V. Functional Assessment

Ambulatory Physiological Monitoring Device

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Purpose—The collection of objective data on the effect of various lower limb prosthesis designs on performance of amputees in the past has been limited essentially to oxygen-uptake measurements and locomotion data taken in laboratory settings. Data taken under such artificial conditions are expensive, and can be misleading because of the limitations inherent in the present systems. As a result, evaluation groups have relied heavily on subjective data reported by subjects using experimental devices. The results are not usually as reliable as investigators consider desirable.

One of the most useful indicators of improved function, comfort, or both, is any change in activity level, or the number of steps taken by the subject over given periods of time. Step counters have been used in the past but have not proven to be useful because the steps taken were not recorded against time in a significant manner.

J. MacGregor, as a Ph.D. candidate, proposed the use of an ambulatory monitoring system that would provide three channels of information recorded against time for a 24-hour period (MacGregor, J. "Rehabilitation Ambulatory "Monitoring," Ch. 18 in *Disability—Proceedings of a Seminar on Rehabilitation of the Disabled*, Kenedi RM, Paul JP, Hughes J, eds. MacMillan, 1979). He used only two channels, one for electrocardiographic signals and one for signals from an accelerometer placed on the chest, to record heartbeats and steps against time.

Progress—Modifications of the MacGregor system permit recordings of heartbeats and steps against time in both analog and digital displays with excellent reliability and extreme accuracy. In addition, whether the patient is standing or sitting is recorded. Counts of steps and heartbeats can be made over periods as short as 20 seconds and as long as 24 hours. The equipment is light enough and sufficiently compact so that ordinary activities of the subject are not impeded.

The system is now being used routinely in the evaluation of the below-knee sockets with flexible brims by the Arthritis Rehabilitation Research Program at the University of Virginia. Other departments and research programs have shown a strong interest in this system.

Preliminary Results—It is believed that the ambulatory physiological system now makes possible scientific evaluation not only of prosthesis components, but of almost any treatment program involving locomotion.

A paper has been written for submission to the *Journal of Rehabilitation Research and Development.* Presentations on the system were prepared for the Annual Conference of the American Physical Therapy Association, June 1986; the Annual Conference of Region VI of the American Orthotic and Prosthetic Association, June 1986; the 39th Annual Conference of the Association on Engineering in Medicine and Biology, September 1986; and the IEEE/EMBS Annual Conference in November 1986.

Long-Term Ambulatory Physiological Surveillance Equipment (LAPSE)

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Purpose—Characterization of the specific extent of a physical handicap and its response to treatment is difficult. The majority of techniques employed are subjective or, at best, are performed on a relatively short time scale in the artificial environment of the hospital or clinic.

LAPSE is intended to study patients over a two-to-three-day span without interfering at all in the intellectual, physical, or social life of the subject. It is based on the acquisition of a very large statistical sample of data relating to patient activity, including changes in posture, mobility, and the associated physiological effort, i.e., heart rate concurrently observed.

Progress—An earlier system based on a miniature analog tape recorder has been superseded by solid-state microprocessor-controlled datalogging elements that can be used to measure or define the lifestyle of the individual patient. Changes brought about by the different managements introduced can be clearly seen from these measurements. Our work is still proceeding on the development of suitable transducers complementary to those already developed. A wide range of clinical applications are under consideration for early implementation.

Predictive Assessment in Prescription of Functional Aids for the Motor Disabled

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Purpose—The goal of this project is to develop data, methods, and theory on which to base prediction of functional gain from therapies and technological intervention. It was proposed that this concept be applied to three handicapping conditions: 1) disabling tremor of the upper extremities; 2) "equinus" and other spastic gait abnormalities; and 3) loss of vocal communication due to impaired articulatory motor control. During the past year, considerable progress has been made in the first two areas. (Work in the last of these areas has for the past two years been supported by other funding.) The motivation for this REC project derives from the impracticality of exhaustive try-it-and-see evaluation of modes of intervention in the clinic.

Progress—During the past year, extensive data have been analyzed from a study of alcoholics with essential tremor conducted collaboratively with Dr. Mindy Aisen, former visiting scientist in the Mechanical Engineering Department at MIT, and Dr. Jorge Romero at the Veterans Administration Medical Center at Brockton. Subjects in that study performed wrist extension/flexion pursuit tracking and postural maintenance tasks presented visually. In some trials, angular displacement was required and various masses were added to the hand. In other trials, isometric torque was required and the display gain was varied.

Preliminary Results—The results show that most of this group of eight subjects had tremor characterized by two frequency peaks, one at 8 to 10 Hz and another at 4 to 7 Hz. The two spectral bands behaved very differently with respect to their variation with the experimental parameters. The lower frequency component was influenced by biomechanical factors, whereas the higher frequency component was not. This is significant in part because it is distinctly different from the response to load factors observed in intention tremor measured in

earlier studies by this group. This outcome supports our expectation that the sequence of mechanical load application and spectral processing may serve as a clinical "probe" into a patient's tremor, one which generates a description of tremor at a level closely related to its physiological mechanism. The working assumption is that such a description stands a greater chance of being predictive of the success of a therapeutic approach than standard methods of clinical evaluation and classification.

In the area of spastic gait, work has continued on the development of the wearable, computer-controlled ankle orthosis simulator. This system, developed here by Brian Maki, applies energy-dissipating torques about the ankle under the control of software running at the time of the experiment on a laboratory minicomputer. By applying different control algorithms, various damping-like load profiles can be tried with changes only in software. The goal is to find the load that minimizes "equinus" and back-kneeing without unacceptable other effects on gait. In order to make the process of identification of optimal values for load parameters more rapid, Tom Hedman had developed an on-line search algorithm that computes the value of an optimization function after each walking trial and adjusts the value of damping constant for the next trial. This methodology has been tried on four cerebral-palsied subjects during the past year. The program was technically successful in all cases, and in one subject a significant optimum with respect to damping constant was found. This outcome supports two tentative conclusions: the technique of human-interactive stimulation can be a practical clinical method for customizing a complaint ankle orthosis for a particular client (or for establishing its ineffectiveness); and, it appears that such an assessment will be essential since the clinical observation of "equinus" does not necessarily predict the effectiveness of such a brace.

Improved Methods of Quantification of Function/Performance

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Purpose—The University of Texas at Arlington (UTA), the Dallas Rehabilitation Institute (DRI), the University of Texas Health Science Center at Dallas (UTHSCD), and the Dallas Rehabilitation Foundation (DRF) have formed a research consortium that established the Center for Advanced Rehabilitation Engineering (CARE). The primary research goal is to develop improved methods for quantification of human performance/function in handicapped individuals. Central to this effort is the computer-automated measurement system developed in the joint UTA/UTHSCD Biomedical Engineering Program.

Progress—The system includes measurements of mental alertness, vision, hearing, speech, steadiness, reactions, tactile sensations, manual dexterity, range of motion, speed and coordination, postural stability and control, selected activities of daily living, strength, resistance to passive motion, and fatigue. Research to evaluate the system's reliability and utility for assessing performance and the function of handicapped individuals has progressed. The system is also used to help answer clinical and scientific research questions.

Future Plans—The laboratory is being expanded to include assessments of gait and proprioception as well as some of the above functions at new body sites. New instruments, a database, and test result report software continue to develop.

Development of a Computer-Automated System for Functional Assessment

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Purpose—We have developed a computer-automated system to quantitatively measure a broad selection of sensory and motor functions. The objectives of this project are to further develop and expand the basic system and to prepare and evaluate two complete prototype systems for evaluation and application studies at our clinical settings, the University of Texas Health Science Center at Dallas (UTHSCD), and the Dallas Rehabilitation Institute (DRI). In this battery of tests, each function is measured during very specific, simple, and short-duration tasks that usually involve responses to computer-generated stimuli. Special-purpose transducer modules have been designed to convert responses into voltages for digitization by computer. Signal processing algorithms compute single number results for most tests that quantitatively indicate the level of a specific function.

Progress—A database management system, with interactive test result inspection capabilities, has been implemented. At present, the database contains more than 2000 subject records of sensory and motor function, divided approximately equally between patients with various handicaps and normal data that are essential to interpret patient findings properly. It is possible, through a computerized process, to collect any or all of more than 200 measures of sensory and motor function, deposit results in the database, and examine an individual's results by comparison to a selected subset of the normal population. Results are expressed in terms of standard deviations from the selected comparison population. During the past year, new cooperative research (which allows replications of the system to be used and evaluated at external sites) has begun between the San Antonio Sports Medicine and Rehabilitation Clinic, St. Paul Hospital Human Performance Center (Dallas), National Rehabilitation Hospital (Washington, DC), Wadsworth VAMC (Los Angeles), and Dallas VAMC. This added to other external sites, all linked together via the common database, at Chicago Shriners Hospital and Cordis Corporation (Miami).

Preliminary Results—The Biocurve Tracer, a large-volume three-dimensional digitizer, has been evaluated for obtaining range-of-motion measures in simple joints as well as the spine. In addition, a method has been developed to use it to measure spinal curvature. Evaluations indicate results comparable to other techniques that do not offer the ease of administration and computer-based logging of results.

While many system measures have been well established and are in regular use, recent work focused on extracting new meaningful measures during established protocols, at no expense of test administration time. Specifically, additional measures of coordination, tremor, fatigue, and posture (via the Biocurve Tracer) have been identified. In addition, quantification of speech motor function has received emphasis during this period. A systematic function-oriented approach, based on our previous measurement philosophy for extralaryngeal sites, has been established and is being evaluated experimentally in this study.

Software for personal computers has been developed to allow interface to the database and display of individual results as well as test-retest comparisons in various easy-to-interpret forms, such as graphical mappings of function to anatomy. Color-coded schemes are used to represent levels of relevant sensory and motor functions at each site. Work in expert systems

to provide more refined information to neurologists, orthopaedists, physical therapists, occupational therapists, and vocational experts has also progressed. One such system employs function measurements; the database; mapping rules (for function to body sites and actions, muscles, and innervation); and dysfunction pattern rules in an attempt to localize and quantify the extent of lesions in the neuromuscular system.

Clinical Evaluation and Application of a Computer-Automated System for Functional Assessment—Part 1

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Purpose—A prototype of the Center's computer-automated human performance measurement system is being evaluated for test-retest repeatability and effects of age, gender, and handedness while gathering normal sensory and motor function data, as well as short-and-long-term stability of patient data. Other research studies involving rehabilitation and investigative applications of the system are being carried out at this center in cooperation with local investigators.

Progress—Significant progress has been made in measurement of screened normal individuals to establish a sensory and motor function database. To date, norms for approximately 150 measures have been obtained with the following age breakdowns for data records: 2 ($\leqslant$10 yrs), 32 (10-19 yrs), 494 (20-29 yrs), 201 (30-39 yrs), 60 (40-49 yrs), 87 (50-59 yrs), 123 (60-69 yrs), 59 (70-79 yrs), 9 ($\geqslant$80 yrs). Many subjects were tested and retested no less than 1 week and no more than 2 weeks later. Test-retest data are being used in large-scale studies of reliability and learning effects. In one study, results indicate that 87 of 102 measurement variables included show very good reliability (reliability coefficient $\geqslant$0.75), and only nine variables indicated significant learning effects. Timed activities of daily living measures were shown to be the least reliable.

Preliminary Results—Data collection for short-term learning (same subjects evaluated repeatedly on 5 consecutive days) and effects of technician and test site (same subjects evaluated at different sites by same technician as well as same site by different technicians) have been completed and analyses are under way. Results are important to document potential sources of measurement variability with the system in typical clinical use. Long-term changes in normal and handicapped function, where subjects are recalled annually for retests, are being studied. Thus far, more than 60 subjects have responded and have been retested.

Patients with progressive neurologic diseases such as Parkinson's disease, multiple sclerosis, myasthenia gravis, Huntington's disease, and chronic low back pain are also being characterized and studied. In 45 post-surgical low back pain patients, preliminary results show some loss of function compared to age-matched norms in every function category measured (including mental status and upper extremity function), although, in general, the loss is greater for lower extremities and whole body balance and reaction functions.

To begin to integrate the system into routine clinical use, local clinicians have been invited to refer individual patients for function measurement workups. Clinicians are provided with printed standard report forms and, if requested, interpretation assistance.

Clinical Evaluation and Application of a Computer-Automated System for Functional Assessment—Part 2

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Purpose—A second prototype of the Center's computer-automated human performance measurement system is being evaluated clinically and used to conduct studies of rehabilitation significance at the Dallas Rehabilitation Institute (DRI). Work at this site has been under way to characterize the function of patients with head injuries, spinal cord injuries and peripheral neuromuscular damage, cerebral palsy, amputated limbs, spinal pain, and arthritis. Data are being used to develop functional profiles and databases of these conditions, as well as to document effects of therapy and recovery trends. Over the past three years, over 650 evaluations have been made on 274 subjects.

Progress—As experience with these patient groups increased, several modifications to test devices were found necessary and adaptations were implemented. Progress in studies of system evaluation and database establishment parallels that detailed for our UTHSCD clinical site, as these studies were jointly undertaken.

Progress continues in the study of head injury patients. The effects of a cognitive remediation program on functional performance are being studied in a subset of head-injured patients, with measurements before entry and at 2-month follow-up intervals. In addition, research to predict level of independence in tasks such as grooming and feeding for basic quantitative measures of function has been initiated. An expert system approach was utilized. Initial results indicated high potential for successful objective classification. A similar approach was utilized to screen head-injured subjects for driver training.

Work continued to progress in quantitative characterization of spinal-cord-injury patients and their rehabilitation progress. A total of 166 evaluations were made, many of which represent retests at regular intervals. This subset database will serve as the basis for evaluating the efficacy of therapeutic regimens as well as for increasing the knowledge regarding spinal cord injury recovery. In addition, handicapped volunteers began to establish a database of stable wheelchair-bound individuals who will participate in studies of long-term exercise value.

Preliminary Results—A questionnaire research survey of quantification requirements to evaluate functional electrical stimulation (FES) effectiveness was also carried out as a first step toward meeting needs in this area. Among findings, it was documented that of the 116 measurements listed in the survey, only 8 were clearly determined to be unacceptable, while 82 were considered to be at least "effective." Results will be used to assess the system's current measurement capabilities in this domain, to promote the use of quantitative measures in documenting FES effectiveness, and to map out research priorities for the future.

Quantification of Mobility Performance for Functional Assessment, Diagnosis, and Therapy of Neuromuscular, Skeletal, and Synovial Joint Dysfunctions

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Purpose—Functional assessment of disabling mobility disorders requires reliable methods for quantitatively documenting the kinematic and dynamic state of the movement-impaired indi-

vidual. Such methods can enhance confidence in determining the effectiveness of surgical and/or rehabilitative procedures. This project involves an assessment process that goes beyond documenting the status of the patient by providing simulations of the consequences of different muscular skeletal surgical procedures, thereby affording the medical practitioner the opportunity to experiment with different approaches, to optimize the parameters of a particular intercession, or decide that the simulated outcome does not warrant the hazards and liabilities of intervention.

Progress—Computer-Aided Surgical Simulation (CASS) is a computer-based system whose antecedent was Computer-Aided Design (CAD), now widely applied in engineering. A similar approach provides the surgeon with a computer graphics display of the patient's anatomy, on which a tentative orthopaedic procedure can be implemented. Representations of the patient's movement patterns in the computer database are altered by the simulated intervention, and the computer displays the effect on the patient's posture, mobility, joint range-of-motion, etc. The surgeon is then free to alter and optimize the procedure until satisfied or perhaps abandon it, all before actual surgical intervention takes place.

Preliminary Results—The project is subdivided into four tasks: mobility analysis, patient-specific anatomical representation, individual muscle activity determination, and surgeon/computer interfacing.

Mobility Analysis. The Selspot TRACK systems at the Massachusetts Institute of Technology and Massachusetts General Hospital have been enhanced and applied in several relevant studies. Accurate and detailed knowledge of the instantaneous axes of rotation of conjugate body segments are essential to confident calculation of movement dynamics. A definitive study of alternate kinematic methods for calculating the instantaneous axes of the segmental joints was conducted using TRACK data from the human ankle, knee, and hip and, for evaluation of experimental accuracy, from a mechanical pendulum. The finite displacement method was shown to be superior. A novel computer display of human movement kinematics, employing solid body segments rather than the typical stick figures and implementing the orientation data from the TRACK system, was demonstrated.

An automatic calibration scheme to compensate for the inherent optical and transducer nonlinearities of Selspot cameras was developed. Improvements were achieved in noise-reduction of kinematic data. A definitive study on the frequency content of gait with implications for the required bandwidth of gait analysis systems was published.

The pressure-sensing instrumented hip prosthesis has been in place now for more than two years and is performing superbly both for the subject's benefit and as a data source. The new information is challenging the traditional understanding of synovial joint mechanics and of muscular action during normal movements. It will profoundly affect orthopaedic surgical practice and rehabilitation following all kinds of major hip surgery.

Patient-Specific Anatomical Representation. The use of computer tomographic (CT) and magnetic resonance imaging (MRI) scan data to generate patient-specific computer-driven color graphic displays of anatomy were advanced both by the development of new software and by the acquisition and networking of new computer hardware. The emphasis is on the automatic extraction via pattern recognition of anatomical contours from the cross-sectional slices produced by computer tomography, the assembly of such two-dimensional information into three-dimensional solid objects for computer display and animation, and on the developments of compact, effective means for the storage and retrieval of great masses of such data.

Surgeon/Computer Interfacing. To be employed effectively by, and accepted by, the medical profession, computer-aided surgical simulation must employ and exploit, in a natural fashion, the inherent knowledge and skills of the orthopaedic surgeon without imposing new additional training burdens. To assess the effectiveness of the anatomical displays, to explore

how best to control simulated surgical intervention, and to evaluate the surgeon's interpretation of the mobility changes brought about by the simulated surgery, a case study of inter-trochanteric osteotomy is under way.

In osteotomy, the surgeon's goal is to deliberately sever the femur, remove a slice or wedge of bone, and reorient the femoral components three-dimensionally so as to put an area of normal cartilage in the load-bearing region, moving the damaged cartilage to an unloaded area. In so realigning the joint, however, the surgeon must continue to satisfy the physiological range of motion of the joint and must not interfere with normal gait patterns.

Upper Extremity Control Utilizing Functional Neuromuscular Stimulation (FNS)

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Purpose—The purpose of this project is to evaluate the performance of a functional neuromuscular stimulation neural prosthesis in paralyzed human subjects for restoration of hand function.

Progress—Since 1978, we have evaluated 26 subjects who have sustained complete traumatic spinal cord injury at the C5 or C6 level. Paralyzed muscles are implanted with chronically indwelling percutaneous electrodes for control of lateral prehension-release and palmar prehension-release. Control is proportional and is provided by a volitional command of the subject, usually via the contralateral shoulder.

Functional assessment of clinical function is accomplished through a four-part testing protocol consisting of sensory evaluation, range of motion, manual muscle testing and muscle excitability, and functional evaluation. The last component of functional evaluation incorporates the Jebsen Hand Test (JHT), performance of isolated basic tasks, performance of coordinated tasks, and performance of integrated tasks.

The majority of testing is with nine subjects who are presently most active in our program and who are provided both grasp patterns. Examples of the various tasks demonstrated by the subjects are: 1) passive grasp (because the system does not necessarily have to be active and the user may wish to accomplish certain tasks without active grasp); 2) active grasp of utensils, books, writing instruments, telephone, cups, etc.; 3) integrated tasks such as pouring, washing, diskette handling, brushing teeth; and 4) advanced tasks such as threading a needle, self-catheterization.

Preliminary Results—Most functional activities required the use of either a passive orthosis (PO) or the neuroprosthesis (NP). For example, feeding with utensils or writing could be accomplished with either the PO or NP. Feeding finger foods and drinking required NP usage. The most dramatic difference was in performance of transition tasks involving grasp, pickup and position, and release. A fork, pen, diskette, napkin, small book, and phone receiver were tested. All tasks required the NP in all subjects with the exception of the napkin, which 9 of 9 could accomplish passively, and the phone receiver, which 1 of 9 could accomplish passively. Because most hand tasks are of a transition nature, we interpret this aspect of performance as significant.

The results of these tests highlighted certain deficiencies in our present program that form the focus of future clinical effort. Goals include improving our training program to provide the subject with better planning strategy and providing smoother means for making transitions between grasping patterns.

We also have begun to apply the hand control technique to stroke/head-injury subjects. To date, one subject has been entered into the project. We have demonstrated qualitatively that flexor spasticity is reduced with short peri-

ods of stimulation, enabling us to provide full hand opening with FNS. Voluntary control of grasp, albeit abnormal mass patterns, is possible in the subject. Thus, at this early stage we are focusing activity on reducing flexor spasticity to enable release functions through functional neuromuscular stimulation.

Nerve-Bundle Conduction Velocity Distributions: Clinical and Research Applications

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Purpose—Measurement of nerve conduction velocity (CV) is an important element in the electrophysiological evaluation of patients with suspected neuromuscular disorders. Conventional methods of determining nerve CV focus predominantly or exclusively on the velocity of the fastest-conducting (largest diameter) fibers in the nerve bundle. The properties of slower-conducting fibers, which constitute the majority of elements in the nerve bundle, are traditionally assessed only indirectly, or not at all.

The capability to estimate the conduction velocities of the various classes of nerve fibers composing the nerve bundle may be expected to enhance the sensitivity and specificity of neuromuscular electrodiagnosis, to improve the functional assessment of injured nerves, and to facilitate the quantitative evaluation of therapies for nerve diseases and injuries.

Progress—We developed a computer-based method for estimating the distribution of conduction velocities (DCV) in the subpopulation of large myelinated fibers composing human peripheral nerves. The method operates on surface-recorded compound nerve action potentials and is distinguished by its generality and its suitability for clinical implementation in the electroneuromyography laboratory.

Preliminary Results—Seven journal articles and one book have been published. Clinical trials were set in motion, and the transition into regular clinical use was set under way at Stanford and at several other laboratories. DCV analysis was applied to the study of experimental nerve repair and regeneration. Discussions were conducted regarding commercial distribution of this technology.

Future Plans—Our hypotheses are: 1) that ongoing clinical trials of DCV analysis will confirm its diagnostic superiority to conventional measures of nerve CV; 2) that DCV analysis will yield insights into the pathophysiology of neuromuscular disorders and nerve injuries; and 3) that DCV analysis may be implemented on existing electroneuromyographic equipment, so as to be more widely available for evaluating patients with neuromuscular disabilities.

Toward this end, DCV analysis has been and continues to be applied in normal individuals, and in patients with diabetic neuropathy, nerve injury, amyotrophic lateral sclerosis, multiple sclerosis, and other conditions. The DCV findings in these individuals are compared and contrasted with those from conventional nerve CV measurements. Different methods of DCV analysis have been compared in normal individuals and in patients. DCV analysis has been implemented on one commercial electroneuromyograph, and a second implementation is under consideration.

Psychiatric Symptoms and the Functional Capacity to Work

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Purpose—The purpose of the present study is to develop and empirically validate an operationalized psychiatric and behavioral assessment protocol to determine vocational capacity in psychiatrically impaired individuals. This is a 3-year project to establish criteria for determining qualifications for Social Security disability payments.

There are two major components of the project: psychiatric symptomatology and a functional assessment of vocational ability. All patients are given a psychiatric evaluation, consisting of structured interviews for determining diagnoses and current levels of symptomatology, before beginning the functional assessment phase of the protocol. Levels of symptomatology are also assessed throughout the functional assessment phase. Following this evaluation, psychiatric patients are randomly assigned to either a 3-day or 3-week assessment of their vocational abilities.

Progress—The functional assessments were conducted in a sheltered workshop setting on the grounds of the West Los Angeles Veterans Administration Medical Center. Subjects were assigned to work on four different tasks during the assessment period. These tasks (i.e., folding and packaging hand-towels; filing index cards; assembling electronic circuits; and assembling the flush mechanism for toilet tanks) assessed a variety of job-related skills. A wide range of measures were collected in this setting, including productivity rate, quality of work, attendance, punctuality, acceptability of appearance, ability to work independently, ability to follow instructions, ability to solve problems in cooperation with others, and interactions with peers. Most of these measures were taken under conditions of both high and low demand.

Preliminary Results—Subjects were divided into four groups for analytic purposes: 1) psychotic—on disability; 2) psychotic—not on disability; 3) nonpsychotic—on disability; and 4) nonpsychotic—not on disability. At this point, 130 subjects have begun the functional assessment phase of the project. Of the 77 subjects assigned to the 3-day assessment, 62 (80.5 percent) completed at least 80 percent of their assigned task assessments. Of the 53 subjects assigned to the 3-week assessment, 32 (60.4 percent) completed at least 80 percent of their assigned task assessments.

These data are important with this population, as absentee rates frequently rise dramatically with symptom exacerbation. Subjects in the psychotic-disabled group have shown the least tolerance for the work setting, dropping out of the study at much higher rates than subjects in the other groups. Subjects in this group also perform more poorly on measures of work performance than those in the other groups.

Future Plans—The protocol of the study calls for 300 subjects, 170 of whom have yet to participate in the project. After all the data have been collected, multivariate analyses will be conducted to determine differences between the groups on psychiatric symptomatology, work performance, the ability to tolerate stress in the work setting, and/or historical variables. A work performance index will be developed as a standard for determining vocational ability. The relationship between psychiatric symptomatology and the functional ability to work will be clarified to a large extent by the results of this study.

Development and Evaluation of Dynamic Pedobarograph (DPBG) System for Clinical Use

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Sponsor: *Scottish Home and Health Department*

Progress—The Department of Medical Physics at the Royal Hallamshire Hospital in Sheffield has developed a system for measuring and displaying dynamic pressures acting between the foot and the floor. The equipment is based on the pedobarograph developed by Chodera of Roehampton and consists of a piece of thick glass illuminated at two opposite edges by fluorescent strip lights. A thin sheet of opaque reflective plastic covers the top surface of the glass. As the subject stands on the plastic, the pressure generated between it and the glass breaks down the total internal reflection of light within the glass. When viewed from below, a variable light image of the foot is observed, the intensity of which is proportional to the magnitude of pressure. The image is recorded by a monochrome television camera and can subsequently be presented as images of pressure distribution.

Future Plans—To justify the provision of a fairly expensive piece of equipment in the orthopaedic clinic, a number of questions must be answered. The project aim, therefore, is first to determine whether the information that is obtained is reliable. It is well known that the response characteristics of the plastic will affect data produced from dynamic measurements. To compensate, the total vertical load applied is correlated with the pressure readings and the areas associated with these pressures. It is intended to perform a series of closely controlled physical tests in order to validate the compensation procedures. Pressure measurements obtained from a walking subject will vary significantly depending on body movements rather than foot deformities. A record of the pattern of body movements will be obtained using two video camera recording systems viewing from the front and the side.

Secondly, we intend to determine if the information is of clinical use to the orthopaedic surgeon. Initially, a variety of data presentation techniques will be used to determine which provides the most useful information. A comparison of the diagnosis from DPBG results will be made with those obtained from other forms of data presentation currently used in the clinic (X-rays, patient examination) in order to assess usefulness of the pedobarograph in providing a more accurate diagnosis.

Finally, the DPBG will be used as a preoperative and postoperative monitor of patients undergoing foot surgery. Initially, we intend to concentrate on *Hallux Valgus*, *Hallux Rigidus* and Claw Toes patients.