FINAL PROJECT REPORT

CHILDREN'S LOWER-EXTREMITY ORTHOTICS PROBLEMS

CHILDREN'S BUREAU GRANT CB-21

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I. INTRODUCTION

The interdisciplinary group of research workers—including physicians, engineers, and other scientists—at the Biomechanics Laboratory has been concerned since 1945 with studies of the human body in motion. A wide variety of investigations has been carried out on the electrical activity of muscles, the energy and power developed in the lower extremities, the rotatory motions of various segments of the body, and the energy expenditure during locomotion of normal persons and of persons with various limitations and disorders of the musculoskeletal system. At first, research was directed toward the problems of amputees; more recently, other types of disability have been studied.

Information obtained in these fundamental investigations, along with the techniques developed, has formed a basis for detailed studies of the problems of bracing of the lower extremities. Initial work on bracing, begun in 1958, had as its objective the determination of needs in this field and the development of a methodology with which problems could be investigated. It soon became clear that expanded biomechanical and medical studies would be necessary to realize the specific objectives: adequate definition of individual requirements for orthotic devices and practical criteria for the design of such devices.

Observations of conventional braces and their shortcomings suggested that a critical factor in the design of a brace would be alignment of its joints with the axes of the anatomic joints to be braced. In order to determine the axes of the ankle and the subtalar joints in a particular individual, a mechanical analog* with adjustable links was constructed; this unit made possible not only the determination of the axes of motion but also measurement of ranges of motion at each joint.* A short leg brace, the University of California System of External Control (Ankle), or UC-SEC(A), was designed on the basis of the mechanical analog. The basic model allows not only hinge-type ankle-joint motion but also rotation at the subtalar joint; these motions can be assisted or restricted by the attachment of springs and other control devices.* The present model has been renamed the University of California Dual-Axis Ankle-Control System (UCDAACS).

A second device* developed before the inception of the present grant was the UC-BL Shoe Insert, a plastic shell constructed to hold the heel firmly and control the motions of the foot during walking in specific and planned ways.

These devices, as well as various accessory devices for fitting and alignment, were originally constructed for adults. To continue the study along the same lines but with the focus on children's bracing problems, it was decided to scale down these and other devices and study their long-range effects. A proposal was submitted to the Children's Bureau, and the project was activated in August 1964.

*See Selected Bibliography, Biomechanics Laboratory Publications.
II. METHOD

During the first thirteen months of the grant period, work was directed toward laying a foundation for a long-term project, to be based on carefully planned follow-up studies of selected children during their growth period. It was necessary to recruit and train additional personnel while maintaining and expanding the existing patient load. Since completion of this first goal, the major activity has been the selection, evaluation, and treatment of children with specific disabilities, in particular pes planus, talipes equinovarus, and axial rotation deformities.

It is clear that several areas of research described in the original four-year proposal could not be activated until others, on which they were to be based, were set up and also until enough time had elapsed for evaluation. The former group includes, for example, the fundamental studies of the effects of growth and function on the development of the joint systems of the lower extremity, clinical studies to determine whether the use of shoe inserts can effect a permanent cure of flatfoot in children, and long-term clinical testing and evaluation of the short leg brace, UCDAACS.

From the beginning, it has been considered that the most important function of this project is the evaluation of disability and its changing manifestations as a basis for scientific corrective procedures and devices. For this reason, immediate attention was given to recruitment of research subjects and planning of record-taking, of diagnostic procedures, and of methods of treatment. To aid in evaluating the patient's condition at any one time as well as changes resulting from treatment, a preliminary version of a Range of Motion Profile Chart (fig. 1), has been developed. This chart will be useful in obtaining, recording, and interpreting patient data.

A. Subjects

Research subjects have been referred by private physicians or by clinics of the University of California Hospitals. In the past year, a valuable source of subjects has been the Children's Foot and Gait Clinic (see below), begun March 1, 1965, and operated in conjunction with the Department of Orthopaedic Surgery of the University of California School of Medicine.

Several visits have been made to Sonoma State Hospital, Eldridge, California, where the large patient population (4,000) provides unusual opportunities for long-term follow-up. A new rehabilitation unit has been constructed there; it includes an orthopaedic appliance shop. When these facilities and staffing of them are completed, an attempt will be made, as part of a future project, to undertake a cooperative venture with the Orthopaedic Service there, particularly in evaluation of UC-EL Shoe Inserts.
Fig. 1. A preliminary version of the Range of Motion Profile Chart, illustrating the nature of the form being considered.

To date, 59 children with an age range of 18 months through 16 years have been accepted as research subjects (see Table). They have the following disorders: pes planus (16), internal rotation deformity of the leg (14), talipes equinovarus (11), external rotation deformity of the leg (6), pes cavus (3), metatarsus adductus (3), drop foot (2), genu valgum (2), and multiple foot deformities associated with cerebral palsy (2).

In addition, 21 adult research subjects, whose treatment was initiated prior to the beginning of this project, are receiving follow-up care; an effort is being made to maintain long-term records on them. They have the following disorders: pes planus (12), arthritis (4), drop foot (4), and traumatic quadriplegia (1).
<table>
<thead>
<tr>
<th>Disability</th>
<th>No. of Subjects</th>
<th>Age Range (yrs)</th>
<th>Total Prs. of Inserts Made</th>
<th>Range in No. of Pairs per Subject</th>
<th>No. of Subjects</th>
<th>Age Range (yrs)</th>
<th>Total No. of Braces Made</th>
<th>Range in No. of Braces per Subject</th>
<th>Total No. of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pes planus</td>
<td>7 M 9 F</td>
<td>1½ to 16</td>
<td>20</td>
<td>1-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
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<tr>
<td>Internal rotation</td>
<td>5 M 9 F</td>
<td>2 to 11</td>
<td>20</td>
<td>1-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14</td>
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<tr>
<td>Talipes equinovarus</td>
<td>1 M 3 F</td>
<td>4 to 11</td>
<td>5</td>
<td>1-2</td>
<td>4 M 3 F</td>
<td>3 to 16</td>
<td>21</td>
<td>1-6</td>
<td>11</td>
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<tr>
<td>External rotation</td>
<td>5 M 1 F</td>
<td>3 to 10</td>
<td>8</td>
<td>1-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Pes cavus</td>
<td>1 M 2 F</td>
<td>11 to 16</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Metatarsus adductus</td>
<td>0 M 3 F</td>
<td>1½ to 13</td>
<td>5</td>
<td>1-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
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<tr>
<td>Drop foot</td>
<td>2 M 0 F</td>
<td>10 to 16</td>
<td>6</td>
<td>2-4</td>
<td>2 M 0 F</td>
<td>10 to 16</td>
<td>6</td>
<td>2-4</td>
<td>3</td>
</tr>
<tr>
<td>Genu valgum</td>
<td>1 M 1 F</td>
<td>3 to 9</td>
<td>3</td>
<td>1-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
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<tr>
<td>Cerebral palsy</td>
<td>0 M 2 F</td>
<td>10 to 11</td>
<td>5</td>
<td>2-3</td>
<td>2 M 0 F</td>
<td>10 to 11</td>
<td>5</td>
<td>2-3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20 M 28 F</td>
<td>1½ to 16</td>
<td>64</td>
<td></td>
<td>6 M 5 F</td>
<td>3 to 16</td>
<td>32</td>
<td></td>
<td>59</td>
</tr>
</tbody>
</table>

*All subjects fitted with braces were also fitted bilaterally with shoe inserts, with the exception of one boy with drop foot who, because of unequal foot length, was supplied with a single insert for the braced extremity.
B. Children's Foot and Gait Clinic

This clinic is held every Monday afternoon from 2 to 4 p.m. at the UC Hospital Orthopaedic Outpatient Clinic, where typical facilities are available. Personnel include the technical staff of the orthotics research project and at least 3 residents, as well as 2 staff physicians, Drs. William R. Murray and James M. Morris, from the Department of Orthopaedic Surgery. From 8 to 20 children are seen each week.

In addition to providing the opportunity for selection of appropriate subjects for intensive study, the program has the benefit of familiarizing the participating residents with new devices and techniques, extending their experience with conventional devices, and affording them an opportunity to work with well-trained orthotics personnel. It offers the orthotics project the opportunity to observe a group of children with a wide variety of foot and gait disorders.

For those children selected as subjects for research, examinations and x-rays required by the Department of Orthopaedic Surgery are supplemented by special films and other photographic records. The orthotics project supplies for these patients appropriate follow-up such as adjustment or refitting of devices when necessitated by growth or other changes.

C. Procedures and Equipment

Procedures for scheduling and handling patient visits to the Laboratory and for recording information have been set up. These include comprehensive medical records as well as the above-mentioned photographic records. When research subjects are first accepted into the project, still photographs and motion pictures are made, and these are repeated at specified intervals, or more frequently as changes in condition warrant.

A special unit for photographing the feet and legs of subjects has been designed and constructed. Pictures are made with a Polaroid MP-3 technical camera and 4" x 5" positive - negative film providing a print and a negative immediately. This equipment makes it possible to obtain routine, standardized photographs of the feet and legs quickly and easily so that progress can be recorded from one visit to the next and comparisons can be made between subjects. In order to obtain informative plantar and posterior views, the barograph (previously used for studies of human locomotion) has been modified for use with the camera.

A second unit has been designed and constructed which consists of a special dolly on which a 16-mm motion-picture camera and lights are mounted. Motion pictures, both at 24 frames per second and in slow motion (64 frames per second), are made of the subjects walking at their normal speeds. Front and rear views taken in slow motion are emphasized, since abnormalities in gait patterns are more readily seen in these projections.
Testing of both units has been completed. A motion picture viewer is taken routinely to the Foot and Gait Clinic so that previous findings can be reviewed quickly and compared with current findings. This has been particularly helpful in orienting new residents to a patient's problem so that continuity in care is assured.

One of the most important diagnostic aids for these studies will be a more precise method than hitherto available for locating the axes of rotation of joints. Possible methods are being investigated under other sponsorship. In the meantime, the adjustable brace has proved extremely useful as an aid both in diagnosis and in fitting of braces. The adjustable brace (fig. 2) is essentially a simplified mechanical analog; the brace joints can be adjusted to correspond to the anatomic ankle and subtalar joints so that interference with motion is virtually eliminated and axial and transverse shifting of the cuff is minimized.

Fig. 2. Adjustable brace being used to locate axes of ankle and subtalar joints for fitting with UCDAACS.