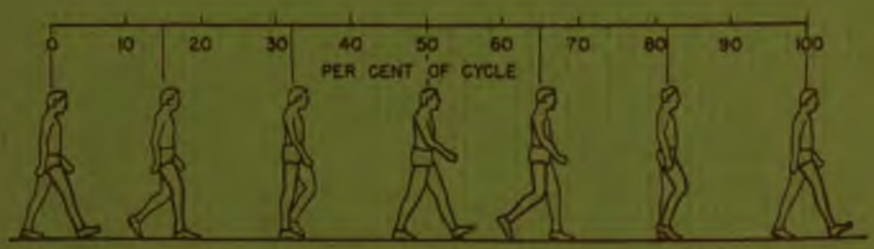
REHABILITATION ENGINEERING

A Plan for Continued Progress



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NATIONAL ACADEMY OF SCIENCES
Washington, D.C. April 1971

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PREFACE

The Federal Government for 25 years has been supporting research and development in limb prosthetics, orthotics, and to a lesser extent sensory aids. From the beginning the Committee on Prosthetics Research and Development and its predecessors have attempted to coordinate and correlate all the work in these areas and to assist in the introduction of the results to clinical application (37). As a result, much progress has been made in the solution of the problems of certain types of disabled people but, as is usually the case, solutions to one set of problems point out the possibilities for solutions to other problems.

In 1966, at the request of the then Vocational Rehabilitation Administration, CPRD developed a set of recommendations for research in orthotics and prosthetics for the next five-year period or so (5). This report seems to have been useful to the sponsors of research and to those planning work during the past four years. Most of the recommendations made in the report have been acted upon. Thus, it seems appropriate at this time to develop a new set of recommendations for the next five to ten years. Sensory aids for the blind and deaf are included as a logical extension to prosthetics and orthotics, and, with the addition of structural internal prostheses, the whole area can be known as rehabilitation engineering.

During the past year CPRD and its Subcommittees have devoted much time to developing such a plan, which is presented here. The main body of the report is divided by subject matter and was developed by subcommittees, panels, and special conferences conducted by CPRD during the past year. Information compiled by the staff for use by conferees is included in the appendixes.

CONTENTS

SYNTHESIS

Research and education in limb prosthetics and orthotics in the United States is making progress at a steady pace in an orderly way with rather well-defined programs in fundamental studies, design and development, evaluation, and education. Amputees and artificial limbs have been studied the longest and represent the most advances, yet further improvements can be predicted. Lower- and upper-extremity orthotics have recently come to receive the attention they deserve and progress is being made in these areas. Spinal orthotics and problems of the back have long been neglected, and work in sensory aids for the blind and deaf-blind has suffered because of a lack of fiscal support.

The Education Program is a productive one, but a reappraisal of its goals should probably be made in view of the changing methods of patient management.

The method of funding research by relatively small grants has been effective, but it appears that the time has come when support of special centers devoted to integrated rehabilitation engineering programs seems desirable.

Given below is a synthesis of the detailed recommendations made by various study groups sponsored by CPRD.

RESEARCH AND DEVELOPMENT

Lower-Extremity Prosthetics

1. Continuation of promotion and teaching of immediate postsurgical fitting and early fitting.
2. Continuation of work on forming sockets directly over the stump.
3. Refinement and standardization of modular prostheses with emphasis on cosmesis.
4. Development of adjustable above-knee sockets.
5. Refinement of suspension methods for above-knee prostheses for geriatric patients.
6. Development of swing- and stance-phase control devices for hip-disarticulation prostheses.
7. Acceleration of final development of knee-disarticulation prostheses using four-bar linkage and swing-phase control units.
8. Determination of feasibility of voluntary control of knee units for above-knee amputees.
9. Acceleration of development of Mauch hydraulic foot-ankle unit.
10. Continuation of development of ankle-rotation mechanisms.
11. Development of improved procedures for measuring distribution of pressures between stump and socket. Both research and clinical instruments are needed.

Upper-Extremity Prosthetics

1. A complete restudy of body-powered prostheses. Studies involving new methods of fitting, harnessing, and modular prostheses should be integrated and completed. Of especial interest are the socket designs developed at Northwestern University for the self-contained prostheses.
2. Improvement in cosmetic appearance of artificial hooks, hands, and arms.
3. A survey of the upper-extremity amputee population to determine the degree of usefulness provided by present prostheses.
4. Increased emphasis on development of controls and sensory feedback mechanisms for externally powered prostheses.

5. Continuation of development of externally powered components at about the same level of effort, recognizing that control of these devices is critical to their success. Electricity is considered the best power source at this time.

Lower-Extremity Orthotics

1. Development of modular, adjustable, temporary orthoses for clinical use.

2. Development of electromyographic signals to control orthotic and natural joints.

3. Development of simple methods for modifying standard shoes to accommodate foot deformities.

4. Development of knee units that will permit better control of the unstable knee.

5. Development of a method to provide assistance to hip motion.

6. Development of a push-off device.

7. Continuation of study of neuromuscular electrical stimulation as a substitute for or supplement to external bracing, and for control of spasticity.

8. Activation of studies to delineate the anatomical and physiological problems in weight-bearing braces.

9. Expansion of the development of orthotic devices for children with spina bifida and for children with cerebral palsy.

10. Continuation of studies on orthotic devices for management of fractures.

11. Establishment of a Panel on Orthotic Aids to encourage further development of such devices as wheelchairs, crutches, and walkers.

Upper-Extremity Orthotics

1. A survey to determine:

    a. The number of patients with various types of dysfunction of the upper extremity.

    b. Rehabilitation potential of each type of dysfunction.

    c. The methods of treatment available for each type of patient.

2. A comparative study of present treatment procedures and devices available for quadriplegic patients.

3. Development of a method to relieve spasticity in hemiplegic patients.

4. Development of improved splints for the rheumatoid arthritic hand to be used with and without surgery, drugs, or both.

5. Study of combinations of surgery, splinting, and functional electrical stimulation.

6. A survey of what is currently being taught to occupational therapists in the field of upper-extremity orthotics, especially in arthritis.

Spinal Orthotics

1. Acceptance of the scheme of categorizing and naming spinal braces developed in recent years by New York University Prosthetic and Orthotic Studies and dissemination thereof through ARTIFICIAL LIMBS, publications of the American Academy of Orthopaedic Surgeons, and catalogs of manufacturers.

2. An analysis of the functions provided by the standard available cervical appliances.

3. An analysis of the functions provided by the standard lumbosacral and thoracolumbar braces and corsets.

4. Continuation of further development and investigation of the effectiveness of the Abdominal Pressure Spinal Support ("Royalite") Jacket developed at the University of California, San Francisco.

5. Development of an implantable transducer for measurement of relative motions between vertebrae.

6. Development of an implantable transducer for measuring disc pressure.

7. Investigation of the usefulness of inflated structures in the design of spinal orthoses.

8. Investigation of the possibilities of electrical stimulation of appropriate muscles to provide a balanced state.

9. Development of improved methods of internal splinting of the spinal column.

10. Development of a prosthetic intervertebral disc.

11. Determination of the factor or factors responsible for "low-back pain."

SENSORY AIDS

1. Although support for research and development in sensory aids for the blind and deaf has been meager, a number of promising devices are emerging, and therefore initiation of a formal evaluation program is strongly recommended.

2. A conference on standards, specifications, and use of the typhlocane is needed.

3. A conference on problems of individuals with severely impaired (low) vision is indicated.

4. A conference on reading machines with emphasis on evaluation techniques is needed.

5. A conference on Braille output devices is needed.

FUNDAMENTAL STUDIES

1. A thorough study of the feasibility of functional electrical stimulation of the neuromuscular system.

2. Further study of the biomechanics of the spine.

3. Continuing studies of normal and pathological human gait, including forces imposed on joints of the lower limb.

4. Initiation of an integrated program for the development of internal prostheses, especially hip, knee, elbow, and finger joints.

5. Acceleration of work in skeletal attachment of external prostheses.

6. Studies to determine the properties of biological materials, biological structures, and the effect of pressure on human tissues.

7. Restoration of studies of biomechanics of the upper extremity.

8. Investigation of the formation and treatment of neuromas.

9. Physiological studies of muscles involving force, length, time, and myoelectric signals.

10. The development of procedures to insure the safety and efficacy of internal structural prostheses.

11. Studies of the interaction between neuromuscular control systems and internal structural prostheses.

SURGERY

1. Study of the response of human tissues to pressure, especially with regard to circulation and wound healing.
2. Study of the formation and presentation of neuroma.
3. Evaluation of osteoplasty techniques as practiced in amputation surgery by Dederich, Murdoch, Deffer, and others.
4. Evaluation of implant procedures designed to increase weight-bearing ability of stumps.
5. Further study of bone overgrowth in amputation stumps.
6. Evaluation of muscle fixation techniques in amputation stumps.
7. Determination of the feasibility of a substitute for the fatty tissues that often protect bony prominences.
8. Revival of studies of the phantom-limb sensation.
9. Continuation of development of improved surgical techniques for management of children with congenital limb deficiencies.
10. Expansion of present efforts in developing methods for attaching limb prostheses directly to the long bones.
11. Reevaluation of the concept of muscle attachment to external prostheses primarily for improved control.
12. Reevaluation of methods of amputation through the foot.
13. Development of new implantable devices for replacement of most of the joints of the extremities.
14. Development of an implantable artificial muscle.
15. Development of methods to control spasticity.
16. Further study of fracture bracing, especially for the femur.
17. Development of better mechanical devices for use in bone-lengthening procedures.
18. Reassessment of techniques for epiphyseal stimulation.
19. Development of better methods of replacing large bone deficits.
20. Continuation of studies involving limb replantation but at a very low priority.

EVALUATION

1. Continuation of the present evaluation program is recommended.
2. Expansion to permit cooperation with countries abroad should result in better exchange of information and thus permit the United States to introduce useful foreign improvements at an earlier date than is now the case.

CHILDREN'S PROBLEMS

1. The formation of four to six specialized centers in the United States to provide prosthetics management for severely disabled child amputees.

2. The development of a Cooperative Clinical Program in orthotics for children parallel to the Cooperative Amputee Clinic Program.

3. The development of locomotion aids in addition to braces.

4. The development of communication aids for children with speech impairments.

METHODOLOGY--REHABILITATION ENGINEERING CENTERS

1. The establishment of multidisciplinary centers to carry out integrated programs of research, development, evaluation, and education in rehabilitation engineering.

2. Subjects that might serve as central themes for study are:

    a. Functional Electrical Stimulation

    b. Internal Structural Prostheses

    c. Upper-Extremity Paralysis

    d. Paraplegia

    e. Hemiplegia

    f. The Effect of Pressure on Human Tissues

    g. Control of Neuromusculoskeletal Systems and Their Substitutes

    h. Problems of the Spine

    i. Sensory Aids for the Blind and Deaf-Blind

    j. Surgical Procedures

    k. Lower-Extremity Prosthetics

RESEARCH AND DEVELOPMENT

LOWER-EXTREMITY PROSTHETICS

Of all the areas covered by rehabilitation engineering, lower-extremity prosthetics is probably the most advanced. Tremendous progress has been made during the past 25 years, especially by the development of rationales for design and fitting of sockets and alignment of prostheses for all levels of lower-extremity amputation; by the design and development of more functional components such as hydraulic knee units; by emphasis on better surgery; and by the perfection and introduction of immediate postsurgical and early-fitting techniques.

Nevertheless, there is need for further work in lower-extremity prosthetics, and the following observations and recommendations are offered.

Postsurgical Management of Lower-Extremity Amputations

The immediate postsurgical fitting of lower-extremity amputations has proved to be an effective means of promoting rapid healing of stumps and has resulted in a dramatic improvement in the amputee rehabilitation process when recommended procedures are followed by a trained surgeon-prosthetist-therapist team (*2*,*7*,*31*).

Immediate postsurgical fitting should be publicized in medical journals and taught in medical schools as the method of choice. Additional means should be found for informing surgeons, who wish to use these techniques, of the necessity for adequate training of the complete amputation-rehabilitation team before immediate postsurgical fitting techniques are attempted. Only those hospitals with adequate personnel and facilities should be encouraged to carry out these procedures.

Direct Forming of a Socket on a Stump

Some success has been obtained at the Veterans Administration Prosthetics Center and the Navy Prosthetics Research Laboratory in forming sockets directly over the below-knee stump. Such a technique obviously should reduce the time necessary to make a socket and also permit easy modification of the socket after it has been formed. Both "Polysar" (*36*) and "Lightcast" have been used up to the present. A transparent material would offer advantages (*9*).

The Veterans Administration Prosthetics Center and the Navy Prosthetics Research Laboratory should continue their respective work on the use of thermoplastic materials for the molding of sockets directly over the stump.

Modular Prosthetics

Modular prosthetic components and assembly systems have been developed and introduced in increasing variety in recent years owing mainly to the needs generated by the immediate postsurgical fitting program. The basic concept appears sound and continued development by commercial manufacturers on an orderly basis should be encouraged.

A major problem in development of modular systems for all classes of amputees and any level of amputation is the lack of suitable cosmetic finish.

An *ad hoc* committee consisting of representatives from prosthetics manufacturers, prosthetics facilities, and research and development laboratories should be formed for the purpose of writing standards and specifications for modular systems for children, adults, and geriatric patients.

After such specifications are available, bids for the purchase of test models of selected components for various types of prostheses should be solicited.

It is further recommended that a special development contract be negotiated with a qualified manufacturer for the development of flexible foam materials which will meet the specifications of flesh-like feel, texture, appearance, resistance to water, and durability. These specifications should be set by an *ad hoc* committee on modular prosthetics.

Adjustable Above-Knee Sockets

Adjustment of the size of above-knee sockets is sometimes necessary when the stump is subject to frequent changes in volume due to weight changes, menstrual cycles, muscle atrophy, edema, etc. It may also be desirable in geriatric patients who have difficulty in donning the prosthesis.

Several systems to provide adjustability have been developed at research centers in the U.S.A., in Canada, and in Denmark. Flexible plastic liners within a rigid shell have been used successfully by Foort in Winnipeg, Sinclair in Miami, Lyquist in Copenhagen, and Wilson at the University of California Biomechanics Laboratory, San Francisco. Inflatable bladders are currently being studied by Hampton at Northwestern University.

The present level of activity in this area is considered adequate and should be continued as time permits.

Suspension of Above-Knee Prostheses for Geriatric Patients

The pelvic belt with hip joint continues to be the most popular suspension for the socket when suction is not used. The currently available ball-bearing or ring-type joints lack durability, are often heavy and bulky, and are considered to be generally unsatisfactory.

The ball-bearing joint developed by Porter at NPRL, Oakland, offers a possible improved design for hip joints. UCBL and NPRL should cooperate on a biomechanical analysis and design of an improved pelvic-belt suspension system for above-knee prostheses for the geriatric patient.

Swing and Stance Control for Hip-Disarticulation Prostheses

The number of patients being fitted with hip-disarticulation prostheses is increasing because of changes in the surgical management of osteosarcoma. The present type of device is similar to the original Canadian prosthesis introduced in 1952, and attention should be given to possibilities for improvement in view of past experiences.

UCBL should assume responsibility for the coordination of efforts at Berkeley, Toronto, and Winnipeg, aimed at improving both the alignment adjustability (modular construction) and swing-phase control and providing more active hip-joint motion during the stance phase (*12*). An *ad hoc* committee with representatives from UCBL, Winnipeg, Toronto, VAPC, and others interested should meet once a year to review progress.

The project will probably require several phases:

Phase 1. Comparison and evaluation of available swing-phase control systems when used in a hip-disarticulation prosthesis.

Phase 2. Development of modular components for thigh structure and development of a method of obtaining better cosmesis.

Phase 3. Biomechanical analysis and development of improved systems for hip-joint control.

Knee Disarticulation

Carry out recommendations of the CPRD Workshop on Knee-Disarticulation Prosthetics held in San Francisco June 22-23, 1970 (*18*).

Voluntary Control of Prosthetic Knee Joints

Electromyogram and various mechanical signals have been suggested as sources for voluntary control of artificial knee joints. This approach is certainly the next phase in the development of improved knee joints. Mauch Laboratories, UC-Berkeley, and VAPC are interested in the development of such systems.

Studies of the use of auxiliary power sources for the control of stance- and swing-phase stability should be carried out by a laboratory with extensive experience in the development of prosthetic components.

Mauch has conceived a hydraulic system which can be controlled by either EMG or by a muscle-hardness sensor under development. It is recommended that Mauch work with Northwestern University.

Foot--Ankle Units

Mauch. A sophisticated new hydraulic ankle is under development by Mauch Laboratories which incorporates a plantar-flexion control, and a dorsiflexion stop which automatically compensates for inclines and rough ground plus control of inversion-eversion and axial rotation.

The Mauch ankle offers promise of a major improvement in foot--ankle function and the development should be completed as rapidly as possible.

University of California Biomechanics Laboratory--Berkeley. UCBL is developing two types of ankle-rotation mechanisms: one with its axis coincident with the pylon center line, and a recent design in which the axis is located forward of the heel cushion and inclined laterally.

Testing of these units should be accelerated in order that drawings for purchase of test models can be made available at an early date.

SACH Foot Specifications

It is possible that the prosthetist in the field will not fully understand the reason for the changes in the shape of commercially available SACH feet that will become available shortly.

Radcliffe should prepare a short paper discussing the rationale for the shape of SACH feet and the interrelationship between SACH-foot function, alignment, and knee stability for both below-knee and above-knee prostheses. The paper could be published in either the *Bulletin of Prosthetics Research* or *Orthotics and Prosthetics*, as deemed appropriate.

Locomotion and Gait Studies

The present effort with emphasis on pathological gait and evaluation of devices is considered adequate. Organization of new facilities for this type of research should be discouraged, because there are at least six laboratories in North America that are well equipped to make locomotion studies.

Pressure Studies

Research aimed at the development of methods for measurement of pressure distributions between stump and socket over the complete stump is considered desirable but should be limited to a few highly qualified bioengineering centers.

A simple clinical pressure-measurement device, such as the small bladder-wafer with preset pressure threshold developed at Rancho Los Amigos Hospital, is considered desirable. These units should be made available to clinical research groups.

Muscle Activity in Amputation Stumps

The Prosthetics Research Study--Seattle should continue their studies of EMG activity in both below-knee and above-knee stumps. Current work involves a comparison between myodesis or myoplasty vs. conventional amputation procedure in below-knee stumps in cooperation with VAPC.

UPPER-EXTREMITY PROSTHETICS

During the early days of the Prosthetics Program a good deal of emphasis was placed on problems of the upper-extremity amputee, and significant improvements were made during the first eight to ten years at which time a sort of plateau was reached. Since then the major effort has been devoted both here and abroad to the application of external power (*4*,*38*). During the past several years the Panel on Upper-Extremity Prosthetics has focused its attention on the status and significance of developments in the area of externally powered components in addition to assessing the current state of the art.

- A review of clinical practice today indicates that:

  A preponderant majority of upper-extremity amputees are being fitted much as they have been for 15 years.

There are no valid indications of increased utilization of upper-extremity prostheses by patients fitted by conventional methods.

Innovation has been noted in the small but continually increasing applications of immediate postsurgical fitting techniques and in the use of direct-forming techniques in socket fabrication.

Small quantities of externally powered components have been introduced randomly into clinic practice.

The potential value of recent developments in external power has heightened the interest of clinicians and patients in upper-extremity fitting.

- As a result of Panel meetings:

Proposed tentative standards for externally powered terminal devices and elbows have been developed (*8*,*14*,*17*).

The clinical significance of current developments in upper-extremity externally powered components has been determined.

Indications for prescription of externally powered elbows and hands have been approximated.

Guidelines for packaging of power sources, wires, and connectors have been developed.

Guidelines for the development of one-site/three-function myoelectric control systems have been established.

The need for design of coordinated joint systems in view of the limited number of useful myoelectric and body control sites has been reinforced.

Limited but increasing clinical evaluation of externally powered components has been encouraged.

External power packs are available for trial with cable-operated prostheses.

Recommendations for Future Work

A high proportion of the available research and development capacity has already gone into upper-extremity prosthetics, particularly in external-power applications. It is important now to try to close the gap between research and the general level of patient care. Work already accomplished and development close to fruition should be exploited in an effort to improve clinical treatment.

Despite the promise of external power, several problems which these systems alone are unlikely to solve are recognized.

Listed below are a number of projects which are considered to be the most fruitful work that can be accomplished within the next three-year period.

Below-Elbow Externally Powered Prosthesis*

This prosthesis is a self-suspended, self-contained, myoelectrically controlled (proportional) prosthesis with interchangeable powered hook and hand. Needed is a soft exterior surface. This prosthesis will have <u>no</u> harness for control or suspension, no control cables, no external wires, switches, or batteries.

The developer should utilize one of the recently developed powered hands or synthesize elements of existing powered hands; develop a powered hook; utilize the techniques developed at VAPC or similar techniques for fabricating soft exterior covers; design suitable self-suspension systems similar to the modified Münster socket used at Northwestern University; and provide myoelectric control by one-site or two-site electrode configurations.

Four of the five major steps in this project are already under way at Northwestern University. The fifth item is under development at VAPC in New York. These two groups should cooperate to accelerate this development.

* long to very-short below-elbow

Above-Elbow Externally Powered Prosthesis

This is a self-contained and self-suspended prosthesis with a powered elbow and interchangeable hand and hook. Forearm segments will be endoskeletal with a soft exterior surface. There will be no apparatus (wires, plugs, batteries, etc.) external to the prosthesis.

The developer should use one of the previously developed powered elbows which may be modified as necessary. The approach should be similar to that recommended for the below-elbow case.

Improved Conventional Prosthesis

A large segment of the unilateral upper-extremity population rates appearance above function and therefore development of limited-function, endoskeletal upper-extremity prostheses with soft cosmetic covers should be undertaken. A system of internal cable controls should be designed to exploit part of the value of endoskeletal structures. Strong efforts should be made to reduce the role of harnessing in suspension by use of new socket designs. New harnessing systems should also be considered.

The cosmetic cover should offer a range of colors and textures and a resiliency approximating normal tissues. It should be durable, providing not less than a year's wear under the normal activities of daily living. It should be highly stain-resistant and readily cleaned by washing.

Controls

Further studies of the control system employing pattern recognition developed at Moss Rehabilitation Center (*23*) should be accelerated. This system of providing subconscious control of three joints simultaneously appears to offer far more than any other system proposed thus far and should receive the highest priority.

The control principles under consideration by Simpson (*33*) in Scotland should be carefully evaluated for their possible use in upper-extremity prostheses for adults and children.

Development of Controllable Shoulder Joint for Shoulder-Disarticulation Patients

There is a need for a shoulder-flexion joint (perhaps with abduction) whose flexion position can be controlled by mechanical friction or hydraulic resistance and operated voluntarily by the patient by a control switch or valve inside the socket.

Wrist Function and Humeral Rotation

In the present designs several normal arm functions are still not available to amputees. Among these are wrist flexion/extension, supination/pronation, and humeral rotation. There is insufficient information available for determination of the relative value of these functions to amputees.

An experimental analysis should be made to determine the functional significance of wrist flexion/extension and supination/pronation for below-elbow and above-elbow amputees. In addition, the relative merit of humeral rotation for short AE and SD amputees should be investigated.

Sensory Feedback

The real significance of various forms of feedback in the control of prosthetic devices has not been demonstrated. Without adequate data it is not possible to guide prosthetic development along these lines and the potential advantages may be either ignored or overemphasized.

Investigation of the significance of feedback arrangements in upper-extremity prostheses should be undertaken.

An experimental analysis of the relative merits of sensory (e.g., position, velocity, force), as put into the subject's peripheral nervous system through various means (e.g., vibration, pressure, electrical stimulation, etc.), should be made.

Survey of Upper-Extremity Amputee Population

It is becoming increasingly difficult to identify realistic design and development goals in the absence of reliable information on the extent of wear and utility of prostheses now in the field.

VA should undertake a survey to determine the utility of present-day upper-extremity prostheses. A similar survey of the civilian upper-extremity population should be made if results of the VA survey so indicate.

LOWER-EXTREMITY ORTHOTICS

Although it was recognized early in the artificial-limb program that much of the fundamental data and experience collected in locomotion studies and the development of artificial-leg components and fitting and alignment techniques would be helpful in improving lower-extremity orthotics, it was not until the early sixties that attention could be given to this matter. As a result, a number of projects have been initiated in this area and at the present time considerable work is being carried out in lower-extremity orthotics (*16*). Emphasis has been given to the development of devices and techniques that provide substitutes for lost functions but do not restrict residual functions.

The following observations and recommendations are offered.

Requirements in New Designs

The basic requirements which should be met in new designs of lower-extremity orthotic devices are:

a. Physiologic compliance, permitting optimum mobility
b. Minimum hardware to accomplish the task
c. Light weight
d. Silence in operation
e. Cosmesis

Modular, Adjustable, Temporary Orthosis for Clinical Use

A device that will allow the clinician to fit a patient quickly and easily for trial to determine adequately the suitable prescription for the patient seems desirable.

Better Materials for Use in Orthotics

Needed are materials for cuffs that can be formed directly over the extremity, for cosmetic uprights that can be reshaped easily without loss of strength, and for joints that provide some degree of shock absorption (*23*).

If such materials were available much time could be saved in fabrication, the appearance could be improved, and more comfort could be obtained.

Synergistic, Neuromuscular Control Systems for Orthoses

More studies involving the use of normal muscle to control a remote joint or muscle by means of EMG signals should be undertaken (*35*).

Modifications to Standard Shoes to Accommodate Foot Deformities and Sensory Impairments in Lieu of Using Special Orthopedic Shoes

Studies to achieve this are needed to allow treatment by more uniform, less costly methods.

Knee Joints for Anteroposterior Control

The following should be studied in reference to control of buckling of the knee:

a. Knee joint with lock
b. Knee joint with extension assist
c. The Swedish Knee Cage (*16*) and the Institute of Rehabilitation Medicine Supracondylar Brace (*16*)
d. Knee orthoses permitting knee flexion during swing phase

Improved Knee Joints for Mediolateral Control

Needed especially is a device for use in the case of varum without involvement of the ankle.

Hip Flexion and/or Extension Assist

Patients who lack adequate hip flexors and/or extensors need some means for controlling the hip in the anteroposterior plane.

Improved Mediolateral Control of the Hip

Voluntary control of abduction/adduction of the hip is needed.

Improved Reciprocating Devices to Provide Hip Motion for Locomotion by Unilaterally as well as Bilaterally Affected Patients

Devices designed by the Ontario Crippled Children's Centre (*15*) should be tried at other centers.

Dynamic Push-off Assist

Dynamic push-off assist for those who lack the necessary musculature for this function is needed.

Foot Architecture

There is a continuing need to utilize devices such as pads, arch supports, and metatarsal supports that can be inserted into a standard commercially available shoe to modify the application of forces and pressures to the foot. While such devices have been used in the past, there is a lack of definitive information available to the orthotist and physician in the proper selection and utilization of such devices with regard to their influence upon foot architecture and foot mechanics. Needed is the definition of size, shape, and placement to achieve particular effects, often in conjunction with other orthotic devices, upon the mechanics of standing and walking for various disabilities.

Criteria should be developed regarding the factors which influence foot architecture.

Neuromuscular Stimulation

Simple exoskeletal devices and mechanisms often fall short of permitting mobility by patients who have developed certain types of spasticity, dystrophy, and other losses of motor and sensory function. Augmentation of the external appliance by excitation or inhibition of pathological muscular and nerve function seems to offer much hope.

Criteria should be developed for using neuromuscular stimulation for orthotic purposes.

Weight-Bearing Orthotics

It is recognized that there is not a direct transfer of technology from the prosthetics field to the orthotics field for weight-bearing applications. The forces and pressures in both below- and above-knee applications may cause severe skin irritation, damage to tissues, vascular problems, and discomfort to the patient.

Studies should be conducted to delineate anatomic considerations for weight-bearing orthoses.

Fracture Bracing

The development of methods for making fracture patients more mobile should be continued (*10*).

UPPER-EXTREMITY ORTHOTICS

The development of devices and techniques to provide function to paralyzed upper extremities is a formidable problem because the human hand and arm together is a most complex system. During the past 15 years considerable effort has been devoted to the development of orthoses for the flail arm, but no one, including the developers, is satisfied with the progress that has been made. Some highly motivated patients have benefited from this work, but the overall results have been discouraging. A number of patients seem to benefit from the devices but fail to use them soon after they leave the hospital. Yet, with advances in medical science, more and more patients with flail upper extremities, especially quadriplegics, are being seen.

The following observations and recommendations are offered.

Acquisition of Demographic Information

There is a great dearth of information in areas essential for intelligent cost-benefit analyses, research planning, and treatment. Some of these are:

1. The extent of the various populations of hand-disability patients.

2. Rehabilitation potentials for the different categories of disabilities. The determination of such potentials should include both humanitarian considerations such as self-care, self-respect, and the like; and economic factors, including employment possibilities.

3. The extent of available treatment procedures and devices, including assistive or manipulative appliances.

A survey should be made to develop the information necessary for making intelligent decisions concerning the field. The results of the survey should include estimates of:

1. The number of patients in each disability group treated with upper-extremity orthoses. The disabilities to be surveyed should include: quadriplegia, hemiplegia, arthritis, and trauma including burns and peripheral nerve injuries.

2. The rehabilitation potential for each group with respect to self-care and vocation.

3. The cost of rehabilitation or treatment services for each group.

It is recognized that little is known of the post-hospital or post-institutional use of upper-extremity orthoses. A systematic investigation of this factor related to level and severity of lesion should be initiated also.

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In parallel with the studies recommended above, immediate steps should be taken to improve current treatment practice for each known disability group, viz.:

Quadriplegia

Known treatment procedures and devices for quadriplegic patients should be subjected to comparative analyses to determine relative merits and prescription criteria for each. Systems to be studied should include those developed at Rancho Los Amigos Hospital, the Texas Institute for Rehabilitation and Research, The Rehabilitation Institute of Chicago, and the Institute of Rehabilitation Medicine, New York University.

Fundamental studies of hand, wrist, elbow, and shoulder motion dynamics and kinematics should be undertaken immediately. Such studies should include hand (wrist) flexion, extension, and deviation positions in relation to the performance of various common tasks and the frequency of use of these positions (*21*). It is recommended that this study be undertaken by a center or laboratory specializing in the analyses of upper-extremity functions. Necessary requirements of such a laboratory are: capability for motion and time studies and related techniques; computer-processing of massive amounts of experimentally obtained data; available populations of normal and handicapped subjects; and consultative availability of a functional anatomist.

With regard to the total rehabilitation engineering effort directed toward the quadriplegic patient (and perhaps other types of patients with upper-extremity disabilities as well), it is noted that braces or assistive devices may be of two broad general types:

1. those that are attached to, or worn by, the patient;
2. those that are not fitted to the patient but rather are attached to a wheelchair, table, desk, or other stable base.

While even less is known about the role and value of the latter group of appliances (or manipulators), their potential appears worthy of assessment. Such assessment should be the responsibility of the major spinal-cord injury centers in the U.S.A., and immediate implementation of such programs is recommended.

Whether devices are attached to the body or detached, the role and value of external power in their operation should be defined and delineated.

The possible value of computer-aided decision-making assistance for the severely handicapped patient should also be investigated in the spinal-cord injury centers.

Hemiplegia

At the present time no specific recommendations are offered concerning static splinting for the prevention of hand deformities or contractures in hemiplegia. However, it is anticipated that recommendations would arise in the future as a result of the recommended studies.

With respect to functional bracing for the hemiplegic, no satisfactory braces are currently available, in part because the spasticity present is a bar to effective bracing. It is recommended, therefore, that the investigation of methods to relieve spasticity should be intensified. Techniques investigated should include neurophysiological stimulation with mechanical as well as electrical inputs. A coordinated effort involving orthopaedic surgery and neurosurgery to study neuromuscular control mediated by both central and peripheral factors is recommended. Current efforts by CPRD in this direction should be intensified and extended during 1970-1971.

The true effect of loss or distortion of sensory inputs on the functions of the hand and arm with available motor power is not known, and it is recommended that a laboratory or center with appropriate psychological and neurophysiological capability study the significance of the loss or distortion of specific sensory modalities on functional capacity.

Rheumatoid Arthritis

Past and current orthotic management of the rheumatoid hand has proven to be ineffective for the most part, although some progress has been made in surgical management. It is recommended therefore that investigation of new orthotic management methods be initiated. Such an investigation should be undertaken by a center or laboratory that has special competence in hand surgery, plastics technology, and access to a wide variety of cases. It is recommended that these investigations include such areas as plastic supportive gloves and internal injection of plastics for joint stabilization.

Peripheral Nerve and Thermal Injuries

It is recognized that upper-extremity disabilities arising from peripheral nerve injuries, especially injuries to the brachial plexus, present complex problems. At this time it is difficult to make specific recommendations in this area. Data arising from studies previously recommended should throw further light on these problems and provide insights concerning required research.

Training of Occupational Therapists in Orthotics

It is apparent that upper-extremity splinting and bracing are being done by occupational therapists as well as by orthotists and physicians. It is recommended that the Committee on Prosthetics Research and Development (CPRD) and the Committee on Prosthetic-Orthotic Education (CPOE) survey training programs for occupational therapists in this area, as well as literature available for this purpose, in order to determine the possible need for intensified or expanded educational efforts. This should be done at the earliest opportunity.

SPINAL ORTHOTICS

Although there are available dozens of designs for back braces, corsets, and cervical supports, nearly all have been developed empirically because very little research has been carried out on the function of the spinal column. The relatively recent work at the University of California (*11*,*29*) has shed some light on the functions provided by the spine and associated musculature and has stimulated interest in research at several other places. The recent survey by Perry (*32*) emphasizes the need for further work in this area.

Three areas considered necessary for future research effort are:

1. Evaluation and improvement of external appliances
2. Design and development of improved internal fixation devices
3. Conduct of fundamental studies in the area of biomechanics of the spine and etiology of back pain.

The following observations and recommendations are offered.

Standardization of Nomenclature

Of fundamental importance to cooperative research efforts and eventually to teaching in spinal orthotics is standardization of the nomenclature. It is recommended that the New York University scheme of categorizing and naming braces, including cervical, thoracic and lumbar orthoses, be given wider publicity by:

a. an article in ARTIFICIAL LIMBS;

b. dissemination of this information through the American Academy of Orthopaedic Surgeons, especially revision of Volume 1 of the *Orthopaedic Appliances Atlas*.

c. use of the nomenclature in revisions to supplies catalogs.

Serious consideration should be given to the prescription of orthotic appliances based upon functional analysis as proposed by the American Academy of Orthopaedic Surgeons (*28*).

External Appliances

Cervical Appliances

A detailed analysis should be made of the functions and limitations of standard available cervical appliances; for example, the so-called soft and hard collars, four-poster cervical brace, and cervical brace with trunk fixation. Specifically, resistance to and limitation of motions about the various axes should be studied by techniques such as carefully controlled cineradiography; also, measurement of unit contact pressures and net forces at the skin-appliance interface (mandibular and occipital regions) should be made. Study should be undertaken as soon as possible, at an institution such as the University of California--San Francisco, where cineradiographic facilities and cooperative effort between radiology, orthopaedics, and bioengineering are available. Both normal volunteers and patients with pathologic conditions of the cervical spine should be studied. Evaluation of such factors as comfort, durability, cost, and ease of fitting should be included. It is expected that this project should be completed within one year. Based upon the results of these studies, it is hoped that improvement in the design of cervical appliances can be subsequently undertaken.

The Abdominal Pressure Spinal Support

The presently available Abdominal Pressure Spinal Support (University of California--San Francisco "Royalite" jacket)(*11*) should continue under investigation at UCSF for function and possible improvements of materials and fitting techniques.

New materials with graduated flexibility (especially those allowing flexible margins for greater comfort) should be evaluated by fabricating comparable appliances over the same plaster model used for the basic "Royalite" jacket. Polyethylene, polycarbonate ("Lexan," a transparent material), and perhaps other materials should be compared with "Royalite." The Engen technique (*20*) for corrugating a thermoplastic material for stiffness (by placing cords on the model before draping the hot, soft material) should be considered. Perforation of the corrugations might also allow some ventilation.

Measurements should be taken to record allowed motions, pressure in the abdominal cavity, venous flow and vital capacity for each of the test braces for comparative evaluation. Work on the "Royalite" jacket and its modifications should be compared with parallel evaluations of seven "standard" back braces presently being undertaken at New York University.

Improved fixation to the pelvis for the basic "Royalite" jacket should be investigated, perhaps utilizing techniques of the Milwaukee scoliosis brace.

Instrumentation for Research Studies

Instrumentation and techniques for studying spinal orthotics should be improved.

A surgically implantable transducer for measuring relative motions between vertebrae, such as linear displacements between the spinous processes, should be developed. The transducer should exert negligible force on the spinous processes and be self-contained if possible (i.e., information would be retrieved by telemetry or by measurements of inductance or capacitance through the skin interface). An organization familiar with surgically implantable transducers (for example, Dr. Ko's group at Case Western Reserve University) should be consulted. Such a transducer would reduce or eliminate radiation exposure now needed by x-ray studies, and in most if not all cases would eliminate the need for pins projecting through the skin; these are troublesome and in most instances inconvenient. Development might take one to two years.

Pending availability of the above transducer, x-ray techniques for measuring motion of vertebrae should be standardized. Implanted radiopaque markers on selected vertebrae, standardized positions and loadings, and defined tube and screen positions should be considered.

Miniaturized pressure gauges suitable for implanting in the nucleus pulposus of the disc (e.g., Dr. Ko's miniature gauges) should be considered, subjected to trial on large animals, and, if appropriate, tested on humans.

Pneumatic Devices

Pneumatic or inflatable bracing should be developed within a feasibility program.

For the Abdominal Pressure (Royalite) brace (*11*), the compression of the abdomen might be provided by an inflatable bag inside an essentially flat abdominal wall.

For cerebral palsy, scoliosis bracing, pneumatic (or hydraulic) bracing or pressure pads, with selective weaves to limit distortion when inflated, should be developed. Such inflated structures would replace metal bars in stiffening corset-like structures; others would serve as pads to distribute appropriate forces over the body.

The concept of pulsating or alternating pressure between adjacent pads to exert intermittently high forces while allowing periodic release of pressure and blood flow to proceed should be pursued. This appliance might first be applied to cerebral-palsy scoliosis where corrective forces have been traditionally limited to low levels by skin tolerance.

An organization with a substantial case load of cerebral-palsy cases, versatile fabrication facilities, and interdisciplinary personnel, including physicians, orthotists, and engineers, would be appropriate for experiments with these pneumatic appliances for CP patients. Cooperation with Goodyear Aircraft's group on inflated structures would be needed. Development of experimental models would probably require at least two years.

Pneumatic devices for muscular dystrophy cases should be developed to permit the patient to vary pressure in a given pad by control valves regulating flow of air or liquid between pads so as to allow alternating or shifting pressures and slight shifts of positions. External automatic or patient-regulated pulsating pads within rigid outer abdominal or thoracic shells might also function as respirators. Similarly, a center with a substantial muscular dystrophy case load, fabrication facilities, and an interdisciplinary team would be needed.

Electrical Stimulation

The possibilities of electrical stimulation of muscles on the convex side (or perhaps of electrical inhibition of muscles on the concave side) of spinal curvatures, perhaps controlled by microswitches sensitive to sagging into the curved position, should be explored. Such work might be initiated very modestly with a commercially available stimulator, but serious investigation on a substantial scale would probably require much more fundamental knowledge of muscle properties, muscle stimulation, and biomechanics of spinal curvatures and rotations.

In view of the obvious need for development in the next few years for bracing in the cervical and lumbar region as well as the relatively satisfactory (although far from perfect) appliances for the thoracolumbar region (including scoliosis), no attempt is made here to suggest development or modification of such appliances. Likewise, at this time, no specific recommendation is made for analysis of beds, mattresses, chairs, or cushions, important as these obviously are in spinal posture, pressure distributions, and pain.

Internal Splinting Devices

Severe spinal deformities are best managed by some form of internal splinting or corrective device in conjunction with external support during maturation of fusion in the involved area. Current devices are only partially successful in achieving these objectives. It is anticipated that, with recent knowledge of the mechanical properties of the vertebral column, improvements in current designs and new concepts of correction and stabilization will be possible. Experimentation with such systems as multipoint fixations, dual-cable, or multi-cable designs for simultaneous correction of curvature and rotation deformities should be encouraged.

In order to define the status of present instrumentation, and to stimulate new approaches to the design and development of improved splinting and fixation devices, a workshop for this purpose is recommended. Participants should include orthopaedic surgeons knowledgeable in the use and problems of such surgical implants, and engineers knowledgeable in biomechanics of the spine and implantation materials.

Basic Research

Experimental studies have produced mechanical data for the isolated spinal column by measurements of stiffness for all its modes of deformation. It is recommended that these studies be expanded to measure the same mechanical constants of the spine with the surrounding musculature and attached structures intact so that this external support (i.e., the support provided by the trunk musculature) may be evaluated in mechanical terms. Data of the spinal column *in vivo* should then be used to analyze those forces developed within this column by the application of back braces or other orthotic devices (internal or external) so that improved designs may proceed on a rational basis. The data from these studies should also be applied to the design and development of a disc prosthesis to replace or reinforce a worn or damaged disc so that normal mechanical function would be approached. This work is currently under way at the University of California but should be encouraged at one or more additional centers.

Instrumentation for these measurements is presently unavailable. It is anticipated that development of such instrumentation will be extremely difficult and time-consuming. Nevertheless, the value of such data warrants the investigation necessary. A time of no less than three years appears reasonable for this study and will require a cooperative approach between bioengineering and medical personnel.

The use of both external and internal support appliances or devices is based on the assumption that restriction of motion is necessary for the alleviation of painful symptoms. This is undoubtedly true in most cases and to some degree in all cases.

However, a glaring basic defect or hiatus in our knowledge hampers a completely rational approach to management of back pain. Specifically, we do not know the etiologic mechanism of pain in the large majority of so-called "low back" patients. Presumably, it is related to disc degeneration, but whether mechanical, chemical, or other unknown factors are directly responsible for the pain remains unknown. Elucidation of the factor or factors responsible is a prerequisite to more rational and significantly improved treatment of so-called "low back pain."

It is, therefore, suggested that a workshop devoted to the fundamental problem of the "Etiology of Low Back Pain" be held at the earliest possible time. Participation would be necessary by individuals knowledgeable in 1) the basic physiology, biochemistry, and pathology of the disc and surrounding structures, 2) the physiologic and psychologic aspects of pain, and 3) mechanical and surgical aspects of the spinal column, specifically the intervertebral disc. It is anticipated that direction for future research activities rather than "definite answers" will be achieved by such a workshop.

SENSORY AIDS

The Federal Government has been supporting research in devices to aid those individuals with sensory deprivation at least since 1944 when the Office of Scientific Research and Development and shortly thereafter the Veterans Administration gave support to the Committee on Sensory Devices of the National Research Council (*6*). Today in the United States there are the following federal and private agencies supporting research in sensory aids for the blind:

1. Veterans Administration
2. Social and Rehabilitation Service, Department of Health, Education, and Welfare (DHEW)
3. National Eye Institute, DHEW
4. National Institute of Neurological Diseases and Stroke, DHEW
5. Office of Education, DHEW
6. Department of Defense (MIT-RLE)
7. Hartford Foundation
8. Seeing Eye, Incorporated

Research efforts can be classified by objectives as follows:

1. Mobility Aids
2. Devices for Independent Reading of Inkprint
3. Improvements in Braille Production and Distribution
4. Other Communication Devices
5. Vision Prostheses
6. Training Methods and Evaluation of Devices

A tabulation of the various research projects currently under way is given in Appendix C.

During the past year the Subcommittee on Sensory Aids has met on four occasions to review various aspects of the research program. At a meeting in Washington, D.C., in October 1969, the work of Mauch Laboratories, Bionic Instruments, Inc., and Haskins Laboratories, Inc., all contractors to the VA, was reviewed. In March 1970, visits were made to The Smith-Kettlewell Institute of Visual Sciences, Stanford Research Institute, Western Blind Rehabilitation Center--Veterans Administration, and the RAND Corporation. In September, visits were made to the American Center for Research in Blindness and Rehabilitation, the Sensory Aids Evaluation and Development Center--MIT, the Sensory Measurement Laboratory--MIT, the Research Laboratory of Electronics--MIT, and the Low Vision Clinic, Boston University Medical Center. In February, the subcommittee met to outline in some detail recommendations for future work.

In addition, the subcommittee sponsored a conference on September 3, 1970, on the C-4 Laser Typhlocane developed by Bionic Instruments, Inc.

The subcommittee offers the following general comments and recommendations with respect to research in aids to the blind.

GENERAL

Support of research in sensory aids for the blind (and deaf-blind) has been meager through the years since World War II when compared with research directed at other disabilities. The small but steady effort is now beginning to show promise. Some experimental devices have now reached a point that much can be gained by relatively large field trials (Mauch Visotoners, Stanford Optacons, Bionic Laser Canes, etc.).

All aspects of the sensory aids research program could benefit by an increase in funding, but highest priority should go to the establishment and operation of an organized evaluation program.

Because there are so little data arising from basic psychological and physiological studies that are of use to development groups, empirical experimentation seems to be the only approach, and thus evaluation programs that provide for this are much needed. This technique has proven to be an effective means of accelerating development and deployment in limb prosthetics and orthotics. At this time, a number of de ices are emerging from research and development that are ready for evaluation.

Evaluation should be carried out by a group or groups independent of the development group.

MOBILITY AIDS

Evaluation of the Bionic C-4 Laser Typhlocane being carried out informally should be continued. The procedures developed could serve as a model for the evaluation of other mobility aids.

The evaluation of the Bionic Typhlocane should be correlated with the evaluation of the Kay ultrasonic spectacles.

Experience with the ten Russell Pathsounders that were built several years ago should be gathered and analyzed to determine if future development of this device should be undertaken.

Other developments such as the Deering light-sensing cane and the Swail radio-compass device should be considered for evaluation.

Work on substitute visual systems such as proposed by Bach-y-Rita and Starkiewicz should be encouraged and perhaps expanded.

INDEPENDENT READING OF INKPRINT

The Stanford Optacon and Mauch Visotoner are considered to be ready for evaluation by an independent group not only to determine whether or not the devices in their present form are useful and should be marketed, but also to collect data that will be useful in developing criteria for the design of future devices.

BRAILLE DEVELOPMENTS

Most of the ongoing work in improved production and use of Braille should be encouraged, but it should be recognized that improvements are restricted by the inherent limitations of Braille itself.

CLOSED-CIRCUIT TV READERS

A number of designs of closed-circuit TV readers has emerged recently, and it is recommended that a conference be held to provide for interchange of information among the design groups and to develop recommendations for future work in this area.

VISION PROSTHESES

Stimulation of the visual cortex to overcome blindness is a fascinating subject. Careful work in this field should be supported at a rate to take advantage of advances in electronics, but the problems of long-term response by the brain to foreign bodies must be constantly considered.

FUNDAMENTAL STUDIES

It is axiomatic that the development of sound criteria for the design of improved devices, techniques, and management practices must be based on data obtained by fundamental studies or basic research, and a balance between fundamental studies and design and development should be maintained.

The following observations and recommendations are offered.

NEUROMUSCULAR CONTROL

Feasibility of Neuromuscular Stimulation

Although considerable work is being directed toward application of electrical stimulation of paralyzed muscle, basic knowledge is still lacking on the reactions of tissue and materials to the stimulation of muscles and nerves over a long period of time. More work and more funding are needed to determine the feasibility of neuromuscular stimulation before further development and application of devices.

Some work in this area is now being done at Case Western Reserve University, Rancho Los Amigos Hospital, and in Yugoslavia in connection with hardware development. These efforts should be intensified and other responsible and interested organizations should be encouraged to participate.

Additional funding and organized efforts will be needed to investigate areas of basic neurophysiology aimed at using neuromuscular stimulation for control. A Workshop on Neuromuscular Stimulation should be held no later than 1973.

STUDIES OF THE SPINE

Biomechanics of the Spine

Spinal orthotics is the area of greatest clinical need. More work and more funding are needed to amplify our scant knowledge of the spine. First efforts should be directed toward increasing our knowledge of the biomechanics of the spine. This work will provide the basis for the design and development of bracing for the back, and surgical procedures.

Some work is now being done by the University of California Biomechanics Laboratory, Case Western Reserve University, and others. These organizations are considered adequate to do the job and should be encouraged to intensify their efforts.

Effects of Disease on the Spine

When the biomechanics of the spine have been defined, additional work and funding will be needed to determine the effect of disease on the spine. This work is essential to enable clinicians to prescribe proper treatment of patients with pathological conditions of the back.

STUDIES OF THE LOWER EXTREMITIES

Locomotion

There are several groups in the U.S. working cooperatively on human locomotion at the present time. These organizations are considered adequate to do the job and should be encouraged with funding to continue their work at least at the same level of effort.

Loading on the Lower Extremities during Various Activities

In order to properly design internal and external prosthetic and orthotic devices, data on the amount of loading on the lower extremities during various activities, such as sitting down, standing up, and transferring from bed to wheelchair, are needed. There is only a small amount of work being conducted in this area. This should be expanded and accelerated.

Biomechanics of the Foot and Ankle

More basic knowledge is needed about the foot and ankle to provide information for the design and development of braces, shoe inserts, and shoe modifications. At present, the University of California Biomechanics Laboratory is the only organization supported to work in this area. Impetus should be given to this effort, and another organization should be encouraged to engage in this research so there are at least two groups working in this area.

INTERNAL PROSTHETICS

Joint Replacement

Much interest and emphasis has been placed recently on the unsolved problems of joint replacement of the hip and fingers and of the knee, elbow, and shoulder as well. There are many people working on these problems, and the present level of funding support should be continued. However, this work needs to be coordinated. A Workshop on Joint Replacement is recommended.

Skeletal Attachment

More needs to be known about the problems of fixation to the bone, tissue response, and shock absorption. The most critical issue is the transcutaneous passage.

Rancho Los Amigos Hospital and others are interested in working in this area. These efforts should be supported.

MATERIALS

Properties of Biological Materials

More basic knowledge is needed about human tissues. Needed are a better definition of the physical properties of bone, muscle, tendons, etc., with the hope of compiling a "handbook" for the bioengineer.

Properties of Biological Structures

After the properties of individual tissues have been determined, additional work will be needed to determine the properties of biological structures. Again, the hope is to compile a "handbook" of these properties for use in design and development of hardware and surgical procedures.

TISSUE RESPONSE TO FORCE

Soft Tissue Response to Local Force

For a large number of applications in prosthetics and orthotics, more needs to be known about the way soft tissue behaves when subjected to local forces. Some work is now being done but expanded effort is needed.

Hard Tissue Response to Local Force

For applications such as fracture bracing and implants, it is also necessary to know the way hard tissue behaves when subjected to local force.

STUDIES OF THE UPPER EXTREMITIES

Biomechanics of the Hand and Wrist

Work in this area is important for the proper medical treatment of people with arthritis, full or partial paralysis resulting from stroke or trauma, and various conditions of cerebral palsy. The University of Iowa and others are working in this area, and these efforts should be sustained.

Biomechanics of the Arm

Further studies of the biomechanics of the arm should be encouraged to obtain information necessary for the design and development of prosthetic arms and orthotic assists.

OTHER PROJECTS

Study of Neuroma

The presence of neuromas is a problem especially to lower-extremity amputees where body weight must be borne by the stump. Nerve-tissue studies are needed to investigate the formation and treatment of neuromas. Dr. Singer at Case Western Reserve University has done a little work in this area.

Study of Muscle Force, Length, and Time

It is possible to produce a three-dimensional graph which would concurrently take into account three variables of muscle function--force, length, and time: for example, by knowing any two, one could determine the third. This information would be useful in the design of devices which must work with or substitute for the human musculoskeletal system. Little or no work is now being done.

Quality Control and Regulation

Needed urgently are procedures to be followed to check the safety and efficacy of internal structural prostheses. The National Academy of Sciences appears to be the most appropriate agency to guide and monitor the work necessary for the development of such standards and procedures.

SURGERY

Amputation surgery in the United States is still being carried out predominantly by general and vascular surgeons who have varying levels of sophistication in this field and generally pessimistic attitudes. The general surgeon has not involved himself in prosthetic rehabilitation of the patient or, as a rule, in development of improved amputation technique. Orthopaedic surgeons are becoming increasingly interested in rehabilitation in general and in prosthetics and orthotics, both external and implanted.

The majority of orthopaedic surgeons in this country are heavily committed to the treatment of trauma, and there is a tendency for complicated reconstructive surgery to be concentrated in medical centers and special hospitals.

Very little attention has been given to scientific study of surgical techniques and their results. Some of the problems associated with both amputation and orthopaedic reconstruction are considered here, and the following observations and recommendations are offered.

AMPUTATION SURGERY

Comprehensive studies of *tissue response to pressure* as regards circulation and stump healing in particular are needed for further improvement in immediate postsurgical fitting, socket design, level determination, and vascular reconstruction. The studies should be carried out by clinical centers with sophisticated research capabilities. A workshop on this subject in the near future is recommended.

Energy expenditure studies for all levels and combination of levels of amputation, and clinical correlations of what this expenditure means to the patient are needed. The research should be carried out by a clinical center with a large amputee load and a biomechanics laboratory.

Nerve-tissue studies in relation to neuroma formation and presentation are needed. The studies should be an assigned project under the supervision of the Subcommittee on Fundamental Studies of CPRD.

Studies on surgical management of bone are needed.

1. *Osteoplasty*--clinical investigations should be expanded and information on techniques more widely disseminated. This work should be performed by clinical services with large amputee loads (*3,19,26*).

2. *Implants in bone* for distal end-bearing stumps (*34*). Existing information should be correlated and further investigative work pursued. This work can be performed by any large clinical amputee center.

3. *Bone overgrowth* (*27*) should be studied as to etiology, prevention, and treatment. It should be carried out in a child amputee center with controlled prosthetic facilities.

Muscle fixation techniques including myoplasty and myodesis (*2, 19,26*) should be evaluated further. The studies should relate to effect on stump strength, gait, circulation, stump shape, and socket design. The relative value of such procedures at different levels of amputation should be determined. The study should be carried out by a clinical service with a large amputee load and controlled prosthetic facilities.

Studies on the feasibility of *fat substitution or replacement* should be considered for protection of bony prominences. The suggested material is silicone gel, and studies could be conducted by any large amputee center.

The phenomenon of *phantom limb* should be studied further with respect to techniques of surgical management. This project should be performed by an amputation center with capable neurophysiological and neurosurgical facilities.

Reevaluation of present *surgical techniques for congenital limb deficiencies*, e.g., proximal femoral focal deficiency and fibular hemimelia, should be carried out along with investigation of new techniques (*1*). Such a project should be done by a child amputee center.

Studies on the *skeletal attachment of external prostheses* should be continued and new investigation encouraged. This involves development of surgical techniques as well as material selection, and should be done by a major amputation center with biomechanical and biochemical engineering inputs.

The concept of *muscle attachment to external prostheses* should be reevaluated. Cineplasty techniques should be reviewed and alternate techniques should be investigated. This work should be done by a major amputation center with a significant number of upper-extremity amputees and controlled prosthetic facilities.

Surgical techniques for the relief of *stump contracture* should be evaluated and standardized, and further surgical procedures designed if necessary. This could be carried out at any major amputation center.

The *knee-disarticulation level* (*30*) should be reviewed and further investigation carried out regarding advantages in gait and energy expenditure over the above-knee level. The relative merits of various surgical techniques to create end-bearing at this level should also be evaluated. These studies should be undertaken by a major amputation center with bioengineering support.

Partial foot amputations should be reevaluated in terms of functional value, and related to the possibility of reconstructive surgical techniques to balance the hind part of the foot. This investigation should be extended to include new design criteria for prostheses at the hind-foot level, and should be performed at a major amputation center with controlled prosthetic facilities.

Education in amputation surgery should be a priority item and extend in particular to the general surgeon at graduate and postgraduate levels. The best approach to this goal is felt to be the encouragement and development of "amputation services" within our large teaching hospitals, whereby the general surgery and orthopaedic staffs would join in providing preoperative, operative, and postoperative care for the amputee. This type of program might well be supported in its initial phases by research and demonstration grants to a select number of centers.

At the postgraduate level, the publication of leading papers on the subject in general surgery journals should be strongly encouraged.

Presentation of significant papers on amputation surgery and amputee rehabilitation at general surgery meetings should also be strongly encouraged.

ORTHOPAEDIC RECONSTRUCTION

Research in *joint replacement* is considered to be a high priority project. More work needs to be done on the hip, in terms of materials and design. The present knee- and finger-joint prostheses need redesign. Neither elbow nor shoulder units are presently available. Adhesive and nonadhesive techniques for fixation require further work, including investigation of dacron velour. This should be done by a clinical center with bioengineering assistance.

Muscle-tendon unit replacement, i.e., implanted artificial muscle, should be investigated by a clinical center with appropriate bioengineering assistance.

Control of spasticity to permit functional orthotic application is needed, especially for upper-extremity cases. It should be done by a clinical center with a neurological disease service.

Fracture Bracing (10)

1. A plastic substitute for plaster, preferably porous, which can be directly applied to the patient and sets rapidly at low temperature is needed.

2. Better components for femur bracing are required.

3. Reinvestigation of internal-external fixation techniques for fracture should be undertaken. New materials which permit crossing the skin barrier may have possibilities. This work needs to be

carried out in a clinical center with a large fracture service and a bioengineering unit.

Limb Augmentation

1. Development of better mechanical devices for bone lengthening is needed.

2. Reassessment of techniques for epiphyseal stimulation is indicated.

Replacement Materials for Fitting Large Bone Defects

This project would somewhat overlap that on the skeletal attachment but should be kept in mind constantly.

Limb Replantation

Limb replantation is a legitimate subject for investigation, although present results are not encouraging.

EVALUATION

It has long been recognized that evaluation of devices and techniques used in prosthetics and orthotics by an agency independent of the developer is a desirable and necessary step in the transition of a device or a technique from the idea stage to clinical use.

Not only does independent evaluation prevent the spending of funds for development and manufacture of useless items but, when carried out effectively, can accelerate the development of an item and also accelerate its introduction into clinical practice. And, in a number of instances, indications for use of devices and techniques far beyond the designers' concepts have been discovered during evaluation, and, therefore, broader use has been made of these developments than was originally contemplated.

It has also been long recognized that evaluation is a difficult, arduous, expensive task. Because of the great number of interdependent variables that enter into the success of prosthetic and orthotic items, it is seldom practicable to employ the scientific method of evaluation. Often it is virtually impossible to obtain a valid control group. The alternative is to fit relatively large numbers of patients under ordinary clinical conditions, keep accurate, comprehensive records of their progress, and make general comparisons with past practices whenever possible.

The Subcommittee on Evaluation of the Committee on Prosthetics Research and Development conducted a pilot program in clinical evaluation in prosthetics and orthotics (*25*) during 1967-1970, and since that time has been under contract with the Social and Rehabilitation Service to conduct a full-scale program. Six organizations (the Prosthetic Education Programs at University of California at Los Angeles, Northwestern University, and New York University; the University of Miami; Rancho Los Amigos Hospital; and Texas Institute for Rehabilitation and Research) have also been funded by SRS to participate in the evaluation program. This arrangement provides an excellent line of communication between research groups and those responsible for education.

The evaluation program appears to be effective in its present form and should be continued essentially as it is being operated during the near future. However, every effort should be made to recognize any changes that are necessary as research programs and education programs develop. Expansion of the evaluation effort to provide for cooperation with countries abroad should result in better exchange of information and thus permit the early introduction of useful foreign developments into the United States (*13*).

It is felt that not less than 10 per cent of the overall research and development effort should be allocated for evaluation.

CHILDREN'S PROBLEMS

In February 1956, CPRD moved from an indirect role in the area of child prosthetics to an active and dynamic one when the Subcommittee on Child Prosthetics Problems was formed. Since that time an impressive list of accomplishments has been recorded, including the formation of the Cooperative Child Amputee Clinic Program in which 30 clinics are now participating.

The following observations and recommendations are offered.

SPECIALIZED CHILD AMPUTEE CENTERS

Severely disabled child amputees require special equipment and treatment if any help at all is to be given. This is the one area where the use of externally powered prostheses seems to be indicated. However, most of the fittings are different from each other and nonstandard equipment and special skills are needed in order to provide for maximum function. For these reasons it is recommended that specialized centers be established throughout the United States to provide for the management of the severely disabled child amputee.

ORTHOTICS

The number of children needing orthopaedic bracing seems to be increasing in spite of the lower incidence of poliomyelitis. Spina bifida and cerebral palsy are responsible for large numbers and present difficult technical problems. However, a number of promising solutions have been offered here and abroad (*15*), and it is recommended that the Cooperative Clinic Program be expanded to include orthopaedic bracing for the purpose of evaluating and introducing new concepts in treatment of children with musculoskeletal deficiencies. Additional research projects in this area should be started.

METHODOLOGY--REHABILITATION ENGINEERING CENTERS

It is felt by the Committee that the program has reached such a degree of maturity that certain centers of excellence could and should be established to carry out integrated programs of research, development, evaluation, and education in rehabilitation engineering. It is felt that programs of this type promise to accelerate progress and reduce the time scale between idea conception and practical application.

Such centers must have strong teaching affiliations with medical and engineering schools and have available a substantial patient load. At least half-a-dozen rehabilitation engineering centers are needed in the near future and they probably should be spread across the country on some sort of a geographical basis.

The objectives of rehabilitation engineering centers should be:

1. To improve the quality of life of the physically handicapped through a total approach to rehabilitation, combining medicine, engineering, and related science.

2. To perform research and development in pioneering areas wherein a center has developed unique capabilities.

3. To collaborate with laboratories and industry to carry new devices and techniques through all phases of research, development, and clinical evaluation to active production and patient use.

4. To make available new devices and techniques to all patients referred to the center.

5. To educate others to provide these devices and techniques to patients throughout the nation.

6. To cooperate with other centers in fitting and evaluating their developments whenever the need is indicated.

7. To provide an environment for education of physicians, engineers, and other technical persons in related life and physical sciences.

8. To communicate effectively with other centers through recognized means and cooperative effort.

The center should be in a clinical setting with a substantial case load and it should have a strong teaching affiliation with both medical and engineering schools. The center should provide for effective interaction in the community where it is located.

The center must have demonstrated ability in rehabilitation engineering and must share a common commitment to the goals of rehabilitation.

EDUCATION AND TRAINING

A major goal of the center must be to educate people to provide better services to patients by providing an environment for the mutual education of medical personnel, engineers, and others. There should be a definite, planned program for education and training. This may include orthopaedic residents, physical medicine and rehabilitation residents, therapists, etc., as well as engineers. The cooperative work/school or the full school with summer internship type of educational programs lends itself well to the operation of a center.

The center should have a well-defined list of work projects with priorities which clearly state the benefits to the patients.

The center must have a broad clinical base for the treatment of patients but may focus on specific areas where competence exists.

The eventual level of funding for a center to perform its objectives in service to patients is estimated at $1,000,000 a year. The level of funding to start a center will vary with circumstances and facilities. A figure of $300,000 for the first year is a reasonable estimate. Miscellaneous sources of funds such as from university alumni, industry, and patents may augment but not substantially reduce the need for a continuing level of support.

Ethics and the relationships of a center to the community and industry will vary from place to place but should be spelled out clearly in the organization of the center. This will include consideration of patents, consulting, outside work, etc. The main criterion in these matters is conflict of interest between the goals of the center and those of the individual.

The center should provide some mechanism for communicating and cooperating with other centers on a meaningful basis. There also should be collaboration with professional groups such as the American Academy of Orthopaedic Surgeons, the Biomedical Engineering Society, and the American Orthotic and Prosthetic Association.

Areas of study recommended for rehabilitation engineering centers as central objectives are:

1. Functional Electrical Stimulation
2. Internal Structural Prostheses
3. Upper-Extremity Paralysis
4. Paraplegia
5. Hemiplegia
6. The Effect of Pressure on Human Tissue
7. Control of Neuromusculoskeletal Systems and Their Substitutes
8. Problems of the Spine
9. Sensory Aids for the Blind and Deaf-Blind
10. Surgical Procedures
11. Lower-Extremity Prosthetics

EDUCATION AND INFORMATION

A most important factor in the effectiveness of the Prosthetics-Orthotics Program has been the Education Program centered largely around the Medical Schools at the University of California at Los Angeles, Northwestern University, and New York University. Through these institutions the results of research are taught to members of the clinic team and thus are made available to patients in an unusually short period of time in contrast to the condition found in other fields. The Prosthetics Program at each of the three schools, originally started for continuing education, is now also concerned with the education of young prosthetists, orthotists, physicians, and surgeons. Several other institutions have courses available for prosthetists and orthotists at the junior-college level.

The institutions offering instruction in prosthetics-orthotics have formed a voluntary organization known as the Council on Orthotic-Prosthetic Education (COPE) for the purpose of interchanging information and solving common problems. The Veterans Administration and the Social and Rehabilitation Service support the Committee on Prosthetic-Orthotic Education of the Division of Medical Sciences, NAS, to advise them in their respective educational programs.

The following observations and recommendations are made.

ANALYSIS OF EDUCATION NEEDS

The initial education programs were developed nearly 20 years ago to provide short-term continuing education to qualified clinical personnel, and thus it was possible to transfer the results of research to clinical application on a broad basis in a relatively short period. To meet the needs of younger people with little or no experience who desired to become qualified, the original three institutions and others have offered a variety of programs for training young prosthetists. Available are eleven-month concentrated "certificate" programs, two-year junior college programs offering an Associate of Arts degree, and a four-year course at the Bachelor level.

Because no one knew exactly what the educational requirements for prosthetists and orthotists should be, all of the courses should be considered to be experimental. A relatively large number of individuals has been graduated from these various courses. It therefore seems appropriate for a thorough analysis to be made of the results and recommendations to be developed for future programs, bearing in mind that, with the introduction of such techniques as immediate postsurgical fitting, early fitting, and fracture bracing, the role of the prosthetist-orthotist has become larger and the responsibility greater.

Included in such an analysis of courses should be education of surgeons, physicians, therapists, and others.

TEACHING MATERIALS

The various education programs have been responsible largely for preparation of texts and other teaching materials used in their respective organizations. Consideration should be given to pooling and coordinating their efforts in this regard in order to save time and achieve a greater degree of uniformity.

OTHER PUBLICATIONS

An analysis should be made of material that needs to be published other than texts required for teaching. The following publications are suggested as being needed, but the list is not necessarily inclusive:

1. Handbooks for amputees and their families
2. Handbooks for other orthopaedic patients and their families
3. Sequel to *Human Limbs and Their Substitutes*
4. General text on management of lower-limb amputees.

AMPUTEE CENSUS

The "Amputee Census" carried out by Glattly (*24*) in 1960 should be carried out again to determine if any differences show up.

CLINIC TEAM

An analysis of experience in the field with clinic teams should be made and, if warranted as a result of the study, the education programs should give more emphasis to clinic-team operation.

LOWER-EXTREMITY ORTHOTICS

At the present time there are a number of developments taking place that promise to change radically the practice of lower-extremity orthotics. The schools offering lower-extremity orthotics should begin preparation for this transition.

SPINAL ORTHOTICS

All spinal orthotics courses should use the nomenclature developed by the New York University Prosthetics-Orthotics Program.

UPPER-EXTREMITY SPLINTING

Occupational therapists for various reasons are applying splints and some types of braces to upper-extremity patients. This set of circumstances should be studied with the idea of establishing courses for this profession if indicated.

REFERENCES

1. Aitken, George T., *et al.*, *Proximal femoral focal deficiency--a congenital anomaly*, National Academy of Sciences, Std. Book No. 309-01734-3, 1969.

2. Burgess, Ernest M., Robert L. Romano, and Joseph H. Zettl, *The management of lower-extremity amputations*, U.S. Veterans Administration, TR 10-6, Aug. 1969.

3. Committee on Prosthetic-Orthotic Education, *Ertl osteoplasty at Valley Forge General Hospital*, Newsletter...Amputee Clinics, 1:1, Dec. 1969.

4. Committee on Prosthetics Research and Development, *The control of external power in upper-extremity rehabilitation, a report on a conference*, NAS Publication 1352, 1966.

5. Committee on Prosthetics Research and Development, *Prosthetics and orthotics, a report of a conference*, Dec. 12-13, 1966.

6. Committee on Prosthetics Research and Development, *Sensory aids for the blind, a report of a conference*, Mar. 30-31, 1967.

7. Committee on Prosthetics Research and Development, *Immediate postsurgical fitting of prostheses, a report of a workshop*, May 18, 1968.

8. Committee on Prosthetics Research and Development, *Sixth Workshop panel on upper-extremity prosthetic components*, Oct. 21-23, 1968.

9. Committee on Prosthetics Research and Development, *Below-knee prosthetics, a report of a symposium*, Dec. 16-18, 1968.

10. Committee on Prosthetics Research and Development, *Fracture bracing, a report of a workshop*, Feb. 28--Mar. 1, 1969.

11. Committee on Prosthetics Research and Development, *Spinal orthotics, a report of a workshop*, Mar. 28-29, 1969.

12. Committee on Prosthetics Research and Development, *Workshop on knee-disarticulation and hip-disarticulation prostheses*, Mar. 31, 1969.

13. Committee on Prosthetics Research and Development, *Research in limb prosthetics and orthotics, a report of an international conference*, Apr. 28--May 2, 1969.

14. Committee on Prosthetics Research and Development, *Seventh workshop panel on upper-extremity prosthetics (externally powered terminal devices)*, July 30-31, 1969.

15. Committee on Prosthetics Research and Development, *Bracing of children with paraplegia resulting from spina bifida and cerebral palsy, a report of a workshop*, Oct. 2-4, 1969.

16. Committee on Prosthetics Research and Development, *Seventh workshop panel on lower-extremity orthotics*, Mar. 9-12, 1970.

17. Committee on Prosthetics Research and Development, *Eighth workshop panel on upper-extremity prosthetics*, Mar. 31--Apr. 2, 1970.

18. Committee on Prosthetics Research and Development, *Workshop on knee-disarticulation prosthetics*, June 22-23, 1970.

19. Committee on Prosthetics Research and Development, *Sixth meeting of the Subcommittee on Sensory Aids*, Feb. 26-27, 1971.

20. Dederich, Rolf, *Amputationen der unteren extremitat*, Georg Thieme Verlag, Stuttgart, 1970.

21. Engen, Thorkild J., *Development of upper extremity orthotics, Part I*, Orth. & Pros., 24:1:12-29, Mar. 1970; *Part II*, Orth. & Pros., 24:2:1-31, June 1970.

22. Engen, Thorkild J., *Research developments of lower extremity orthotic systems for patients with various functional deficits*. Progress report for the period 9/1/69-10/31/70, SRS Grant 23-P-55233/6-02.

23. Finley, F. Ray, *Electromyographic patterns of multiple muscle sources*, in *The control of external power*, NAS Publication 1352, 1966.

24. Glattly, Harold W., *A preliminary report on the amputee census*, Artif. Limbs, 7:1:5-10, Spring 1963.

25. Kay, Hector W., and A. Bennett Wilson, Jr., *Clinical evaluation of prosthetic and orthotic devices and techniques*, Committee on Prosthetics Research and Development, Report E-1, 1969.

26. Loon, Henry E., *Below-knee amputation surgery*, Artif. Limbs, 6:2:86-99, June 1962.

27. Lusskin, Ralph, *et al.*, *The control of adventitious bone formation in amputation surgery with silicone polymer implants*, Inter-Clin. Information Bull., 8:3:7-16, Dec. 1968.

28. McCollough, Newton C., III, Charles M. Fryer, and John Glancy, *A new approach to patient analysis for orthotic prescription--Part I: the lower extremity*, Artif. Limbs, 14:2:68-80, Autumn 1970.

29. Morris, J. M., D. B. Lucas, and B. Bresler, *Role of the trunk in stability of the spine*, J. Bone and Joint Surg., 43-A:3:327-351, Apr. 1961.

30. Murdoch, George, *Levels of amputation and limiting factors*, Ann. Roy. Coll. Surg., Engl., 40:204-216, Apr. 1967.

31. Murdoch, George, *Immediate postsurgical fitting--an editorial*, Prosthetics International, 3:8:2-7, 1969.

32. Perry, Jacquelin, *The use of external support in the treatment of low back pain*, Artif. Limbs, 14:2:49-57, Autumn 1970.

33. Simpson, D. C., *An experimental design for a powered arm prosthesis*, Health Bull., C.M.O. Scottish Home and Health Dept., XXIII, No. 4, 1965.

34. Swanson, Alfred B., *Improving the end-bearing characteristics of lower-extremity amputation stumps--a preliminary report*, Inter-Clin. Information Bull., 5:5:1-7, Feb. 1966.

35. Waring, W., *Investigation of myoelectric control of functional braces, final report*, Attending Staff Association, Rancho Los Amigos Hospital, Downey, Calif., 1968.

36. Wilson, A. Bennett, Jr., *A material for direct forming of prosthetic sockets*, Artif. Limbs, 14:1:53-56, Spring 1970.

37. Wilson, A. Bennett, Jr., *The prosthetics and orthotics program*, Artif. Limbs, 14:2:1-18, Autumn 1970.

38. Yugoslav Committee for Electronics and Automation, *External control of human extremities, the proceedings of the international symposium*, Dubrovnik, 1966.

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MAJOR PROJECTS IN THE UNITED STATES COORDINATED BY THE COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT

PROSTHETICS AND ORTHOTICS

Organization and Responsible Investigator	Major Area(s) of Investigation	Sponsoring Agency*
Army Medical Biomechanical Research Laboratory Washington, D.C. Orlyn C. Oestereich Fred Leonard	Development of Prosthetic and Orthotic Materials and Devices	U. S. Army
Baylor University Houston, Tex. Lewis A. Leavitt	Kinesiological and Quantitative Evaluation of Prosthetic Fit and Gait Analysis in Amputees and Vocational Implications	SRS
California, University of Los Angeles, Calif. Harlan C. Amstutz	Functional Long-Leg Brace Research	SRS
	Prosthetic and Orthotic Evaluation Procedures	SRS
John Lyman	Fundamental and Applied Research Related to the Design and Development of Upper-Extremity Externally Powered Prostheses	VA
	Fundamental Studies of Patient-Prostheses/Orthoses Externally Powered Control Interfaces	SRS
Arthur Moss Yoshio Setoguchi	Child Amputee Prosthetics Project	MCHS
California, University of San Francisco and Berkeley Charles W. Radcliffe Howard D. Eberhart James M. Morris	Design of Prosthetic and Orthotic Devices and Biomechanical Studies of Locomotion	VA

* Abbreviations:

MCHS - Maternal and Child Health Services
NEI - National Eye Institute
NINDS - National Institute of Neurological Diseases and Stroke
OE - Office of Education
SRS - Social and Rehabilitation Service

All of the above are within the Department of Health, Education, and Welfare

VA - Veterans Administration, Prosthetic and Sensory Aids Service

Appendix B . 2

Organization and Responsible Investigator	Major Area(s) of Investigation	Sponsoring Agency
California, University of San Francisco, Calif. Verne T. Inman	Electrical Stimulation of Afferent Fibers as a Means of Reducing Spasticity	SRS
	UC-BL Dual-Axis Ankle-Control System	SRS
H. J. Ralston	Dynamics of the Human Body during Locomotion	SRS
R. F. Steidel	An Engineering Analysis of the Human Spinal Column	SRS
Cambridge Hospital Cambridge, Mass. Richard Warren	Immediate Postoperative Fitting	VA
Case Western Reserve University, Cleveland, O. Victor H. Frankel	Pathomechanics of Disorders of the Locomotor System	SRS
Donald Gann	Cybernetic Orthotic/Prosthetic Systems Development	SRS
Olgierd Lindan	Application of Medical Engineering to Automation of Selected Aspects of Patient Care and Rehabilitation	SRS
Duke University Durham, N. C. Leonard Goldner	Pneumatic Prosthesis Research Project	SRS
Emory University Atlanta, Ga. J. V. Basmajian	Radiographic Study of Hip Dysplasia in Cerebral Palsy	MCHS
Georgetown University Washington, D.C. George W. Hyatt	Biophysical Evaluation of Healing Bone	SRS
Harvard Medical School Boston, Mass. Richard Warren	Survey of Lower-Extremity Amputations	VA
Illinois, University of Chicago, Ill. Jorge O. Galante	A Study of Spinal Orthotics in Idiopathic Scoliosis	SRS

Organization and Responsible Investigator	Major Area(s) of Investigation	Sponsoring Agency
Iowa State University Ames, Iowa Allan Potter	Myoelectric Brace Development	SRS
Johns Hopkins University Baltimore, Md. Gerhard Schmeisser Woodrow Seamone	Development and Evaluation of Externally Powered Upper-Limb Prosthesis	VA
Louisiana State University Baton Rouge, La. Eugene F. Tims	Development of Instrumentation for Insensitive Limbs	SRS
Massachusetts Institute of Technology Cambridge, Mass. Igor Paul	Performance Testing of Artificial Joints	SRS
Mauch Laboratories, Inc. Dayton, Ohio Hans A. Mauch	Research and Development in the Field of Artificial Limbs	VA
McDonnell Douglas Astronautics Co. Huntington Beach, Calif. S. S. Viglione	Detection and Prediction of Epileptic Seizures	SRS
Miami, University of Coral Gables, Fla. Augusto Sarmiento	The Development of Functional Methods of Treatment of Tibial, Femoral, and Forearm Fractures	SRS
	Evaluation of Prosthetic-Orthotic Devices	SRS
	Study of the Development of Refined Fitting Procedures for Lower-Extremity Prosthetics	VA
Michigan, University of Ann Arbor, Mich. G. E. Sharples	Child Amputees: Disability Outcomes and Antecedents	MCHS
Moss Rehabilitation Hospital Philadelphia, Pa. Richard Herman	Rehabilitation Biomedical Engineering: Orthotics Design	SRS
	Upper-Extremity Prosthetics	SRS
	Neuromotor Control Systems: A Study of Physiological and Theoretical Concepts Leading to Therapeutic Application	SRS

Organization and Responsible Investigator	Major Area(s) of Investigation	Sponsoring Agency
Navy Prosthetics Research Laboratory Oakland, Calif. D. W. Rohren Charles C. Asbelle	Lower-Extremity Prosthetic and Orthotic Development	U. S. Navy
New York University New York, N. Y. Leon Bennett	Stump Stress Analysis (Mathematical Model)	VA
Sidney Fishman	Clinical Evaluation of Prosthetic and Orthotic Appliances	SRS
	Fit and Alignment Studies of Spinal Braces and Lower-Extremity Prostheses	SRS
	Child Prosthetic and Orthotic Studies	MCHS
Richard Lehneis	Bioengineering Design and Development of Lower-Extremity Orthotic Devices	SRS
Ralph Lusskin	The Control of Adventitious Bone Formation with Plastic Implants	SRS
Northwestern University Chicago, Ill. Charles M. Fryer	Demonstration of Prosthetic and Orthotic Devices and/or Techniques	SRS
Robert G. Thompson	Prosthetic-Orthotic Research	VA
Rancho Los Amigos Hospital Downey, Calif. Donald McNeal	Investigation of Electronic Systems for Neuromuscular Disabilities	SRS
Vert Mooney	Orthotic and Prosthetic Evaluation Center	SRS
Roy Snelson	Feasibility Study of the Use of Transparent Sockets and Modular Prostheses in Clinical Practice	SRS
Texas A&M Research Foundation College Station, Tex. Paul H. Newell, Jr.	The Improvement of Prosthetic and Orthotic Devices through Materials Research, Analysis, Design, Clinical Testing, and Team Evaluation	VA

Organization and Responsible Investigator	Major Area(s) of Investigation	Sponsoring Agency
Texas Institute for Rehabilitation and Research Houston, Tex. Thorkild J. Engen	Research Developments of Lower-Extremity Orthotic Systems as They Relate to Patients with Various Functional Deficits	SRS
U. S. Public Health Service Hospital Carville, La. Paul W. Brand	Study of the Prevention of Deformity in Insensitive Limbs	SRS
VA Hospital Richmond, Va. Charles L. McDowell	Immediate Postoperative Application of Upper-Extremity Orthoses	VA
VA Hospital San Francisco, Calif. Wesley Moore Albert Hall	Study of Below-Knee Amputation for Vascular Insufficiency	VA
VA Hospital Seattle, Wash. Ernest M. Burgess Joseph H. Zettl	Immediate Postoperative Prosthesis Fitting and Ambulation	VA
VA Prosthetics Center New York, N. Y. Anthony Staros	Research, Development, and Testing of Prosthetic and Orthotic Devices and Techniques	VA
Virginia, University of Charlottesville, Va. Warren G. Stamp David W. Lewis	Fitting of Lower-Extremity Prosthetics	SRS

SENSORY AIDS*

Albert Einstein College of Medicine New York, N. Y. Herbert G. Vaughan Herbert Schimmel	Electrocortical Prosthesis Feasibility Study	SRS
Argonne National Laboratory University of Chicago Argonne, Ill. Arnold P. Grunwald	A System for Compact Storage of Information on Magnetic Tape Readable by Touch as Braille Characters by Means of a Portable Reading Machine	OE

* This is an expanded listing and includes projects not presently coordinated by CPRD

Organization and Responsible Investigator	Major Area(s) of Investigation	Sponsoring Agency
Association for Computing Machinery New York, N. Y. T. D. Sterling	Investigation of Optimum Employment Procedures in Computing (Blind)	SRS
Atlanta Public Schools Atlanta, Ga. Ernest L. Bentley	A Demonstration of Reader Services for the Visually Impaired Utilizing the Telephone as the Medium	OE
Biodynamics, Inc. Cambridge, Mass. Charles R. Budrose	Design, Fabrication, and Evaluation of a Braille Learning Aid	OE
Bionic Instruments Bala Cynwyd, Pa. Thomas A. Benham J. Malvern Benjamin	Development of Obstacle Detectors for the Blind	VA
Cybernetics Research Institute Washington, D.C. Haig Kafafian	Study of Man--Machine Communication Systems for Disabled Persons	OE
Department of Children and Family Services Springfield, Ill. Thomas J. Murphy	Postural Determinants of the Blind	SRS
Gallaudet College Washington, D.C. James M. Pickett	Research on Frequency Transposition for Hearing Aids	OE
Hadley School for the Blind Winnetka, Ill. Donald W. Hathaway	Development of a Braille Medical Dictionary	SRS
	Development of Correspondence Courses for Personal Reading Aids for the Blind	VA
Hartford, University of West Hartford, Conn. Bernard Z. Friedlander	Automated Language Tests and Enrichment for Deaf Infants	MCHS
Haskins Laboratory New Haven, Conn. Franklin S. Cooper Jane Gaitenby	Research on Audible Outputs of Reading Machines for the Blind	VA

Organization and Responsible Investigator	Major Area(s) of Investigation	Sponsoring Agency
Johns Hopkins University Baltimore, Md. Louise Sloan	Use of Optical Aids	NEI
Louisville, University of Louisville, Ky. Emerson Foulke	The Development of Accelerated Speech as a Useful Communication Tool in the Education of Blind and Other Handicapped Children	OE
Maryland, University of College Park, Md. G. Donald Causey Earleen Elkins	Development of Improved Techniques for the Analysis of Hearing Aid Performance	VA
Joseph W. Wiedel Paul A. Groves	Tactual Mapping:Design, Production, Reading, and Interpretation	SRS
Massachusetts, University of Amherst, Mass. I. B. Thomas	Speech Analyzing Aids for the Deaf	NINDS
Massachusetts Institute of Technology Boston, Mass. Robert W. Mann	Sensory Aids Development and Evaluation	SRS
Mauch Laboratories, Inc. Dayton, O. Hans A. Mauch Glendon C. Smith	Development of Personal Reading Machines for the Blind	VA
Michigan, University of Ann Arbor, Mich. Geraldine T. Scholl	Vocational Adjustment Follow-Up Study of Groups of Visually Handicapped	SRS
National Accreditation Council for Agencies Serving the Blind and Visually Handicapped New York, N. Y. Ray L. Troutman	Development of Standards and Evaluation Criteria for the Production of Reading Materials for the Blind and Visually Handicapped	OE
Alexander F. Handel	Strengthening Services for the Visually Handicapped through the Application of Standards	SRS

Organization and Responsible Investigator	Major Area(s) of Investigation	Sponsoring Agency
National Industries for the Blind New York, N. Y. Robert C. Goodpasture	Development of a Sheltered Workshop Laboratory to Serve Agencies for the Blind	SRS
New York Medical College New York, N. Y. Stanley Taub	Development of a Removable Prosthetic Larynx	SRS
North Carolina Museum of Arts Raleigh, N. C. Charles W. Stanford, Jr.	Development and Operation of Mary Duke Biddle Gallery for the Blind	SRS
Northeastern University Boston, Mass. Ladislav Dolansky	Demonstration of the Instantaneous Pitch-Period Indicator (Amplitude, Intonation,Duration) in Classroom of Deaf Children	OE
Northwestern University Evanston, Ill. Raymond Carhart Wayne O. Olsen	Development of Test Procedures for Evaluation of Binaural Hearing Aids	VA
Queens College Flushing, N. Y. J. H. Kerman	Tactile Communication of Speech to the Deaf	NINDS
San Francisco Bay Area Speech and Hearing Society San Francisco, Calif. George Hospiel	Measurement of Acoustic Parameters for Speech Compression Transportation	SRS
Stanford University Stanford, Calif. James C. Bliss John G. Linvill	Research and Development of Tactile Facsimile Reading Aid for the Blind	OE
Tennessee, University of Knoxville, Tenn. Carl W. Asp	Effectiveness of Low-Frequency Amplification and Filtered-Speech Testing for Pre-School Deaf Children	OE
VA Hospital Hines, Ill. John D. Malamazian Harvey L. Lauer	Clinical Application of Reading and Mobility Aids for the Blind	VA

Organization and Responsible Investigator	Major Area(s) of Investigation	Sponsoring Agency
West Virginia University Morgantown, W. Va. In-Meei Neou	Educational and Vocational Aids for the Blind	OE
Western Blind Rehabilitation Center, VA Hospital Palo Alto, Calif. Loyal E. Apple	Clinical Application Program in Reading, Mobility, and Other Aids for the Blind	VA

For a more detailed list on Sensory Aids for the Blind, please see Appendix C

PROJECTS IN THE DOMINION OF CANADA WHICH COOPERATE CLOSELY WITH THE OVERALL PROGRAM

Organization and Responsible Investigator	Major Area(s) of Investigation
Prosthetic/Orthotic Research Unit Ontario Crippled Children's Centre Toronto, Ont. Colin A. McLaurin	Development of a Wide Variety of Upper-Extremity and Lower-Extremity Body-Powered and Externally Powered Prosthetic and Orthotic Devices for Children
Rehabilitation Institute of Montreal Montreal, Que. Maurice Mongeau	Development of Externally Powered Upper-Extremity Prosthetic Devices, with Special Reference to Children
Prosthetics/Orthotics Research and Development Unit Manitoba Rehabilitation Hospital Winnipeg, Man. James Foort	Development of a Variety of Prosthetic Devices with Special Reference to Lower-Extremity Requirements
The University of New Brunswick Bio-Engineering Institute Fredericton, N. B. R. N. Scott	Orthotics and Prosthetics Systems Research with Special Emphasis on the Employment of Electromyographic Signals as Controls

SOME CURRENT RESEARCH ACTIVITIES IN SENSORY AIDS FOR THE BLIND

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List No.	Project No.	Description	Organization	Personnel	Sponsor	Start Date	Estimated Recent Annual Expenditure
			M O B I L I T Y				
001		Improving Visual Performance of the Partially Sighted Using Low Vision Aids	American Center for Research in Blindness and Rehabilitation 770 Centre Street Newton, Mass. 02158	Leo Riley Donald Korb			
002		Development of a Collapsible Cane for the Blind. Ultrasonic aid with tactile output	National Research Council of Canada Ottawa 7, Ontario, Canada	James Swail			
003		Development of Production Model of MIT Collapsible Cane	Hycor, Incorporated North Woburn Industrial Park Woburn, Mass. 01801	Ronald Blecher			
004		Development of One-Piece and Collapsible Typhlocanes made from Boron-Stiffened Epoxy	Bionic Instruments, Inc. 221 Rock Hill Road Bala Cynwyd, Pa. 19004	J. M. Benjamin, Jr.	VA	1968	
005		Rigid-Fold Collapsible Cane for the Blind	Utah School for the Deaf and Blind Ogden, Utah	Wayne Noble			
006	V1005M-9217	Obstacle Detectors for the Blind	Bionic Instruments, Inc. 221 Rock Hill Road Bala Cynwyd, Pa. 19004	J. M. Benjamin T. A. Benham N. Ali	VA	1961	$ 4,000
007		Ophthalmological Safety Study of Model C-4 Laser Typhlocane	Army Joint Laser Safety Team Frankford Arsenal Philadelphia, Pa.	George Bresnick	VA	1969	*
008		Evaluation of Model C-4 Laser Typhlocane	California State College Los Angeles, Calif.	Robert Eisenberg	VA	1969	*
009		Evaluation of Model C-4 Laser Typhlocane	Central Rehabilitation Section for Visually Impaired and Blinded Veterans Veterans Administration Hosp. Hines, Ill. 60141	John D. Malamazian Jay Whitehead	VA	1969	

010		Evaluation of Model C-4 Laser Typhlocane	Cincinnati Association for the Blind 2045 Gilbert Avenue Cincinnati, Ohio 45202	David P. Koper Robert R. Scheffel	VA	1970	*
011		Evaluation of Model C-4 Laser Typhlocane	Institute of Blind Rehabilitation Western Michigan University Kalamazoo, Mich. 49001	Donald Blasch Stanley Suterko	VA	1970	*
012		Evaluation of Model C-4 Laser Typhlocane	Missouri School for the Blind St. Louis, Missouri	Lawrence Hapeman	VA	1970	*
013		Evaluation of Model C-4 Laser Typhlocane	The Seeing Eye, Inc. Morristown, N.J. 07960	Robert Whitstock	VA	1970	*
014		Evaluation of Model C-4 Laser Typhlocane	Western Blind Rehabilitation Center Veterans Administration Hosp. Menlo Park, Calif. 94025	Loyal E. Apple William Ekstrom	VA	1969	
015		Ultrasonic Spectacles for the Blind	Electrical Engineering Dept. Canterbury University Christchurch, New Zealand	Leslie Kay			
016	V1005P-376-A	Evaluation of the Kay Guidance Device (Torch)	American Center for Research in Blindness and Rehabilitation 770 Centre Street Newton, Mass. 02158	Leo Riley	VA	1965	$ 5,850
017		Tests on Performance with the Kay Ultrasonic Aid	Institute of Occupational Health Haartmaninkatu 1 Helsinki 25, Finland	Jyrki Juurma			
018		Research on Mobility of the Blind	Blind Mobility Research Unit University of Nottingham Nottingham, England	J. A. Leonard			
106	RC-8-S	Sensory Measurement Research	Massachusetts Institute of Technology Cambridge, Mass. 02139	Robert W. Mann	SRS		X
107		Clinical Application Program in Reading and Mobility Aids for the Blind	Central Rehabilitation Section for Visually Impaired and Blinded Veterans VA Hospital, Hines, Ill. 60141	John D. Malamazian	VA	1967	X

201	RC-18-S	Sensory Aids Evaluation and Development Center	Massachusetts Institute of Technology 292 Main Street Cambridge, Mass. 02142	Robert W. Mann Vito Proscia			X
019		The Dearing Light Sensing Typhlocane as an Aid to the Blind	L. M. Dearing Associates, Inc. 12345 Ventura Boulevard Suite R Studio City, Calif. 91604	LeRoy M. Dearing			
020		Development of an active infra-red mobility aid for the blind	Forrest M. Mims 6901 Zuni SE A-12 Albuquerque, New Mexico 87108	Forrest M. Mims		c1967	
021		Orientir -- An ultrasonic transceiver with audible output for environment sensing	Helmholtz Eye Research Institute RSFSR Sadovaya-Chernogriasskaya 14-19 Moscow K-64, USSR				
022		Clicker for the Blind	University of Nottingham Nottingham, England	R. L. Beurle			

List No.	Project No.	Description	Organization	Personnel	Sponsor	Start Date	Estimated Recent Annual Expenditure
			INDEPENDENT READING OF INKPRINT				
101	EY-0005	Use of Optical Aids	Johns Hopkins University Baltimore, Md. 21218	Louise L. Sloan	NEI		$ 24,000
102		A Closed-Circuit TV System for the Visually Handicapped	American Foundation for the Blind, Inc. 15 West 16th St. New York, N.Y. 10011	Leo Levens			
103		A Closed-Circuit TV System for the Visually Handicapped	Sinai Hospital 6767 West Outer Drive Detroit, Michigan	Morris Mintz			
104		Building A Closed-Circuit TV Reading Aid	Johns Hopkins University Baltimore, Md. 21218	John H. Kuck			
105	RD-3206-S	Television Systems which Aid the Visually Handicapped	Rand Corporation Santa Monica, Calif.	Samuel M. Genensky	SRS	1970	$ 75,000
106	RC-8-S	Sensory Measurement Research	Massachusetts Institute of Technology Cambridge, Mass. 02139	Robert W. Mann	SRS		$ 38,000
107		Clinical Application Program in Reading and Mobility Aids for the Blind	Central Rehabilitation Section for Visually Impaired and Blinded Veterans VA Hospital, Hines, Ill. 60141	J. D. Malamazian H. L. Lauer	VA	1967	$ 11,863
108	V1005P-365-A	Optophone Trials	American Center for Research in Blindness and Rehabilitation 770 Centre Street Newton, Mass. 02158	Leo H. Riley	VA	1964	$ 390
109		St. Dunstan's Reading Machine Research	St. Dunstan's 191 Marylebone Road London, N.W. 1, England	Mary Jameson			
110		Lexiphone Reading Machine for the Blind	University of British Columbia Vancouver 8, B.C., Canada	Michael P. Beddoes			

111	7-1112	Research and Development of Tactile Facsimile Reading Aid for the Blind	Stanford Research Institute 333 Ravenswood Avenue Menlo Park, Calif. 94025	James C. Bliss John G. Linvill	OE	1968	$363,000
112	EY-00450	Research Toward a Reading System for the Blind	Stanford Research Institute 333 Ravenswood Avenue Menlo Park, Calif. 94025	James C. Bliss	NEI		$104,000
113	V1005M-1943	Personal-type Reading Machines	Mauch Laboratories, Inc. 3035 Dryden Road Dayton, Ohio 45439	Hans A. Mauch Glendon C. Smith	VA	1958	$111,414
114	V1005M-1253	Outputs for Reading Machines	Haskins Laboratories, Inc. 270 Crown Street New Haven, Conn. 06510	F. S. Cooper J. Gaitenby	VA	1957	$ 52,000
115	V1005P-5321	Spelled Speech as an Output for Reading Machines for the Blind	Metfessel Laboratories Los Angeles, Calif. 90043	M. L. Metfessel (Deceased) C. Lovell	VA	1960	Nil
116		Evaluation and Implementation Procedures for Reading Aids for the Blind	National Bureau of Standards Technical Analysis Division Gaithersburg, Md.	Ralph Schofer John Aellen		1970	
117	5 P01 GM 14940-03 5 P01 GM 15006-03 5 T01 GM 01555-03 DA 28-043-AMC-02536(E)	Cognitive Information Processing Group Activities	Research Laboratory of Electronics Massachusetts Institute of Technology Cambridge, Massachusetts 02139	M. Eden F. F. Lee S. J. Mason D. E. Troxel K. R. Ingham	NIH & DOD (USA) (USN) (USAF)		
118		MAGNAVISION - Assisting the visually handicapped to READ and WRITE	Apollo Lasers, Incorporated 6365 Arizona Circle Los Angeles, California 90045 (213) 776-3343	Fred P. Burns		1970	
119		Closed-Circuit TV Magnifiers	Boston University Medical Center Low Vision Clinic 750 Harrison Avenue Boston, Massachusetts 02118	John Asarkof Philip Davis			

120		Conversion of Typewritten or Printed Text into Speech	Faculty of Electrical Engineering, University of Ljubljana Yugoslavia	Arsen Šurlan J. Virant Silvin Leskovar Ljubo Pipan			
121		Spell-Talk (An audible output method for rendering the information in perforated tape or other machine storage means audible and intelligible).	Carnegie-Mellon University Frew Street Pittsburgh, Pa. 15213	Richard Longini		1968	
122		Electronic Tracer engraving machine with special application for the blind; makes embossed reliefs from ink-print originals; also makes matching embossed dies	Jens Scheel - Mechanische Geräte Gasstrasse 16 221 Itzehoe Germany	Jens Scheel			
123		Development of a Personal Print Reader for the Blind	University of Virginia School of Engineering Dept. of Electrical Engineering Charlottesville, Va. 22901	E.S. McVey J.W. Moore R.L. Ramey			

SOME CURRENT RESEARCH ACTIVITIES IN SENSORY AIDS FOR THE BLIND

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List No.	Project No.	Description	Organization	Personnel	Sponsor	Start Date	Estimated Recent Annual Expenditure
			BRAILLE DEVELOPMENTS				
201	RC-18-S	Sensory Aids Evaluation and Development Center	Massachusetts Institute of Technology 292 Main Street Cambridge, Mass. 02142	Robert W. Mann Vito A. Proscia	SRS	1967	$ 75,000
202		Development of a High-Speed Braille System for More Rapid and Extensive Production of Information Material for the Blind	Sensory Aids Evaluation and Development Center M.I.T. 292 Main Street Cambridge, Mass. 02142	Vito A. Proscia	HF	1967	$ 90,000
203	7-1185	Development of an Expanded Reading Code (Braille) for the Blind (Augmented Braille Code)	Perceptual Alternatives Lab. University of Louisville Louisville, Kentucky 40208	Emerson Foulke	OE	1967	$ 35,470
204		Design, Fabricate, and Evaluate a Braille Learning Aid	Biodynamics, Inc. Cambridge, Mass.	Charles R. Budrose	OE	1968	$ 56,200
205	8-0144	A System for Compact Storage of Information on Magnetic Tape Readable by Touch as Braille Characters by Means of a Portable Reading Machine	Argonne National Lab. Argonne, Illinois	Arnold P. Grunwald	OE	1968	$ 43,000
206		Study of Computer Automation of the Processes of Producing Braille Music and Mathematical Texts	American Printing House for the Blind 1839 Frankfort Avenue Louisville, Kentucky 40206	Virgil Zickel			
207		Improvements and Innovations in Braille and Other Tactile Displays	Howe Press of the Perkins School for the Blind 175 North Beacon Street Watertown, Mass. 02172	Harry J. Friedman			
208		Cassette dictionary and "card player" attachment for tape recorders. For teaching Braille.	Bio-Dynamics, Inc. 33 Cambridge Parkway Cambridge, Mass. 02142	Theresa Lyons (06-26-70)			

209		Automated Braille Production	Deutsche Blindenstudienanstalt 355 Marburg/Lahn Am Schlag 8, West Germany	Wolfgang Sorke			
210		Inkprint and Braille Produced by Master and Slave Arrangement of Two Typewriters, an adapted regular machine and an IBM Braille Typewriter.	Connecticut Technical Corp. 3000 Main Street Hartford, Connecticut 06120 203, 522-6167	Harold M. Kneller			
211		Phylab Brailler produces a tape embossed in braille at same time an inkprint typewritten page is produced by typist. NPL also working on multifont character recognition machine to braille on a tape.	National Physical Laboratory of Israel, Hebrew University Jerusalem, Israel Electro-Optical Industries P.O. Box 1165 Rehovoth, Israel	Harry Tabor			
212		A Modular Unit for Constructing Braille Displays	The MITRE Corporation Box 208 Bedord, Mass. 01730	Norman B. Sutherland		c. 1969	
213		UNIBRL: A Universal Braille Reader	Albuquerque, N.M.	David Mick			
214		Braille Keyboard with Passive and Active Modes	University of Kansas Lawrence,Kansas	Michael Shonyo			
215		Development of Braille Verifier for Blind Typists	Visual Prosthetics Laboratory Dept. of Mechanical Engineering West Virginia University Morgantown, West Virginia 26506	In-Meei Neou Roy S. Nutter Yen-Tsung Lin Albert Garcia Wayne F. Erwin,Jr.			

SOME CURRENT RESEARCH ACTIVITIES IN SENSORY AIDS FOR THE BLIND

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List No.	Project No.	Description	Organization	Personnel	Sponsor	Start Date	Estimated Recent Annual Expenditure
			OTHER COMMUNICATIONS FOR THE DISABLED				
301	5-1050	The Comprehension of Rapid Speech by the Blind	Center for Rate Controlled Recording University of Louisville Louisville, Kentucky 40208	Emerson Foulke	OE	1965	$ 73,345
302		Develop Microfilm Reader and More Economical Tape Cassette System for Use by the Disabled	Library of Congress Division for the Blind and Physically Handicapped 1291 Taylor Street, N.W. Washington, D.C. 20542	Robert Bray Ralph Garretson			
303		Investigation of Two-Channel (Stereo) Disc Recording for the Presentation of Annotated Texts	American Printing House for the Blind 1839 Frankfort Avenue Louisville, Kentucky 40206	Carson Y. Nolan			
304	RD-2575-5	Measurement of Acoustic Parameters for Speech Compression Transposition	San Francisco Bay Area Speech & Hearing Society San Francisco, California	George Hospiel	SRS		$ 13,000
305	7-0533	Study of Man-Machine Communication Systems	Cybernetics Research Institute 2233 Wisconsin Avenue, N.W. Washington, D.C. 20007	Haig Kafafian	OE		$199,000
306		All-Electronic Speech Compression System with Adjustable Compression Ratio	Richard F. Koch 67 Smith Street Lynbrook, N.Y. 11563 516, 599-3489	Richard F. Koch			
307		Embossing Arabic Letters and Numbers on New Raised-Line Polyethylene Paper: An Aid for the Blind	Nu-Vu Products Company 45 East Lockwood Webster Groves, Missouri 63119	Ruth L. Barr		1969	
308		Steno-Dot fixed position, phonetic, high-speed machine writing for the blind	STENO-DOT, Incorporated 5963 E. 31st St., Suite 103 Tulsa, Oklahoma 74135	A. E. Masek, Jr.			

309		Evaluation of a Communication Aid for Deaf-Blind Persons	National Center for Deaf-Blind Youths and Adults 105 Fifth Avenue New Hyde Park, New York 11040	L. Eugene Zumalt Sallie Silver Lynne Chadwell		c. 1970	
310		"Chromatone," a Three-Channel Color to Sound Converter	Malibu Scientific Company P.O. Box 475 Malibu, California 90265	George A. Work			

List No.	Project No.	Description	Organization	Personnel	Sponsor	Start Date	Estimated Recent Annual Expenditure
			VISION PROSTHESES				
401	RD-2667-S	Electrocortical Prosthesis Feasibility Study	Albert Einstein College of Medicine 1300 Morris Park Ave. Bronx, N.Y. 10461	Herbert G. Vaughan Herbert Schimmel	SRS	1968	$ 37,000
402	RD-2444-S 5 S01 FR 05566-07	Development of a Visual Substitution System	The Smith-Kettlewell Institute of Visual Sciences 2340 Clay Street San Francisco, Calif. 94115	Paul Bach-y-Rita Carter C. Collins Benjamin W. White	SRS, NIH and others		
403		Opticron, a device with TV camera input and a tactile sensorial pad output on the back. cf. List No. 402	CSI Processing Corporation Commercial, Scientific, and Industrial Data Processing and Systems Analysis Service 218 Del Parque Street Santurce, Puerto Rico	Zaid Diaz Gandia			
404		Integrated Mobile Aid for the Blind	Case Western Reserve University Cleveland, Ohio 44106	Wen C. Lin Wen H. Ko		1969	
405	NIH 70-2279	Visual Prosthesis	Center for Brain Research University of Rochester Rochester, New York 14627	R. W. Doty J. R. Bartlett N. Negrão	NIH	1970	
406		Brain Stimulation to Produce Phosphenes	Massachusetts General Hospital	Daniel A. Pollen William H. Sweet David Tracy Wilfred Burns	NIH	1970	
407	NIH 70-2278	Artificial Eye Project	Institute for Biomedical Engineering University of Utah Salt Lake City, Utah	William H. Dobelle L. J. Stensaas Michael Mladejovsky	NIH	1970	
408	NIH 70-2275	Sensory Prosthesis Project NINDS	Huntington Institute of Applied Medical Research 734 Fairmount Avenue Pasadena, Calif. 91105	Robert H. Pudenz	NIH	1970	

409	NIH 70-2277	A Study of Electrical Stimulation of the Visual System to Determine Feasibility of a Sensory Prosthesis	The Johns Hopkins University School of Medicine Baltimore, Maryland 21205	Natalia P. Chapanis S. Uematsu A. E. Walker Gerald E. Loeb	NIH	1970	
410		Prosthetic Visual Devices	Department of Ophthalmology University of Florida College of Medicine Gainesville, Florida, 32601	William W. Dawson	Intra-mural	1968	
411		Sensations Produced by Electrical Stimulation of the Visual Cortex	Maudsley Clinic, Denmark Hill London, S.E. 5, England Dept. of Neurological Surgery and Neurology United Cambridge Hospitals Cambridge, England	Giles S. Brindley Walpole S. Lewin			

List No.	Project No.	Description	Organization	Personnel	Sponsor	Start Date	Estimated Recent Annual Expenditure
			EDUCATIONAL, TRAINING, VOCATIONAL				
501	V1005P-977-A	Correspondence Courses--Training of Blind and/or Deaf-Blind	The Hadley School for the Blind 700 Elm Street Winnetka, Ill. 60093	D. W. Hathaway M. Butow	VA	1967	$ 2,925
502		Development of a Training Course for Use with the Kay Ultrasonic Aid for the Blind (The Torch)	St. Dunstan's 191 Marylebone Road London, N.W. 1, England	Edward Elliott Robert Sharpe (Evaluated the Training Course)		1967	
503	RD-2689-S	Investigation of Optimum Employment Procedures in Computing (Blind workers)	Association for Computing Machinery 211 East 43 Street New York, N.Y. 10017	T. D. Sterling	SRS	1968	$ 19,000
504		Research and Development of Devices for the Blind (Audible carpenter's level, multimeter; improved Tella-touch, optical probe; Tactile speech indicator)	American Foundation for the Blind 15 West 16 Street New York, N.Y. 10011	Leo Levens			
505		Research and Development of Devices for the Blind	Royal National Institute for the Blind 224-8 Great Portland St. London W. 1, England	John C. Colligan E. Venn			
506		Research and Development of Devices for the Blind	SVEN/SVCR Bromma 3 Stockholm, Sweden	Karl Montan			
507	RD-2557-S	Tactual Mapping: Design, Production, Reading, and Interpretation	University of Maryland College Park, Md. 20740	Joseph W. Wiedel Paul A. Groves	SRS		$ 16,000
207		Improvements and Innovations in Braille and Other Tactile Displays	Howe Press of the Perkins School for the Blind 175 Beacon Street North Watertown, Mass. 02172	Harry J. Friedman			
508		Specialized Recordings, Adapted Instruments, and Custom-Built Devices for the Blind	Science for the Blind 221 Rock Hill Road Bala Cynwyd, Pennsylvania 19004	Thomas A. Benham			

List No.	Project No.	Description	Organization	Personnel	Sponsor	Start Date	Estimated Recent Annual Expenditure
		ADMINISTRATIVE, ADVISORY, BIBLIOGRAPHIC, EVALUATION, IMPLEMENTATION, INFORMATION DISSEMINATION					
602		International Research Information Service (IRIS)	American Foundation for the Blind, Inc. 15 West 16 Street New York, N.Y. 10011	Leslie L. Clark			
603		Research and Development Div. Prosthetic and Sensory Aids Service	Veterans Administration 252 Seventh Avenue New York, N.Y. 10001	Eugene F. Murphy Howard Freiberger	VA		
604		Subcommittee on Sensory Aids Committee on the Interplay of Engineering with Biology and Medicine	National Academy of Engineering 2101 Constitution Ave., N.W. Washington, D.C. 20418	Robert W. Mann C. W. Garrett			
605	V1005M-1914	Subcommittee on Sensory Aids Committee on Prosthetics Research and Development	National Academy of Sciences 2101 Constitution Ave., N.W. Washington, D.C. 20418	Richard E. Hoover A. Bennett Wilson, Jr.	VA	1965	$ 1,000

* VA funds not expended on this project. The organization shown graciously agreed to assist with the research without receiving remuneration from the VA.

‡ This project has activity in more than one of the main categories of this tabulation. An entry has been made under each relevant category but the over-all funds are shown under only one entry as the specific allocations to the several areas of activity are not known.

Sponsor Abbreviations:

HF - Hartford Foundation
NEI - National Eye Institute
OE - Office of Education, U.S.
SRS - Social and Rehabilitation Service
VA - Veterans Administration
NIH - National Institutes of Health
DOD - Department of Defense

Revised April 1, 1971

COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT
NATIONAL ACADEMY OF SCIENCES

U.S. Prosthetics and Orthotics Research and Development
Funding and Patient Population Estimates for Fiscal Year 1970

Introduction

The statistics below were compiled to show funding in relation to need for help in determining overall direction of prosthetics and orthotics programs. All figures are intended to show only gross comparisons and trends; their sources are explained in the appendix.

Statistics

Cost of Prosthetic and Orthotic Services $60,000,000(a)

Cost of Prosthetic and Orthotic Research and Development $ 4,226,500(b)

Percentage of R&D to Services: $\frac{\$4,226,500}{\$60,000,000}$ or 7%

Patient Population(c):

Amputees	311,000	32% Upper-Extremity 68% Lower-Extremity		
Orthotic Patients	3,370,000	29% Upper-Extremity 54% Lower-Extremity 17% Spinal	--	18% Paralyses 82% Deformities

Relative Funding of Prosthetic and Orthotic Research and Development(d):

	Lower-Extremity Prosthetics	Lower-Extremity Orthotics	Upper-Extremity Prosthetics	Upper-Extremity Orthotics	Spinal Orthotics	TOTAL
Fundamental Studies	$ 431,000	$ 506,500	$ 183,500	$ 562,000	$ 31,000	$1,714,000
Design and Development	284,000	469,000	476,000	211,500	13,000	1,453,500
Evaluation	295,800	301,300	400,400	33,500	28,000	1,059,000
TOTAL	$1,010,800	$1,276,800	$1,059,900	$ 807,000	$ 72,000	$4,226,500
Publications (e)						125,000
Administration (e)						201,000
					TOTAL	$4,552,500

Percentage of Administration to R&D: $\frac{\$201,000}{\$4,226,500}$ or 5%

Comparisons Based on Above Statistics:

	Patient Population	% of Total Patient Population	R&D Funding	% of Total R&D Funding(f)
Prosthetics	311,000	8%	$2,070,700	49%
Orthotics	3,370,000	92%	2,155,800	51%
Total	3,681,000	100%	$4,226,500	100%

	Patient Population	% of Total Patient Population	R&D Funding	% of Total R&D Funding(f)
LEP	210,000	6%	$1,010,800	24%
LEO	1,808,000	49%	1,276,800	30%
UEP	101,000	3%	1,059,900	25%
UEO	987,000	27%	807,000	19%
SO	575,000	15%	72,000	2%
Total	3,681,000	100%	$4,226,500	100%

Cost of R&D per Patient:

LEP	$ 4.80
LEO	.71
UEP	10.50
UEO	.82
SO	.13

Age of Patient Population(g):

Amputees --	7%	under 21 --	22,000
	58%	21-65	180,000
	35%	over 65	109,000
	100%		311,000 total
Orthotic Patients because of Paralysis --	7%	under 21 --	42,000
	51%	21-65	303,000
	42%	over 65	250,000
	100%		595,000 total
Orthotic Patients because of Deformities --	30%	under 21 --	833,000
	54%	21-65	1,498,000
	16%	over 65	444,000
	100%		2,775,000 total

Discussion

The amputee population of 311,000 seems to be a good estimate. As of July 1, 1969, Great Britain had about 88,000 (1) amputees in a population of 55,700,000 (2). Assuming a similar incidence of amputation in both countries, the extrapolated U.S. amputee population would be 88,000 x $\frac{203,000,000}{55,700,000}$ or 321,000, which correlates closely with the U.S. Public Health Service estimates of 311,000.

The CPOE survey (3,4) estimates of 15% UE to 85% LE amputees indicate fewer arm amputees than the 32% UE to 68% LE amputees that the Public Health Service survey shows. This difference is likely due to the fact that the CPOE survey was of prosthetic facilities and does not include amputees not fitted with prostheses. The PHS survey was of 84,000 households containing 268,000 people.

There is no cross-check which can be obtained on the orthotic patient population estimate of 3,370,000. However, the estimate of 575,000 spinal orthotic patients is likely low because there are about 6,978,000 people with back or spinal "aches and pains" which were not included and at least some portion of which are being treated with corsets and braces.

In looking at the statistical comparisons, the most obvious conclusions are:

1. The number of orthotic patients to amputees is about 10:1 whereas the amount of research money presently allocated is about 1:1. CPRD and others in the past several years have been directing increasingly more attention and allocations to the field of orthotics to improve this situation.

2. Even though the estimate of spinal orthotic patients is likely low, there is still a great need for research in back bracing. This is verified by the relatively rude state of patient service now generally in practice.

3. There is a need for the design, development, and evaluation of upper-extremity braces. In proportion to the number of UE orthotic patients, little effort is being devoted to getting better braces on these people. This is borne out by the relatively small number of UE orthotic patients actually wearing braces.

4. A relatively large percentage of paralytics and amputees are over 65 years of age (and the estimates are likely low because the PHS surveys do not include the institutional population, such as people living in nursing and convalescent

homes and VA centers). This confirms the growing need for special prosthetic and orthotic focus on the elderly.

5. A relatively large percentage of people who are orthotic patients because of structural deformities are under 21 years of age. This is especially evident where the lower extremity is involved, and the actual number of these young patients is large. The figures point to the need for greater attention in their behalf.

July 1969

Appendix

(a) The cost of prosthetic and orthotic services was obtained by extrapolation as follows:

According to Glattly (5), the Veterans Administration pays for about 12.7% of prostheses in the U.S., and according to Talley (6), the VA spent $3,309,691 on prostheses in FY 1968. (The more recent CPOE survey (4) showed the VA paying for 14.3% of prostheses, but this figure did not reflect Medicare payments, which were just starting at that time. The 12.7% seems like a better estimate at present.)

Therefore, about $\frac{\$3,309,691}{12.7\%}$ or $26,100,000 was spent in FY 1968 on prosthetic services. Adjusting this figure for the two-year increase in population gives $\$26,100,000 \times \frac{203,000,000}{199,000,000}$ (7) or $26,600,000 for FY 1970.

Assuming the ratio of Certified Orthotists to Certified Prosthetists is proportional to the cost of orthotic to prosthetic services, then $\$26,600,000 \times \frac{758}{648}$ (8) or $31,200,000 was spent for orthotic services.

A total of $26,600,000 + 31,200,000 or $57,800,000 was then spent on prosthetic and orthotic services. Adding the estimated cost of Army and Navy services, which were not included in Glattly's figures, brings the total to about $60,000,000.

(b) The cost of prosthetic and orthotic research and development was obtained from actual funding figures for the Department of Health, Education, and Welfare (including both Social and Rehabilitation Service and Children's Bureau) and VA and from funding estimates for the Army and Navy.

(c) Patient population estimates were obtained from the U.S. Public Health Service and are based on the July 1965-June 1967 survey, which updates presently published figures (9). The survey includes the civilian, noninstitutional population. The information was presented by the PHS in the following manner (The parentheses show the PHS figures updated for the two-year increase in population.):

Absence of arm(s) or hand(s), except fingers only	97,000 (99,000)
Absence of leg(s) or foot(feet), except toes only	204,000 (208,000)
Absence of arm(s) and leg(s)	4,000 (4,000)

Paralysis, total or partial, of upper extremity(ies)	58,000 (59,000)
Paralysis, total or partial, of one lower extremity	58,000 (59,000)
Hemiplegia	368,000 (376,000)
Paraplegia	68,000 (69,000)
Quadriplegia	31,000 (32,000)
Back or spinal impairment ("aches and pains")	6,841,000 (6,978,000)
Back or spinal deformity	564,000 (575,000)
Upper-extremity impairment ("aches and pains")	2,257,000 (2,302,000)
Upper-extremity deformity	709,000 (724,000)
Lower-extremity impairment ("aches and pains")	5,492,000 (5,602,000)
Lower-extremity deformity	1,447,000 (1,476,000)
Multiple and ill-defined impairments and deformities not elsewhere classified	1,943,000 (1,982,000)

Prosthetic and orthotic patient population estimates were based on the above figures in the following manner:

UE amputees: 99,000 + ½(4,000) or 101,000
LE amputees: 208,000 + ½(4,000) or 210,000
Total amputees: 101,000 + 210,000 or 311,000

UE paralysis: 59,000 + ½(376,000) + ½(32,000) or 263,000
LE paralysis: 59,000 + ½(376,000) + 69,000 + ½(32,000) or 332,000
Total Paralysis: 263,000 + 332,000 or 595,000

UE deformity: 724,000
LE deformity: 1,476,000
Spinal deformity: 575,000
Total deformity: 724,000 + 1,476,000 + 575,000 or 2,775,000

Total UE orthotic patients: 263,000 + 724,000 or 987,000
Total LE orthotic patients: 332,000 + 1,476,000 or 1,808,000
Total spinal orthotic patients: 575,000
Total orthotic patients: 987,000 + 1,808,000 + 575,000 or 3,370,000

The above estimates assume that all patients with deformities need braces and all patients with impairments ("stiffness," "weakness," "pain," "spasms," "swelling," etc.) do not need braces. This is obviously a give-and-take situation, but it is difficult to arrive at more meaningful estimates from information available. The multiple and ill-defined impairments and deformities were excluded because the large portion do not involve the extremities and spine and because the others cannot be readily classified.

(d) Funding provided to each prosthetic and orthotic activity was obtained from the sponsoring agencies. Funding for specific areas within each activity was estimated from grant and contract proposals and reports.

(e) The costs of publications and administration include the activities of the CPRD and its publication Artificial Limbs and the activities of the VA Research and Development Division and its publication Bulletin of Prosthetics Research.

(f) Excluding the costs of publication and administration explained above.

(g) Estimates similar to those under (c) were obtained for age groups under 17, 17-65, and over 65. These estimates were extrapolated to obtain the estimates for age groups under 21, 21-65, and over 65.

References

1. This unpublished figure was obtained from various sources in the United Kingdom.

2. U.S. Census Bureau Information Service.

3. Harold W. Glattly, M.D., "A Statistical Study of 12,000 New Amputees," Southern Medical Journal, November 1964, p. 1375.

4. Barbara R. Friz, M.S., and Frank W. Clippinger, Jr., M.D., "The Facility Case Record Study," Orthotics and Prosthetics, March 1969, p. 11.

5. Harold W. Glattly, M.D., "Aging and Amputation," Artificial Limbs, Autumn 1966, p. 1.

6. William H. Talley, "Prosthetics Research--A Cost Reduction Program," Bulletin of Prosthetics Research, Fall 1968, p. 3.

7. U.S. Census Bureau: Population July 1, 1967--about 199,000,000; July 1, 1968--about 201,000,000; and July 1, 1969--about 203,000,000.

8. American Orthotics and Prosthetics Association registry of practicing, certified prosthetists and orthotists including the 1969 certifees: 404 CP's, 514 CO's, and 244 CPO's.

9. "Prevalence of Selected Impairments, United States, July 1963-June 1965," Dept. of HEW, Public Health Service.

COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT
NATIONAL ACADEMY OF SCIENCES

U.S. Sensory Aids Research and Development
Patient Population and Funding Estimates for Fiscal Year 1970

Estimates

Patient Population

Visually Impaired	--	1,280,000(a)	--	Those People Who Cannot Read Newsprint
Hearing-Impaired	--	1,705,000(b)	--	Those People Who Cannot Understand Speech
Speech-Impaired	--	1,350,000(c)	--	Those People with Speech Defects

Age of Patient Population

Visually Impaired	--	4%	under 21(d)
		27%	21-64
		69%	65 and over
Hearing-Impaired	--	7%	under 21(e)
		39%	21-64
		54%	65 and over
Speech-Impaired	--	53%	under 21(f)
		35%	21-64
		12%	65 and over

Causes of Impairments

Vision	--	31%	disease(g)
		30%	cataract
		5%	injury
		3%	congenital
		11%	other
		20%	unknown
Hearing	--	23%	illness(h)
		14%	accident
		6%	congenital
		3%	presbycusis
		40%	other
		14%	unknown

Speech	--	11%	vascular lesions, central nervous system(i)
		9%	congenital
		49%	other
		31%	unknown

R&D Funding(j)

Allocation:

	Vision	Hearing	Speech	Total
SRS	$ 460,000	$ 13,000	$ 38,000	$ 511,000
VA	199,000	60,000	0	259,000
OE	506,000	629,000	76,000	1,211,000
NEI	128,000	0	0	128,000
Hartford Foundation	90,000	0	0	90,000
Total	$1,383,000	$702,000	$114,000	$2,199,000

Funding per Patient:

Visually Impaired -- $\frac{\$1,383,000}{1,280,000}$ or $1.08 per patient

Hearing-Impaired -- $\frac{\$\ ,702,000}{1,705,000}$ or $ .41 per patient

Speech-Impaired -- $\frac{\$\ 114,000}{1,350,000}$ or $ .08 per patient

Miscellaneous Estimates

Visually Impaired

Unofficial estimates by the Division of Services for the Blind, SRS, Department of Health, Education, and Welfare, place the number of legally blind people in the U.S. at 420,000.

The use of aids by the visually impaired is estimated as follows(k):

Cane (with or without another person)	--	247,000
Another person		196,000
Talking books		78,000
Braille		12,000
Dog guide		very small number

Approximately 168,000 persons receive financial assistance because of their vision impairments(k).

It is estimated that there are over 100,000 people who cannot read ordinary newsprint and cannot understand ordinary speech(l). Most of them are in the 65 and over age group.

Of a total of 294,000 practicing M.D.'s, there are about 9,100 ophthalmologists(m).

There are about 17,000 optometrists, 23,000 opticians and optical technicians, and 400 orthoptists(n).

Hearing-Impaired

There are nearly 1,000,000 people using hearing aids(o).

Of a total of 294,000 practicing M.D.'s, there are about 5,600 otolaryngologists(m).

There are about 850 people certified in audiology by the American Speech and Hearing Association(p).

There are about 16,000 people employed as audiologists and speech pathologists, about 50 per cent of whom are working in primary and secondary schools(p).

Speech

There are about 4340 people certified in speech pathology by the American Speech and Hearing Association(p).

Appendix

(a) According to the U.S. Public Health Service (reference 1, page 1), there were estimated to be 1,227,000 people in the U.S. at the time of their 1963-1965 survey who were over six years of age and could not read ordinary newsprint even with glasses or were under six years of age and had no useful vision in either eye. Updating this number for the increase in U.S. population from July 1965 to July 1969 gives:

$$1{,}227{,}000 \times \frac{203{,}000{,}000}{195{,}000{,}000} \text{ (2)} \quad \text{or} \quad 1{,}280{,}000$$

(b) According to the U.S. Public Health Service (reference 3, page 4), there were estimated to be 1,592,000 people in the U.S. at the time of their 1962-1963 survey who could not understand ordinary speech without the use of hearing aids. Updating this number for the increase in U.S. population from July 1963 to July 1969 gives:

$$1{,}592{,}000 \times \frac{203{,}000{,}000}{189{,}400{,}000} \text{ (2)} \quad \text{or} \quad 1{,}705{,}000$$

(c) According to the U.S. Public Health Service (reference 1, page 1), there were estimated to be 1,298,000 people in the U.S. at the time of their 1963-1965 survey who had speech defects of one sort or another. Updating this number for the increase in U.S. population from July 1965 to July 1969 gives:

$$1{,}298{,}000 \times \frac{203{,}000{,}000}{195{,}000{,}000} \text{ (2)} \quad \text{or} \quad 1{,}350{,}000$$

(d) These figures were obtained (reference 1, page 24) in age categories under 25, 25-64, and 65 and over. The under age 25 estimate was interpolated to arrive at the under 21 and 21-64 figures.

(e) These figures were obtained (reference 3, page 21) in age categories under 17, 17-64, and 65 and over. The under age 17 estimate was extrapolated to arrive at the under 21 and 21-64 figures.

(f) These figures were obtained (reference 1, page 11) in age categories under 25, 25-64, and 65 and over. The under age 25 estimate was interpolated to arrive at the under 21 and 21-64 figures.

(g) These figures were obtained from reference 1, page 25. Glaucoma, other local eye diseases, and general diseases are grouped under "disease."

(h) These figures were obtained from reference 3, page 37.

(i) These figures were obtained from reference 1, page 36.

(j) The money being spend on sensory aids research and development was obtained from actual funding figures for the Social and Rehabilitation Service (Dept. of HEW), the Veterans Administration, the Office of Education (Dept. of HEW), and the National Eye Institute (Dept. of HEW). The Hartford Foundation funding is for a specific, known project.

(k) These figures were obtained from reference 4, pages 11 and 42. They reflect estimates of a 1963-1964 Public Health Service survey.

(l) This estimate was obtained from reference 3, page 43.

(m) These estimates were obtained from reference 5, page 128.

(n) These estimates were obtained from reference 5, page 199.

(o) This estimate was obtained from reference 3, page 9.

(p) These estimates were obtained from reference 5, page 191.

References

1. "Prevalence of Selected Impairments--United States--July 1963 to June 1965," National Center for Health Statistics Publication Series 10, Number 48, Public Health Service, Dept. of Health, Education, and Welfare.

2. U.S. Census Bureau, Dept. of Commerce.

3. "Characteristics of Persons with Impaired Hearing--United States--July 1962 to June 1963," National Center for Health Statistics Publication Series 10, Number 48, Public Health Service, Dept. of Health, Education, and Welfare.

4. "Characteristics of Visually Impaired Persons--United States--July 1963 to June 1964," National Center for Health Statistics Publication Series 10, Number 46, Public Health Service, Dept. of Health, Education, and Welfare.

5. "Health Resources Statistics--1968," National Center for Health, Statistics Publication Number 1509, Public Health Service, Dept. of Health, Education, and Welfare.

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