Journal of Rehabilitation Research and Development
Rehabilitation R & D Progress Reports 1983

Spinal Cord Injury

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Spinal Cord Injury R&D

In this section, under the broad heading of Spinal Cord Injury R&D, reports in the following general areas will be found: **Electrical Stimulation and Gait Analysis; Robotics; Mobility Aids** including **Wheelchairs, Wheelchair Accessories, Controllers and Lifts, Decubitus Ulcer/Seat Cushions, Automotive Adaptive Equipment; ADL and Recreation; Treatment and Training; Diagnostics and Information; Spinal Trauma, Musculoskeletal Rehabilitation; Information.**

ELECTRICAL STIMULATION AND GAIT ANALYSIS

LIBERTY MUTUAL, NIHR, SWEDEN

VOLUNTARY NERVE SIGNALS FROM PRIMATES

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In order to control additional degrees of freedom in our electromechanical prosthesis (the Boston Elbow) according to our concept of using control signals most directly related to the movement to be duplicated, neuroelectrical signals obtained from the severed nerves in the arm will be required. An elaborate experiment was initiated using a primate trained to perform movements duplicating two desired functions of the Boston Elbow. By using either wrist or finger movements, the primate was trained to track a computer-generated moving target. A juice reward was given for each correct response and the computer kept score of the results. After the training period was completed, two of our previously designed recording electrode units were successfully implanted in its arm around each of the two nerves controlling finger extension/flexion and wrist rotation. Both sensory and motor-nerve signals from wrist and finger motions were recorded while the primate performed the tracking tasks. The signals were processed and analyzed using a digital computer. The preliminary results indicate a correlation between the intended task and neuroelectric activity in each nerve ■

NIHR REC

RESTORATION OF UPPER LIMB FUNCTION THROUGH FES

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These studies are the core area of research in the center. The purpose of the project is to develop and evaluate systems employing functional electrical stimulation to provide control of hand movement. These studies are being performed in conjunction with the VA Rehabilitation Engineering R&D program, and the current status is detailed in a progress report that appears elsewhere in this issue ■

VAMC CLEVELAND

FUNCTIONAL NEUROMUSCULAR SYSTEMS FOR UPPER EXTREMITY CONTROL

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Part 1. Development of Upper Extremity Orthoses Employing Electrical Stimulation

A neuroprosthetic system has been developed to restore upper-extremity control through application of functional neuromuscular stimulation. This tech-

nique enables the C5 and C6 level quadriplegic to utilize his hand functionally.

System Description — Subjects with C5 or C6 level function are candidates for use of the system. Control of the system employs a voluntary command generated by the patient to activate coordinated movement of the hand. This voluntary command proportionally regulates the output of up to four channels of stimulation. The stimulus output of each channel is modulated according to a coordination algorithm determined in laboratory studies, to provide satisfactory motion for the set of muscles and electrodes employed in the particular individual.

System Implementation — Muscles to be stimulated are those which can be used to provide either a lateral prehension/release or palmar prehension/release and have the lower motor neuron intact. Generally eight or nine muscles are implanted, including the finger flexors (flexor digitorum superficialis and profundus), finger and thumb extensors (extensor digitorum communis and extensor pollicus longus), and thumb intrinsics (abductor pollicus brevis, flexor pollicus brevis, and adductor pollicus). These muscles are implanted with percutaneous coiled wire electrodes.

Portable Functional Electrical Stimulation System — A portable functional electrical stimulation system utilizing a microprocessor has been developed. Incorporation of the microprocessor has resulted in a user device which can be programmed to accept and process a variety of user-generated commands and to output complicated stimulus patterns. The availability of these enhanced stimulus regimes and more complex user-control algorithms enable us to tailor the device to a larger population of potential users.

System Use: The microprocessor-based portable electrical stimulation system has provided us with a functionally more powerful system than our earlier discrete logic systems. The advantages that are most evident are the simplicity in fabrication of each unit, the ease in establishing input control processing and output stimulation schemes, and the fact that each unit is identical and not patient-specified prior to the assembly of the device. With previous systems, much time was spent in hardware fabrication due to variations in the user control algorithm.

Patients' Use of Functional Stimulation System — Subjects are provided with the functional system for training and use. The use of the system is incorporated into the regular inpatient occupational therapy program. The occupational therapist and rehabilitation engineer jointly train the subject. Patients may be fitted with the system as soon as they are medically stable and ready to accept an assistive device.

Thirteen patients have been provided with the FES hand assist system.

Patients use the system for combing hair, brushing teeth, applying toothpaste to toothbrush, shaving with electric or safety razor, washing face and neck, eating and drinking, writing, and self-catheterization. The patient wears his neuroprosthesis throughout the day to have the flexibility of independently performing a functional task at his discretion.

The present system has had 344 user-months of evaluation. Some of the problems encountered include external cables (connecting electrodes and control transducer to the stimulator) which are encumbering, and percutaneous electrodes which require maintenance of the implant site. (To overcome these problems, we are presently developing an implantable stimulator.) However, despite these deficiencies, at the present level of development the FES system is sufficiently reliable and functional and it is, in general, prescribed and used as the primary functional orthosis for high level spinal injury patients at our Center.

Part 2. Implantable Systems for Stimulation of Skeletal Muscle

An implantable muscle stimulator has been developed using semi-custom integrated circuit technology. The unit is reliable, small, lightweight, has low power consumption, allows freedom of movement, and is intended for permanent usage.

The stimulator circuitry is externally controlled and powered by a single encoded radio-frequency powering carrier. Up to eight independently controlled stimulus output channels are provided, with the output channel selection, stimulus pulse width, and stimulus pulse frequency all under external control. A constant-current biphasic stimulus pulse is used, in which the stimulus current amplitude can be programmed by a single resistor value. The stimulator circuitry has been implemented in thick film hybrid form, and has been undergoing laboratory evaluation for 16 months.

The stimulator circuitry has been encapsulated in glass-ceramic packages for use with long-term animal evaluation. Hermetically sealed titanium packaging, suitable for implantation in human subjects, is currently being developed. Stimulating electrodes have been developed that are mechanically reliable and provide stable stimulus characteristics.

Both laboratory testing and animal evaluation have been performed. In vitro studies are ongoing to

determine the responses of the electrodes to extended periods of stimulation. Animal evaluation has been used to address the overall system performance; stimulators have been operational in animals for more than 10 months.

The development of this system consists of three main areas; electronics, packaging, and stimulation electrodes ■

VA RR&D CENTER PALO ALTO

NEUROMUSCULAR MODELS WITH APPLICATION TO REHABILITATION AND TO FES OF PARALYZED MUSCLES

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■ Participants in the Neuromuscular Model project were the following:

From the Rehabilitation R&D Center, PAVAMC: **Felix E. Zajac, Ph. D.**, and **Michael R. Zomlefer, Ph. D.**

From the Department of Electrical Engineering, University of Maryland: **William S. Levine, Ph. D.**, and **Jean-Pol Chapelier.**

Need — Spinal cord injured persons and others with severe motor disabilities need to regain use of their extremities.

Our knowledge of how the CNS coordinates muscles and how this array of muscle action affects motion of the limbs and the interaction of the limbs with the environment is scant.

Approach — Motor control physiologists studying body motion have focused on understanding single-joint movement using EMG, kinesiological, single unit and in vivo force recordings. Except for descriptions of the neuromuscular events correlated with the movement under study, these studies have resulted in few predictive theories for motor control. On the other hand, biomechanicians have studied movement by computing joint torques and forces from measurements of body motion using as a basis dynamical models of multi-jointed structures. While such studies have been fruitful, particularly in the design of artificial joints, they have had limited success in enhancing our knowledge of intermuscular coordination.

Analytical and computational models of the neuromuscular system can be used to understand the role of tendon elasticity and muscle strength, elasticity, speed, and coordination on body movement. Optimization theory applied to neuromuscular control has the potential to define the pattern by which single muscles ought to be coordinated for the body to achieve a specific motor task. Critical to these models is a representation of muscle that uses the fundamental properties of muscle as a basis, and yet is simple enough for computer implementation.

We chose an approach to muscle modeling that is robust. It purports that generic to skeletal muscle and tendon is architecture (i.e., the geometric composition of sarcomeres and the geometric relationship of muscle to tendon) and sarcomere dynamics. The approach assumes that one model will differ in complexity from another primarily because the sarcomere properties deemed important to understand one motor behavior may differ from those of the other. Tendon properties and origin-insertion geometry are included, since we are interested in assessing how energy storage mechanisms in tendon and muscle contribute to human movement.

Status — At the moment we are using this model to study the quadriceps muscle. We find that computed isometric torque-angle and isokinetic torque-velocity curves are similar to those obtained by subjects exercising in a Cybex instrument. We are exploring ways to use data collected non-invasively in the clinic to estimate tendon and muscle properties of the rectis femoris and vasti groups (e.g., the number of sarcomeres in the muscle fibers, the physiological cross-sectional area of each muscle group, and tendon elasticity).

Development of a more complex neuromuscular model of lower limbs is planned. The model will be developed to assist in gaining an understanding of how sensitive standing and walking are to muscle strength, elasticity, coordination, and other factors. This approach can be used to suggest optimal strategies of muscular coordination needed to restore standing and walking in the spinal cord injured person via functional electrical stimulation ■

VA RR&D CENTER PALO ALTO

UTILIZATION OF SOMATOSENSORY SIGNALS IN THE GUIDANCE OF VOLUNTARY MOVEMENT

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Need — Disease or injury of the nervous system often results in a loss of the somatosensory information requisite for the execution of skilled motor performances. This consequence extends to the use by individuals of myoelectrically controlled pros-

theses or electrically activated musculature, where visual feedback remains the sole means of performance monitoring. Unfortunately, we have comparatively little understanding of how somatosensory cues enter into voluntary movement programming — and we will need this knowledge both to understand sensorimotor dysfunction and to develop effective restorative measures.

Approach — On the basis of earlier studies, we have hypothesized that the CNS interprets somatosensory cues differently during movement than it does during quiescence. Such movement-related alterations in processing should be detectable in a variety of ways, among them:

1. Changes in the electromyographic (EMG) properties of short-latency reflexes evoked by somatosensory inputs;
2. Changes in the properties of cortical somatosensory evoked potentials (SEPs) triggered by those inputs; and
3. Changes in the conscious perception or interpretation of somatosensory cues.

We have explored all of these possibilities using techniques in which the EMG, SEP, and perceptual consequences of sudden movement perturbations are recorded in human subjects attempting to perform prescribed motor activities with forearm, wrist, or index finger.

Status — The character of voluntary motor effort has indeed proved material in prescribing CNS reactions to somatosensory input. Thus, for example, we have found that the "normal" Sherringtonian reciprocal reflex linkage between antagonistic muscle pairs can be "reversed" into a co-active relationship when the CNS voluntarily uses such muscles against nonskeletal, external loads. We have also observed that brief perturbations of joint position during voluntary activity are neither correctly perceived, nor capable of SEP production — even though the same perturbations generate both potent SEPs and proper perceptual reports during motor quiescence. It thus seems quite clear to us that any scheme for utilizing somatosensory feedback to improve prosthetic or "natural" motor skills will require more than just the literal transduction of physical signals (position, force, velocity, etc.). Provision must also be made to identify those times during a motor performance when the CNS is best capable of making use of such data.

Pending — Our present aim is to characterize quantitatively the relationship between voluntary motor effort and changes in somatosensory processing. To date, for example, we have demonstrated a nearly linear relationship between the amplitude of SEPs evoked by movement perturbations and the error rates of subjects attempting to identify certain perturbation properties. A similar relationship may hold between SEP amplitude and the rate of force alterations (both increases and decreases) in an isometric motor task. We also anticipate further studies in which we attempt to characterize the voluntary "intent" of moving subjects by identifying those variables of movement (e.g., EMG, force, directionality, etc.) that appear to be most closely regulated ■

NIHR REC

SENSORY SUBSTITUTION USING ELECTROCUTANEOUS STIMULATION

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The objective of this project is to develop feedback devices that will provide information about grasp force and extent of hand opening to persons having asensory hands. The intended users will mainly be upper-limb amputees who are fitted with myoelectric terminal devices, and C5 and C6 level spinal injury patients who are using functional neuromuscular stimulation systems to achieve functional grasp.

Electrodes — The subdermal electrodes that are initially being evaluated are made of tightly coiled, fine stainless steel wire, similar to those developed by Caldwell and Reswick.

The electrodes have been allowed to remain in place for many months. A cumulative total of 16 electrodes have been implanted in seven adult male subjects.

Stimulus Parameters — Stimuli consisted of monophasic, capacitively coupled, rectangular pulses presented either as single pulses or bursts. For the case of subdermal stimulation, a constant-current source was used, but when the skin was stimulated using surface electrodes, a constant-voltage source was employed. Pulse widths of 10-100 microseconds have been tried and these consistently elicited clear, distinctive sensations reported as having a "tapping" or a vibratory quality (depending on the stimulus frequency) which was localized to the electrode site.

Threshold Stability — Thresholds for electrocutaneous sensation using identical subdermal electrodes are found to require levels of current in

the range of 0.3-6.0 milliamperes (ma), the level seems to depend upon conditions for each individual electrode and becomes apparent only after it has been installed.

The distribution of the threshold currents for 16 electrodes at approximately 7 days following implantation is shown in Figure 1. The thresholds range from 0.3 to 6.0 ma with a mean of 1.4 ma. For 8 of these electrodes that were studied for at least 30 days, the mean current was 1.2 ma at day 7 and this value was unchanged at day 30. These data indicate that the electrodes retain their ability to stimulate the skin within reasonable limits of current. Mechanical stability of the electrodes within the tissues appears to be adequate.

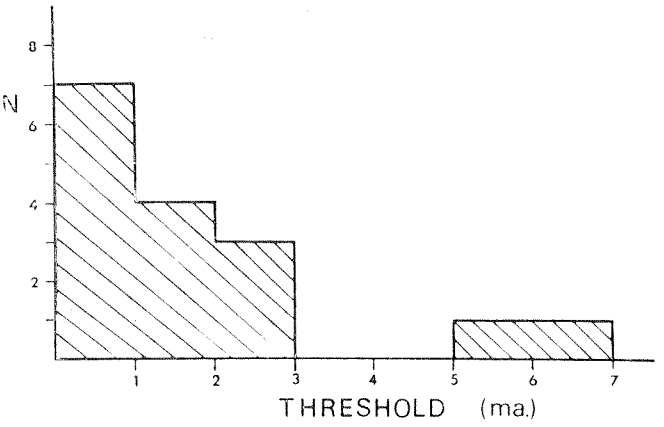

FIGURE 1
Distribution of threshold current for subdermal electrodes.

Dynamic Operational Range — A considerable variation in dynamic ratio has been found among the several electrodes that have been installed. Since the geometry of the electrodes themselves was carefully controlled, we attribute their performance variability to our inability to position them under the skin at identical depths and with identical proximity to the neural elements that the electrical stimuli excite. A further source of variability in the dynamic ratio derives from each individual's subjective impression of the level of discomfort that constitutes an unacceptable electrocutaneous sensation. It should be pointed out, however, that in the same individual, one electrode installation may feel very "good", in terms of its ability to induce clear, distinct, and comfortable sensations, while another electrode which is placed in the same skin region under apparently identical conditions, might have less favorable qualities.

Fortunately, the performance characteristics of each electrode after it was installed remained consistent over the course of weeks or months that each was studied. A particularly "good" electrode thus remained so. In a few cases, electrodes that initially induced less comfortable sensations improved with "aging". This latter effect may coincide with the development of a fibrous tissue sheath about the electrodes during the process of encapsulation.

Accommodation and the Choice of Sensory Codes — The effects of accommodation would be expected to be particularly troublesome where intensity-modulation sensory codes are to be employed, because the accommodation manifests itself as a decrease in the subjective magnitude of the stimulus intensity. For the case of a tactile substitution device in which information about grasp force is to be provided, if the stimulation is only given during the actual act of grasping an object and is turned off after the object is released, the skin area receiving the stimulation will be in a constantly changing state of accommodation and recovery from accommodation. This difficulty can be minimized by employing a frequency-modulation code to signal the level of grasp force, since the fidelity of the frequency code should be less dependent on accommodation effects. For this reason, our efforts have been largely directed towards the development of a suitable frequency-modulation code, which will be discussed below.

Just Noticeable Differences of Frequency — JNDs of increases in frequency were determined over a range of 2-100 Hz for several subjects, in order to determine the usable range and the theoretical resolution that would be available if grasp force was encoded by an electrocutaneous frequency-modulation code. A psychophysical technique, the "Dual Staircase Method" was implemented in a computer-assisted algorithm and used to obtain data.

Figure 2 shows the results that were obtained with one well practiced subject, using subdermal stimulation versus more conventional surface stimulation.

The significance of our findings is that the use of a subdermal electrode for stimulating the skin allowed the subject to discriminate at least 15 JNDs of frequency in the range of 2-55 Hz, whereas only 11 JNDs could be discriminated when a surface electrode was employed.

The superior performance of the subjects when the subdermal stimulation was employed versus surface stimulation was verified in another experiment, in which three subjects were tested for JND values at six standard frequencies (2, 5, 10, 20, 30, and 50 Hz). Twelve experiments in all were conducted on each of the three subjects. There were two electrode locations and two types of electrodes at each location (i.e., two implanted subdermally

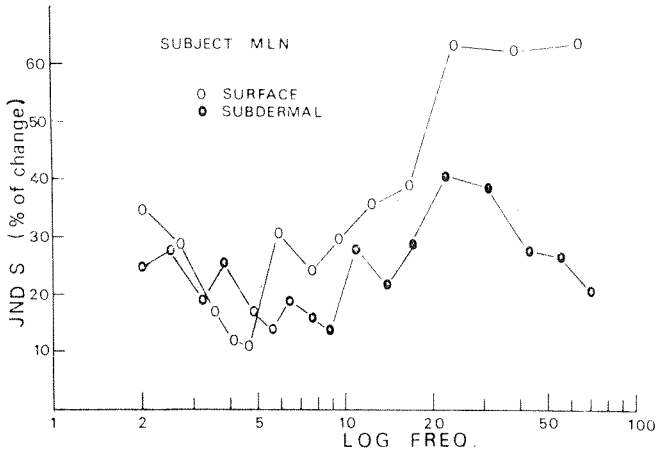

FIGURE 2
Successive JNDs of frequency using subdermal versus surface electrocutaneous stimulation.

and two that could be fixed onto the skin surface just over each subdermal electrode). Three independent evaluations of the JND tests for each electrode type/location pair were performed.

The data indicate that, for frequencies that are beyond 20 Hz, the subjects were able to discriminate smaller changes in frequency when the stimuli were presented with subdermal electrodes as compared to when surface electrodes were used. When the averages for the JNDs (expressed as percent change of frequency) were compiled separately for the subdermal electrodes and for the surface electrodes of each of the three subjects, the JNDs of frequency from 2-100 Hz were found to be on the average lower for the subdermal electrodes than for the surface electrodes by 25 percent, 10 percent and 23 percent, respectively, for the three subjects.

Choice of Stimulus Parameters — Subjects have consistently noted that stimuli which consist of bursts of high frequency pulses feel more comfortable than do single isolated pulses. A comparative evaluation of subjects' performance of a tracking task was conducted, using a frequency-modulation code in which the repetition rate of a burst of pulses (each burst consisting of 6 pulses of 50 microseconds duration and interpulse interval of 1 microsecond) versus a frequency modulation code in which the repetition rate of a single 50-microsecond pulse was modulated. A series of stepwise changes in frequency (each step consisted of a 2 JND change) covering a range of approximately 2-40 Hz was presented to the subject whose task was to detect each of the frequency changes. Preliminary results reveal that single-pulse codes are superior to burst codes if the frequency changes are centered at relatively high frequencies, but they are poorly discriminated at lower frequencies. Conversely, bursts of pulses afford more easily discriminated frequency changes when the frequencies are low, but are not clear at higher frequencies. A superior frequency-modulation code results when the number of pulses in each burst is made to vary with the burst-repetition-frequency presented ■

VA RR&D CENTER HINES

INVOLVEMENT OF MULTIPLE CORTICAL AREAS IN TACTILE SENSATIONS

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It is now generally accepted that certain neurological functions, especially those dealing directly with sensory input or with muscle control, can be ascribed to rather localized areas of the brain. When a stroke affects one of these cortical areas, a characteristic loss of sensation specific to one sense (such as touch) occurs with little or no loss to the others.

One of the aims of rehabilitation is to attempt to restore the function of the lost sense. However, so little is known about how the brain processes neuronal signals in a normal case — let alone in an injured brain — that many of the rehabilitative procedures are based on pragmatic and historical concepts. If we had a more precise understanding of brain function, we might be able to predict what sorts of deficits might be seen after a specific lesion, and whether we might be able to structure the rehabilitation process to enhance any residual capacity.

We have been using cats to study how the various portions of the brain that deal with the sense of touch interact. There are two main cortical regions (per each half of the brain) that deal with the sense of touch. They are known as the somatosensory areas and are heavily interconnected. They serve as the first cortical relays for touch sensation as it is processed and passed onward to other areas of the brain (for instance, to the motor cortex). We are beginning to study how the neural activity evoked in the two somatosensory areas by skin touch is patterned, and how the activity in one of these regions changes when the other is temporarily inactivated by topical injection of a local anesthetic. By being

able selectively to inactivate a small portion of the brain, we are hopefully able to produce an animal model for reversible stroke ■

NIHR REC

EFFECT OF STIMULATION PULSE DURATION ON COMFORT IN CONTROLLED MOTOR CONTRACTIONS

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Introduction — Studies conducted at this institution and elsewhere have shown that stimulus waveform can significantly affect the comfort of transcutaneous electrical stimulation. One stimulation parameter that is highly significant is pulse duration. However, none of the studies reported in the literature have reported objective assessment of the range of pulse duration that should be used to minimize discomfort.

A study involving 12 volunteer subjects was conducted to determine the most comfortable range of pulse duration between 12 and 800 microseconds (μs). The study also provided information as to how much more torque could be produced by the preferred pulse duration than was possible with less preferred pulse durations, thereby demonstrating the relative importance pulse duration has on comfort.

Comparisons of pulse durations were conducted at amplitudes resulting in the same physiologic response of torque generation. In order to better control factors influencing the assessment of comfort, and to reduce testing time, a computer-controlled microprocessor-based stimulator was designed and built to control automatically the electrical stimulation of subjects and the collection and analysis of data.

Methodology — A DEC MINC-11/23 computer was the host controller of the data collection and analysis procedure. It communicated with a microprocessor-based stimulator in controlling the stimulation and in retrieving subject data. The stimulator output current was directly proportional to a control voltage supplied by a 12-bit digital-to-analog converter providing a resolution of 1 in 4096. The stimulator output waveforms were controlled by a programmable timer which generated biphasic rectangular current-regulated pulses with variable duration with a resolution of one microsecond (Fig. 1).

Twelve subjects, all female, participated in this study. Four sessions, each conducted on a separate day, were used to establish a preferred comfort range for pulse durations of 12-800 μs and to assess how much more torque could be generated using a pulse duration that was preferred over one that was not preferred.

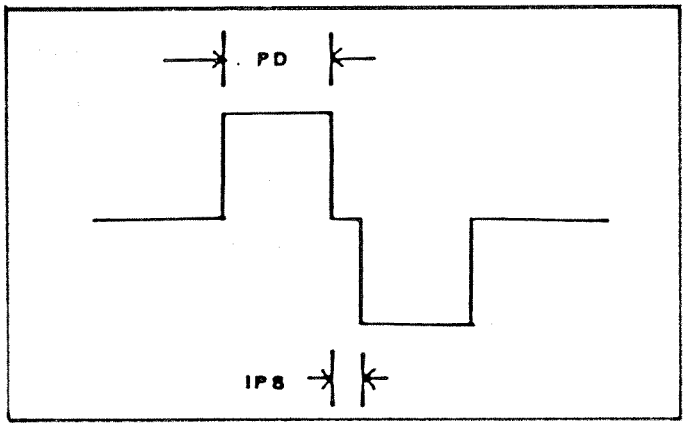

FIGURE 1.
Symmetrical biphasic waveform. PD = pulse duration (10 μs ⩽ PD ⩽ 1000 μs) and IPS = interphase separation (IPS = 25 μs).

Results — Ten female subjects completed the entire 4 day testing protocol. From the 5 runs with the least variance of torque in Session 2, subjects ranked their pulse-duration preference. The longest pulse duration, 800μs, was chosen 19 times, 300 μs was chosen 14 times, 100 μs 11 times, 30 μs 5 times, and 12 μs 1 time.

Torque Comparisons — Those whose preferred pulse duration was 300 μs and least preferred pulse duration was 12 μs tolerated an average of 211 percent greater torque when using 300 μs than when using 12 μs.

Comparing 300 μs to 800 μs, the six subjects who preferred 300 μs tolerated an average of 77 percent greater torque when using 300 μs than when using 800 μs. The three subjects who preferred 800 μs tolerated an average of 26 percent greater torque when using 800 μs than when using 300 μs.

This study demonstrates that a significantly greater amount of torque (211 percent) can be generated in the quadriceps when a 300-μs pulse duration is used, compared to torque generated using short pulse durations. Although three subjects preferred 800 μs to 300 μs, the torque differences were not significant. Consequently 300 μs was considered to be the overall preferred pulse duration ■

LIBERTY MUTUAL, NIHR, SWEDEN

DECOMPOSITION OF THE MYOELECTRIC SIGNAL

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The central nervous system controls muscle force by acting on the motor unit, a group of muscle fibers innervated by one nerve fiber, which forms the functional building block of the muscle. The activity of motor units can be studied by analyzing the electrical signal originating from the muscle fibers (the myoelectric signal), which can be detected by an electrode inserted in a contracting muscle. This is possible because each motor unit may be identified by its particular waveform in the myoelectric signal.

A system has been developed in our laboratory to examine the motor control of concurrently active motor units. This system consists of a means of recording myoelectric signals from needle electrodes implanted in a muscle, digitizing the information, preprocessing the information to improve the signal quality, running a sophisticated computer program to separate the individual motor unit firings from the total myoelectric signal, and then running other computer programs to combine and analyze the data. We have consistently striven to improve its performance, ease of use, and applicability to different experiments.

The myoelectric signal acquisition has been automated to increase the reliability of the data collected and the speed at which data are acquired. A minicomputer (PDP-11/34) is currently used as experiment controller. Under the directions of the operator, the computer controls the position of the tape recorder which stores the detected signals, monitors data quality, provides instructions and tasks for the subject of the experiment, and compiles a tabulation of all the operations performed during an experiment.

The newly developed multichannel recording electrode described above allows simultaneous recording of three independent differential channels of myoelectric signals. (The electrode previously used provided only two independent channels.) The addition of one independent channel of information reduces the data processing time by facilitating recognition of the motor unit action potentials in the recorded signal.

These improvements have greatly increased the ease of use and reliability of the decomposition system and have significantly reduced the time required to run an experiment and to analyze the data. This new tool will allow us to perform various types of experiments that were previously impossible to perform. It further enables us to perform them in numbers previously impossible ■

LIBERTY MUTUAL, NIHR, SWEDEN

HOW INDIVIDUAL MUSCLES ARE CONTROLLED: RELATIONSHIP BETWEEN FIRING RATE AND RECRUITMENT OF MOTOR UNITS

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The central nervous system controls the force being generated by a muscle by either varying (recruiting) the number of muscle fibers (motor units) that contract or by varying the rate (firing rate) at which they are stimulated to contract.

We have pursued our work in the investigation of control muscles as detailed in the two papers by De Luca et al. in J. Physiol., 1982. In those two papers, it was shown that different muscles utilize recruitment of motor units and increase the firing rates of motor units to different degrees when muscle force is to be increased. The present work is aimed at studying the effect of the recruiting of a motor unit on the firing rate of other previously activated motor units. Data was collected from the tibialis anterior muscles in the leg and the first dorsal interosseous muscles in the hand of three subjects.

In all records from the tibialis anterior muscle, we have observed an inhibitory effect of recruiting a new motor unit on the firing rate of previously activated motor units. In the first dorsal interosseous muscle, which primarily uses rate coding of its force output, the same effect has been observed, although not as consistently as in the tibialis anterior muscle. To our knowledge, this is the first time that a direct linkage has been demonstrated in these two mechanisms which regulate muscle contractions. The

functional significance of this interplay between recruitment and firing rate in a muscle is that smooth control of muscle output can be achieved by a local, hard-wired computing circuitry, thus sparing the central nervous system resources ■

LIBERTY MUTUAL, NIHR, SWEDEN

HOW INDIVIDUAL MUSCLES ARE CONTROLLED: STATISTICS OF MOTOR UNIT DISCHARGES

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The data from previous experiments was analyzed to look at the statistics of motor unit discharges during various muscle contractions. In these previous experiments, bipolar needle electrodes inserted in a subject's muscle were used to record the myoelectric signal produced when the subject maintained a contraction at a constant force level. The signals were then decomposed (according to the technique described elsewhere) to yield the firing times of several concurrently active motor units in the muscle.

The study involved the analysis of the power spectrum estimates of the firing rate of motor unit discharges. This was an attempt to investigate the presence of a low-frequency (approximately 1.5 Hz) modulation in the firing rate of the motor units noted during our previous studies. A computer program was used to convert firing time information into a train of unit impulses spaced at the appropriate firing times. This was then high-pass filtered to remove the DC component of the firing rate, Fourier transformed, and processed to yield an estimate of the power spectrum. This estimate was then smoothed by a low-pass filter to yield a lower variance estimate of the power spectrum. Power spectra for several different motor units of one contraction were then averaged to see if a peak corresponding to a common low-frequency oscillation could be obtained. The results revealed that a statistically significant peak could be found in only a few cases, suggesting that the common low-frequency oscillation seen in the firing rates of motor units cannot be modeled by a steady oscillation in the motor output. However, further analysis did reveal that the firing rate statistics of the motor units had negligible effect on the power density spectrum of a myoelectric signal which consists of the electrical signal from at least six motor units ■

LIBERTY MUTUAL, NIHR, SWEDEN

INTERACTION OF MUSCLES DURING CONTRACTIONS

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This study is directed at clarifying the role of agonist and antagonist muscle interaction during muscle contractions and initiation of movement.

The myoelectric signal from two forearm muscles (flexor pollicis longus and extensor pollicis longus) is acquired using the technique described in the project report on the Decomposition of the Myoelectric Signal (page 52). These two muscles are the sole effectors of the distal joint of the thumb. During an experiment, the subject is required to perform several tasks while the myoelectric signal is recorded. The original experimental protocol has been extensively modified following indications derived from pilot experiments. Such modifications include tracking of predictable and unpredictable trajectories and voluntary co-contractions of the two muscles that do not actually produce a net torque output at the joint. The purpose of the above tasks is to relate the firing rate behavior of the motor units in antagonist muscle under various working conditions.

Using the new protocol, three partially successful experiments have been performed. (The experimental difficulties encountered were the primary factors that promoted a wide revision of the data acquisition and processing technique as described in the project report on Decomposition of the Myoelectric Signal.) The current data has begun to show rather interesting aspects of the interaction of the opposing muscles ■

VA RR&D CENTER PALO ALTO

A STATIONARY BICYCLE ERGOMETER TO STUDY INTERLIMB COORDINATION OF HUMAN LEGS

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Need — It is necessary to understand interlimb coordination in order to develop rehabilitation strategies for persons with gait disturbances.

Disturbances in gait can be due to disturbances in balance, interlimb coordination, or both.

To reduce the level of conscious awareness needed to control a complex motor task, the CNS has developed strategies such that only a few, rather than many, parameters are needed to control the movement. In locomotion, for example, the basic pattern of alternation of flexor and extensor activity and interlimb timing may be generated at the spinal level with hierarchical supervision effected through supraspinal channels. However, in biped locomotion, balance is probably as important to locomotion as alternate movement of the legs.

Approach — To assess whether disturbances in gait are from disturbances in balance or interlimb coordination, an apparatus is needed so that interlimb coordination can be studied alone without the influence of balance.

Status — We have designed and built a prototype stationary bicycle ergometer with unique features. The features are that the two pedals can be placed at a range of phase relationships spanning 0 to 360 degrees and so that the two legs can pedal at different speeds.

Pending — This apparatus will let us assess whether this approach can be used to elucidate pathological interlimb coordination mechanisms in persons with a variety of neurological and musculoskeletal disabilities ■

NIHR REC

TRUNK EMG, VECTOR, AND GAIT ANALYSIS OF PATIENTS WITH INCOMPLETE S.C.I.

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The purpose of this study was to determine the extent to which the trunk and upper limbs are used in spinal cord injury patients for balance and support.

Method — Eight male incomplete spinal cord injury patients between the ages of 19 and 35 (mean 26.4 years) have been tested. There were three cervical, two thoracic, and three lumbar injuries. All were traumatic injuries resulting from motor vehicle accidents (three), gunshot wounds (four), or fall (one) within the past 18 months.

Two patients in the cervical group had bilateral AFOs. The third used a single AFO. One thoracic patient had no lower limb orthoses, while the other had an AFO/KAFO. Each of the lumbar patients had different orthoses (bilateral AFOs, AFO/KAFO, bilateral KAFOs).

Trunk muscle function during ambulation was recorded by placing paired 50-micron wire electrodes bilaterally in the upper (L_1) and lower (L_4) paraspinus muscles, the external oblique, and rectus abdominus. Crutches instrumented with force transducers measured arm assistance. Knee and ankle motion were recorded with electrogoniometers. Velocity, stride length, cadence, and the single and double limb support patterns were obtained by walking the subject over a known 6-meter walkway while wearing footswitches. A ground reaction force vector was obtained from a concealed force plate in the walkway; this vector was superimposed on the image of the subject ambulating by means of split-beam photography. Torques about the hip, knee, and ankle joints were calculated from the height of this vector times its perpendicular distance from the joint. The resultant value was divided by body weight times leg length, for patient-to-patient standardization.

Results

Walking Aids: In the cervical spinal injury group, one patient walked without crutches, another used a roll walker for balance and the third used crutches applying 6–8 lb of force. Among the patients with thoracic injuries, one used a single crutch (40 lb) and the other relied on two crutches, exerting 20 lb per crutch. The physiologic ambulator in the lumbar group used two crutches (60 and 45 lb). Of the other

two patients, two crutches were used on one (40 and 15 lb) and the other person used one crutch, exerting 45 lb.

Stride Characteristics: Seven of the eight patients were classified as household ambulators having a gait velocity of 30–60 meters/minute. The eighth patient was classified as a physiological ambulator with a gait velocity of less than 30 meters/minute. With the exception of the physiological amublator, there were no significant differences in velocity or foot-support patterns between the groups.

Abdominal Muscle Action: The rectus abdominus was not used by the cervical group, while this muscle was active unilaterally in one thoracic level patient. All of the lumbar group used the rectus at 50 percent of maximum intensity.

With the exception of the physiologic ambulator, the cervical group had the greatest number of muscle groups demonstrating spastic or continuous activity, which was followed by the thoracic group. This latter group had no activity in 50 percent of the external oblique muscles tested. The lumbar group had little spasticity and no muscle groups showing continuous activity.

The lower erector spinae muscle was generally most active during ipsilateral heel strike. The upper erector spinae, external oblique, and rectus abdominus worked roughly together during ipsilateral terminal stance to mid-swing ■

NIH MUSCULOSKELETAL

LOCOMOTION, MUSCLE FUNCTION AND METABOLISM

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This project has three main objectives:

1. To determine the manner in which muscles and populations of fibers within muscles are recruited and used during locomotion as animals increase speed and change gaits.
2. To investigate the relationship between muscular activity and the upper and lower limits of metabolism.
3. To test the hypothesis that the structural elements of muscle are quantitatively matched to functional needs.

A "force platform-film analysis technique" will be employed to: (i) correlate cross-sectional area of muscle groups that are active (as determined using a "glycogen loss technique") with the forces generated by these muscles; (ii) compare the active fraction of the total cross-section of muscle groups at gait transitions and during peak accelerations in animals of different size; and (iii) test and refine the hypothesis that the intrinsic velocity of shortening of the active muscle fibers is a major determinant of the energetic cost of locomotion.

The physiological parameters will be measured that determine the flow of oxygen from the capillaries of the active muscle fibers to the mitochondria and of ATP from the mitochondria to the cross bridges, under the limiting conditions of maximum oxygen uptake. Morphometric measurements will be made to quantify the spatial relationships between mitochondrial membranes, capillaries, and cross bridges of muscle fibers in major locomotory muscles of animals having very different aerobic capacities and intrinsic velocities of shortening. Then, an attempt will be made to match the physiological and morphometric measurements ■

NIHR REC

EVALUATION OF ABNORMAL MOTOR CONTROL

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The objective of these studies is to measure quantitatively the mechanical and neural components of the response to joint-angle disturbances interjected during maintained voluntary contractions. The first step in this process was to characterize the response properties in normal subjects, with particular regard to the dependence of responses on the magnitude and direction of the disturbance and on the initial torque and angle prior to the disturbance. In subsequent studies, the same measurements, in patients with movement disorders such as spasticity, will reveal whether alterations in the regulatory properties of the stretch reflex are present under pathological conditions.

In the time since the last progress report, the modifications to the equipment and software that were required to enable the study of regulated position disturbances (as opposed to the regulated torque disturbances that were studied previously) were completed. The modification made it possible to separate the dependencies of stiffness on angular disturbance size from the dependence on initial torque. It also made it possible to measure the passive component of stiffness, and by subtraction from the total stiffness, the active component of stiffness.

Stretch reflexes were studied at the interphalangeal joint of the thumb in adult normal subjects. Torque, joint angle, and electromyographic activity of the

flexor pollicus longus muscle were measured.

The responses to equal-but-opposite disturbances were approximately symmetrical, indicating nearly equal stiffness regardless of the direction of the disturbance. The electromyographic responses under these conditions were not symmetrical, but were indicative of a much larger reflex response to stretch than to shortening. These findings are in agreement with previous studies in stretch reflexes in human biceps and in decerebrate cat soleus muscles, where it was postulated that the reflexes compensated for the opposite nonlinearity of muscle response to stretch.

The increment in torque (angle) in response to a disturbance of angle (torque) was a nonlinear function of the magnitude of the disturbance. The torque was proportionally larger for small disturbances than it was for large disturbances. This general nonlinear shape was observed regardless of the initial torque or position, but the magnitude of the torque increase was larger with larger initial torques. That is, the stiffness increased with initial torque. The contribution of the passive stiffness to the total stiffness was significant, but was usually less than 25 percent. The dependence of stiffness on initial angle has not yet been studied systematically.

The responses also showed hysteresis. A torque increase (producing joint extension) followed a short time later by an equal but opposite torque decrease did not move the joint back to its original position. Instead, the joint stayed at a slightly more extended position. The magnitude of the hysteresis increased with the initial torque.

In summary, the stretch reflex properties have been shown to depend in systematic ways on the initial torque and the amplitude and direction of the disturbance. This indicates that the mechanical properties of the muscles with reflexes intact are not well regulated, and that quantitative comparisons of stretch reflexes in normal subjects with those in subjects with movement disorders can only be carried out with careful matching of the experimental conditions ■

NIHR REC

QUANTITATIVE INTERPRETATION OF EMG DURING GAIT

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This project is directed at demonstrating the utility of the derived relationships between physical muscle variables and the onset of the MES to clinical treatment. While many isolated parameters of gait, including joint moments and mechanical energy, have been studied and have been shown to elucidate the mechanics of walking, muscle length and rate of change of length have been largely ignored.

A general three-dimensional mechanical model of the lower-limb musculature was developed to approximate muscle length changes in both normal and pathological gait.

Based on muscle length, lengthening velocity, and MES data, the following results were obtained from a limited study of normal gait:

1. The tibialis anterior and hamstrings begin their electrical activity at their peak lengthening velocity;
2. Two-joint muscles show less change in length per unit length during gait than one-joint muscles, due to the interaction of joint rotations;
3. The knee joint is less influential than the ankle or hip joint to the length changes in two-joint muscles;
4. Before the period of weight acceptance, vasti muscles are fully active and ready to work in a springlike manner.
5. The muscle lengths show differences as a function of walking speed, especially when muscles are actively shortening.

Based on muscle activity and external joint moments, we observed that two-joint muscles showed electrical activity in phase with the external joint moment at the distal joint. Co-contraction appeared to be present whenever needed for stability of posture. Co-contraction across the hip and knee was found whenever the joint moments were small, i.e., whenever there was a possiblity of a moment change from flexion to extension or vice versa, even if the moment does not actually change direction. An exception occurs when the vasti muscles are preparing for weight acceptance by activating before heel strike.

Thus far, we have investigated the relationships between muscle electrical activity and mechanical parameters for three spastic patients. In these subjects with equinus gait, reflex activity in the calf muscles right after heel strike could be determined (i.e., as the muscle was rapidly lengthened in a ramp [linear] mode, the ankle joint moment increased with about a 50 msec latency). But in the period of weight release, the calf muscles do have an active role in producing power at the ankle joint as in the normal case. Additionally, the spring-like behavior at the knee during the period of weight acceptance was not observed in these patients as it was in normal subjects. The knee joint was steadily extending from the beginning of the period by the extension torque at the hip joint.

Finally, the pattern of electrical activity in the pathological cases differed from that seen in the

normal cases. In the normal cases, the MES showed a gradual rise in amplitude to a maximum followed by a relatively sharp drop in amplitude, while the pattern was just the opposite in the pathological cases ■

NSF

MODELING, CONTROL, AND SIMULATION OF HUMAN MOVEMENT

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This research program continues support of work in the areas of modeling, control, and computer simulation of human movement. The research encompasses four areas, as follows:

1. Modeling of the dynamics of human movement embodying the skeleton, ligaments, and muscles;
2. Control of movement through muscle activity, gravity, support, and joint structure.
3. Digital computer simulations to verify and confirm validity and effectiveness of the models and the control algorithms, and comparison of these simulations with available physiological measurements.
4. Development of a modular computer network for the above studies.

This is a 3-year continuing grant ■

NSF

ENGINEERING MODELING OF NEUROLOGICAL CONTROL MECHANISMS

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The research objectives are the systematic identification of the dynamics of the human motor system; the definition and determination of the parameters of its various components by means of mathematical modeling. Movement around the ankle, the elbow, and the wrist joints will be studied for the investigation in normal human subjects. The stretch reflex will be used as a test probe to study underlying neural mechanisms of posture and to measure system changes during control of voluntary movements.

The expected results are a better understanding of (i) input-output characteristics of the components of the motor systems and their equivalent mathematical models, and (ii) the motor functions at the spinal cord level in normal human subjects ■

NSF

EMG SIGNATURE DISCRIMINATION FOR CONTROLLING ELECTRICAL STIMULATION OF PARALYZED LIMBS FOR PARTIAL FUNCTIONAL RESTORATION

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We propose to continue research on combining EMG temporal-signature-discrimination-based control of functional electrical stimulation of paraplegics and stroke-related hemiplegics. These concepts, using above-lesion EMG signal signatures, have successfully been applied to a T-6 complete paraplegic who thus accomplished standing up, sitting down, and several primitive walking steps between bars (for balancing, not weight-carrying), at complete EMG control (and no hand-switch control). We propose to continue this research, concentrating on filtering of the effects of spasticity on the EMG signature control, and the use of EMG feedback from the stimulated limbs in the control system for the purpose of separating the stimuli signals from the feedback EMG.

System size reduction and the speeding up control will also be undertaken ■

NIH MUSCULOSKELETAL

CONTROL OF HUMAN LOCOMOTION

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A neglected field has been the contribution of operant conditioning to human locomotion. The proposed work will continue to study operant (discriminative stimulus) control of muscle electrical activity, EMG, and movements as people walk on a motorized treadmill.

One major aim of the work is to understand cooperation or competition between muscles of different actions or at different joints when coordination is controlled by public events that are remote from the moving muscle. Separate or co-control that is produced over one or more muscles may reveal possibly obligatory neural or biomechanical machinery. A computer will deliver lights, judge subsequent EMG responses, and deliver a high or low tone after a success or failure, respectively.

A second major aim is to search for presumptive movement-produced stimuli — private events, such as mechanical deformations of tissue that excite

proprioceptors or tactile receptors.

During the coming year, work to date for both aims will be summarized and extended. This work has shown an extensive role for operant conditioning in human motor control. Wholesale shifts in rhythmic locomotor patterns will continue to be examined for their implications as to eye-limb coordination. In addition, investigations so far have amply documented the existence of movement-produced stimulation. In the next year, some experiments will attempt to specifically condition such "private" control.

Results as a whole will help to establish the reflexive or acquired origins of movement to aid understanding of (i) bodily mechanisms of rhythm generation, and (ii) learning of movements and/or movement sense by normal or gait-disordered individuals ■

NIH MUSCULOSKELETAL

LOCOMOTION — BLOOD FLOW AND METABOLISM

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The long-term goals reflected in this project are:

1. To determine the manner in which muscles and populations of fibers within muscles are recruited during locomotion; and

2. To investigate the relationship between muscular activity and muscular metabolism.

In previous work, the spatial recruitment patterns that occur within and among mammalian muscles during exercise have been described. Also, it recently has been found that the magnitude and distribution patterns of blood flow within and among muscles of rats vary with the fiber-type composition of the muscles and with locomotory speed, and that muscle blood flow increases at a constant speed with time during exercise to fatigue.

It has been concluded from this work that muscle blood flow patterns are closely related to muscle fiber recruitment patterns. Two immediate questions emanate from previous work:

1. Are the absolute magnitudes and the patterns of blood flow observed with and among the rat muscles representative of other mammals, or are they unique to laboratory rodents?

2. Are progressive changes in muscle fiber recruitment responsible for the gradual elevations in muscle blood flow that occur over time during exercise, or are other mechanisms involved?

To answer the first of these questions, blood flows within and among the muscles of pigs and dogs will be determined during exercise. To answer the second, three hypotheses will be tested that may explain the progressive increases in muscle blood flow that occur with time during exercise: that (i) the elevations result from progressive recruitment of additional motor units in the muscles as fibers fatigue; (ii) that the elevations result from a progressive rise in body temperature; or (iii) that the elevations result from progressive accumulation of vasodilator substance in the muscles. Answers to these questions would significantly further understanding of the patterns of muscle fiber activity that occur during exercise and accompanying metabolic support of the muscular activity ■

VA RR&D CENTER PALO ALTO

THE SPINAL LOCOMOTION PATTERN GENERATOR IN HUMANS

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Need — Spinal cord injured patients and others with severe gait disorders have the need to walk in order to improve their mobility and gain independence.

Current techniques to restore locomotor function in these patients have revolved about either the use of external mechanical aids (walkers, crutches, canes, etc.) or, more recently, the use of functional electrical stimulation to activate select groups of lower-limb muscles. For a combination of technical and cosmetic reasons, these approaches have, in general, not led to restoration of walking for the disabled community. All of these solutions chose to ignore the possible presence of any intact spinal cord control of lower limb muscles.

Approach — Extensive experimental work over the past few decades has shown that many mammals (e.g., dogs, cats, rabbits, rats) can perform stepping locomotor activity after a complete spinal cord transection. These spinal stepping experiments have led to a much better understanding of spinal cord function in the control of locomotion. However, one investigator's attempt to extend this experimental work to primates has failed to elicit rhythmic limb activity. There have been few reported attempts in the literature to systematically observe the presence (or absence) of stepping in spinal cord injured patients. It is therefore unknown whether human sub-

jects with spinal cord transection can perform rhythmic stepping movements with their legs suspended above a moving treadmill.

It is the thesis of this study that humans possess some form of spinal "pattern generator" for locomotion.

Volunteer patients will be suspended in a modified parachute harness over a moving treadmill belt. The sole stimulus to the patient will be a plantar contact of his foot with the belt. Any leg movement will be recorded with a video system, while electromyographic activity will also be measured from lower-limb muscles.

Status — The outcome of this proposed work will have a significant impact on the course of future spinal stepping experiments in both humans and animals. The absence of locomotor activity in humans would force neurophysiologists to re-examine existing models for spinal cord injury, and perhaps work more extensively with preparations that better resemble those found in spinal cord injured humans. On the other hand, the presence of spinal stepping in our subjects would strengthen the relevance of existing animal work in the area, and create the groundwork for more quantitative studies with human subjects. Evidence leading to the existence of spinal "locomotor pattern generators" would be an exciting development, suggesting the possibility of simple controllers for the generation of locomotion in humans with spinal cord injuries ■

NIH MUSCULOSKELETAL

MEDIAL GASTROCNEMIUS MUSCLE FUNCTION IN LOCOMOTION

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The specific hypothesis that the central nervous system control of locomotion is focused on distinct parts of individual muscles, rather than whole muscles or synergistic groups, will be tested by recording the activity of single motor units in distinct parts of the triceps surae muscle group of cats during a broad range of stepping behaviors. Each motor unit recorded will be carefully characterized using physiological criteria, and its location in the muscle examined by glycogen depletion and histochemical analysis. The pattern of recruitment of motor units in each part of each of the muscles will be correlated with the physiological properties of those units. These patterns will then be compared between different parts of the muscle to determine if motor units are recruited with any level of independence in different parts of the same muscle.

The results of this study are expected to have significance in establishing guidelines for studies of the mechanisms and the specificity of motor control during behavior. They are also anticipated to be of use to clinicians, especially in neurology and rehabilitation medicine, in the diagnosis, treatment, and evaluation of patients with disorders of movement, especially those involving the locomotor apparatus ■

NIH MUSCULOSKELETAL

ORIGIN OF LIMB POSITION AND MOVEMENT SIGNALS IN HUMANS

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This project will study how the awareness of static limb position and the sense of limb movements in humans are derived from sensory inputs from joint, skin, and muscle. The tests involve matching one limb or digit to its opposite, detecting movements or misalignments from the matched position, and estimating the magnitude of a misalignment or the speed of a movement. Using healthy adult volunteer subjects, tests will first be done to develop procedures that can distinguish movement sense and position sense, and then to establish baseline performance levels. Evidence indicates that these two senses are different. The effect of eliminating various inputs using local anesthetic block will then be tested. Some tests will use patients having a complete rupture of the Achilles tendon.

A major goal is to test the hypothesis that muscle spindles provide necessary and sufficient sensory input for limb position sense, and that skin and joint contribute little or nothing. The hand is an exception; cutaneous inputs are in some way involved in kinesthesia in the fingers, but not in other joints, like the knee. How the hand differs in this and other respects will be tested.

Finally, whether gamma control of spindle activity is essential to position accuracy will be tested in subjects (i) with relaxed muscles; (ii) with partial (gamma) block of motor nerves; and (iii) using recordings from spindle afferents in humans to see if there is a change (reflecting gamma activity) during position discriminations.

Once the source of the position and movement detectors and more about coding and fusimotor control are known, meaningful experiments on animals can be done for detailed neurophysiological research ■

VAMCRICHMOND

SINGLE UNIT STUDY OF MUSCLE AFFERENTS IN HUMAN MOVEMENT

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An electrophysiology laboratory has been established at the VA Medical Center, Research Service, Richmond, Virginia, to monitor and record single unit afferent nerve potentials from muscle receptors in the awake, unanesthetized human. The major receptor presently recorded is the muscle spindle, although the golgi tendon organ, and cutaneous receptors such as touch, pressure, and joint receptors, are readily recorded. Potentials are recorded from the median nerve at the elbow and mid-upper arm, and the posterior tibial nerve in the popliteal space. Electromyograms and joint range are simultaneously recorded with the receptor action potentials.

Single unit action potential activity is recorded using manually inserted insulated tungsten wire electrodes, electrolytically tipped and impedance-measured at 100–150 kilohms at 1,000 hertz. Electrical stimulation through the recording electrode allows for muscle receptor nerve fascicle isolation, which results in a rapid muscle spindle nerve fiber location.

A device to record wrist and finger range of movement is being custom designed and fabricated, in cooperation with Bioengineering and the Orthotic Laboratory. The device should be available for experimental testing in the near future.

A Texas Instruments 990-5 computer is being incorporated into the system to initiate programs for quantitation of results.

Preliminary recordings in normal subjects are directed at determining criteria for receptor identification and monitoring muscle afferent activity during rest, passive stretch, muscle twitch, reflex, and voluntary movement. Initial records suggest that some receptors fire spontaneously at rest (as determined by the lack of electromyogram and torque changes), and that receptors can be facilitated by remote muscle contractions without initiating overt contractions of the receptor-bearing muscle.

It is projected to study muscle afferent activity in patients with hyperactive syndromes and phasic movements (Parkinsonian and cerebral vascular accident patients). The overall objective of the project is to study the interactions of the alpha motor-fusimotor systems in human normal and pathological movement ■

NIHR REC

DEVELOPMENT OF MATERIALS FOR IMPROVED IMPLANT / TISSUE COMPATIBILITY: PERCUTANEOUS PASSAGE

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Objective: The overall project objective is to develop a permanent percutaneous implant. The purpose of this section of the project was to determine if epidermal ingrowth is necessary in the development of a successful percutaneous implant.
Summary: 24 porous vitreous carbon implants and 18 smooth pyrolytic carbon implants were implanted in six minature pigs as percutaneous devices. The implants were harvested through a 10-week time span. Histologically, the surrounding tissue reaction exhibited an intense inflammatory response at the 8-week and 10-week time periods. All of the vitreous carbon implants failed at the 10-week harvest due to fracture of the implant. Both types of implants were concluded to be unsuccessful percutaneous devices in the present model ■

LIBERTY MUTUAL, NIHR, SWEDEN

NEW ELECTRODES FOR DETECTING MYOELECTRIC SIGNALS

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Many parameters relating to the activity of a muscle during contraction may be studied by analyzing the electrical activity (myoelectric signal) originating from the muscle fibers. This signal can be detected by placing electrode contacts on the surface of the skin directly above the muscle, or by inserting a thin needle containing metallic contacts directly into the muscle. Both surface and needle recording electrodes are necessary to completely evaluate parameters of muscle activity.

To maintain consistent results during surface measurements of the myoelectric signal, a standard surface-recording electrode has been developed.

The contacts of the standard electrode are in the form of two one-centimeter-long parallel bars of silver, spaced 1 centimeter apart. The bars are mounted directly on a small epoxy package containing a high-quality preamplifier. Using this configuration, the electrode exhibits the mechanical and electrical stability necessary for low-noise myoelectric recordings. It is hoped that this standard electrode design will be adopted by other researchers.

To analyze activity of individual muscle fibers, an electrode much more selective than the surface electrode is necessary. A needle electrode inserted into the muscle fulfills this requirement. During the past year, an improved needle electrode capable of recording multiple channels of information was designed. A rectangular array of four 75-micrometer diameter electrode contacts was fabricated in the side of a thin surgical needle near its tip. At the other end of the needle, a lightweight plug allows electrical connections to external equipment. Because of its capability to selectively record from individual and/or small groups of muscle fibers, this electrode is particularly useful for detecting muscle signals that may be decomposed, allowing the identification of electrical pulses that are associated with individual muscle fibers.

Both the new surface and needle electrode designs greatly simplify the task of obtaining reliable and accurate signals used to study muscle activity ■

ROBOTICS

VA—JHU/APL

WHEELCHAIR CONTROL AND ROBOTIC ARM/WORKTABLE SYSTEM FOR HIGH-SPINAL-CORD-INJURED PERSONS

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Current Robotic System Described — The APL robotic system utilizes a structured worktable concept, i.e., components are located on the worktable in a manner that allows the robot to use prestored motion trajectories to carry out desired functions. This concept makes manageable, for example, the difficult task of putting a single sheet of paper into a typewriter. To control the robot, the user calls up the desired program by applying an appropriate head motion to a chin controller. The robotic system is designed for the highly disabled person who is unable to use his upper or lower limbs but who has nearly full motion of the head and neck. These residual motions are used to control the system by means of a chin-operated controller mounted on the wheelchair. This controller also enables the quadriplegic to operate the electric wheelchair. This duality of control gives the quadriplegic much-needed mobility as well as the opportunity to perform manipulative activities with the robot arm.

Significant improvements were made to the system to improve the efficacy of the robot arm in performing a variety of activities including user self-feeding, positioning, loading and operating a typewriter, handling a telephone and reading materials, and using a personal computer. Most significant among these new developments is simplified programming of robotic arm motions — this can now be carried out by an occupational therapist or the quadriplegic user himself or herself with substantially less training and effort than previously.

The addition of a chin-operated system for Morse Code input now greatly facilitates use of a personal computer by the quadriplegic user.

The telephone handling system on the worktable has been improved to expedite placing and receiving calls. The modules of the telephone are taken from a standard commercial unit and repackaged to minimize the effort required to use the telephone. The mouthstick is utilized to turn the phone on and to touch-dial the desired phone number through an integrated pulse repertory dialer. The robot arm lifts the receiver from an out-of-the-way position on the work table and delivers it to the user's ear. The arm is then free to perform other functions. The microphone is located in the mouthstick holder on the worktable and can be addressed directly by the user. For maximum privacy, the user has the option of speaking very softly into the mouthpiece end of the mouthstick. The sound is transmitted through the lumen of the mouthstick to a hole in the mouthstick holder which communicates directly with the microphone. This system will be evaluated during the second phase of testing at the Richmond VA Medical Center.

Improved Multimode Self-Feeding — One of the most important tasks that the robot arm worktable system enables the totally quadriplegic user to accomplish is self-feeding. A new development has significantly improved this feeding capability. A spoon has been modified with a wire bail type of clamp. This device allows the user to eat bulky food items such as sandwiches, hot dogs, toast, french fries, or large pieces of lettuce as well as food prepared in bite-sized or smaller morsels. In response to

the user's command signals, the robot slides the spoon beneath the desired item of food. If the user perceives that the food item extends so far beyond the edge of the spoon as to be unstable, the user signals the robot to close the bail down onto the food item. The food item is grasped in a manner similar to fingers grasping a cookie against the thumb. After eating the edges of the food item, the user signals the robot to lift the bail so that he can eat the central remnant directly from the spoon and without contacting the bail with his mouth.

Food may be eaten from two standard bowls or a conventional dinner plate. In the prestored program for bowl eating, the spoon is preprogrammed to go into the bowl, pick up a bite-sized portion, scrape the bottom of the spoon to remove drippings, and proceed to the user's mouth. When eating, the user may switch to any of several eating modes, e.g., from bowl to plate or from plate to bowl. The self-feeding mode was tested at APL and at VA Medical Center in Richmond, Virginia, and found to show significant promise as a practical eating arrangement.

CLINICAL EVALUATION
VA Medical Center, Richmond, Virginia

The system was evaluated by three C3 quadriplegic volunteers, none of whom had any upper limb function. The first worked with the system for 6 weeks and ate 25 meals with it. At the conclusion of his evaluation period, he had formed a very favorable impression of the value of the system. He found the eating capability of this system to be significant since it freed him from having an aide feed him and permitted him control over the order and speed with which he ate his meal.

The second used the system for 1 week and ate 1 meal with it. He rejected the system and withdrew from the project with the explanations that his wife performed all services for him provided by the robot arm, that she did it much better.

The third worked with the system for 3 weeks and ate 13 meals with it. He initially rated the eating function as only "satisfactory." He was especially enthusiastic about using the computer; he elected to spend 19 hours in use of the computer subsystem■

DEVELOPMENT AND EVALUATION OF A ROBOTIC AID FOR THE SEVERELY DISABLED

VA Rehabilitation Research and Development Center
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Palo Alto, California 94304

■ Participants in the Robotic Aid project were the following:

From the Rehabilitation R&D Center, PAVAMC, and the Design Division, Mechanical Engineering Dept., Stanford University: **Larry J. Leifer, Ph. D.; Urs Elsasser, Ph. D.; Stefan Michalowski, Ph. D.; H. F. Machiel Van der Loos, Ing. Dip.; Charles E. Buckley, M.S.; Charles Wampler, M.S.; John Jameson, M.S.; Walter Conti, M.S.; John Walecka, M.S.;** and **Allen R. Curran, M.S.**

From the Spinal Cord Injury Service, PAVAMC: **Inder Perkash, M.D.**

From the Design Division, Mechanical Engineering Dept., Stanford University: **Bernard Roth, Ph. D.**

From the Rehabilitation R&D Center, PAVAMC: **Karen G. Engelhardt, B.A.**

Need — Severe physical disability, such as that caused by high-level spinal cord injury, leads to a drastic disruption of manipulative capabilities. It is asserted that robotic technology, applied to the needs of the disabled, can help in bridging the gap between individuals whose perceptual and intellectual powers remain intact and the environment they no longer control.

Approach — In setting out to apply robotic technology to the field of rehabilitation, the current state of commercial industrial robotics was used as a starting point, adding those enhancements required to produce an assistive device that can be of use to a severely disabled individual. Specific use was made of the following technological and theoretical advances.

1. The availability of a suitable manipulator;
2. Theoretical understanding of robot motion;
3. Progress in speech recognition and synthesis; and
4. Advances in microprocessor technology.

There exist two distinct versions of the Robotic Aid: a Clinical System and a Laboratory System. The former is a complete manipulation aid whose design is stabilized to a degree that allows intensive evaluation trials at the VA Medical Center in Palo Alto. The laboratory system, located at the Department of Mechanical Engineering at Stanford University, serves as a research tool for developing new hardware and algorithms. Major components of the laboratory system will be integrated into the Clinical System as they reach maturity.

Status — The Clinical Robotic Aid consists of an anthropomorphic electromechanical arm with six degrees of freedom which allows the user to position and orient the hand arbitrarily within a spherical

working envelope of approximately 3 feet in diameter; an Arm Controller comprising six motor controllers and a DEC LSI-11/2 based computer which solves kinematic equations of the arm; and a System Controller in the form of a Zilog MCZ 1/25 computer which serves all input/output devices.

Input devices are: discrete voice recognition unit, two degrees-of-freedom head control unit, six degrees-of-freedom joystick, teachbox, and keyboard.

Output devices are: voice synthesis unit, display console, and flat panel display. There is also a two-fingered hand which is equipped with touch sensors in the form of microswitches located on four sides of each prismatic finger.

The Robotic Aid has been integrated into a custom-designed multipurpose environment that includes a work surface, a microwave oven, a refrigerator, and a number of small appliances.

The disabled user communicates with the Robotic Aid primarily through the speech recognition/synthesis subsystem. A vocabulary for efficient motion control has been designed, and an innovative software environment, UNIZCSYS (for UNIfied Arm Control SYStem), has been created. The manipulator control language allows the user to define the direction of movements and the orientation of the hand in one of three coordinate systems. It facilitates changes of speed through explicit and implicit commands and lets the user choose between continuous and discrete motions. The manipulation vocabulary has undergone several modifications and today consists of 58 commands.

In addition to the real-time control scheme used to "pilot" the manipulator through its workspace, the Robotic Aid can be programmed to go through any desired sequence of motions.

The Robotic Aid is used at the VA RR&D Center in Palo Alto for the purpose of user training and device evaluation. To date, more than 90 people have been trained in the use of the Robotic Aid. One-third of the users are disabled individuals, mostly high-level quadriplegics.

Considerable effort was spent on developing training procedures, including the preparation of a comprehensive manual. A methodology to assess the efficacy of different training techniques was outlined, based on the theory of Locus of Control: this work was carried out in collaboration with the Psychology Department at Stanford University.

The continuing evaluation effort has yielded information leading to significant improvements in system performance. Voice recognition errors in the form of substitutions were singled out as the paramount source of user frustration. Consequently, the control vocabulary was modified to reduce substitution errors, and recognition thresholds were adjusted to favor non-recognition over substitution errors.

An on-line update feature was implemented to eliminate problems with persistently misrecognized words.

Visual cues were included on the manipulator to help the user recognize the system's main axes of motion.

Voice output was improved by choosing better phoneme representations of the synthesized messages.

A miniature hand-mounted TV camera was tested as a means of facilitating manipulation. Users expressed the desire to employ such a system as a viewing device to gain visual access to places that are out of sight for the wheelchair-bound person.

Personal impressions were studied, using formal interviews and questionnaires. The advantages of a Robotic Aid were corroborated by the many users who could imagine such a device in their home settings. Tasks mentioned most often were: obtaining a drink of water, cooking and serving a meal, eating, handling clothes and other personal belongings, and vocational applications.

Pending — Range-Sensing Hand: A hand with improved sensory capability was built. Electro-optical reflective sensors provide range information which can be used to facilitate grasping, the most time-consuming part in manually controlled "pick-and-place" operations. It also allows the user to keep the hand aligned with a surface.

Mobility — The Omnibase: A mobile platform was designed. This mobile base is unique in that it uses the principle of omnidirectionality; i.e., its three degrees of freedom in the plane of motion are uncoupled. The key to this are three wheels, each consisting of a ring of freewheeling rollers arranged along the sides of a triangle. By driving the three wheels in a coordinated fashion, the vehicle can move along any path in any desired orientation. The Omnibase carries with it the manipulator plus all the necessary controller hardware. Battery power is sufficient for a minimum of 1 hour of operation.

Evaluation continues, and is now focused on acquiring data for successful user profiles, and on exploring new applications for vocational and recreational uses of the Robotic Aid ■

MOBILITY AIDS WHEELCHAIRS

VAMC ATLANTA

ANTI-ROLLBACK WHEELCHAIR WHEEL

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Purpose — This wheel is engineered to be an easily retrofitted item for standard manual wheelchairs, to give them the capability of anti-rollback when ascending hills and ramps.

Progress — The first demonstration unit has been completed and has performed in a satisfactory manner. Modifications were made to increase the structural strength of key elements. All calculations for loading and stresses have been completed and preparation of the engineering drawings for a final production prototype is underway.

Future plans — Efforts to construct several units for use in evaluation at the Atlanta Veterans Administration Medical Center will continue as funding permits. The team is continuing to seek commercial interest for the production of the unit ■

NIHR REC

ENERGY COST OF WALKING AND WHEELCHAIR PROPULSION RELATED TO PHYSICAL IMPAIRMENT

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The energy requirements of ambulation and/or wheelchair mobility were studied in spinal cord injury, myelodysplasia, and lower limb fracture patients. Alterations in the relative demand of ambulation caused by varying lower-limb-cast walking surface (cast boots vs. walking heel vs. rocker heel), and by various degrees of restricted knee motion, were documented in normal subjects. All testing was conducted in the Pathokinesiology Laboratory of Rancho Los Amigos Hospital.

Instrumentation and basic test procedure for energy-cost measurement, footswitch gait analysis, and joint electrogoniometry were common to all five studies within this project. Variations in testing protocol unique to each study are described within the appropriate sub-sections of this report.

Oxygen uptake analysis was derived from the modified Douglas Bag collection technique. A thermister was used to detect respiration rate. Heart rate was measured via surface electrodes. Blood pressure was monitored using a standard pressure plethysmograph and stethoscope. Cadence was measured by means of a contact-closing heel switch located in the sole of the subject's shoe on the uncasted side. Indoor testing was performed on a level 15-meter-long walkway.

A contact closing insole footswitch system was used to provide velocity, cadence, average stride length, single and double limb support times, and swing-stance ratio. All data were recorded on analog tape and displayed on an oscilloscope.

In two studies, an electrogoniometer was used to measure dynamic knee motion.

1. Ambulation in Below-Knee Plaster Casts

Results: Subjects using the DePuy walking heel and the castboot showed no significant differences in rate of O_2 consumption ($p<.10$). Both the castboot (.182 ml/kg-m) and the DePuy heel (.187 ml/kg-m) however, were significantly less efficient ($p<.001$) than free walking (.154 ml/kg-m). The average heart rates during ambulation were not significantly different ($p<.02$). Average velocity with the DePuy heel (63.6 m/min was significantly less ($p<.01$) than free walking (73.1 m/min). For this group no significant differences were found in any of the mechanical gait variables.

2. Lower Limb Fracture Patients

Results: Physiological steady-state could not be attained by the majority of patients indicating the rigorous demand crutch-walking places on orthopaedic patients. Respiratory rate evidenced a statistically significant difference between males and females ($p<0.05$), but heart rate did not. Females had a heart rate of 158 beats/min and a respiratory rate of 32.5 breaths/min; while males had a heart rate of 148 beats/min and a respiratory rate of 24.7 breaths/min.

Velocity also showed a statistically significant difference ($p<0.05$) between males and females wearing a SLC. Females walked at a rate of 46.8 m/min, taking 84.5 steps/min, with an average stride length of 1.16 m. Males walked at a rate of 58.0 m/min, took 95.3 steps/min, with an average stride of 1.23 m.

There was no difference between men and women in rate of oxygen uptake or net oxygen cost per meter. Rate of oxygen uptake and net oxygen cost per meter were 12.4 ml O_2/kg-min and 0.26 ml O_2/kg-m respectively for females; and 15.5 ml O_2/kg-min and 0.27 ml O_2/kg-m for males.

The type of cast led to a statistically significant difference in both heart rates (Fig. 1) and respiratory rates. Patients ambulating with SLC had a heart rate of 153.7 beats/min and a respiratory rate of 29.1 breaths/min, which was greater than those patients with LLC who had a heart rate of 130.3 beats/min and a respiratory rate of 18.4.

Stride characteristics evidenced no statistically significant differences between the two cast groups but both were slower than normal. Velocity (Fig. 2)

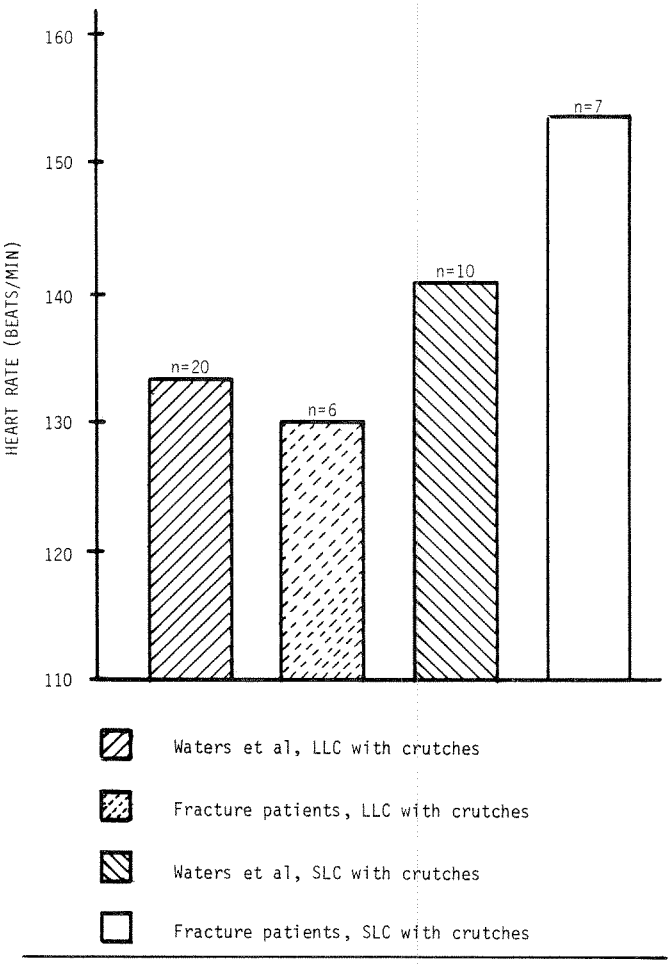

FIGURE 1.
Comparison of values for heartrate of normal adult males and normal fracture patients.

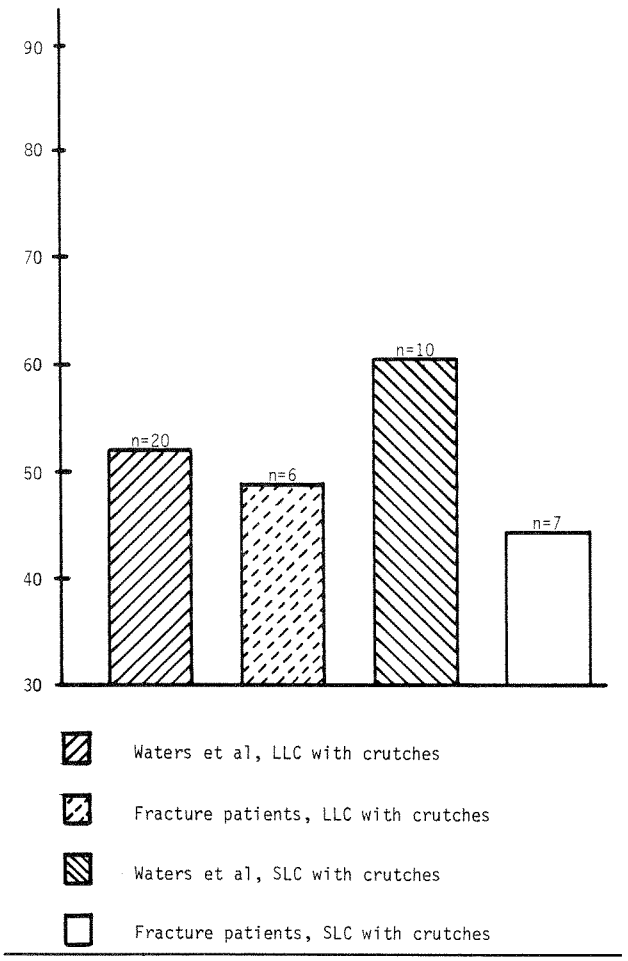

FIGURE 2.
Comparison of values for velocity of normal adult males and normal fracture patients.

was 43.9 m/min, with cadence of 89.1 steps/min and average stride length of 1.16 for the non-weightbearing gait of the SLC patient. The LLC ambulator walked at a velocity of 48.7 m/min, having a cadence of 80.0 steps/min and taking an average stride length of 1.20 m.

There was a statistically significant difference in net oxygen cost per meter between patients ambulating with a SLC versus the less efficient LLC ($p<0.05$), but not in rate of oxygen uptake. Rate of oxygen uptake for SLC ambulators was 13.7 ml O_2/kg-min with a net oxygen cost of 0.26 ml O_2/kg-m; while patients ambulating with LLC had a rate of oxygen uptake of 16.2 ml O_2/kg-min with a net oxygen cost of 0.35 ml O_2/kg-m.

3. Ambulation with A Flexed Knee

Results — Oxygen consumption was increased at all three values of knee restriction (Fig. 3).

Velocity was significantly reduced in all restricted walking trials ($p<.01$).

Stride length demonstrated the same pattern as velocity. At 20 degrees of restriction, mean stride length was 1.28 meters, a significant decrease from 1.37 meters when knee motion was unrestricted ($p<.01$).

Significant changes in peak angle ranges between unrestricted and restricted walking were evident.

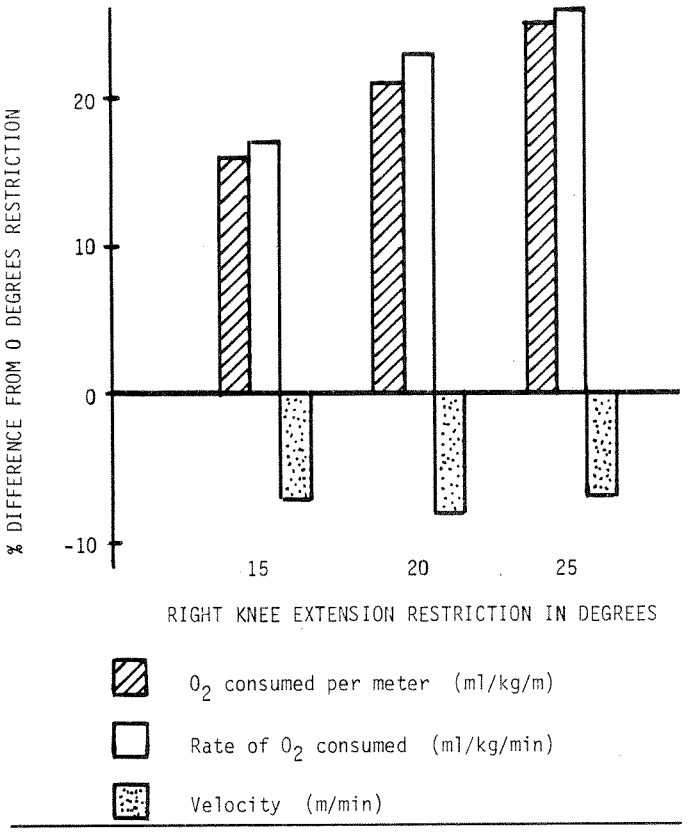

FIGURE 3.
Changes in means of selected O_2 and gait variables with right knee extension restriction.

Dorsiflexion increased significantly at 20 degrees of knee flexion to 10 degrees, from 8 degrees of dorsiflexion seen with no knee restriction ($p<.01$). Mean plantarflexion with unrestricted walking was 25 degrees.

4. Walking and Wheelchair Propulsion in Myelodysplasia

Results — Six of eight patients requiring bilateral KAFOs preferred walking with a swing-through crutch-assisted gait. Three of six patients using only one KAFO (with or without an AFO on the opposite limb) preferred walking with a reciprocal gait and crutches. None of 14 patients using only AFOs chose a reciprocal gait pattern.

Wheelchair Propulsion: Wheelchair ambulation proved to be the least costly and most efficient means of transportation.

5. Walking and Wheelchair Propulsion in Spinal Cord Injury

Results

Wheeling Versus Walking: A statistically significant difference was found in all measured parameters when wheelchair propulsion was compared to walking. The mean heart rate was lower (121 bpm versus 140), velocity higher (73 m/min versus 28), rate of oxygen uptake lower (11.4 ml/kg-min versus 14.3) and efficiency better (94 percent versus 31 percent) during wheelchair propulsion.

Level of Injury: Partitioning patients by their level of neurological spinal cord injury did not prove a sensitive index of energy expenditure.

Orthotic Management: The amount of partial motor recovery below the highest normal neurologic level proved the most sensitive indicator of energy cost. The group with bilateral KAFOs employed a swing-through gait. The rate of oxygen consumption was higher (17.1 ml/kg-min) than either of the other two groups (bilateral AFOs and KAFO/AFO) who used a reciprocal gait (14.3 and 14.1 ml/kg-min). There also existed a significant difference in the energy cost per-meter-travelled between the bilateral KAFO user and those who wore a KAFO and AFO (.59 ml/kg-m versus .36).

No substantial differences were found between the KAFO/AFO subjects and those in bilateral AFOs. Both had a similar velocity (30 m/min versus 26), rate of oxygen consumption (14.1 ml/kg-min versus 14.3), and energy cost (.36 ml/kg-m versus .46) ■

MOBILITY AIDS
WHEELCHAIR ACCESSORIES

VA RR&D CENTER HINES

FOR WHEELCHAIRS: A HEELSTRAP RETRACTOR AND A SHOCK-ABSORBING SEAT SUSPENSION SYSTEM

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Heelstrap Retractor — The heelstrap on many unpowered wheelchairs can lead to situations that are both troublesome and hazardous. In order to get out of the wheelchair, the user most position the footpedals vertically. This can be done only if the heelstraps are forcefully pushed toward the front of the footpedal. If that is not done, the heelstrap prevents vertical positioning of the footpedal and the footpedal then presents an obstacle that could trip the user as he leaves the chair.

The heelstrap retractor solves this problem by forcing the heelstrap to the proper position as the footpedal is raised. This is accomplished with an inexpensive coil spring that is easily attached to the chassis of the wheelchair. A thin metal finger at the end of the coil spring contacts the heelstrap. Raising the footpedal causes the finger to rotate, pushing the heelstrap forward and out of the way. This eliminates potential hazards and makes it easier to vertically position the footpedal.

Reproduction samples of the heelstrap retractor are available for consumer evaluation.

Seat Suspension — Road shocks and vibrations pose a crucial problem to users of unpowered wheelchairs. The severity of the problem can range from an annoyance to aggravation of pressure sores (decubiti). Many suspension systems have been posed to minimize the problem.

The problem with most is that they require extensive modification of the wheelchair. Manufacturers are reluctant to adopt such designs. This Center's design does not require such modifications to the wheelchair. Rather than adding suspension to the chassis, as in previous designs, this design has suspended the seat. Suspension is accomplished with spring-loaded, post-type shock absorbers located between the upper and lower parts of the wheelchair chassis. A shock absorber is located near each corner of the seat ■

NIHR REC

THE SIMPLE WHEELCHAIR INSERT

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The purpose of the project was to develop a low-cost, wheelchair-based postural insert for cerebral palsied children with mild quadriplegic involvement, in the 7 to 10 year age bracket. Nearly all commercially available inserts are not specifically designed for this group of children. The moderately involved child requires relatively less postural support and restraint than is commonly offered, but more freedom in mobility for transferring and for self-propelling a wheelchair. This disparity between the child's needs and the features offered by the commercially available systems is further aggravated by the relatively high price of between $800 to $1200 for commercially available insert systems. This system is designed to be low in cost and simple enough to install and adjust without specialized technical input.

The design of this device was started by considering the needs of the user in seating, mobility, and equipment management. A desired posture was identified, as was the level of support likely to be needed to achieve it as applied over different body segments.

Anthropometric data was gathered, and the compromises were made for fit, support, and adjustability. All the while, in the background, consideration was given to the manufacturing process. It became apparent that the chief trade-off here was the simplicity of manufacture for adjustability of the device.

Initial design has been completed. A prototype is available for brief trials by San Francisco Bay Area disabled children who meet the criteria for age, size, and diagnosis. The investigators are interested in determining how well the simple wheelchair insert meets the functional needs for support and mobility, if it is appropriately sized and proportioned, and how it is received by the primary and secondary users.

Following design refinements, prospective manufacturers will be contacted and asked to tender submissions for commercial production of the seat ■

NIHR REC

AN EVALUATION METHODOLOGY FOR COMPARATIVE TESTING OF MODULAR SEATING SYSTEMS

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A Side-by-Side Trial methodology was developed at the Rehabilitation Engineering Center, Children's Hospital at Stanford, as a process to evaluate functional and technical features of four commercially available modular wheelchair seating systems and to determine: (i) the specific features and components of a modular seating system which improve or decrease user function, (ii) technical modifications which could be made on existing seating systems to better meet functional needs of users, and (iii) necessity for the development of a new modular seating system. Using a side-by-side evaluation methodology, child subjects with the diagnosis of cerebral palsy are fitted in each of the four seating systems and perform specific functional activities. Each seating system is rated on ability to provide postural control, effects on certain functional activities, manageability by a parent, and technical characteristics.

It was found that a modular seating system that effectively positioned a child had a positive effect on performance of most functional activities. Components of the system, however, can restrict some functions. Fixed footrests, and abduction units that were not user operable, decreased performance in transfers. The relationship between a modular seating system and its wheelchair base influenced effectiveness of the system. The relationship of the footrests to the seating system affected overall posture. The relationship of the seating system to location of the wheels influenced mobility. Appearance was important to therapists and parents and was generally the first feature considered when assessing a system. Although manageability of a system by a parent was considered important, the parent tended to place the child's needs first. They indicated a willingness to put up with a cumbersome system if it helped improve posture and function of their child.

The Side-by-Side Trials have been a useful method of gathering comparative information about modular seating systems. The methodology developed for this project could be useful in the comparative evaluation of other seating systems and other assistive devices ■

NIHR REC

EVALUATION OF AN ANTI-THRUST SEAT

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The Anti-Thrust Seat was developed in 1981 by the REC Special Devices Service. The seat was designed to control the unwanted forward motion of the pelvis which is exhibited during extension, particularly in those clients with cerebral palsy. The design has also proved successful in controlling forward pelvic drift in clients with muscular dystrophy, myelomeningocele, spinal cord injury, and others with no active extension but who exhibit a tendency to "slip out" of the wheelchair seat.

The Anti-Thrust Seat is currently undergoing clinical evaluation by the REC research staff to determine its effectiveness in maintaining upright posture, inhibiting involuntary movement caused by abnormal reflex patterns, and thereby decreasing the frequent repositioning required to maintain an optimal seating position.

These preliminary data are encouraging. Fifty percent of the subjects report that repositioning is never necessary, that 87 percent are able to sit in the Anti-Thrust Seat for approximately 5 to 8 hours or more per day with an optimal amount of comfort (four of five on scale of one to five). Fifty-seven percent of the subjects report an improvement in posture particularly in the cerebral palsied segment of the subject population. And 92 percent report the seating system is comfortable.

The evaluation of the Anti-Thrust Seat thus far suggests some design modifications. These include decreasing the thickness of the front edge of the wedge cushion with possible changes in the plastics used for the solid base. In general, the preliminary clinical trial results suggest that the Anti-Thrust Seat design is effective in the treatment of seating problems frequently occurring as a result of cerebral palsy or other muscular diseases which affect gross motor patterns and therefore postural control. Possible directions for future research are: (i) further clinical evaluation of the Anti-Thrust Seat design on a larger subject population, (ii) study of the effect of the Anti-Thrust Seat in reducing muscle tone, and (iii) longitudinal study on the long-term effectiveness of the Anti-Thrust Seat in decreasing the need for surgical intervention to control contractures and other deformities.

Negotiations are currently underway with potential manufacturers to make the Anti-Thrust Seat available commercially ■

MOBILITY AIDS CONTROLLERS AND LIFTS

VAMC ATLANTA

ALTERNATE VEHICLE FOR THE PHYSICALLY DISABLED: A FEASIBILITY STUDY

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Rehabilitation R&D Program
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To design systems and subsystems for an alternate to present powered wheelchairs. This is a graduate feasibility study.

Progress — The first electronic control system is under construction with the power modulator system driving actual wheelchair motors in bench testing. Programmable portions of the control system have been designed using an 8748 microprocessor. The printed circuit board has been constructed and encoder construction has begun. Initial testing of the power circuits under loading has been successful and the system is functioning reliably with high efficiency.

Future plans — Plans are to continue construction and within 3 months to implement the system on a present wheelchair to determine its ability to meet user requirements dynamically. An effort is being made to locate a manufacturer for the system, since it can be used with present powered chairs as well as with potential future models of differing design ■

HHS, NIGMS Grant

MYOELECTRIC CONTROLLER FOR ORTHOTIC/PROSTHETIC SYSTEMS

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The aim of this project is the development of techniques and implantable instrumentation necessary of high-spinal-cord-injured patients and amputees to obtain multiple command control signals from residual musculature, in order to activate upper-limb orthotic and prosthetic appliances. Emphasis will be given to producing command signals with sufficiently high signal-to-noise ratios for the execution of finely controlled movements ■

VA RR&D CENTER HINES

NEW DESIGNS FOR PERSONAL LIFTS

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For many disabled people, a lift is required for transfers in and out of a wheelchair. The most commonly used lifts are large, heavy, and difficult to maneuver. Despite these liabilities, current designs present a simple solution that works well.

Over the past few months, this Center has worked to develop a design for a personal lift that would retain the desirable features of simplicity and efficiency while avoiding the problems of size and weight.

One design replaces the heavy metal construction of standard lifts with lightweight composite graphite. This effects about a 50 percent weight reduction without sacrificing strength or stability. The basic design of the lift was retained for its simplicity and efficiency. We are now in contact with manufacturers regarding projected market costs of our new design.

The other design completely replaces current lifts. It attempts to combine the function of both a lift and a powered wheelchair. The new "Proteus-Lift Chair" is designed for individuals who cannot transfer independently, such as the spinal cord injured (C5 through C8), cerebral palsy and geriatric patients etc. The new "Proteus-Lift Chair" (i) eliminates the need to store and/or transport two separate (wheelchair and patient lifter) units; (ii) makes it unnecessary to manually push or pull patients while they are suspended from the liftpost — the drive mechanism of the unit accomplishes these tasks; (iii) can lift patients electrically, using the batteries of the unit as a power source if this option is desired; (iv) can "reach around" bathroom fixtures such as a toilet or washbasin and can reach under furniture with not more than 3 inches of clearance; and (v) has detachable low-profile front casters needed to negotiate the 3-inch floor clearances mentioned above. Standard-size casters can be attached easily to the chassis to give the lift chair unit the identical capabilities of conventional power wheelchairs.

The purpose of the new lift/chair design is to provide a better, safe way to transfer the severely disabled from place to place and to eliminate much of the need for physical strength on the part of the assisting individual ■

VA RR&D CENTER PALO ALTO

ULTRASONIC HEAD CONTROL UNIT

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The Ultrasonic Head Control Unit (UHCU) is an electronic device that is designed to allow quadriplegic individuals to express their will and control their environment. Two Polaroid ultrasonic sensors are employed in this design. In the commercial application, camera focusing is accomplished by ranging the distance from the camera to the subject. In this rehabilitation application, two separate sensors are directed at the user's head. The two distance ranges, one from each sensor to the head, and the fixed separation of the sensors, describe a triangle whose vertices are the two sensors and the user's head. The offset from the base line and center line of the two sensors can be calculated from a set of geometric relationships. This information is then used to map the user's head position into a control space.

The main advantage of this type of interface is that no mechanical contact between the sensors and the user's head is required. That effectively separates the user from the device being controlled. Users should not feel "wired up" or confined, as is frequently the case with other interfaces. The remote-sensing nature of the UHCU should result in a socially acceptable and cosmetically pleasing man/machine interface.

Another desirable characteristic of the UHCU is its speed of operation. Typically, 20 samples of head position are acquired per second. Devices that the UHCU controls, can thus be manipulated quickly. The UHCU can be directly substituted in many applications where a joystick is currently utilized. The real-time action and proportional-control nature of the UHCU make it faster to operate, and more precisely controllable, than the discrete-command characteristics of voice recognition units.

Status — Several applications of the UHCU are being considered and one has been implemented. In a mobility application, the UHCU has been attached to an electric wheelchair. The user of the "Smart Wheelchair" tilts his/her head in the direction that he/she wishes to travel. The farther the head is tilted off the vertical, the faster the wheelchair travels in the direction of the tilt. Two versions have been constructed; one utilizing an Everest and Jennings Model 3P, the other employing an Invacare Rolls IV manual chair that has been motorized with the addition of a Solo Products Power-Pac. In this application, the user initiates head control operation by activating a switch with the back of his/her head. The UHCU then performs a calibration sequence by ranging to the user's rest head position. The device then activates the wheelchair motors and the user can then command the motion of the chair. At any time, the user can press the head switch to stop the chair. In both designs, the sensors are mounted behind the user, so that maximum access to the chair for transfers is obtained. These wheelchairs are currently undergoing evaluation.

Pending — Several other applications of the UHCU are being implemented. In the first of these, the unit will be incorporated in the robotic arm system. The arm's voice-command mode will be retained and head-position control will be added. It is hoped that the UHCU, with its real-time input, will augment the discrete and relatively slower input that voice command produces. By combining the two input mechanisms, a more efficient robotic arm control is anticipated.

The next application uses the UHCU as an alternate input for a commercial communication board. This two-dimensional board uses either a single switch or a joystick to access the letters or words at each row-column location. The UHCU will be used in its joystick emulation mode to allow physically disabled speech impaired individuals access to communication.

The final application is similar to the previous one. In this project, however, the display portion of the communication device is a CRT or a custom display. In this manner, the letter or word at each row-column location can be dynamically changed. By employing an anticipatory scheme (the next letter or word is conditioned by the previous selection), the time to construct a given word or sentence could be reduced. This type of product, a head-position-controlled keyboard, has both vocational and communication applications ■

[1]Dr. Gaines is with the Spinal Cord Injury Service, Palo Alto VA Medical Center (PAVAMC).
[2]Margaret Barker is with the Rehabilitation Engineering Center, Children's Hospital at Stanford.

VA RR&D CENTER PALO ALTO

DEVELOPMENT AND EVALUATION OF WHEELCHAIR FEEDBACK CONTROLLERS

VA Rehabilitation Research and Development Center
Palo Alto VA Medical Center, Palo Alto, California 94304

■ Participants in the Wheelchair Feedback Controller project were the following:

From the Rehabilitation R&D Center, PAVAMC: **Robert E. Smith, MSME; William H. T. La, Ph. D.; David Sergio Napolitano, MSEE; Douglas E. Ives, MSME;** and **Larry J. Leifer, Ph. D.**

From the Spinal Cord Injury Service, PAVAMC: **Inder Perkash, M.D.**

Need — This project has as its goal the development of a wheelchair feedback controller intended to ease the control burden of the powered wheelchair user. Presently, most motor controllers are "open loop", i.e., the motor driving signal is not affected by the actual motion of the motor that is controlled. Because the motor controller does not independently react to disturbances in its environment (such as uneven ground, slopes, loss of traction), it is left to the vehicle operator to compensate for those variations from the ideal operating surface.

Another factor that impacts the driving burden experienced by the power wheelchair user is the fact that the controller's characteristics rarely acknowledge the unique abilities of the individual, due to the complexity and expense involved in manufacturing analog controllers with the appropriate signal conditioning capabilities.

Approach — In order to address these problems, the investigators decided to use microprocessor technology to perform the logic operations required to control an electric wheelchair.

The proposed path of development was, first, to model the physical characteristics of various types of wheelchairs mathematically for subsequent computer simulation of different types of control algorithms. Soon after the beginning of this project, the Palo Alto VA Medical Center acquired a Singer-Link Digital Image General System (DIGS). The DIGS will be used to perform the controls simulation and user preference portions of this investigation, in tandem with investigations of real wheelchair hardware.

The optics of the device provide a virtual image of the user's surroundings focused at infinity, with a 30 degree by 50 degree field of view. This, coupled with the use of the motion base included with the machine (to provide motion cues to the subject's vestibular system) provides the user with a compelling illusion of a real vehicle.

Status — The simulation portion of this project is presently awaiting the completion of building modifications to house the simulator at the Western Blind Rehabilitation Center. On the other hand, the development of the actual hardware for a micro-computer-based wheelchair controller has gone forth. It was decided early in the planning stage that a development path embodying "first principles" design methodology was preferable to the alternative of modifying currently existing wheelchair controllers to accept an add-on microprocessor.

The research group had plans to address the issues of efficiency and controller operating noise.

These considerations have had two results. First, the development of a very flexible and powerful controller logic development system with the capability of supporting virtually any control algorithm implementable on an 8-bit microcomputer. (A corresponding 16-bit system with hardware floating point capability is planned for this fall.)

The second consequence has been the development of a power amplifier using up-to-date technology. These are solid state "H bridge" power systems based on power MOSFET (Metal Oxide Semiconductor Field-Effect Transistor) devices which have become readily available in the capacities necessary only in the past few years. These devices have lower drive requirements than conventional bipolar transistors, resulting in a lower parts count, and thus, indirectly, greater reliability.They are able to switch faster than their bipolar counterparts (making possible efficient super-audible switching frequencies), and have smaller losses in the power range of common wheelchair cruising. These advantages combine to make them the device of choice in many state-of-the-art power control applications, and industry sources predict that prices and device losses will continue to fall in the future as the technology matures.

A test protocol for the evaluation of the various control algorithms has been outlined. Two groups of wheelchair "test pilots" will be used. The first will be an expert group, well-trained in the use of the simulator and familiar with the correspondence between the simulated and real vehicles. The second group will be composed of naive users, to insure that the preferences indicated by the first group do not reflect the so-called "test pilot syndrome" which is the ability of sufficiently expert pilots to operate even "uncontrollable" vehicles.

Two test sites are in preparation: the first is a simulation of a local shopping center used for mobility training, representative of a relatively benign environment. The second will be an obstacle course, including demanding maneuvering challenges (such as may be found while maneuvering in interior environments), as well as the classic geographic features used to test the mettle of a motor controller (e.g., compound slopes). The shopping center

data base obviously has a counterpart in the real world, making validation of the simulated environment relatively simple.

Pending — Refinement of the initial algorithms developed for the controllers will continue, and it is expected that one of these systems will be installed on a conventional castered wheelchair late this fall. Further, an interface between the wheelchair controller and the DIGS system remains to be built, so that the vehicle simulator can make use of the actual controller logic hardware and software built for the wheelchairs; this will facilitate the validation of the computer models developed for the vehicles involved in the study ■

MOBILITY AIDS
DECUBITUS ULCERS
CUSHIONS

NIHR REC

TISSUE PRESSURE MANAGEMENT SYSTEM

Rebecca Williams
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at The Institute for Rehabilitation and Research (TIRR), in the Texas Medical Center
1333 Moursund Ave., Houston, Texas 77030

Objective: To improve the quality of life and increase the independence of disabled individuals through the prevention of pressure sores.

Summary: For the last decade, the Rehabilitation Engineering Center at The Institute for Rehabilitation and Research (TIRR) has been directing its clinical and research activities towards the prevention of pressure sores. Through the cooperative efforts of physicians, therapists, engineers, orthotists, and nurses, a comprehensive program has been developed which has successfully reduced the recurrence of pressure sores over a 2-year period by about 80 percent. This program includes routine activities such as clinics, rounds, cushion and mattress evaluations, and patient education programs. The clinical activities have continued to expand to include pilot programs at other facilities, consultations for other hospitals and the Texas Rehabilitation Commission, and inservices to share the REC's research and clinical results ■

NIHR REC

ROLE OF REGIONAL STRESS AND STRAIN DISTRIBUTION IN THE PATHOPHYSIOLOGY OF DECUBITUS ULCERS

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Objective: To develop a mathematical model, capable of predicting changes in tissue pressure and blood flow, based upon radiographically obtained measurements of underlying bone geometry and interface pressure measurements.

Summary: The purpose of this project was to measure certain physiological variables necessary for construction of a first-approximation, predictive, computer simulation of the effects of external loading on a well-defined anatomical location. Such a mathematical model could be extremely useful in the evaluation of load-relieving devices and in the determination of prophylactic management regimes for high-risk decubitus ulcer patients.

Our hypothesis was that we could predict changes in tissue pressure and blood flow based upon radiographically obtained measurements of underlying bone geometry and interface pressure measurements. To accomplish this aim we devised experiments to (i) Make accurate measurements of interstitial tissue pressure, (ii) Correlate interstitial pressure with accurate measurements of interface pressure at different loads, (iii) Describe 3-dimensional force deformation in the tissues directly over a bony prominence with as much accuracy as possible, and (iv) Measure tissue blood flow, with and without loading, as accurately as possible. The past 3 years were used to collect and analyze this data ■

NIHR REC

PATIENT ACTIVITY MONITORING

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Objectives:

A. Develop unobtrusive instruments to monitor specific patient activities and/or devices over extended periods of time, both in hospital and following discharge.

B. Incorporate these instruments into clinical settings for routine use by the professional staff.

C. Evaluate the usefulness of these instruments as clinical tools.

Summary: This project is concerned with studying the activity and behavior patterns of patients with long-term physical handicaps. The major emphasis is to gain a more objective quantitative, and realistic description of what these patients actually do, during hospitalization and after discharge. It is assumed that this information could provide important insights, not currently available, into the rehabilitation process, and could help in the evaluation of programs and devices specifically developed to treat, ameliorate, and/or prevent pressure effects on tissues. The major conclusions of this study include:

A. Instrument-based longitudinal unobtrusive monitoring of selected specific patient activities over extended periods of time is both possible and practical in an inpatient rehabilitation setting.

B. Two relatively unobtrusive instruments — the Rest Time Monitor and the Sit Time Monitor — have been designed, fabricated, tested, and introduced into clinical settings for routine use by the professional staff and for use as research tools.

C. Longitudinal, objective, and quantitative measures of patient activities are useful clinical tools for assessing performance by individual patients and for comparing an individual's progress to standard performance curves.

D. The major findings of two research studies using the RTM showed that:

1. SCI patients who experience infection tend to spend significantly less time out of bed during the 3 weeks just prior to the onset of infection than do those patients who do not experience infections.

2. Fever and certain X-rays (especially IVP) are negatively correlated with time out of bed. These two events showed the highest degree of relationship to time out of bed among 17 selected events.

3. There is no evidence to support the hypothesis that the RTM can be used as an early-warning signal for thromboembolic problems or pressure sores.

4. Time out of bed is an important and convenient indicator of participation ■

NIHR REC

THE INFLUENCE OF ENVIRONMENTAL AGING UPON THE LOAD-BEARING PROPERTIES OF POLYURETHANE FOAM

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Objective: This study examines the possible contribution of environmental exposure to the breakdown of polyurethane foams that are used in the fabrication of wheelchair cushions.

Summary: The effects of environmental exposure upon the loadbearing properties of nine polyurethane foams commonly used for wheelchair cushion construction were studied. Test pieces with and without stretch cloth covers were aged in the open air in Houston over the period of April to October, 1982. The indentative resistance of each test piece was measured initially and at frequent intervals during the exposure period. Differences in hardness changes between covered and uncovered specimens were found to be not significant, with all foams displaying a sharp rise in indentation resistance within the first 2 weeks of aging, followed by a gradual decrease to an average hardness of 65 percent of the initial value over a 6-month period. The hardness changes were found to be strongly correlated with the density, thickness, and initial indentation of the test pieces. Foams of maximum density and minimum practical hardness are recommended for wheelchair cushion construction, to minimize the adverse effects of environmental aging upon the support properties of these devices ■

NIHR REC

THE INFLUENCE OF INFLATION PRESSURE ON THE EFFECTIVENESS OF AIR-FILLED WHEELCHAIR CUSHIONS

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Objective: The purpose of this study was to determine the relationship between interface pressure and the inflation pressure of air-filled wheelchair cushions. This information was intended to provide guidelines for further research in the design of a pressure indicator system that could be used to optimize the use of air-filled cushions.

Summary: Seating pressures were found to be dependent on the inflation pressure of the air cushion. This relative relationship for three commercially available cushions (i.e. RoHo, Gaymar Sof-Care, Bye-Bye Decubiti) is displayed in Figure 1. In all three cushions, underinflation produced a greater sensitivity than overinflation. This implies that overinflating the cushion is less dangerous than not inflating it enough.

A direct relationship between weight and internal pressure was determined; this may be expressed as: inflation pressure = .165 (weight in lb) + 4.5 mm Hg■

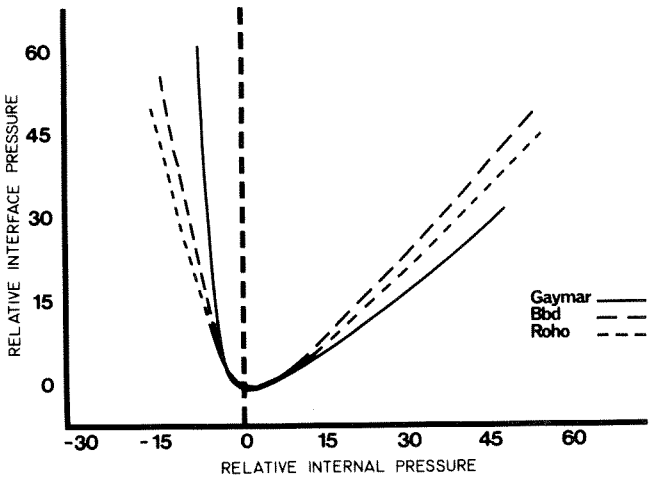

FIGURE 1
Pressure relationship for three commercially available cushions.

NIHR REC

THE RELATIONSHIP BETWEEN URINARY EXCRETION OF GLUCOSYL-GALACTOSYL HYDROXYLYSINE AND DECUBITUS ULCER FORMATION

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Objective: The primary objective of this study was to see if a temporal relationship exists between decubitus ulcer formation and urinary excretions of hydroxylysine glycosides. Specifically we wanted to see if there was any disproportionate rise in excretion of glucosyl-galactosyl-hydroxylysine preceding the formation of a decubitus ulcer.

A secondary but necessary objective was to develop a method for obtaining a complete amino acid profile, including the hydroxylysine glucosides, from urine samples.

Summary: The sample studied during this grant period consisted of 5 normal male control subjects and 10 male subjects with recent spinal cord injuries. The ages varied from 4 to 52 years and the subjects had no previous history of chronic diseases. The gylcoside content of the urine was evaluated on aliquots of 24-hour samples. The samples were also analyzed for creatinine content so that the results, when expressed as μ moles per gram of creatinine, eliminated variations due simply to differences in body size.

Although the ratio of glucosyl-galactosyl-hydroxylysine to galactosyl-hydroxylysine of the patients was not widely different from the ratio observed for the controls, the total increase in hydroxylysine glycoside excretion by the patients hints at a disturbance in the normal collagen turnover. None of the patients have developed skin ulcers to date. This would seem to be in line with the hypothesis that the ratio of glucosyl-galactosyl-hydroxylysine to galactosyl-hydroxylysine goes up prior to decubitus ulcer formation or stays roughly normal otherwise ■

VAMC PALO ALTO

SEATING SYSTEM FOR BODY SUPPORT AND PREVENTION OF TISSUE TRAUMA

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Veterans Administration Medical Center
Palo Alto, California 94304
Rehabilitation Engineering Center
Children's Hospital at Stanford
Palo Alto, California 94304

The purpose of this project is to develop a total seating system that aids in the prevention of pressure sores and enhances the orthopedic management of the spinal cord injured. The centerpiece of this system is the Veterans Administration Seating Interface Orthosis (VASIO). The VASIO is a wheelchair seat cushion designed to redistribute pressures away from the osseous points and onto the more pressure-tolerant areas of the lateral flanks of the buttocks and the posterior thighs.

The version of the cushion for paraplegics (VASIO-P) was tested on 66 patients (57 thoracic, 9 cauda equina) and found to be effective in distributing pressures over the seating surface to levels well tolerated by the patients. Skeletal deformities were found to influence significantly the effectiveness of the cushion in distributing pressure to tolerable levels.

The VASIO-P is not recommended for use by quadriplegics who are unable to independently reposition themselves on the cushion. During the original study, it was found that those who were either malpositioned by an attendant or who became malpositioned through spasticity or other causes were often subjected to unacceptably high pressures. Failure of the patient to maintain his pelvis centered on the cushion typically results in abnormally high pressures beneath one ischial tuberosity and the contralateral trochanter.

A new cushion is being developed for quadriplegics. This cushion (VASIO-Q) is being designed to provide lower peak pressures than the VASIO-P and to compensate for malpositioning of the patient. Several design concepts are being clinically evaluated. Results are still preliminary but appear promising ■

MOBILITY AIDS
AUTOMOTIVE ADAPTIVE EQUIPMENT

NIHR REC

ADAPTIVE STEERING SYSTEMS

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In adapting conventional steering systems to the needs of drivers with severe disabilities, the required effort and range of limb motion may need to be reduced. This requires an increase in overall gain of the steering system — which reduces its margin of stability. Interactions between the driver and vehicle act as a closed-loop control system and have been studied using McRuer's "crossover" model.

A steering ratio that varies with steering wheel position and vehicle speed is desirable for the disabled driver. The study also revealed that the two most important parameters for vehicle stability are driver time delay and steering ratio. Guidelines for varying the steering ratio with vehicle speed and steering wheel position have been developed for a range of driver time-delays; they place a limit on allowable variations in steering ratio.

This variable steering ratio could be implemented with a microprocessor-controlled steering system. An experimental system has been built and tested. That system has not yet been mounted in the vehicle; however, it does show the feasibility of using a microprocessor to implement variable-ratio steering that can be adapated to the needs of a particular individual ■

NIHR REC

DESIGN AND DEVELOPMENT OF DEVICES AND SYSTEMS

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A new prototype of the sedan ingress-egress system has been made with the cooperation of Creative Controls, Inc., a potential manufacturer. The system consists of a double-pivoted power-operated arm attached to the car floor. This arm supports the wheelchair and its occupant while the wheels

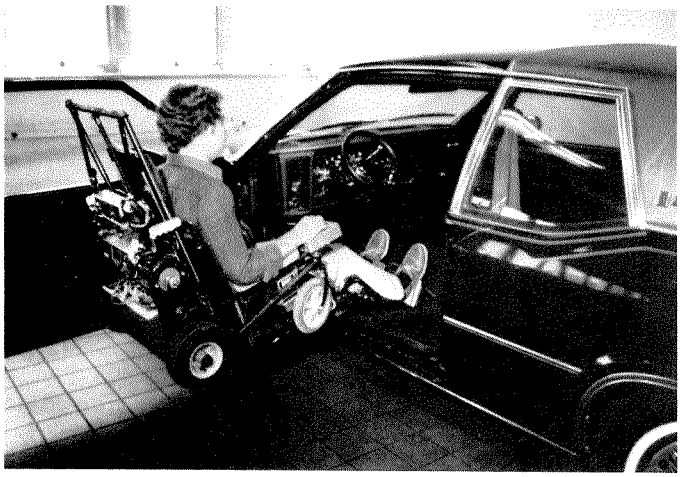

FIGURE 1
Wheelchair and occupant in position to enter vehicle. Wheels are retracted by ball-screw actuator.

retract for rotation into the driver's position (Fig. 1, 2). The car door is also opened and closed by the arm actuator. This system is presently installed in an Oldsmobile Omega and will soon be installed in a 2-door Dodge 400 sedan. These vehicles were donated by General Motors and Chrysler Corporation, respectively.

As the system development is transferred to the manufacturer, the UM REC is studying the potential use of the new minivans scheduled to begin reaching the market this fall. Chrysler Corporation has made a full-sized minivan model available for the analysis of entry systems and wheelchairs compatible with this vehicle. A wood and plastic wheelchair model with a lowering seat allows us to study an occupant entering this vehicle as the driver or as a passenger (Fig. 3, 4). This study is expected to continue as these smaller vans become available ■

FIGURE 2
Wheelchair is being rotated into driving position by supporting arm.

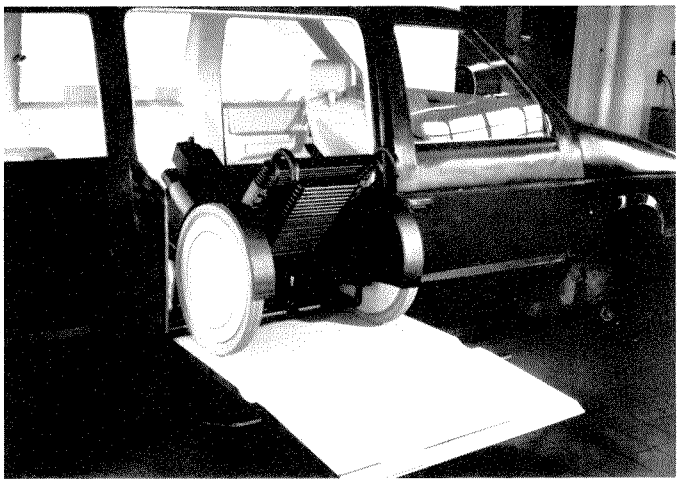

FIGURE 3
Reclining chair enters minivan model via raised ramp.

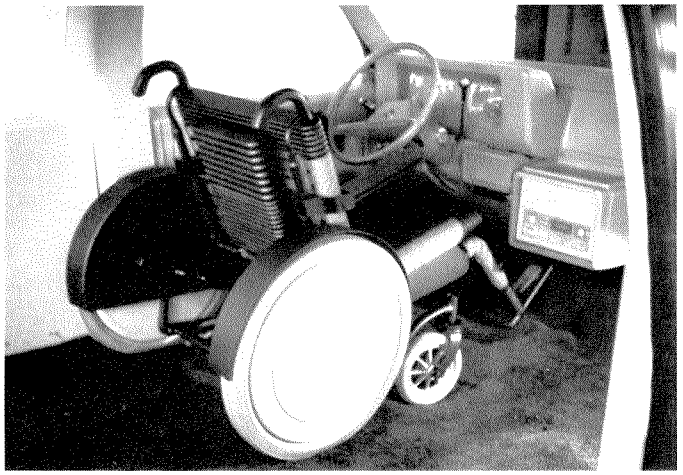

FIGURE 4
Model Wheelchair in driving position in minivan model.

NIHR REC

ASSESSMENT OF PERFORMANCE CAPABILITIES OF THE DISABLED DRIVER

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A part-task driving simulator has been used in an ongoing program for the training and evaluation of persons with perceptual and psychomotor disabilities. Decisions based on simulator evaluations need to be validated by testing driving performance on the road, and an instrumented automobile was used to evaluate the same 8 persons who had previously been evaluated on the simulator.

A Dodge Omni with hand controls was used for on-the-road testing. A compact accelerometer was mounted on the transmission for the recording of longitudinal and lateral acceleration. A force transducer was mounted to record the frequency and severity of braking action. Potentiometers were mounted to record steering control. The driving course was essentially the same as the one previously developed by the UM REC for use in the remediation of perceptual/cognitive deficits.

Each subject was given a trial session. This was followed by a data collection session on another day. On sebsequent but not necessarily consecutive days, two more trial sessions were held, followed by a final data-collection session.

A record was kept of lateral and longitudinal acceleration, steering control deviations from a centerline, the average and maximum values of the linear travel of gas and brake pedals, and of the subjective observations made over the driving course. Testing is in progress to determine the correlation between simulator and actual driving performance ■

NIHR REC

REMEDIATION OF DEFICIENT DRIVING SKILLS IN PERSONS WITH BRAIN DAMAGE

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The purpose of this study was to develop and validate a system for teaching driver readiness skills to persons with brain damage so that they could proceed to a formal on-the-road disabled driver education program. A study was designed to test the hypothesis that systematic training utilizing a small motorized vehicle (modified AMIGO wheelchair) would have a positive effect upon driving an automobile among the population with acquired brain damage.

Twelve brain-injured subjects and four non-brain-injured subjects completed the evaluation and training protocol. The protocol included (i) a pre-training intraffic driving test, (ii) a pretraining cognitive/perceptual evaluation, (iii) a second pretraining intraffic driving test, (iv) a second pretraining cognitive/perceptual evaluation; (v) eight 2-hour training sessions with the modified AMIGO wheelchair, (vi) posttraining intraffic driving evaluation, and (vii) a posttraining cognitive/perceptual driving evaluation.

Preliminary results reflecting the driver educator's rating of each subject indicated that nine of the brain-

injured subjects showed improvement of at least 1 rating point (on a 5-point scale) with 2 improving ½ a scale point and 2 remaining the same. In addition, three participants improved significantly to be recommended to take a state driving test ■

NIHR REC

REMEDIATION OF PERCEPTUAL/COGNITIVE DEFICITS: EFFECTS ON DRIVING PERFORMANCE

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The driving performance of persons with brain damage is directly related to the extent of their perceptual damage. Specifically, persons with brain damage who scored well on certain perceptual tests tended to show good driving performance. These findings suggest that therapeutic techniques capable of improving the impaired perceptual skills might also improve driving performance.

This hypothesis received tentative support in our pilot study and was more thoroughly tested in the present study. Specifically, we have investigated (i) the modifiability of perceptual deficits of persons with brain damage by simple paper-and-pencil techniques, and (ii) the effects of such techniques on subsequent driving performance.

Eight subjects participated in the study. Standard perceptual tests were used to evaluate pre- and post-training perceptual capabilities. Driving performance was evaluated on a specially designed and validated intraffic driving course.

Training exercises were designed to foster improvements in visual scanning, directed eye movements, spatial perception and discrimination, figure/ground differentiation and visual imagery. Each subject received a total of 8 to 10 hours of individualized training.

The results indicated that (i) perceptual skills improved following the perceptual training; (ii) the training was associated with improved driving performance; and (iii) the degree of improvement in driving performance was directly related to the degree of perceptual improvement ■

NIHR REC

WHEELCHAIR RESTRAINTS

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The UM REC occupant protection project is aimed at studying the problems and issues of providing effective wheelchair and occupant restraint for severely disabled persons and at working toward the development and implementation of effective devices and solutions. During the past year, a prototype wheelchair add-on restraint system and head restraint (Fig. 1) were developed and tested at the 30 mph/20G crash-severity level. The performance was excellent, and design efforts are currently underway to modify

FIGURE 1
Prototype wheelchair add-on restraint system with head restraint.

this initial design so that it is easily manufactured and fitted to wheelchairs, and will be acceptable to the user. The testing of commercially available and prototype restraint systems continues at the University of Michigan Transportation Research Institute.

UM REC personnel continue the information dissemination process about wheelchair restraints through formal presentations and articles. Reports are distributed to interested persons, and slide presentations and films are often loaned. Trips to the field to followup previous correspondence provide a useful and sometimes necessary exchange of information ■

NIHR REC

INTERFACING DISABLED DRIVERS TO VEHICLE SECONDARY CONTROLS

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Many disabled drivers have the functional capabilities to operate the primary controls (steering, throttle, and brake) of a vehicle. Some of them may have few if any functional capabilities remaining for operation of secondary controls in a safe and practical manner.

The primary purpose of the interface laboratory is to develop methods and guidelines for interfacing disabled drivers to secondary controls in a motor vehicle. A computer secondary-control simulation system is being developed to evaluate disabled persons. Results of testing will be used to establish general methods and guidelines ■

VAMC ATLANTA

DRIVER SITUATION SIMULATOR

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This system is intended to be used to evaluate disabled-driver controls presently on the market, to evaluate a disabled driver's ability to use such controls quantitatively, to provide a tool for disabled driver training, and to be a research tool for new control development.

Progress — The first system is operable, using a modified arcade game called "Grand Prix", and is implemented on an Apple II Plus microcomputer. Newer software is now being written with better interactive graphics. The control platform or base is a wooden mock-up using real controls coupled electronically to the computer. The system has had a good reception among therapists, researchers, and disabled users. (This design was a winner at the 1982 RESNA Student Design Competition.)

The software package is approximately 30 percent complete at this time and the hardware design is proceeding on schedule. The system has had considerable user and therapist input to date and has had considerable approval even in its primitive form.

Future plans — Plans are to continue with software and hardware development to arrive at a driver-situation simulator in 9 months. This will be completed at the Atlanta Veterans Administration Medical Center with the considerable assistance of medical personnel and user input ■

ADL AND RECREATION

NUREP

MODULAR MOUTHSTICK SYSTEM

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A mouthstick system has been designed and developed by NUREP and the Rehabilitation Institute of Chicago, Occupational Therapy Department, which incorporates a combination of desirable features based on a review of existing literature and examination of commercial systems. This lightweight mouthstick system enables users to independently change a variety of appliance tips and adjust shaft length for performing academic, vocational, and avocational activities.

Components of this modular mouthstick system which could be manufactured in kit form include the following:

1. A custom mouthpiece (to be fabricated by dentist).
2. A telescoping shaft consisting of a fiberglass arrowshaft which can be slid in/out of an aluminum tube by the user. To extend the shaft, the user pulls it out like a telescope by a tab on the distal end; the shaft is shortened by pressing the distal end against a fixed object.

3. A shaft/appliance-holder tube-latching mechanism consisting of a round-head screw which holds a rubber "O" ring against a threaded insert; the insert is bonded into the distal end of the arrowshaft.

4. Three appliance-holder tubes fabricated from Delrin plastic.

5. A mounting system consisting of an aluminum bracket (which positions the appliance holder tubes) attached to an adjustable camera clamp.

A custom-fit mouthpiece is fabricated using an aluminum bite fork which is covered with a pliable football mouthguard material. The dental impression is obtained by pressing an articulated plaster model of the teeth into the mouthguard material which is warmed and softened.

The mouthstick system is now commercially available without the telescoping shaft and mouthpiece ■

VA RR&D CENTER PALO ALTO

DEVELOPMENT OF RECREATIONAL BICYCLES FOR THE DISABLED

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VA Rehabilitation Research and Development Center
Palo Alto VA Medical Center, Palo Alto, California 94304

Need — As a recreational activity engendering both physical and emotional vitality, bicycling is particularly appropriate for an individual facing barriers in mobility and participation.

Approach — Our approach has been to continue the development of the arm-powered bicycle, called the Handbike (previously called the Para-Bike), and begin development of the Handbike Tandem for disabled and able-bodied individuals to ride together. Development has been carried out on a prototype/evaluation basis.

Status — Four prototypes of the Handbike have been completed to date. The latest version features adjustable side casters which touch down at desired lean. They can also be fastened down to hold the Handbike upright for four-wheel maneuverability indoors. A folding crank tower has been added to facilitate transfer to and from a wheelchair.

Development of the Handbike is now complete, and a company has begun production.

A first prototype of the Handbike Tandem has been built and is currently being test-ridden. Like the Handbike, the Handbike Tandem is a bicycle, with lean-adjustable side casters. It features a Handbike in the front and a standard foot operated bicycle in the back. With dual steering, the Handbike Tandem may be ridden as a single-rider vehicle from either the front or the back.

Pending — The design of a second prototype of the Handbike Tandem is in progress. Because of the success of the first Handbike Tandem prototype, it is expected that a second prototype will complete the pre-production development ■

TREATMENT AND TRAINING

LIBERTY MUTUAL, NIHR, SWEDEN

TOPICAL ANESTHESIA: A NEW TREATMENT METHODOLOGY FOR PATIENTS WITH STROKE

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Application of topical anesthesia to the skin has been used in our laboratory in the past 3 years for the purpose of improving the control of movement in patients affected with spasticity. Desensitization of cutaneous receptors has been found to modulate the excitability of selective motoneurons so that discrete active movement patterns can be performed. Utilization of these active movements in functional activity requires a long-term process of relearning, as well as reprogramming of the movements executed by the nervous system. Possible accessory neural pathways and switching mechanisms could be activated in the central nervous system which could compensate for the loss at the site of the lesion.

The short-term effect of application of topical anesthesia has been studied on 70 patients afflicted with spasticity of different pathologies.

During the past year, a new force platform with computer-assisted measurements of the forces applied to the feet was installed and is employed in our

experiments. Stabilograms (degree of the center of gravity sway during static standing) are being recorded in stroke patients before and after application of topical anesthesia to the lower limbs. Furthermore, photoelectric light cells have been constructed in order to accurately measure the speed of limb movement (either during walking cycles or during rapid repetitive movements of the arm and leg).

Preliminary analysis of the gait data demonstrated a substantial decrease in the asymmetry between the lower limbs during the walking cycle. Substantial increases in angular displacement of the hip, knee, and ankle joints, as well as smoothness and speed of movement, were also noted after a 1-month period of treatment with topical anesthesia. Computerized axial tomography records (CAT scans) revealed that patients with lesions in specific areas of the brain realized the greatest amount of improvement in their movement capability. Again, as previously reported, no measurable improvements were noted after a 1-month period of treatment with a placebo spray.

During the past year, we made two additional noteworthy observations. In one of our subjects, functional recovery has continued to increase for 3 years after termination of the treatment program. Such progress is not usually seen in similar patients who have received different treatments. The second interesting observation was made on a patient with chronic head injury (18 years) and on a stroke victim (12 years). In both cases, immediate improvements in their active movement patterns were noted when the topical anesthesia was applied.

Recently, we have begun to use another topical anesthetic (10 percent Xylocaine). Preliminary observations indicate that it should provide even more dramatic results than with 20 percent Benzocaine ■

LIBERTY MUTUAL, NIHR, SWEDEN

TOPICAL ANESTHESIA: POSSIBLE USEFULNESS IN PATIENTS WITH CEREBRAL PALSY

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Cerebral Palsy is a major congenital disorder which is manifested by spasticity, flaccidity, ataxia or athetosis. Patients with cerebral palsy are usually afflicted with one or more of these motor control disorders. The use of topical anesthesia in the improvement of motor control of spastic-type cerebral palsy has been tested in six patient (four children and two adolescents). Videotape analysis of active movement patterns were recorded before and 30 minutes after the application of topical anesthesia (20 percent verify the short-term effect of topical anesthesia on muscular activity). The range of movements of the lower-limb joints was measured in one patient using conventional methods. Electrophysiological and gait studies were also performed on two patients to correlate the physiological and functional changes in the neuromuscular system after desensitization of the skin.

Preliminary results demonstrated a rapidly manifested short-term increase in joint mobility and reduction of muscular stiffness, as well as an increase in active movement patterns of the upper and lower limbs, after application of topical anesthesia. These results varied in degrees among different patients. Gait analysis demonstrated an increase in stride length and walking speed as well as a shift of the temporal component of the gait cycle toward normalcy. Subjective observation by the patients and their guardians also indicated an increase in the active movement pattern of the lower limbs ■

LIBERTY MUTUAL, NIHR, SWEDEN

TOPICAL ANESTHESIA: POSSIBLE USEFULNESS IN PATIENTS WITH NEUROGENIC BLADDER

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The application of topical anesthesia in the control of neurogenic bladder for patients with spinal cord injury has continued in the past year. These patients have considerable difficulty in voiding their bladders due to their inability to voluntary relax the muscles which control the opening of the bladder.

Two patients with spinal cord injury at T6 and T12 were tested. The patients were catheterized with a specially designed trilumen catheter under aseptic conditions. The intrabladder and intraurethral pressures were measured during gradual infusion of the bladder with a radio-contrast solution (Furandantin). The entire urodynamic study was monitored with an image intensifier and was videotaped. The myoelectric signal of the external urethral sphincter muscle

was also recorded before and 30 minutes after application of topical anesthesia to L1, S2, and S3 dermatomes near the scrotum and the upper part of the thigh. Patients with assynergic bladder (simultaneous contractions of the detrusor bladder and sphincter muscles) were selected for the study.

Experiments are in progress to identify which of the various topical anesthetics is the most effective in decreasing the synergistic muscular contractions in patients affected with spinal cord injury. Preliminary results are encouraging. Mapping of the skin areas which control the bladder synergy is foreseen ■

VA RR&D CENTER HINES

AN ENHANCED UNDERSTANDING OF THE SPINAL PHARMACOLOGICAL SUBSTRATE FOR THE NEURAL MECHANISMS UNDERLYING BLADDER DYSFUNCTION AFTER SPINAL TRAUMA

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The precise underlying neurological cause for bladder dysfunction after cervical, thoracic, or lumbar spinal trauma is unknown. Recent evidence from two different areas suggests that a peptide called enhaphalin, that is produced within the body and that acts much like morphine, may play a key role: (i) patients who have undergone injections of morphine-like compounds onto the spinal cord for pain relief often exhibit problems in urination; and (ii) morphine-sensitive receptors have been found in that part of the sacral spinal cord that controls urination. We hypothesize that a morphine antagonist (i.e., a competitive blocker) like naloxone might prove extremely beneficial in helping restore bladder function if applied to the spinal cord just after trauma. In fact, naloxone given systemically (i.e., IV) does appear to have a helpful effect on restoring both skeletal muscle and bladder function in the long term spinal patient.

Our results to date indicate that in six normal (i.e., uninstrumented and awake) dogs, the bladder volume at which urination began was raised significantly after spinal morphine, and that this change was reversed by spinal administration of naloxone. Such changes in micturition threshold that follow spinal morphine injection resembled very closely the changed thresholds that we later saw following spinal transection in these dogs. Further, there was a reduction of micturition thresholds in two of the three acutely transected dogs given spinal naloxone. While further experimentation is necessary, these preliminary results do highlight a possible role of the endogenous opiates in producing bladder dysfunction after spinal trauma. We are now extending these pharmacological studies to our chronically instrumented animals ■

VA RR&D CENTER HINES

VOICE-OPERATED APPLIANCE CONTROL AND SWITCH

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Recent advances in voice recognition technology have provided low-cost integrated circuits capable of speaker-independent recognition of up to 16 words. This center has developed two devices to demonstrate the usefulness of this technology to disabled people.

One device is called the voice-operated appliance control (VOAC). The VOAC allows its user to operate up to 256 electrical devices with three simple voice commands: "go ahead," "search" and "stop." "Search" causes the VOAC to sequentially display its three basic control modes: "all on," "all off," and, "select." When the desired mode is displayed, it is selected by saying "stop." The user executes the mode by saying "go ahead." Selecting "all off" or "all on" will turn all units off or on. Selecting "select" allows control of individual units. "Faster" and "slower" control the display rate at all times.

In the select mode, the VOAC sequentially displays the numbers of available units. A unit is selected by stopping the display when the unit's number appears. When the unit has been selected, the VOAC sequentially displays functions available for that unit. Possible functions are "on," "off," "bright," "dim," and "momentary." The latter will turn a unit on until the user says "stop." As before, functions are selected by stopping the display and saying "go ahead."

The voice-operated switch (VOCALINK) is designed to replace the two-position switches used to activate many electrical devices for disabled people. These switches can be breath-activated (sip/puff) or operated by small movements of the lips, tongue, forehead, arm, leg, or foot.

The two switch positions are replaced with the words "go ahead" and "stop." These words can be used alone or in combination to control most devices.

A third word "repeat" can be used to repeat the basic control words or word combination. This feature is particularly useful with devices that use scanning, such as TV remote controls.

VOCALINK consists of two separate units: a voice-recognition module and a control module. The voice recognition module determines what word has been said, and transmits a code for that word to the control module. The control module interprets the code and activates one of two electronic switches ■

VA RR&D CENTER PALO ALTO

NERVE REPAIR AND EVALUATION

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Need — The lack of objective methods for assessing the extent of nerve injury and regeneration compels physicians to rely on subjective criteria in making clinical decisions regarding type and timing of care; it also hampers the search for better methods of nerve repair. These are significant problems because present methods of peripheral nerve repair, even those employing modern microsurgical techniques, rarely result in regeneration sufficient for full functional recovery. Two microsurgical repair methods, epineurial suture (ES) and fascicular suture (FS), are in common use. Neither method has been shown to be clearly superior.

The invasion of scar tissue into the repaired nerve is considered to be a significant barrier to regeneration. A new technique, termed tubulization, utilizes a tube or wrap of biocompatible membrane to re-oppose the ends of severed nerve and to shield the regenerating axons from the ingrowth of scar. This method may have other advantages in that it produces total circumferential alignment of the nerve or fascicle, is relatively noninvasive, and contains (and possibly directs) the sprouting axons. The materials used for these repairs have included tubes and membranes of vein, Silastic, fibrinogenic material, collagen, and polyglycolic acid (PGA, adsorbable suture material).

The enhancement of regeneration through the development of more sophisticated surgical alignment techniques, the application of pharmacological agents, or the use of other modalities has been hindered by the lack of quantitative means of monitoring the regenerative process and evaluating the extent of functional reinnervation. Preliminary results of a parallel investigation of surgical repair techniques and methods for evaluating functional regeneration are presented.

Approach — Histological techniques are the most frequently used quantitative methods of evaluating the extent of regeneration following repair. The fiber diameter histogram (FDH) is obtained by determining the number of axons within specific cross section diameter ranges; the count:diameter data are normally presented in histogram form. The FDH is used to evaluate the number and maturity of the regenerated axons. Longitudinal architecture of the axons at the repair site is a more qualitative means of evaluating repair technique success.

Histologic assessments often correlate poorly with the functional conduction properties of the regenerated axons; it is for this reason that the distribution of conduction velocities (DCV) approach has been used to evaluate repair methods. The DCV is the electrophysiologic counterpart of the histologic FDH. It is typically plotted as a histogram, showing the relative contribution to the compound action potential (CAP, related to the number of axons) from axons conducting in specified velocity classes. The DCV provides information on the conduction properties of the entire population of fibers within the bundle, whereas classical measures of maximum conduction velocity (calculated from the waveform onsets) and CAP amplitude primarily represent only the fastest fibers within the bundle.

The DVC of mixed nerve (both sensory and motor) can be obtained by the "deconvolution" of two CAPs recorded at sites separated by a known distance (2CAP). The deconvolution technique can be applied to two muscle action potentials (MAP) evoked by stimulation at two sites along the nerve to derive the DCV of motor axons (2 MAP). The motor DCV can also be obtained by a collision neurographic technique (CMAP). This technique employs the interaction of two CAPs evoked by carefully timed stimuli to limit conduction to a small range of conduction velocities. These DCV techniques have also been applied to humans for the evaluation of perhipheral neuropathies.

Status — The median and ulnar nerves of 13 primates, Macaca Fascicularis (Crab-eating monkey), were used as the model for investigating repair techniques.

The nerves were exposed at the wrist and then transected. The nerves were then repaired by the ES method (14 nerves), or by the FS method after dis-

section to the fascicular level (16 nerves). Tubulization was done at the fascicular level (FT) using split PGA tubes (17 nerves). Five nerves were not repaired, a 1.0 cm segment being removed and submitted for preoperative histologic evaluation.

Preliminary analysis of the electrophysiologic data from a small number of primates showed no significant difference in regeneration between the three repair methods. There was a significant difference between the repaired and unrepaired nerve regeneration. Histologic evaluation showed generally better longitudinal architecture of axons at the repair site of nerves repaired with the FT technique than those repaired by other techniques. FDH evaluations have not been completed at this time.

Pending — Pending are FDH analyses of all nerves and an analyses of remaining DCVs. Also pending is a study of the effects of tension on regeneration in the same animal model. Due to the lack of a clearly superior surgical repair method, other modalities specific to the regenerative process, such as pharmacological agents, will be investigated. To aid the surgeon in determining the course of treatment, methods for evaluating the extent of injury, preoperatively and intraoperatively, are being developed to allow the full potential of the new repair methods to be realized ■

VA RR&D CENTER PALO ALTO

A LEARNING LABORATORY FOR THE DISABLED

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It is hypothesized that an interactive learning lab that provides disabled users with independent access to video information will be a useful tool in rehabilitation programs. Key features of such a system will be its accessibility to users with varying capabilities (from high-level quadriplegics to able-bodied), its capacity for abundant video information, and the quality of giving users both real and perceived control of the system. Additionally, it should be able to test the users on material presented and save that data for interpretation or studies.

Design of such a system presents three major challenges. The first is to design a "library" system for the video material.

The second design challenge is to specify an interface, or set of interfaces, that allows all users to access the system as naturally and efficiently as possible at their level of ability.

Finally, the system must be designed to be compact and portable, yet at the same time provide isolation for the user.

Status — A concept-proving prototype Learning Laboratory (LLab) has been designed and constructed using an Apple II+ computer, a Panasonic VHS video-tape player, and a Scott Instruments Shadow/VET voice recognition unit. This prototype will be used in the Palo Alto VA Medical Center Spinal Cord Injury Service to provide both technical and clinical feedback for the design of the next-generation system.

Although documented testing has yet to begin, several important facts have already been learned about the system. First, only a very small body of knowledge exists in the field of interactive video education. It is apparent that this prototype will serve as a test-bed for developing good interactive video lesson planning techniques. Secondly, there are few high quality, up-to-date video tapes available dealing with spinal cord injury. Finally, since the system's computer is able to record large amounts of data about each session, the LLab is emerging as a powerful research tool. Studies ranging from interface use to the psychological impact of different educational styles can be carried out with the LLab ■

NIH MUSCULOSKELETAL

SKELETAL MUSCLE ADAPTATIONS INDUCED BY TRAINING

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This project is concerned with skeletal muscle function, energy metabolism, and biochemical adaptations induced by exercise training. Particular attention is given to the response of the different skeletal muscle fiber types, since each fiber is characterized by distinct biochemical and physiological properties. Further, these distinctions probably have a direct influence on the adaptive responses induced within each fiber type by exercise training.

Aspects of adenylate metabolism and the purine nucleotide cycle in working muscle and during recovery will be evaluated. This evaluation will include an assessment of the factors that are important in the activation of AMP deaminase in vivo and the amine source for adenylate resynthesis following

intense muscle use in rats. The involvement of certain amino acids in energy metabolism will be evaluated during steady-state muscle use with an isolated perfused hind-limb preparation. The energy contribution of branched-chain amino acid oxidation, the extent of oxidative deamination of glutarate, and the mode of amine nitrogen elimination from the working muscle will be determined.

A major adaptation induced in skeletal muscle by training is an increase in the capacity for ATP provision via oxidative metabolism. The impact of this adaptation on the above processes will be made. In addition, investigations with muscle stimulated in vitro will be performed to explore the physiological significance of the adaptive changes induced by training ■

NIHR REC

FACILITATION OF VOLUNTARY CONTROL USING TRACKING TASK TRAINER

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Introduction — A microprocessor-controlled tracking task trainer has been developed at this institution for training reciprocating motion. Results recently compiled on a study over the period of a year, for a group of 20 subjects selected from the outpatient population at Rancho, reveal significant improvement in functional ability for those patients in the study receiving regular tracking-trainer treatment. Functional improvement was measured as an increase in the number of turns of a wrist-motion task designed to test reciprocating motion ability, and by two indices generated by the tracking trainer: "ONTIME," the amount of time that the patient correctly tracks the target during a task, and "ERROR SCORE," an integral of the tracking error during a task.

Methodology — The Tracking Trainer was developed using a Digital Equipment Corp. MINC 11/23 computer for software design, and a Tektronix 8001 microprocessor development lab for hardware design and software/hardware integration. The system presents a randomly moving target on a video monitor for a patient to track by means of an electrical goniometer placed about an affected joint. The Trainer can be used for both coordinated motion treatment and measurement of patient motor-control progress. The device is based on the Motorola 6800 microprocessor and has many control options available to the therapist using the device. These options include target shape and motion parameters, treatment times, and patient compensation parameters.

Twenty hemiparetic patients were selected from the patient population at Rancho Los Amigos Hospital.

Results — Results of the study showed significant differences between the Study and Control groups.

For the Control group, a 17.9 percent increase in ONTIME was seen as compared to 43.9 percent for the Study group. Correspondingly, there was a decrease of only 13.1 percent in the ERROR SCORE for the Control group while the ERROR SCORE for the Study group dropped 32.6 percent. In the functional test, the Study group improved an average of 3.3 turns in 45 seconds while the Control group improved only 0.7 turns. Comparing the two measurement techniques to each other (the ONTIME and ERROR SCORE versus the turning test) it is seen that similar ratios exist when data from the Study and Control groups are compared. For the turning test, a ratio of approximately 4.7 to 1 for the Study group is seen compared to the Control group and for the Tracking Trainer indices the ratio is approximately 2.5 to 1. The progress of a Study and a Control patient was compared over the course of three weeks for ONTIME and ERROR SCORE.

Conclusion — It has been shown that the use of the Tracking Trainer can improve functional ability in the control of a reciprocating motion task ■

NIHR REC

THE CONTROL EVALUATION-AND-TRAINING KIT

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The Control Evaluator and Training Kit (CETK) is a portable microprocessor-based device used as a tool for systematic, quantitative assessment and training for using controls with assistive devices. This tool is used to collect comparative information regarding a disabled person's ability to control assistive devices used for mobility, communication and environmental control.

The Control Evaluator and Training Kit is designed to provide to the professional community working with disabled individuals a tool to evaluate and train

for control of assistive devices. Used with the publication "A Guide to Controls: Selection, Mounting, Applications," decisions could be made regarding a person's ability to use standard controls and whether specialized help would be needed to identify an appropriate control.

Quantitative evaluation is needed to compare control site/control combinations identified during an initial evaluation to develop a list of controls, rank-ordered according to optimal use by the client. The measures include the client's speed and accuracy in activating the control, and the degree to which the performance with a control can be repeated over time, i.e., from week to week.

The measurements that are monitored with the CETK are trial time, frequency (activations/sec), latency (reaction time to either release or activate a switch), duration (length of activation) and performance errors. These measurements are used to collect data regarding speed, accuracy, fatigue, and repeatability.

Based on these performance measurements, each of the control site/control combinations initially determined to be potentially useful are rank ordered. From that list, the user and the examiner may select according to the device to be operated and according to the user's preference, based on experience with the control using the CETK.

Other current research projects in the communication and control area include:

- Use of speech recognition as a method of controlling assistive devices by individuals with unintelligible but consistent speech
- Applications of alternatives to keyboards
- Development of systems to increase opportunities for people with physical limitations to have access to computer systems
- A comparative study of control and display principles which affect efficient use of communication aids for severely physically disabled individuals ■

VAMC BRONX

CAPUCHIN MONKEYS AS AIDES FOR QUADRIPLEGICS

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Pilot project research has shown that capuchin monkeys have the potential to be as valuable to high-level quadriplegics as guide dogs are now to the blind. Current goals and the progress made on each is as follows:

1. The standardization of training procedures for teaching monkeys a basic repertoire of skills. Approximately two-thirds of the training procedures used in teaching a basic repertoire of skills have been standardized, and are described in a 100-page illustrated training manual. By following the instructions in this manual, inexperienced college students have successfully trained naive monkeys with only occasional help from a training supervisor.

2. The redesign of equipment which allows the disabled user to direct, reward, and punish his animal helper. The shock/buzz remote-control harnesses used to discipline the monkeys have been reduced in size and weight. A variable-level shock control has been added to the unit. Powder reward dispensers which frequently clogged have been replaced with inexpensive manually operated liquid-reward dispensers.

3. A directory of new skills which can be taught to monkeys. Only four new behaviors have been added to the basic list. It seems as if most high-level quadriplegics share many of the same basic needs.

4. Placement of 3-4 monkeys per year with new owners. Three additional placements have been made since June of 1982. Feedback has resulted in a better understanding of the type of situation in which these animal aides can be of most value.

5. The evaluation of all placements. A proposal is being prepared for submission to the VA Prosthetic and Sensory Aids Service requesting an independent evaluation of simian aides.

6. A cost/benefit analysis for the disabled recipient and the health care system. Preliminary results indicate the financial and psychosocial benefits derived from owning a simian aide outweigh the costs. A more formal analysis awaits data that will be collected during the independent evaluation.

7. An analysis of the type of organization which can train and place simian aides on a larger scale. A detached outline of an organization has not only been drawn up, but established. Helping Hands: Simian Aides for the Disabled, Inc. was incorporated in New York State in October of 1982 as a nonprofit organization ■

DIAGNOSTICS AND INFORMATION

NIHR REC

IMPROVING THE VOCATIONAL PROSPECTS OF THE SEVERELY DISABLED

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Projects of the Center — The following report covers the period from July 1, 1982, to June 30, 1983.

Evaluation Project — The efforts of the Evaluation Project relate primarily to the Available Motions Inventory (A.M.I.). The latter is an evaluation system which identifies physical competencies as they relate to refining the utilization of the data derived from the A.M.I. Don Malzahn is Director of this project.

Independent Living Project — This project of Rehabilitation Engineering Center has consistently supported the main charge of the Center which is occupationally related. Employed disabled persons must have schemes whereby they can operate independently in their home setting and for personal care at the workplace.

Aspects of independent living which have been addressed this grant year are requirements for independent access from home settings, requirements for independent living in kitchen and bathroom areas of the home, and availability of commercially produced items to meet such needs. Elmer Hoyer is Director of this project.

COS Unit Project — This is an experimental vocational diagnostic and training project. Some aspects which have been researched this grant year are the effectiveness of posture seating, and worksite modifications in enhancing work performance. In conjunction with the evaluation project, analysis was made of work-related skills having value in predicting subsequent work performance. Marcia Perry is Director of this project.

Technical Brief Publication — A Tech Brief is published periodically by this Center. It features descriptions of devices which alleviate limitations of disability in worksite or daily living settings ■

NIHR REC

A COMPUTER-AUTOMATED SYSTEM TO ASSESS FUNCTION OF HANDICAPPED INDIVIDUALS

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For more than two decades, members of this group have been developing and evaluating batteries of tests for assessing functions of handicapped individuals. Their most recent test battery is computer-automated and includes assessments of mental alertness, vision, hearing, steadiness, reactions, sensations, speed and coordination, posture, selected activities of daily living, strength, and fatigue.

The site of this work, the Neurofunction Laboratory at the Health Science Center, is now being expanded to include assessments of gait, range of motion about various body joints, and propriopception; existing tests are being improved; and the laboratory's utility as a device for assessing the functions of handicapped individuals is being evaluated. Patient groups will include those with spinal cord injuries, brain injuries, stroke, adult cerebral palsy, spina bifida, back disabilities, amputated limbs, multiple sclerosis, Parkinson's disease, Huntington's disease, peripheral neuropathies, tardive dyskinesia, and myasthenia gravis. Studies will also be done to determine the reliability of test measures, and the effects of age, gender, learning, and handedness in normal individuals. Results of studies with normal individuals will be used to establish a data base from which patient data can be scored as a percentage of normal function, adjusted for age and gender.

After applicability to specific patient populations has been determined, the Neurofunction Laboratory will be used to evaluate the effectiveness of new drugs, surgical procedures, and rehabilitation treatments, as well as to assist in patient diagnosis and disability evaluation.

Primary funding for this effort comes from a grant recently awarded by the National Institute of Handicapped Research for the purpose of establishing a

Rehabilitation Engineering Center for functional assessment of the handicapped. The grant went to a consortium of four institutions: the University of Texas at Arlington, the Dallas Rehabilitation Institute, the University of Texas Health Science Center at Dallas, and the Dallas Rehabilitation Foundation. The consortium was organized by investigators with an interest in rehabilitation engineering ■

NIHR REC

QUANTITATIVE ASSESSMENT OF MUSCULAR FATIGUE

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Experiments to determine how handedness, gender, and force level relate to the process of localized muscle fatigue have been completed over the past year. A total of 40 normal adult subjects have been tested according to the following categories: 10 right-hand-dominant males, 10 right-hand-dominant females, 10 left-hand-dominant males, and 10 left-hand-dominant females.

The first dorsal interosseous (FDI) of the hand was tested bilaterally in each subject during constant-force isometric contractions at predetermined force levels. A device called the Muscle Fatigue Monitor (MFM) developed at this laboratory, and recently updated under separate sponsorship, was used to track the median frequency of the surface myoelectric signal recorded from the FDI. The median frequency is considered to be an optimal parameter for objectively and quantitatively measuring changes in the power spectrum of the myoelectric signal which are related to localized muscle fatigue. This data is presently being analyzed with specific reference to measurements of the initial median frequency (the median frequency during the initial 2 sec of a contraction) and the rate-of-change of the median frequency during each sustained muscle contraction. Comparisons of these measures between corresponding contralateral and ipsilateral FDI muscles will be investigated, and the effect of handedness, gender, and force level of contraction will be determined.

Preliminary results suggest that contralateral FDI muscles have different performance characteristics, which are related to hand dominance and possibly to anatomical and/or physiological differences. Handedness should therefore be considered in the design of research studies or treatment programs where fatigability may be a factor, when contralateral limb muscles are compared.

During 1982, clinical applications of the MFM were investigated with further tests on patients affected with muscular dystrophy. Two patients with Duchenne muscular dystrophy tested in our pilot study last year were retested, and these results compared favorably to the patients' clinical course. In addition, other forms of muscular dystrophy were investigated including limb-girdle, myotonic, and Becker dystrophy. Suspected carriers and other family members were also tested. Analysis of these data with the MFM indicates that, in most patients and carriers, the median frequency does not decrease during sustained isometric contractions, particularly at higher force levels.

In order to determine the applicability of this technique for screening and evaluation of patients with muscular dystrophy and other neurological disorders, further tests with the MFM on patients and age-matched controls are planned ■

LIBERTY MUTUAL, NIHR, SWEDEN

THE MUSCLE FATIGUE MONITOR

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Our study, directed at developing a technique for objectively measuring the rate of fatigue in contracting muscles, has led to the design of a device called the Muscle Fatigue Monitor. This device tracks the median frequency of the myoelectric signal detected on the skin above the muscles. (The median frequency divides the power density spectrum into two halves.) Changes in the value of the median frequency appear to be correlated to the progression of localized muscle fatigue.

The present laboratory device is capable of recording and plotting a single channel of information. To perform more complex fatigue experiments, a multiple-channel muscle fatigue device was required. After evaluation of the additional device requirements, a new design was implemented, utilizing digital microprocessor circuitry to process, store and display the median frequency signal. The new device is capable of processing up to four channels of median-frequency information, and an additional four external channels of information such as force,

position, or torque. It also monitors the incoming myoelectric signals for error conditions such as out-of-limit signal or artifacts. The resultant information from each channel can be plotted in a four-color graph, along with text information about the experiment or, if desired, can be stored on cassettes for later evaluation.

The new muscle fatigue monitor is structured for flexibility, allowing rapid change of both hardware and software programming to suit individual experiments. It is also physically small enough to fit inside a briefcase, allowing easy transportation ■

LIBERTY MUTUAL, NIHR, SWEDEN

CLINICAL APPLICATION OF THE MUSCLE FATIGUE MONITOR

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The Muscle Fatigue Monitor has been used in the past 2 years to attempt to assess muscular dysfunction in patients affected with peripheral nerve injury, chondromalacia patellae, and muscular dystrophy. By providing the clinician with a reliable and objective measure of localized muscle fatigue, the Muscle Fatigue Monitor could be useful in the diagnosis, evaluation, and treatment of muscle disorders.

We have investigated further the usefulness of this device in patients with muscular dystrophy. Patients from 4-15 years of age were asked to produce constant force through isometric contractions sustained at various durations and force levels. The myoelectric signals were recorded from the tested muscle group (biceps in the arm and quadriceps in the leg) and analyzed using the Muscle Fatigue Monitor to compute the median frequency of the power density spectrum.

Two Duchenne muscular dystrophy patients tested in our pilot study last year were retested this year: and the results compared favorably to the patient's clinical course. The time rate of change of the median frequency was distinctly abnormal and very similar in all tests. The mother (a carrier) of one Duchenne muscular dystrophy patient was also tested and her findings were surprisingly similar to those of her son. Patients with other forms of muscular dystrophy are also being investigated. Two myotonic dystrophy patients and one limb-girdle dystrophy patient have been tested, as well as some family members ■

NIHR REC

ANTHROPOMETRICAL STUDIES: FUNCTIONAL CAPABILITIES OF AN SCI POPULATION

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Efforts have been directed toward the preliminary tasks that will insure the collection of relevant and meaningful data. A sample target population for initial testing has been defined as those persons who have suffered trauma to the cervical spine resulting in functional quadriparesis and the inability to transfer from a wheelchair. The functional capabilities of persons in the target group are being studied qualitatively by observing these individuals in the activities of daily living, including driving-related activities. A literature review has been conducted to determine the availability of relevant data and the problems and methods of previous investigations of this nature ■

NIHR REC

EVALUATION OF UPPER-EXTREMITY FUNCTION IN CHILDREN WITH CEREBRAL PALSY

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Adaptation of the current data acquisition and handling system used for gait analysis, to evaluate upper-limb activities, has been completed. This included (i) adaptation of computer software for acquiring, analyzing, and plotting data of non-repetitive nature and of longer duration than a gait cycle, and (ii) fabrication and testing of the appropriate chamber and equipment.

An appropriate series of tasks and protocols which can be conducted in a reasonable amount of time were also established. The average time needed for an evaluation was determined as approximately 2-1/2 hours. This consists of 50 minutes for patient orientation to the lab environment and clinical evaluation, 60 minutes to prepare the subject for testing, and 35 minutes for actual testing.

The Gait Analysis Laboratory system was modified to examine the kinematics of upper limb motion (limb-segment motion, shoulder, elbow, and wrist joint angular displacement and velocity changes,

the trajectory of the reach, and the phasing of the grasp).

Data is derived from the films using our Graf Pen sonic digitizer. A total of 20 points are recorded from each frame. Frames at which the various key events of the movement occur (hand lift-off, object touched, object lift-off, object arrives at destination) are marked to determine phases of the movement. The computer is programmed to calculate prescribed information about the quality of the movement, its timing features, its accuracy, its fluidity, and the refinement of the serial ordering of its constituent behavior.

Normal subjects were filmed as they reached to pick up objects from a table in front of them with their right hand. We have found that there is minimal intra- and inter-subject variability in most reaches to a particular object in a particular location. A list of features which describes the dynamics of reaching behavior has been constructed. Features have been identified in both limb-projection and handshaping phases of reaches. Some features vary systematically with the spatial position of the object; for example, the peak velocity of the movements varied with amplitude. Other features are invariant; for example, the percentage of the eventual trajectory traversed when the limb reached peak velocity was invariant with respect to all of the stimulus and effector conditions incorporated in the experiment ■

VA RR&D CENTER HINES

MEASUREMENT OF TRUNK STRENGTH AND FLEXIBILITY IN LOW BACK PATIENTS

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Complaints of low back pain (LBP) are shared by 80 to 90 percent of the adult population. The trunk musculature plays a significant role in maintaining the stability of the spine in different postures. Pathologic changes within the spine often result in abnormal flexibility of involved spinal segments. Such instability of the spine has been considered to be a key mechanical factor in the etiology of LBP. Therefore, quantification of trunk strength and analysis of available trunk flexibility can lend insight to the relationship of these mechanical factors to LBP.

An instrument system is being developed to provide a measure of the isometric trunk strength of a subject in different attempted postures such as bending forward, backward, and sideways directions, twisting, and combinations thereof. This measurement system will also be able to quantify the range of motion of the spine and its distribution within the lumbar and thoracic regions for the different modes described above.

The second phase of the study will use this device to collect data from normal subjects and from patients with low back pain. These data will be used to compare the trunk strength and flexibility in these two populations, in order to identify parameters that can be used to evaluate biomechanically the patients with LBP. It is expected that, upon completion, this study should result in a clinical tool for an objective evaluation of treatment effectiveness ■

VA CONTRACT

RESIDUAL BLADDER VOLUME DETERMINATION FOR SPINAL-CORD-INJURY PATIENTS

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A complete system has been constructed and combined with a full set of computer programs to calculate bladder volume. This system takes scans of the bladder in a known scanning pattern, applies the necessary correction factors to the threshold-detected front and rear bladder wall locations, smooths the data and applies a simple integration algorithm to calculate bladder volume. The preliminary experiments on human subjects indicate that the approach gives accurate measurements of bladder volume.

Design of the system was supported by laboratory experiments performed to validate theoretical calculations of correction factors to be applied to the threshold values used to detect the front and rear bladder walls. Flank steak sections of known thickness immersed in a water tank were used in that work; the sections were formed into planar and circular targets to provide simulated bladder walls at known positions and angles of incidence. Correction factors were developed to account for the effect of pulse width, pulse length, angle of incidence of the ultrasonic pulse on the target, and radius of curvature of the target.

The experimental results validated the need for and accuracy of the correction factors, up to angles of incidence of approximately 55 degrees. (Signal loss at higher incidence angles caused the accuracy to decrease.)

Multiple reflections have been determined not to

be a significant problem if a proper TGC curve is used.

Future work will extend these results in order to improve the accuracy of the system ■

NIHR REC

PREDICTIVE ASSESSMENT IN PRESCRIPTION OF FUNCTIONAL AIDS FOR THE MOTOR DISABLED

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The goal of this project is to develop data and theory on which to base prediction of functional gain from technological intervention. It was proposed that this concept be applied to three handicapping conditions:

1. Disabling tremor of the upper limbs;
2. Loss of vocal communication due to impaired articulatory motor control; and
3. "Equinus" and other spastic gait abnormalities.

With respect to tremor, the present objective is to establish empirically the effect of three hypothetically-useful characteristics of device-control interfaces on the accuracy of displayed movement. The protocol requires that the subjects perform discrete target acquisition and continuous pursuit tracking tasks on a computer-generated video display. They accomplish this by manipulation of either a conventional displacement-sensing joystick or one that rigidly senses isometric force. The control signal can be displayed directly, with low-pass filtering, or with integration which provides control of cursor velocity. Data collected to date shows a significant improvement in signal-to-noise ratio of performance for each of four adult neurology patients disabled by intention tremor, when at least one of the unconventional experimental conditions (force-sensing, filtering, or velocity control) is introduced. While the effects of velocity control and filtering are more nearly consistent across subjects, it appears from examination of several objective performance measures that the best choice of interface characteristics will be etiology-dependent. The data base is being extended at present and, in particular, the difference between the effect of on-line and off-line application of filtering is being determined.

With respect to non-vocal communication, the instrumentation necessary to present touch targets of varying size and position on a large flat panel which generates coordinate signals for finger contact has been completed under other funding (NINCDS). This test panel allows collection of abstract movement data from which a microcomputer program will calculate the predicted words/minute rate for a given user and communication device. Data now being taken is intended to establish how much data must be collected in order to make predictions of mean rate with particular levels of accuracy. For this purpose, subjects are chosen to be present users of devices, and the target sequence is selected by the computer to emphasize those movements most frequently required by the subject's accustomed device. Key issues are the random variance of subjects' movement time and the systematic variation with movement distance, direction, position, and target size. A predictive assessment procedure of clinically acceptable duration will require considerable interpolation among tested values of these movement parameters, and the limits on this data manipulation are being determined.

The spastic gait project, active during the previous REC year, will restart in the Fall of 1983. That work will continue use of the wearable computer-interactive ankle orthosis simulator, which allows generation of energy-absorbing torque profiles across the ankle during gait. The objective will be to generalize upon the single-subject data already collected which shows that the inappropriate ankle extension of equinus can be virtually suppressed by a compliant brace applying a damping-like load during particular portions of the gait cycle. Regression of improvement in gait measures against easily-assessed parameters such as leg length, body weight, walking cadence, and reflex properties will be attempted, in order to determine whether orthosis load parameters may be chosen predictively for each patient. That would permit full-blown gait studies to be eliminated from the clinical assessment of patients for whom a compliant orthosis is being considered ■

SPINAL TRAUMA

HHS, NIGMS GRANT

TRAUMATOLOGY OF THE HEAD AND SPINE

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Computer simulations with a human finite element model should yield the data needed for the prevention of cervical region injuries commonly associated with vehicular accidents. The objectives of this project are the construction of structural finite element computer models of a human and a rhesus monkey head and neck. Experimental data obtained from monkeys will serve to validate the monkey model for simulation purposes. These data, together with in vitro material properties and failure characteristics of the spine of cadavers, will then be used to validate the human finite element model for dynamic simulations ■

VA RR&D CENTER PALO ALTO

STABILIZATION TRANSPORT SYSTEM (STS) — A TREATMENT-COMPATIBLE TRANSPORT SYSTEM FOR SPINAL INJURY PATIENTS

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Need — An improved spineboard with traction is needed to reduce the risk of trauma to cervical spine injury patients during transportation and treatment. It should be compatible with transport equipment, computed tomography (CT) scanners, standard radiographic equipment, and hyperbaric oxygen (HBO) chambers.

Approach — Our approach has been to develop working prototypes of the Stabilization Transport System (STS), have them field-tested at local spinal injury centers, and upgrade the functional specifications for subsequent prototypes.

Status — Two prototypes of the STS have been developed to date. The first prototype, of X-ray radiolucent mahogany, laminate construction, incorporated constant-tension-spring traction to minimize traction force disturbance during transport. The second prototype, a composite of fiberglass over a styrofoam core, was built to determine the applicability of a composite construction for ease of manufacturing. This second prototype included an alternative constant-tension-spring traction system configuration. Both prototypes incorporated posture stabilization (padded structural restraints and belts), and padding to minimize pressure-sore development. The fiberglass composite second prototype exhibited diffraction patterns in CT scan tests. However, the fiberglass composite was considered a mock-up for a carbon fiber composite which is expected to be radiolucent.

Three of the first STS prototypes were built. Two of these have been in use and testing at Santa Clara Valley Medical Center in San Jose, California, for more than 2 years. The third has been readied for field testing at R. K. Davies Hospital in San Francisco. The second STS prototype requires minor upgrading before it will be ready for specific field testing at either of these spinal-cord-injury centers ■

VA RR&D CENTER HINES

MATHEMATICAL MODELING OF THE HUMAN SPINE: IMPLICATIONS FOR THE SURGICAL CORRECTION OF SPINAL DEFORMITIES

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Structural deformities of the spine such as scoliosis, kyphosis, and spondylolisthesis are treated surgically when conservative treatment using braces or orthoses fails to stabilize the trunk. A typical surgical

treatment modality involves correction of the spinal curve by instrumentation such as Harrington distraction or compression rods, segmental wiring, or other techniques. Each instrumentation system exerts certain forces and moments on the spine so as to reduce its curvature.

The purpose of this study is to develop a computer model to help the clinician select the most appropriate instrumentation system for a given patient. To accomplish this, the model must closely predict the individual mechanical spinal response for each patient. Thus, in the past, general models which were based solely upon in-vitro experimental data were deemed unacceptable. Alternatively, a computer model has been developed that utilizes an optimization procedure to identify the mechanical properties of an individual human spine, such that the model's 3-dimensional displacement response matches that of an in-vivo spine. Data required for this model are easily obtainable for each patient from roentgenographic recordings of their spinal response to simple traction loadings. This model utilizes 3-dimensional finite element beams to simulate each motion segment. The optimization is performed interactively at a computer terminal and incorporates a graphics display to help the analyst in the identification process. With the mechanical properties thus established, a computer simulation can be performed to examine the efficacy of various corrective procedures and instrumentations ■

VA RR&D CENTER HINES

MATHEMATICAL MODELING OF THE HUMAN SPINE: IMPLICATIONS FOR THE ORTHOTIC MANAGEMENT OF SPINAL DEFORMITIES

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Mild to moderate curvatures of the spine are most often treated conservatively using an orthosis such as the Milwaukee brace or the Wilmington jacket. The mechanics of curve progression is of considerable interest to the clinician, due to its implications to patient selection for orthotic treatment as well as choice of an orthosis.

The purpose of this study is to investigate the stability of a scoliotic curve with and without bracing as a function of the degree of initial curvature (at the time of orthotic intervention) and of the amount of stabilizing transverse load exerted by an orthosis on the spinal curve. Mathematical modeling of the spine-orthosis system involves inelastic buckling analysis of an initially curved and transversely loaded flexible column. The model can simulate the interaction of different types of orthoses with the spinal curve.

This analysis suggests a biomechanical explanation as to why larger curves are more progressive than smaller curves, and why bracing is effective in only small and moderate degrees of scoliosis. This analysis should aid in patient selection and prediction of results ■

VA RR&D CENTER HINES

PASSIVE ELECTRICAL PROPERTIES OF THE SPINAL CORD

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The electrical impedance of the spinal cord can be modeled as a resistor and capacitor in parallel. Assuming that we could effectively eliminate electrode polarization, we tested this model by connecting a high-impedance resistor in series with the cord, using a high frequency input signal and comparing the voltage change and phase shift in relation to the input signal.

Wistar rats weighing approximately 300 gm were anesthetized by an intraperitoneal injection of chloral hydrate. Laminectomies were performed exposing the lumbar-thoracic region of the spinal cord. The rats were suspended in a spinal stabilization frame to eliminate respiratory motion artifact.

Either silver or chlorided-silver electrodes fabricated in our laboratory were used. The electrodes were exposed 0.5 mm from the tip with a tip diameter of 5 μm and a shank diamter of 2 mm away of 200 μm. They were inserted into the cord at a depth of 1 mm and held 2 cm apart, using micromanipulators. A resistor in the range of 100 kilohms was connected in series, and a current signal at a frequency of 100 kilohertz and a voltage below stimulation threshold was applied. The input signal and the signal off the cord were measured and compared using a Dynatrac 393 Lock-in Amplifier.

The measurements obtained from the cord produced resistivity measurements. The mean was determined to be 147.51 ohm-cm + 28.27 ohm-cm at probability of 0.05. This result falls within the range which Ranck determined for cats (Expt. Neurol., 11:451-63, 1965). The capacitive reactance unfortunately was unobtainable with our present equipment. The input impedance of Dyntrac is shunted by a 40 picofarad capacitor that gives the machine a capaci-

tance sensitivity limit of 1 picofarad. Since our measurements showed only this 40 picofarad phase shift, we surmised that the capacitance of the cord was less than 1 picofarad.

In conclusion, at 100 kilohertz the longitudinal impedance of the spinal cord in Wistar rats consists mainly of a resistive component. The resistivity was found to be in a range of 135 to 172 ohm-cm. The capacitive component of the cord was essentially nonexistent, with an upper limit of 1 picofarad. In view of the reported resistance of pia mater and CSF, 50-100 ohm-cm^2 and 64 ohm-cm respectively (Med. & Biol. Engng. 5:271-93, 1967), it is suggested that the electrodes should be placed below the pia mater in order for minute currents to be effective ■

VA RR&D CENTER HINES

POSSIBLE STABILIZING EFFECTS OF NGF ON SPINAL FIBERS

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Much of the present research aimed at assessing the potential for recovery following spinal injury is concerned with the evaluation and stimulation of regenerative events in injured CNS neurons. Usually, the effect of a pharmacological intervention on regeneration is evaluated in terms of neurite elongation or return of electrophysiological function. In many instances, in situ anatomical studies of axonal regrowth and reorganization of injured tissues are used as an index of the effects of substance being tested for its effects on regeneration. Similarly, studies probing the effects of modulators of regeneration on recovery of function rely on whole-animal functional recovery as indexed by neurological or behavioral criteria. One problem with these assessments is that it is difficult to distinguish between primary effects of CNS tissues under study, and secondary effects acting perhaps through other non-CNS tissues.

As an example, there are reports that NGF (nerve growth factor) may act on CNS targets. Most interestingly, it has been suggested that NGF may accelerate regenerative events in CNS. To test this hypothesis, rats were injured by the modified Allen technique, and were treated with NGF in order to assess if NGF had beneficial effects. 1251-NGF was used to determine if the NGF was acting directly on central structures. Our results suggested that the beneficial effects on injured spinal fibers were secondary effects due to the action of NGF on peripheral dorsal root ganglia ■

VAMC WEST HAVEN

MECHANISM OF CERVICAL SPINE INJURIES

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The specific goals of this project are to determine:

1. The forces needed to produce injuries in vitro in a three vertebrae segment of human cervical spine;
2. The displacements and deformations of the vertebrae and spinal canal during injury;
3. The stiffness of each spine specimen before and after injury; and
4. The roentgenographic (CT-scan, etc.) changes due to the injury.

Progress to Date — Several cervical spines have been harvested and preserved at – 20 degrees centigrade. The injury production apparatus has been built. Two canine spines have been fractured in the apparatus. Both spines were subjected to pure compression. Only the compression force was monitored during the injury; at this time no motion data was recorded. CT-scans and X-rays were taken of each segment before and after injury. A segment-holding jig insured accurate positioning.

The results from the tests indicate that the apparatus works well. It is capable of fracturing vertebra at high speeds (over one m/s). Future work will include the refinement of the injury production apparatus, implementation of data sampling by computer, and the collection of motion data ■

VAMC PALO ALTO

EVALUATION OF FIXATION METHODS FOR THE CERVICAL SPINE

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Little quantitative data exists as to the effectiveness of fixation devices used in the treatment of spinal injuries. Until the quantitative data is obtained, the physician will lack substantive information for the selection of the best treatment.

The goals of this study are: first, to collect data on

methods of internal stabilization of the cervical spine. This data will assist the physician in selecting the appropriate treatment. The devices that will be evaluated are interspinous wiring, interspinous wiring with transverse pins, segmental facet wiring, and an experimental device — a "U-rod".* The second goal is to pursue an improved system of internal fixation which will be stronger and more durable than current methods. That would reduce the risk of failure, and the need for external stabilization. In this progress report, work towards the first goal will be discussed, since work on the "design phase" is just beginning.

To record spinal motion, a specially designed motion transducer is mounted between C5 and C6 (1). The transducer measures all six degrees of freedom continuously while the spine is in motion. The motion is resolved into 3 rotations and 3 translations of the C6 vertebrae relative to the C5 vertebrae. The rotations are accurate to about a degree. Translations are sensitive to the transducer installation, and thus allow comparison between devices on a given spine, but not between different spines.

Protocol — The intact spine is loaded in each direction, with vertebral motion being recorded. The spine is then disrupted between C5 and C6, and instrumented with a stabilization device. (The disruption consists of cutting through all structures except the anterior longitudinal ligament. This corresponds to a rather severe injury, and is thus a demanding test for fixation devices.)

Preliminary Results — Sample data show that, as expected, the dominant rotation is axial, with coupling to lateral and A/P motion being apparent. The limits of motion are considerably greater than in the intact spine, with interspinous wiring permitting the greatest motion. Stiffness is similar between the U-rod and the intact spine, with interspinous wiring being slightly more compliant.

Because this data is from only one spine, and because the protocol is still being refined, these data samples cannot stand alone. However, they illustrate that the apparatus can provide very precise and complete data on the motion of the spine. In addition to allowing a comparison of stabilization devices, this data promises to enhance our overall understanding of the motion of the spine ■

*The U-rod is simply a 5/16 inch stainless steel rod which has been bent so that it runs up one side of the spinous processes, across to the other side, and down the other side of the spinous processes. It is also contoured to the curvature of the spine. It is wired in segmentally, much like Luque Rods, from C4 through C6.

HHS, NIGMS GRANT

HEAD / NECK / UPPER TORSO RESPONSE TO DYNAMIC LOADING

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The purpose of this project is the construction and instrumentation of a 3-D model of the head, neck, and upper torso containing artificial structural elements of the major organs and anatomical features such as: major vessels, ribs, major muscles, heart, lungs and spinal column. The model will be used to study impact dynamics and to formulate a mathematical model to evaluate possible protective devices for the human body ■

MUSCULOSKELETAL REHABILITATION

NIHR REC

MULTICENTER TRIAL OF THE L.E.S.S. TECHNIQUE FOR SCOLIOSIS TREATMENT

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The purpose of this project was to determine whether the Lateral Electrical Surface Stimulation (L.E.S.S.) technique developed at Rancho Los Amigos Rehabilitation Engineering Center would be as effective in the hands of other clinicians as it had been for the originating investigators.

Patients studied were juvenile or adolescent idiopathic scoliotics within current selection guidelines for the Milwaukee brace or other conventional orthoses. Within that population, a subgroup was selected for separate analyses because of the high probability of continued curve progression.

The major curve (the deformity component defining treatment) had to have a magnitude from 20 deg to 45 deg. Major curve magnitudes less than 30 deg had to show clear evidence that the deformity was actively progressing at the time of observation. For curve magnitudes of 20 deg to 24 deg, the curve must have progressed at least 10 deg in the immediately preceeding 6 months and be documented on at least two X-ray films. For major curve magnitudes of 25 deg to 29 deg, the curve must have progressed at least 5 deg in the last 6 months. With these immature

patients, curves of 30 deg or more were assumed to be highly progressive.

The patient population consisted of 548 patients from 54 clinics in North America and Western Europe. The curvatures were subdivided into a normal risk, 20-29 degree group, and a high risk, 30-45 degree group. Nineteen percent (19%) of the patients belonged to the selected "protocol" group. Eighty-nine percent (89%) of the population had been treated less than 2 years.

To assess the immediate effects of beginning treatment during active deformity progression, the curvature progression rate calculated over an interval immediately preceeding treatment was compared with the interval immediately after initiating treatment.

Treatment was terminated prior to skeletal maturity in 24 percent of the patients. No cause was stated in 14 percent, while the remaining 10 percent was distributed between noncompliance (50%), skin irritation (20%), intolerance (7%), and other (23%). Of all dropouts, progression occurred in 63 percent (15 percent of total population) and no change in 37 percent.

Despite a relatively high incidence of minor adverse effects, we could only identify 15 patients of the 548 (less than 3 percent) who appeared to be forced to discontinue treatment because of the adverse effects. The vast majority of problems were reversible and manageable. By far, the most common adverse effect was skin irritation.

These data indicate that the external stimulation technique originated at Rancho Los Amigos Rehabilitation Engineering Center stabilizes actively progressing juvenile or adolescent scoliosis, at least until spinal maturity ■

VA RR&D CENTER HINES

BIOMECHANICAL STUDY OF TREATMENT MODALITIES FOR LUMBAR DISC DISEASE

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Lumbar disc disease is a common problem facing the orthopedic surgeon and neurosurgeon. Patients suffering from this condition with neurologic deficit, and unresponsive to conservative therapy, have routinely been treated surgically by laminectomy and discectomy. Recently, however, there has been an increasing interest in a more "conservative" treatment: dissolution of disc material by chymopapain injection. After extension animal studies and clinical trials, such "chemonucleolysis" has been approved in the U.S. A physician treating lumbar disc protrusion must now choose between two effective treatment options — laminectomy or discectomy, or chymopapain injection.

The purpose of this investigation is to compare the biomechanics of these two treatment methods in the laboratory, utilizing cadaver specimens of the human spine. Specifically, the study is aimed at examining the changes in the loadbearing behavior of the disc and the facet joints immediately following either of these treatment methods. It is hoped that a better understanding of alterations in the biomechanics of the lumbar spinal segments will significantly aid the physician in selecting a method of treatment ideal for a patient ■

NIHR REC

AUGMENTED-FEEDBACK SCOLIOSIS ORTHOSIS

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The Augmented Feedback Scoliosis Orthosis (A.F.S.O.) uses tactile feedback to motivate patients with idiopathic scoliosis to perform a specific spinal exercise while wearing the orthosis. (It also provides passive correction when the person is not doing the exercise.)

The conventional thermoplastic T.L.S.O. (thoracic-lumbar-sacral-orthosis) relies on purely passive correction. The conventional Milwaukee orthosis is often prescribed in conjunction with an exercise program to encourage the patient to actively decrease his/her scoliotic curve for brief periods each day. The Feedback Orthosis combines the features of passive correction with a "built-in" electronically monitored exercise program. When the person performs the "lateral shift" spinal exercise correctly, a timer inside the orthosis is activated which unobtrusively reminds them to do the exercise again in about 40 minutes. The newer A.F.S.O.'s count the number of shifts done by the patient up to a period of 3 months.

Of the 16 patients in the current series, 11 have been followed 12 months or longer. Of these 11, four major curves have decreased five degrees or more, four were unchanged, and three have progressed more than five degrees. Five patients have been followed for less than 12 months. One patient was treated surgically because of progression, and three have been eliminated from the study because of noncompliant follow-up. These preliminary results

are no worse than anticipated with conventional Milwaukee bracing or T.L.S.O.'s.

The current orthoses are prototypes that are under clinical evaluation. The device has not been proved clinically effective and is therefore not yet ready for release as a treatment mechanism ■

VAMC DALLAS

OBJECTIVE ASSESSMENT OF HUMAN SPINE FUNCTION

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The University of Texas Health Science Center at Dallas, Orthopaedic Surgery, and The University of Texas at Arlington, Biomedical Engineering

The purpose of this project is to develop an objective assessment of patients with low back pain through the application of power spectrum density techniques to myoelectric signals obtained in the course of endurance testing. For many reasons (e.g., deep muscles, lack of right versus left comparisons, multiple small segments), it is difficult to obtain quantitative information on gross strength and fatigue or endurance of lumbar spine muscles. Myoelectric signal techniques, although developed primarily to assess muscle function of the upper and lower limbs, may lead to an improved understanding of human lumbar spine function and to a reduction of economic and social costs of low back pain.

Results of our initial studies were reported at the Orthopedic Research Society meeting in Anaheim, California, in the Spring, 1983. Since then we have designed and are completing construction of an isometric trunk-strength device. It utilizes a heavy frame that places the patient in the standing position. The patient is stabilized at the feet, knees, pelvis and chest, with the knees bent slightly to decrease the effect of hamstring tightness. We designed the device to be compatible with a prototype frame which may soon be available commercially for clinical testing and training.

Much work remains to be done before myoelectric signal power spectrum frequency analysis comes into clinical use. The technique offers an opportunity to demonstrate right/left imbalance in trunk muscle function, to give endurance information complementary to gross strength tests, to demonstrate evidence of progress in rehabilitation programs, and possibly to identify substandard effort ■

LIBERTY MUTUAL, NIHR, SWEDEN

BIOFEEDBACK DEVICE

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As a result of a collaborative effort by engineers in our laboratory, physical therapists in Children's Hospital Medical Center in Boston, and patients, a myofeedback device called "Myobeeper" was designed and constructed. This device provides an audible tone and light display which are proportionally indicative of the level of a muscle contraction. It accomplishes this task by processing the myoelectric signal detected from the surface of the skin.

Three generations of this device were field-tested in busy medical centers to determine its acceptance and usefulness to clinicians in the daily operation of their environments. Myobeeper was widely accepted by clinicians as a compact, portable, and lightweight device that was convenient and easy to use. Its usefulness as a myofeedback instrument was determined by the variety of its applications to treatment needs and by its ability to obtain immediate, reliable, and objective data that could be documented. The salient feature of the device which rendered it so useful in clinical environments was the dry electrode used to detect the myoelectric signals. This electrode is capable of detecting the myoelectric signal within 2 seconds after coming into direct contact with the skin. This device has attracted the attention of a manufacturer who is actively pursuing the possibility of producing it ■

VA RR&D CENTER HINES

THE DEVELOPMENT OF AN INSTRUMENTED ANIMAL MODEL TO STUDY THE NEURAL MECHANISMS UNDERLYING BLADDER DYSFUNCTION AFTER SPINAL TRAUMA

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If a patient survives the initial trauma of spinal injury, more than likely he will have a problem regulating his bladder function. Such bladder dysfunction can be life-threatening, since it can lead to kidney infection and damage. Most of the neurological research into the paralysis and/or spasticity of muscle following spinal trauma has focused on skeletal muscles. Much less has been aimed at understanding bladder dysfunction following such trauma. Moreover, there remains a need to develop an animal model of such dysfunction where the animal is awake and able to interact (at least above the lesioned area) with his environment, so that the animal's bladder function can be studied over the long term. With such a model, the effects of various new pharmacological and surgical interventions or electrostimulation techniques could be assessed.

We have adapted techniques developed for cardiovascular research to produce such a model, in which bladder performance can be continually evaluated through a knowledge of the relationship between bladder volume and pressure. Such a relationship, clinically called a cystometrogram, yields information about the functional state of the bladder. Under surgical anesthesia, we implant into the bladder a state-of-the-art miniature (4 mm diam) transducer to measure pressure. At selected sites on the bladder surface, pairs of small ultrasonic crystals are placed. Their distance apart can be measured and used to determine bladder volume. We also can install leads to measure detrusor and pelvic floor muscle electrical activity (EMG). The leads for these devices are then tunnelled under the skin to exit from the back of the animal's neck, and are protected in a vest worn by the animal. So far, we have instrumented siz monkeys. The bladder function of these animals has been observed before and up to 1 month after instrumentation. The model has worked well. It now gives us a tool to monitor bladder function and dysfunction before and after spinal trauma ■

NIH MUSCULOSKELETAL

EXERCISE-TRAINING: EFFECTS ON MUSCLE FATIGUE

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The primary objective in this project is to continue experiments designed to elucidate the effects of use (exercise-training and chronic electrical stimulation) on fast and slow skeletal muscle, and determine to what extent and by what mechanism exercise training protects against the development of fatigue. The long-term objective is to understand the molecular mechanisms controlling muscle function and how they are altered by exercise-training and by fatigue, so that this knowledge can be used in the prevention of fatigue and disease and in rehabilitative medicine. The effect of endurance training and high-intensity, short-duration exercise training on muscle function and the etiology of muscle fatigue will be studied in the rat.

The physiological studies will include an in situ evaluation of the contractile properties of the slow-twitch soleus and fast-twitch extensor digitorum longus (EDL), and in vitro studies of these muscles plus the fast-twitch superficial region of the vastus lateralis (SVL) at rest and during acute contractile activity. The intracellular H^+ ion concentration will be directly measured using pH-sensitive glass microelectrodes and pH changes during work will be determined. The pH changes will be correlated to alterations in substrate levels and contractile properties, to assess the role of H^+ in muscle fatigue. The skinned fiber preparation will be used to determine how exercise training and fatigue affect sarcoplasmic reticulum (SR) and myofibrillar function. The contribution of myofibrillar and SR ATPases to the total activity will be determined and these activities correlated to maximal shortening velocity and force transients, respectively. The sarcoplasmic reticulum (SR) will be studied to determine how exercise training and muscle fatigue affect the kinetic properties, phosphorylation, and gel electrophoretic patterns of this membrane system.

The effect of chronic electrical stimulation on the contractile properties of rat fast and slow skeletal muscle will be determined, using both the whole muscle and skinned-fiber preparation. The SR and myosin proteins will be analyzed and alterations correlated to specific changes in mechanical properties. These experiments are designed to test the hypothesis that the SR controls the intensity and duration of the active state, while the maximal speed of unloaded shortening is dependent on the myosin ATPase activity ■

NIH MUSCULOSKELETAL

ADAPTION OF MUSCLE TO HIGH-RESISTANCE EXERCISE

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The objectives of the research are to further define the process whereby the neuromuscular system adapts to high-resistance (weightlifting) exercise, and to investigate the mechanisms that control exercise-induced muscle growth.

Adult cats are operantly conditioned to flex their right wrists against increasing resistance to receive a food reward. This procedure has the advantage of inducing significant hypertrophy in the muscles of the right limb, while the muscles of the left limb can be used for comparative studies. Increases in both muscle fiber cross-sectional area (hypertrophy), and number (hyperplasia), are thought to occur in response to weightlifting exercise, and this study will seek definitive experimental evidence as to the contribution of each of these mechanisms to exercise-induced muscle growth.

In the study, the ultrastructural and histochemical features of exercised muscle fibers that are undergoing necrosis and regeneration will be characterized. It is anticipated that this project will provide insight into the mechanisms controlling muscle fiber necrosis and elucidate the stem cell population involved in regeneration. This study will provide a unique opportunity to investigate muscle fiber turnover induced by physiological stress. Also, quantitative ultrastructural measurements of muscle fibers will be made to provide insight into the reorganization that occurs in response to exercise. The physiological, histochemical, and morphological characteristics of motor units will be determined in the wrist flexor muscles. Adaptive changes in the motor unit properties in response to exercise will be investigated.

These studies will be the first extensive survey of the mechanical properties of forelimb motor units. In addition, no studies have assessed exercise-induced changes in the motor unit properties. These studies are made all the more important by the observations of exercise-induced muscle fiber necrosis and regeneration and the possibility of hyperplasia, to determine if these processes are independent of nervous system (motor) control.

This study will continue to elucidate the dramatic structural and functional alterations that occur in the neuromuscular system in response to prolonged weightlifting exercise. An understanding of how muscle adapts to physiological stress should provide insight into the pathophysiology of muscle ■

LIBERTY MUTUAL, NIHR, SWEDEN

MUSCULAR FATIGUE AND THE MYOELECTRIC SIGNAL

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Previous reports have indicated that the myoelectric signal can be reliably used as an objective measure of localized muscular fatigue in humans. A major effort of this project is to identify the various parameters of the myoelectric signal which will optimize the detection and assessment of localized muscular fatigue. It is suspected that a change in the muscle fiber conduction velocity may be a significant factor during fatigue which may alter the characteristics of the myoelectric signal. Therefore, the muscle conduction velocity will be directly measured during fatigue with surface recording techniques and compared with the various derived parameters representing certain characteristic changes in the myoelectric signal.

Parameters which track the shift in the power density spectrum of the myoelectric signal, and parameters of the myoelectric signal, such as zero-crossing and RMS values, will be compared and analyzed to achieve the most accurate, precise, and reliable representation of either the metabolic state of the muscle or a quantitative indication of its fatigue properties. Once the optimal parameter or parameters have been selected, this technique will be valuable in a clinical environment due to its completely noninvasive approach.

We have started experiments to monitor the behavior of the myoelectric signal during both static and dynamic isometric contractions. The dynamic contractions will provide a greater understanding of the interactions between blood flow and the fatigue properties of muscle. These experiments could predict the performance of muscles during strenuous activity, as required in some work environments or during exercise activities ■

NIH MUSCULOSKELETAL

CONTROL OF MUSCLE PROTEIN METABOLISM DURING EXERCISE

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The broad objective of this research is to study the changes that occur in protein metabolism as a result of exercise, and to establish the underlying biochemical mechanisms which bring about these changes. In research already completed, it has been clearly established that an acute bout of exercise (either running or swimming) causes a decrease in the rate of muscle protein synthesis and increased rates of protein degradation in muscle and liver. Preliminary evidence from the lab, and reports from other investigators, suggest that an acute exercise bout also increases the rate of amino acid oxidation.

During the next granting period it is proposed to further study the effect of an acute exercise bout on protein synthesis, protein degradation, and amino acid oxidation. To determine mechanisms involved in the decrease in protein synthesis in muscle, the effect of exercise on the various components of protein synthesis will be determined: charging of t-RNA, initiation of peptide synthesis, and peptide elongation. An experiment will be conducted to investigate whether an acute bout of exercise increases alanine production by the isolated epitrochlearis muscle.

In addition, an investigation of the biochemical regulation on leucine oxidation in muscle during exercise will be continued ■

NIH MUSCULOSKELETAL

SKELETAL MUSCLE REHABILITATION FROM LIMB IMMOBILIZATION

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Skeletal muscle will be from limbs that are rehabilitating from atrophy caused by a prior 7-day period of hind-limb immobilization in rats. The specific aims of the research plan are to:

1. Determine the synthesis rates of actin and cytochrome c in skeletal muscles at the sixth hour, second day, and fourth day of recovery from the prior 7-day immobilization. Synthesis rates are estimated in vivo by the constant infusion of ^{3}H-tyrosine, measurement of the specific radioactivity of either purified actin or purified cytochrome c, measurement of the specific radioactivity of tyrosyl-tRNA, and calculation of the estimated rate of fractional synthesis per day.
2. Determine the role of anabolic steroids and of various exercises (treadmill running, weight lifting, and electrical stimulation) in addition to "normal" cage activity on the synthesis rates of actin and cytochrome c in skeletal muscles on the second day of recovery from the prior 7-day period of hind-limb immobilization.
3. Determine the threshold of exercise duration needed to increase the synthesis rate of actin and cytochrome c in skeletal muscle on the second day of recovery from a prior 7-day period of hind-limb immobilization.
4. Determine the sensitivity to increasing exercise duration of the amount of increase of actin or cytochrome c synthesis rates.
5. Determine the content of actin mRNA and of cytochrome c mRNA in skeletal muscles at the sixth hour, second day, and fourth day of recovery from a prior 7-day period of hind-limb immobilization. The content of actin mRNA or cytochrome c mRNA will be semiquantitated by dot hybridization with cDNA for actin mRNA from rat skeletal muscle and a genomic clone of rat liver cytochrome c, respectively.
6. Determine the content of actin mRNA and cytochrome c mRNA in skeletal muscles in the 3rd and 24th hours after an exercise bout when exercise is performed on the second day of recovery from the prior 7-day period of hind-limb immobilization ■

INFORMATION

NIHR REC

DEVELOPMENT OF WORKSHOPS AND RELATED INSTRUCTIONAL MEDIA FOR NATIONWIDE DISSEMINATION OF TECHNOLOGICAL INFORMATION

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Introduction — This project proposed development of two workshops and related instructional materials to disseminate information to disabled consumers and allied health professionals which would assist them in solving their own or their client's problems in specific areas. Selection of the topic areas for the workshop and media was based on a community survey and numerous requests for information. The

workshops were conducted locally, and the materials were developed for national distribution.

Methodology — The technique used to identify workshop topics of concern to disabled consumers and allied health professionals was a community-based survey. A questionnaire which utilized forced choice and open-ended questions was sent to a wide variety of consumer groups and service-providing agencies during October, 1981.

Progress — Two topics were selected for workshop and media development, based on the results of the community survey and on personal contact with consumers with disabilities and allied health professionals. The selected topics — Home Organization and Home Access — were developed and presented two times each for a total of four workshops. The participants in these workshops included consumers with physical disabilities, their family members, and allied health professionals. The workshops were conducted as a preliminary step to development of audio-visual materials which could be distributed nationwide. In this way, information on these topics of concern to many persons with physical disabilities would have impact on far more individuals than if the information was limited to one geographic area. Conducting the workshops allowed incorporation of consumer comments and suggestions into the development of audio visual materials ■

NIHR REC

INFORMATION DISSEMINATION AND SERVICE DELIVERY

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Communication with the professional and user communities continued through the participating of the UM REC staff at RESNA, at the Association of Driver Educators for the Disabled (ADED), and other meetings.

Publication of the UM RECorder continues on a schedule consistent with UM REC needs. The UM RECorder and other UM REC publications are transmitted to the National Rehabilitation Information Center (NARIC) in Washington and to the National Clearinghouse on Rehabilitation Materials in Stillwater, Oklahoma for permanent storage and distribution ■

NIHR REC

EDUCATION AND TRAINING, RESOURCE INFORMATION

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Community Education — A workshop series entitled, "Special Problems in Rehabilitation Engineering," was conducted in the spring of 1982. It included one-day and two-day offerings, such as: Seating Needs for Children; Adult Seating and Tissue Trauma Management; and Language, Computers and Communication.

The Rehabilitation Engineering Clinical Internship was started at this Rehabilitation Engineering Center in 1979. It is designed to provide multidisciplinary clinical training to an individual with a background in engineering interested in applying his/her expertise to the rehabilitation needs of the disabled. The program accepts one applicant per year (November-October) and focuses on patient contact across a variety of clinical services and settings.

Information dissemination activities include the development of an independent technology resource center (Tools for Living in the Community); a publications office; support of the Abledata Information Service; and development of resource guides and bibliographies, and data sheets ■