned for manipulandum are meant to serve two purposes. Empirical results demonstrating consistent superiority of a particular loading scheme in selective suppression of a particular tremor type will provide a basis for design of practical compliant orthoses for people disabled by that tremor. Further, even if generalizations concerning effective loads cannot be found, the manipulandum may be viewed—along with the single analysis package developed for this work—as the prototype of a clinical assessment and prescription tool. Viewed as a multi-degrees-of-freedom controllable “Cybex” machine, it could provide a means for establishing for an individual client the optimal loading scheme for selective tremor suppression.

Prospective Study of Factors in Back Pain Disability

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Sponsor: *National Institutes of Health*

Purpose—This application requests funding to identify risk factors for chronic back pain disability. The proposed study will draw on our existing database of physical, psychological, and work-related pre-morbid data. This database is unequalled in population size and scope of independent variables.

Furthermore, this study will provide the longest follow-up of any such study to date. A better understanding of risk factors would provide a solid foundation for establishing appropriate programs to prevent chronic back pain disability, to enhance return to work, and to reduce the impact back pain

has on the industrialized nations of the world. Our goal is to continue monitoring our subject population of 3,020 individuals so that risk factors for the development of chronic back pain disability can be identified.

Our efforts to establish this database have been supported to date by NIOSH; however, NIOSH has stated that the evaluation of chronic disability is beyond their scope of interest and has limited our funding to analysis for the prediction of acute industrial back injuries. To stop without evaluating chronic back pain disability would ignore the 10 percent of back injuries that cause the most suffering and account for approximately 80 percent of the total cost for back problems.

Progress—We have already found that the first 26 subjects who developed disabling back problems of at least a 3-month duration have a significantly different fitness level than their age-matched controls. With two more years of follow-up we estimate another 15 to 21 subjects will develop chronic back pain disability. An increased number of subjects in the chronically disabled category would add to the statistical power for the evaluation of other variables.

Preliminary Results—Our results to date indicate that it is highly probable that analysis of premorbid data can predict chronic back pain disability and greatly increase our understanding of this expensive healthcare problem.

Regaining Functional Abilities after Hip Fracture

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Sponsor: *National Institutes of Health*

Purpose—The objective of this study is to determine patterns in and factors influencing older persons' return of prior functional abilities following hip fracture. The results are anticipated to be a base for design of nursing interventions/programs/discharge plans that assist patients and families cope with this disabling event.

Specific aims are to examine: 1) patterns in resumption of activities of daily living (ADL), mobility, instrumental activities of daily living (IADL), and perceived return to normal in persons discharged to their own homes and to nursing homes; 2) the relevance to post-hospital progress of certain prior conditions and events, psychological states and perceived readiness for discharge of patients and their actual and potential family caregivers; 3) problematic aspects of the recovery period; and, 4) the congruence of patients' and caregivers' expectations of progress with actual progress.

The design is prospective and descriptive, with data collection by interview at four points: pre-hospital discharge, 2, 8, and 14 weeks post-discharge. The main sample will be 120 white female

patients age 60 and over admitted from home who have undergone surgical repair of a hip fracture and approximately 100-120 family members designated as caretakers after home discharge or temporary nursing home placement. A small comparison group of 20 male patients and their caregivers also will be followed.

Patients will be drawn from orthopedic units in three community hospitals. Instruments are the ADL/Mobility and IADL Scales, and Activity Index (perceived return to normal), a short form of the Profile of Mood States, and parallel forms of Readiness for Discharge and Symptom Distress Congruency Scales. Additional patient data will be drawn from hospital records. Data analysis will include repeated measures analysis of variance with different grouping and control factors to address patterns in the resumption of activities, multiple regression, and possibly time series analysis to address influence of independent variables, and correlations to examine relationships of mood states and incongruent expectations with progress in recovery.

Gross Motor Attainments in Eleven to Fourteen-Year-Old Children with Down's Syndrome

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Sponsor: *NeuroMuscular Research Center*

Progress—Data collection for this study was completed during the preceding year. Sixty-two children with Down's Syndrome were seen in addition to 20 of their normal siblings. Thirteen other children with Down's Syndrome were seen at their homes. These children were part of an original group of 89 children with Down's Syndrome who were followed for the first 3 years at the Developmental Evaluation Clinic of Children's Hospital in Boston.

Data have been analyzed on the first two segments of the study. Gross motor test results using the Peabody Scales indicated that the best performance of the children was in ball play. Their area of greatest

difficulty was static and dynamic balance. The analysis of height, weight, and maturational data suggests little or no relationship of any of these factors to motor performance.

The next part of the analysis will examine the relationship of early motor milestones in Down's Syndrome to later motor performance. This will be followed by an evaluation of the relationship of postural sway to clinical measures of balance using stabilogram measurements. This study should lead to a better understanding of motor behavior in individuals with Down's Syndrome, one of the leading causes of mental retardation.

Orthokinetic Orthoses: Clinical Efficacy Study in Non-Drug Analgesia of Post-Trauma Chronic Pain

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Sponsor: *Orthokinetics Research Foundation*

Purpose—The purpose of this study was to investigate the clinical efficacy of orthokinetics treatment by application of orthokinetic orthoses (cuffs) to the upper extremities of patients with chronic pain secondary to: 1) tendonitis of occupational origin; 2) lateral epicondylitis due to cumulative trauma disorder; and 3) medial epicondylitis ("golfer's elbow"). The orthokinetic orthosis was designed and fabricated from spandex-reinforced elastic roller bandage material.

Progress—The three subjects had severe, disabling, chronic pain which was not mitigated by alternative treatments: massage, analgesic or anti-inflammatory medication, gentle stretching, icing, and ultrasound. The range of time since onset was 6 months to 5 years. The orthokineses analgesia treatments comprised single-subject time-series designs, consisting of orthokinetics treatment phases with application of orthokinetic orthoses to the upper extremities,

interspersed with nontreatment negative control phases, and placebo-sham treatment positive control phases. The patients were treated in occupational or physiotherapy clinics, then instructed on proper wearing of their orthokinetic orthoses for continued analgesia during activities of daily living, work, and avocation. Their progress was followed for up to 2 years after orthokinetics treatment for analgesia. The criterion measure was Present Pain Intensity (PPI) based on the McGill Pain Questionnaire.

Results—1) The patient was a 26-year-old female physical therapist with disabling chronic pain secondary to tendonitis of the left forearm refractory to massage therapy and analgesic cream application. Orthokinetic orthoses were fabricated and applied to the left proximal forearm and wrist. The time-series consisted of phases: nontreatment (negative control A1, 2 min, PPI = 3); sham treatment (positive control C, PPI = 3); orthokinetics treat-

ment (B1, 2 min, complete temporary analgesia, PPI = 0); second nontreatment (negative control A2, 5 min, reversal of analgesia, PPI = 3); second orthokinetics treatment (B2, 3 hours with work as a physical therapist involving strenuous muscle activity, e.g., patient lifting, complete and irreversible analgesia, PPI = 0). The patient has remained free of pain for two years. The orthokinetics treatment time-series was A1-C-B1-A2-B2, administered to the patient single blind, and the resulting analgesia supported internal validity and clinical efficacy of the orthokinetic orthosis application.

2) The patient was a 56-year-old man with severe chronic pain of left elbow, forearm and wrist, secondary to left lateral epicondylitis due to cumulative trauma disorder, sustained during two decades of employment as a metal worker in the automotive industry, with heavy repetitive muscular exertion of the upper extremities. His disabling pain was refractory to physical therapy by icing, ultrasound, and gentle stretch. He was treated by application of orthokinetic cuffs to forearm and wrist. In the nontreatment phase (A1, 30 sec, PPI = 4) pain was severe. In the orthokinetics treatment phase (B1, 30 sec, PPI = 2) partial analgesia was achieved, with reversal in the following nontreatment (A2, 30 sec, PPI = 4) and placebo treatment (C, 30 sec, PPI = 3) phases. In the second orthokinetics treatment phase (B2, 30 sec, PPI = 2), partial analgesia was replicated. The patient was instructed on correct application of the orthokinetic orthoses (cuffs) during unsupervised purposeful activities of daily living; he was seen again two weeks later, when he presented in the physiotherapy clinic without pain, and his attending physician accordingly cancelled contemplated treatment by anti-inflammatory steroid injection for pain mitigation. The orthokinetics treatment time-series was A1-B1-A2-C-B2, administered to the patient single blind, and the resulting analgesia supported internal validity and clinical efficacy of the orthokinetic orthosis application.

3) The patient was a 33-year-old man with chronic pain secondary to medial epicondylitis due to a blow

to the right medial epicondyle three months prior to presenting at the occupational therapy clinic. His treatment consisted of a time-series A1-C1-A2-C2-A3-B1-A4-B2, in which the orthokinetics treatment phases B1 and B2 comprised application of three orthokinetic orthoses to the right arm, forearm, and wrist. The results were: in control phases A1, C1, A2, C2, A3 (1 min, PPI = 3), pain was unmitigated. In orthokinetics treatment phase B1 (1 min, PPI = 0), complete temporary analgesia was achieved; in the nontreatment phase A4, gradual reversal of the analgesia occurred (40 min, PPI = 0 - 3); and in the second orthokinetics treatment phase B2, complete orthokineses analgesia was replicated (1 min, PPI = 0). The single blind orthokinetics treatment outcomes supported internal validity of orthokineses analgesia.

Future Plans—Currently, plans for the project include exploration of clinical efficacy of orthokineses analgesia in osteoarthritis, and chronic pain secondary to athletic injuries of the upper and lower extremities. Projected plans include a long-term cooperative clinical trial on the generalizability (external validity) of the application of orthokinetic orthoses in disabling conditions with chronic pain, as well as a long range basic research study plan concerned with testing of a proposed neurophysiological mechanism of orthokineses analgesia. This proposal invoked stimulation by orthokinetic orthoses of cutaneous non-nociceptors, with resulting analgesia through inhibition of dorsal horn nociceptors by an enkephalinergic interneural mechanism, which will be tested utilizing the opiate antagonist naloxone for blocking enkephalin from access to its receptor.

Publications Resulting from This Research

Rehabilitation of Chronic Upper Extremity Pain in Post-CVA Hemiparesis; Tendonitis; and Lateral Epicondylitis by Orthokineses Analgesia. Neeman RL, Costanzo DM, Cline JE, Neeman M, *Canadian Journal of Rehabilitation* 1(1):17-28, September 1987.

The Quantitative Assessment of Knee Orthoses for Control of Ligamentous Instability

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Sponsor: *Science and Engineering Research Council*

Purpose—The object of this project is to quantitatively assess the effectiveness of some of the knee orthoses commonly prescribed for ligamentous injuries and to identify the components of brace design which cause them to act as they do. Using this information, it is hoped to optimize the design of braces prescribed for knees with particular types of instability. It will be interesting to compare these results with the current thinking on brace design.

Progress—The braces being tested include all the commonly used types from simple knee sleeve, through “sports” braces to the “cage” type. The stiffness characteristics of each brace across a joint space are first determined statically by placing it on a model leg consisting of solid calf and thigh sections split at the joint space. The thigh section is constrained, while the calf section can be loaded in such a way as to produce anterior/posterior, medial/lateral, internal/external and valgus/varus loading on the calf section of the brace being tested. This gives the across-joint stiffness of a brace; any deviations from these values while in normal use being attributable to the effective degree of fixation

between brace and bones via the soft tissues.

The braces are then tested dynamically, using an electrogoniometer system which measures the three rotational and three translational motions of the tibia relative to the femur. The goniometer system is designed to be attached to the patient’s leg around the brace so that the two systems do not interfere with each other.

Preliminary Results—The patient is first tested without a brace to obtain a gait pattern for each leg. Comparison of these two then gives the instability artifacts on the pattern of the pathological knee which should be reduced by any effective brace. The gait patterns are then recorded for the pathological knee while using different braces. The degree of effectiveness of each brace is indicated by the reduction in instability artifacts.

In addition, if the brace acts contrary to its theoretical behavior, exhibiting a greater or lesser stiffness than expected in a certain direction, then deductions can be made regarding the efficiency of the fixation between the brace and the underlying skeletal structures.

A Survey of the Current Clinical Use of Gait Analysis in the UK

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Purpose—The principal purpose of this study was to determine the nature and extent of the current clinical usage of the numerous gait analysis and assessment centers in the UK. In addition, a database of the gait centers capable of and willing to provide a clinical service was to be compiled. This would include a profile of each center in terms of equipment available and current areas of specific interests and expertise. Finally, the opinions of the principal workers in the field as to the current status, and future potential, of gait analysis and assessment, were to be canvassed.

Progress—A postal questionnaire was devised, consisting of four basic sections: 1) equipment available; 2) current research interests; 3) clinical service commitments; and, 4) the subjective views of the respondents. This was circulated to 35 centers in both clinical and academic establishments, with known past or current interest in gait analysis and assessment. A total of 25 responses have been received, of which nine stated no current commitment to gait analysis.

Preliminary Results—The survey has provided use-

ful data on the equipment and facilities available in each center, together with details of the service available to prospective referring clinicians, and this data is being incorporated into an updatable database which it is hoped to make more widely available.

The respondents generally felt that gait analysis techniques have a clinical context, if not yet routinely, but the number of referrals to the centers, especially when taken in conjunction with the broad spectrum of pathology types being seen, is still quite small. Of the centers responding with a current interest in gait studies, ten were involved in some clinical work, though only six were seeing more than five patients per month. In recognition of this, a number of areas worthy of further work were identified by the respondents, including work on the methods of data presentation and on the education of the general clinical community. It was also recognized that greater dialogue is required both be-

tween the centers involved in gait analysis and assessment, and with clinicians, in order to more clearly define realistic objectives.

Future Plans/Implications—It is planned to repeat this project at regular intervals, to allow the progress and development of gait analysis and assessment techniques in the clinical environment to be closely monitored, both to stimulate the necessary dialogue between centers and to help in identifying any major areas of concern. In addition, it is hoped that the database of gait analysis centers will be regularly updated and made available to interested parties. A collaborative project to this end with other workers in this field is in the process of development.

The data resulting from this study have been presented at a conference and are in the process of publication.

Anterior versus Posterior Walkers for Children with Cerebral Palsy: A Gait Analysis Study

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Sponsor: *Special Children's Center, Inc.*

Purpose—Posterior walkers are becoming the support of choice for children with cerebral palsy. Their proponents claim more upright and safer ambulation. Our research team attempted to explain this clinical observation by comparing gait studies of seven children.

Progress—We used one style of anterior and one style of posterior walker. Each child walked with each type of walker. Assignment of order was random. Children were filmed with high-speed motion picture film (60 frames/second). Results were obtained by use of a Vanguard Motion Analyzer. Key points of hip flexion, knee flexion, trunk flexion, and ankle flexion were compared. Stick figures were created for key points of the gait cycle. Data for each subject was compared for each condition.

Preliminary Results—Results demonstrated that the posterior walker resulted in decreased hip and trunk flexion or a more upright posture. Knee flexion was

decreased at heel strike and midstance. Decreased double support time was also significant. Statistical significance was determined by a paired T test with significance less than 0.05. Pediatric clinicians have begun using posterior walkers and have judged that they allow clients to be more upright, therefore safer while walking. Our study provides a beginning objective confirmation of this clinical judgment. Decreased hip, trunk and knee flexion at midstance indicates a more upright posture. Decreased double support time indicates improved stability allowing more complete weight shift. This study offers biomechanical rationale for the choice of posterior walker for children with cerebral palsy.

Future Plans/Implications—We are currently adding more subjects to our study as well as looking at differences between two- and four-wheeled walkers. We presented this information in a poster format at the National APTA conference in San Antonio, Texas in June 1987.