

# Journal of Rehabilitation Research and Development

## Rehabilitation R & D Progress Reports 1983

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### International Prosthetics / Amputation

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- B. Orthotics
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# Reports from Other Nations

## Prosthetics/Amputation R&D

### LOWER LIMB PROSTHETICS

#### AIST (JAPAN)

##### **ACTIVE ARTIFICIAL LEG**

National Research and Development Program for Medical and Welfare Apparatus  
Agency of Industrial Science and Technology  
Ministry of International Trade and Industry  
1-3-1, Kasumigaseki, Chiyoda-ku  
Tokyo, Japan

The artificial leg being developed in this program is equipped with a drive unit ("rotary actuator") to the knee and the ankle, and sensors at the sole. Motorized devices are also being developed that will enable the user to stand up, crouch, keep a half-rising posture, walk on level ground, walk on a rough road, etc. The first prototype has been tested ■

#### STRATHCLYDE

##### **A SYSTEM FOR MEASURING LOWER LIMB PROSTHETIC LOADINGS DURING OUTDOOR ACTIVITIES**

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A prosthesis must be of strength adequate to withstand the loads applied to it by the patient during various activities. The prosthesis should also have

a low mass, to allow low energy expenditure by the patient. To obtain a compromise between these two conflicting factors of strength and mass, it is necessary to obtain accurate information of the loads applied to a prosthesis in the course of daily activities.

At the University of Strathclyde, a system employing a six-channel strain-gaged pylon transducer and knee-angle electrogoniometer has been used for several years to study amputee loading patterns. The pylon transducer itself was designed to be as short as possible in order to accommodate the majority of below and above knee amputees. Using this system, loading data for design and mechanical testing purposes have been accumulated. The results were used in the formulation of the "Standards for Lower Limb Prostheses" (Philadelphia 1978, ISPO publication). The multichannel cable, which is used to connect the transducer to the bridge amplifiers and associated electronics, has, however, restricted the subject to the confines of the laboratory. In order to investigate amputee activities outdoors, it was necessary to eliminate this umbilical cable. This was done by recording the transducer signals on a specially built eight-channel portable system which can be carried by the amputee. The system utilizes standard C120 cassette tapes and allows an uninterrupted recording time of 1 hour outside the confines of the laboratory. A custom-built playback unit allows analysis of the results. The system has been used over the last year on amputees, and the effect of different types of terrain on limb loading has been studied.

Financial assistance for this project was received from the Scottish Home and Health Department ■

STRATHCLYDE**BIOMECHANICAL EVALUATION OF SACH AND UNIAXIAL FEET**

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 Wolfson Centre  
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A review of prosthetic prescription practice reveals that in Britain about 80 percent of below and above knee amputees are fitted with uniaxial feet, whereas in the United States, about 80 percent are fitted with SACH feet. Although subjective studies to compare the two types of feet have been carried out, only limited attempts to acquire comparative objective data have been reported.

In this work, an evaluation method was developed to assess the performance of the two feet. It includes a subjective assessment procedure and a biomechanical evaluation of the function of the two feet and their effects on whole-body kinematics and lower limb kinetics. A suite of computer programs has been devised to facilitate the calculation of the results. Data are acquired by three Bolex H16 cine cameras and two Kistler force plates. This set-up allows three-dimensional analysis on the prosthetic and contralateral sides of the subject.

The investigations undertaken permitted the interchange of the ankle/foot in the experimental prosthesis without changing the rest of the components. Six below-knee and five above-knee amputees have been studied. No clear trend of preference for either type of foot was evident from the subjective survey; in general, the patients showed a preference for the foot to which they were accustomed. The kinematic and kinetic analysis, however, showed differences in function between the two prosthetic feet. It was found that the movements of the uniaxial foot were much closer to the movements of a normal foot than were those of a SACH foot. On the other hand, the load patterns at the ankle of the SACH foot were closer to those of the normal foot. A full report describing the evaluation methodology and significance of the results is being prepared for publication at a later date ■

STRATHCLYDE**BIOMECHANICS OF HIGH STRESS LOWER LIMB ACTIVITIES**

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 Wolfson Centre  
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The load actions to which the lower limb joints are subjected during stressful activities are investigated. Healthy volunteers perform tasks including walking, running, hopping, long jump, squat thrust, jump down, and twisting turn. Two Kistler force platforms record the ground reaction forces and moments, and synchronised three-dimensional cine film data allow the calculation of ankle, knee, and hip moments. Care is taken to reduce variability of the performances, and initial results indicate good repeatability.

Several calculations of the joint structure loadings suggest that joint surfaces and ligaments must transmit greatly increased loads (20 percent to 100 percent) from those encountered during normal level locomotion. Results should be published in late 1983 ■

STRATHCLYDE**STUDY OF ALIGNMENT IN LOWER LIMB PROSTHESES**

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Alignment of a prosthesis is defined as the position of the socket relative to the foot and other components. During dynamic alignment the prosthetist, using subjective judgment and feedback from the patient, aims to achieve the most suitable limb geometry for best function and comfort. In the past, it was generally believed that a given patient could be satisfied only with a unique "optimum" alignment. However, work carried out at the University of Strathclyde showed that a patient's requirements may be satisfied by any one of several alignment configurations. (Solomonidis 1980).

The purpose of this project is to carry out a systematic study in order to establish the range of acceptable alignment and to understand the patient's tolerance in relation to dynamic alignment. It also aims to investigate the effect of alignment variation on amputee gait.

Twelve below-knee (BK) and 12 above-knee (AK) active amputees are being studied. Five experienced

prosthetists are carrying out several alignments of each subject under clinical conditions on several occasions. Following dynamic alignment, the prostheses are accurately measured using custom-built apparatus. A six quantity load transducer is incorporated into the shank of the prosthesis, and force platforms are utilized for acquisition of loading data. Three-dimensional cine and TV systems, together with goniometry, are employed for the collection of kinematic data. Much of the experimental data has been collected and analyzed. Interpretation of the data has proved time-consuming, due to the complexity of the problem and the interaction of many parameters. Examples of typical findings are as follows:

For a certain BK patient fitted 19 times, the antero-posterior (A/P) socket tilt varied from 1 to 11 degrees and the A/P shift from 0.4 cm to 2.4 cm.

For a given patient, two different but perfectly acceptable alignments resulted in considerable quantifiable changes in gait characteristics. For instance, one alignment caused an AK amputee to exert a maximum moment by the hip extensors 30 percent greater than necessary for the same prosthesis using a second alignment. Similarly, compensation by the contralateral side can show a 50 percent change in moment values at the hip from one alignment to another.

Financial assistance for this project was given by the Scottish Home and Health Department ■

# ORTHOTICS

STRATHCLYDE

## ENHANCEMENT OF LIMB FUNCTION BY MEANS OF FES

**Principal Investigators:** B. J. Andrews, J. P. Paul, C. M. van Griethuysen, and G. Day

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New areas of application for FES are being explored alongside more traditional orthotic methods used for locomotion and upper limb function. The following is an outline list of our present projects:

A programmable stimulator has been developed that allows a double-blind evaluation of the effectiveness of various waveform parameters. This stimulator enables any set of waveforms to be applied in a randomized sequence. A dynamometer system has also been developed so that the generated muscle force actions may be recorded. Our present studies relate to student volunteer subjects. However, studies will be extended to subjects with various neurological disorders in the near future. This project is funded in part by the Medical Research Council (UK).

A microcomputer system has been developed for controlling the application of biofeedback and FES combinations to enhance upper limb function. Biofeedback data presentation is derived from orthotic splints instrumented with goniometers. Present studies relate to wrist/elbow function for cerebral palsied children and hemiplegic adults. The project will be extended to include other neurological disorders. Ultimately, it is envisaged that a small body-worn system will be produced for everyday use. This project is funded by the Action Research for Crippling Diseases (UK).

An active hand-extension orthosis is under development for application following hand surgery. The system maintains cyclic hand mobility in the post-operative period and aims to prevent formation of tendon adhesions and to reduce edema.

Closed-loop joint control and spasticity regulation systems are being investigated. These projects aim to develop enhanced orthotic devices for upper and lower limb function. This project is funded by the Multiple Sclerosis Society (UK) ■

STRATHCLYDE**LOAD ANALYSIS OF KNEE-ANKLE-FOOT ORTHOSES**

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Knee-ankle-foot orthoses currently being prescribed to patients are reported as heavy and cumbersome. Despite their apparently robust construction, failures frequently occur, indicating that the design is unsatisfactory. Strength and mass are thus interrelated parameters between which a compromise must be reached if an effective device is to be obtained. Furthermore, the proportions of the total load being taken by an orthosis have apparently not been evaluated. These can be influenced by the fitting technique employed by the orthotist.

The purpose of this study is to measure and analyze the loads acting on the orthosis and the patient's limb during ambulation. Orthosis loading data are acquired by means of custom-built equipment consisting of four multicomponent load-measuring transducers, amplifiers, and a multiplexer. By simultaneous recording of ground-to-foot forces and body movements, the proportion of loads carried by the affected limb may be derived.

From the work carried out so far, it is evident that the maximum anteroposterior bending moment of  $\pm 18$  Nm, recorded on the orthosis during level walking, constitutes a critical type of loading. Stress calculations indicate that a load of this magnitude can lead to premature fatigue failure.

Financial assistance for this study was given by the Scottish Home and Health Department ■

DERBY O&DRC (GT. BRITAIN)**THE DEVELOPMENT OF MECHANICAL TESTS FOR ORTHOPAEDIC CALIPER KNEE JOINTS**

Mr. R. P. Scothern

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This 3-year research project sponsored by the Department of Health and Social Security aimed to provide useful information regarding the development of a British Standard on caliper knee joints. The project looked at the wear and development of rotational free play in bale lock and ring lock calipers and the four point bending properties of the same joints.

The results of excessive mechanical wear of caliper knee-joint lock mechanisms can be disastrous, as the patient relies completely upon the support provided by the locked hinges. Wear rigs were designed to lock and unlock two types of joint whilst in the presence of small induced preloads in the lock during opening. This situation was found to best represent the environment in which the hinges were actually used. The rigs were pneumatically controlled and took the general form shown in Figure 1.

The caliper arm to the left of the pivot was clamped firmly whilst the right-hand arm remained free to rotate about the pivot and was only retained in the horizontal position by the pivot lock. The slight contact pressure between the sliding surfaces of the lock was maintained by the dead weight resting upon the end of the caliper. Due to the tendency for the free arm to swing downwards once the pivotal lock was released, provision was made for raising both the bar and the weight to enable the pivot to be re-locked and the weight to be reapplied.

The wear was monitored optically using the auto-collimator principal which allows accurate measurement of rotations of the order of one minute of arc. Though tests were conducted upon both the ring and the bale lock, the latter suffered appreciably more surface damage than the ring lock and therefore a greater proportion of the report was devoted to the bale lock.

Figure 2 shows the wear curve for a large bale lock and it will be noticed that the wear rate reduces significantly after an initial period of very rapid wear. It seems likely that this transition is associated with the eradication of the breached furrows. It is difficult to determine any direct relationship between the magnitude of the applied load and the level (in terms of minutes of arc) at which this transition took place. Certainly for the medium lock the transition points

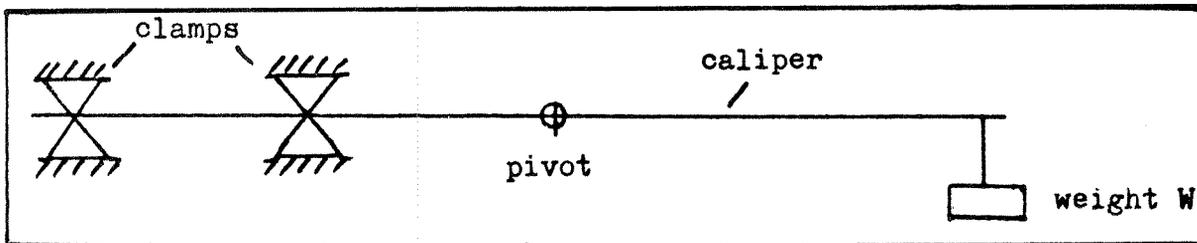


FIGURE 1

Sketch of the general form of the pneumatically controlled wear rig used to lock and unlock a knee-joint mechanism in the presence of a small induced preload in the lock during opening.

do appear to be higher than those of the large bale lock. This suggests that the higher contact stresses due to the smaller area of the medium bale may be responsible. This evidence, and the considerable scatter within groups, suggest that it is the mechanical properties and surface finish which determine the magnitude of the damage.

There was considerably less surface damage to the sliding faces of the ring lock and, at the very most, the growth in rotational free play was only some 25 minutes of arc. Figure 3 is the result of a series of tests upon MASSER ring locks, and once again there is no apparent connection between the wear rate and applied loads. Loads were deliberately applied in excess of those likely to be encountered in service, to see if there was any adverse effect

upon the wear rate. There was, however, no marked increase in the wear rate for this particular joint, and in fact, for most of the joints the increase in free play was less than the free play already present before the tests commenced.

The "in service" loading of a caliper joint is as yet unknown, but the major component is most likely to consist of a bending load; axial and torsional loading may also be present but any attempt to model a complex loading system would only hinder the interpretation of the results and make comparisons between different designs difficult. Therefore, a rig designed to apply pure bending moment across the face of a caliper lock (consisting, essentially, of a modified four-point bending arrangement) was fitted within a standard tensile testing machine. Record-

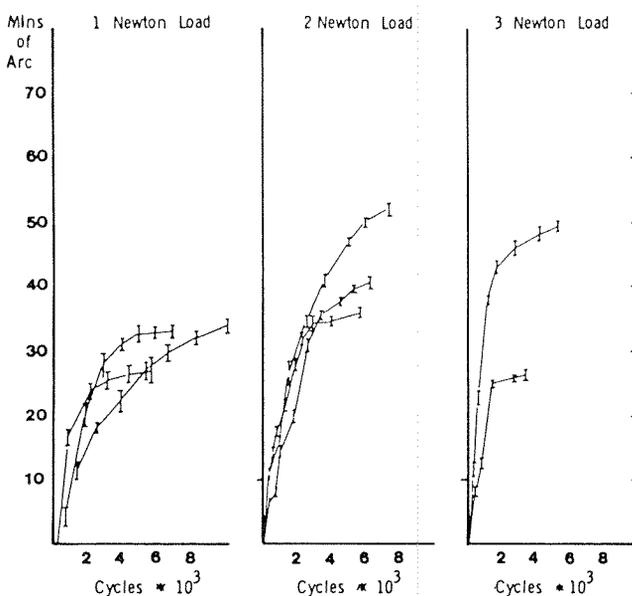


FIGURE 2

The growth of rotational free play in a large bale lock for a range of applied loads. Rate of wear reduces significantly, the authors note, after an initial period of very rapid wear.

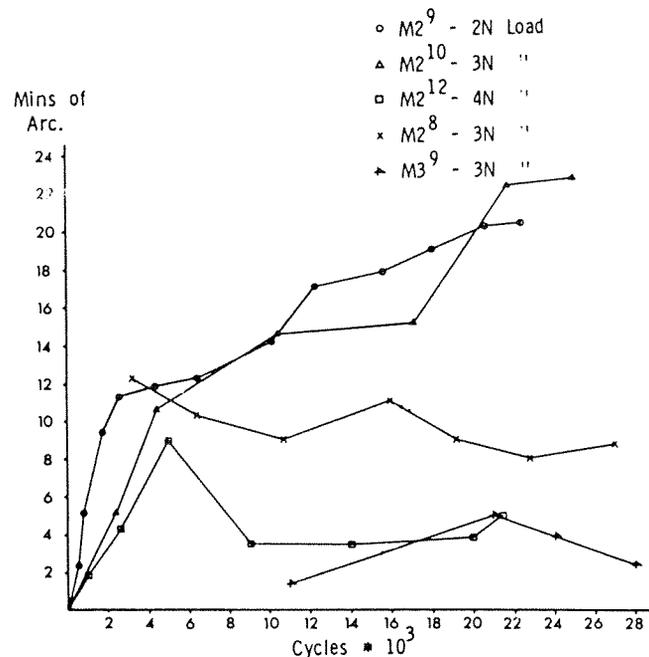
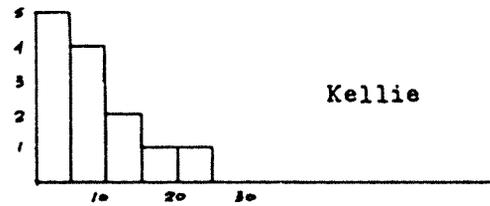
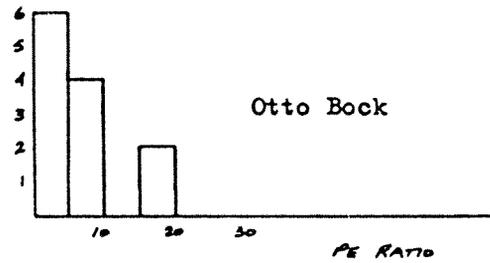
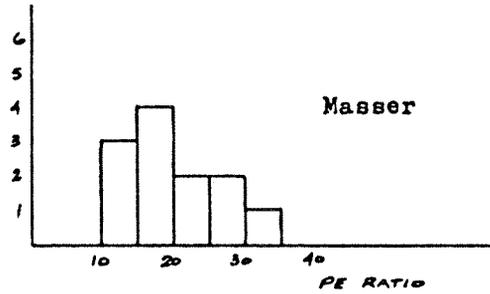
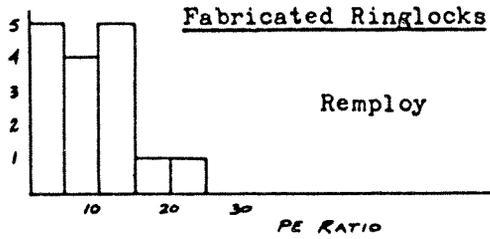


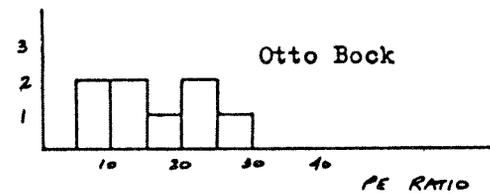
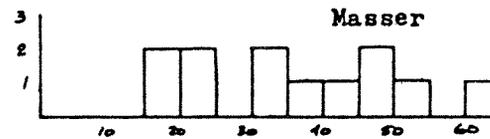
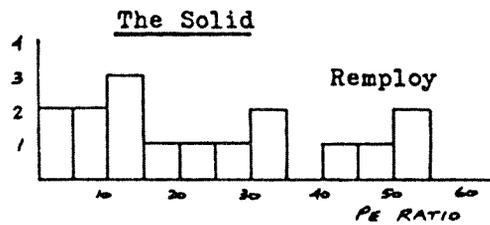
FIGURE 3

The result of a series of tests on a particular brand of ringlock: curves show no apparent connection between wear rate and applied loads, the authors point out.

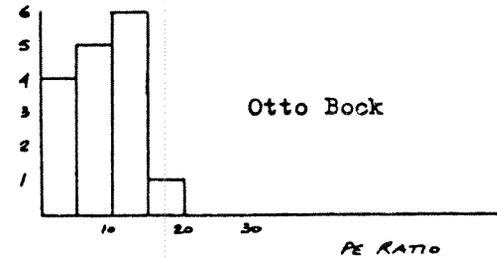
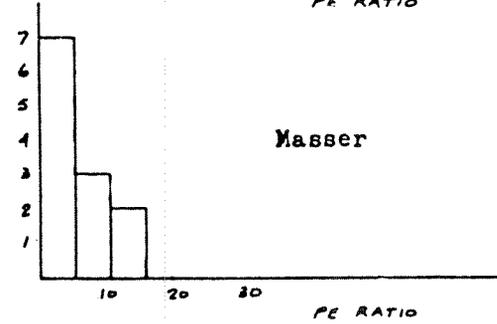
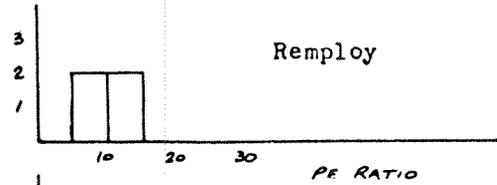
REPORTS FROM OTHER NATIONS



Ringlocks machined from

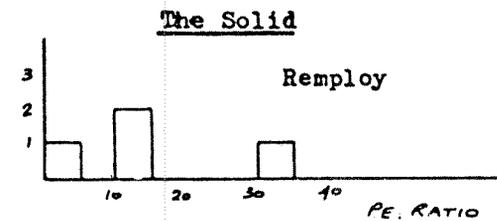


Fabricated Barlocks



Kellie

Barlocks machined from



**FIGURE 4**

Distribution of PE ratio for four categories of knee joints. PE ratio (ratio of plastic to elastic energy) proved useful in assessing mode of failure, independent of the bending moment required to produce the failure. See text for analysis.

NZDRC (NEW ZEALAND)**FOLDING WALKING STICK**

New Zealand Disabilities Resource Centre  
Palmerston North Hospital Board  
Private Bag  
Palmerston North, New Zealand

The folding walking stick, mentioned last year, has been extensively tested by the Industrial Processing Division of the DSIR in Lower Hutt. This has resulted in valuable design information which has been used to strengthen the walking stick considerably. The device will soon be made available through the Centre.

**Vehicular Mobility**

Present work includes a special hand control for adapting cars with a standard gearshift. The hand control combines not only braking and acceleration functions but the clutch as well.

A Honda Civic automobile has been modified extensively and now incorporates many of the basic pieces of equipment that have been developed to date. In addition, other assessment equipment which can be temporarily installed in the client's vehicle is also under development ■

# HIP AND KNEE JOINT REPLACEMENTS

STRATHCLYDE**LOWER LIMB FUNCTION FOLLOWING UNILATERAL HIP JOINT REPLACEMENT**

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Previous biomechanical investigations in this department have shown significantly abnormal joint-loading patterns at both hips and knees to be present even 1 year following hip joint replacement. There was also a difference between results obtained using different prosthesis types. The current investigation is concentrated on comparing two devices: the Charnley and C.A.D. Muller total hip replacements. These

ings of applied load and beam rotation enable the energy absorbed during bending to be calculated, and the magnitude of elastic and plastic components provided a basis for assessing the mode of failure. Brittle failures and the release of excessive elastic energy were considered to be potentially dangerous.

In assessing the results of the bending tests, the ratio of plastic to elastic energy (PE ratio) was used. This ratio was particularly useful as it provided a good assessment of the mode of failure independent of the bending moment required to produce the failure. Ductile failures produce a high PE ratio, the opposite being true of brittle failures.

Figure 4 shows the distribution of PE ratio for four categories of knee joints. There are a number of observations to be made from this figure:

1. Those ring locks machined from the solid exhibit PE ratios frequently in excess of 40 whilst their fabricated equivalents seldom exhibit a PE ratio above 25.

2. Amongst the fabricated ring locks, the MASSER joints are superior, never exhibiting a PE ratio less than 10. This was due to correct porportioning between rivet strength and the cross section of the caliper side steels deformed plastically.

3. The bale locks are inferior to the ring locks — both machined and fabricated joints. This was due to the early shear failure of bearing pins. Invariably the side steels were far too strong and stiff in relation to the main bearing screws.

Many recommendations have been made to the British Standards Institution (BSI) and it is inappropriate to include them all here. However, certain points can be raised regarding the usefulness of the PE ratio. It is proposed that joints which exhibit PE ratios of 10 or more are considered satisfactory, those with PE ratios of 5 to 10 warrant careful attention, and joints exhibiting a PE ratio of less than 5 are to be regarded as possible candidates for re-design.

Many of the recommendations made to the BSI are concerned with the testing procedures, but many other factors are considered such as a choice of materials, standard of workmanship, assembly, and interpretation of test results ■

devices differ not only in design, but also in the surgical approach used, e.g., trochanteric osteotomy versus partial division of the glutei. The phasing of muscular contraction may also differ as a result.

The assessment is in two principal parts. First, biomechanical testing using the Strathclyde TV-computer system and Kistler forceplates, together with simultaneous multichannel EMG recording using a PDP 11/34 computer. Second, physiological cost of gait, based on heart rate changes at various speeds, to evaluate a physiological cost index. Some patients will also be fitted with 24-hour miniature tape recorders to monitor activity and heart rate in the domiciliary environment. Tests will be performed preoperatively and at 6, 12, and 24 months postoperatively. Initial results should be published in 1984 ■

#### STRATHCLYDE

#### **EXAMINATION OF RETRIEVED IMPLANTS**

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Examination of retrieved implants to determine corrosion, wear, and metallurgical condition is being undertaken. A method using a computer controlled SEM with microanalysis facilities is currently being developed. With these facilities it is hoped to be able to study segregation of constituents and impurities, as well as to obtain accurate analyses. The condition of failed implants may then be compared with those routinely removed or obtained at post-mortem. Recommendations on any necessary improvements in process control could then be offered.

Eventually, it is hoped to study the metal deposits found in the adjacent tissues. Automatic tracking techniques will prove a valuable asset ■

#### STRATHCLYDE

#### **EVALUATION OF WALKING AIDS IN THE GAIT OF TOTAL HIP REPLACEMENT PATIENTS**

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Bioengineering Unit  
Wolfson Centre  
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Walking aids are prescribed to hip arthroplasty patients to provide stability and mobility. The purpose of this study is to determine the extent to which the walking aid is used in terms of weight-bearing relief of the lower limbs. Three aids are being studied: namely; walking frame, elbow crutches, and walking sticks.

Initial experiments have used instrumented elbow crutches or walking sticks in conjunction with force platforms and three-dimensional cine film data. The loads carried by left and right aids are measured, enabling the load actions transmitted by wrist, elbow, and shoulder joints to be calculated. Force-platform measurements make it possible to analyze knee, and hip joints in a similar fashion. It is possible then to evaluate the efficacy of the particular aid being used by the patient.

It is planned to simplify the system of data collection in order to perform the measurements in the hospital wards. This approach will enable the patient's gait to be analyzed at each point in the rehabilitation procedure ■

#### STRATHCLYDE

#### **EVALUATION OF INTERTROCHANTERIC FRACTURE REPAIR**

**A. C. Nicol, I. G. Kelly, and J. P. Paul**

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Bioengineering Unit  
Wolfson Centre  
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The difficulty of repairing intertrochanteric fractures to the femur in cases of osteoporosis has led to the mechanical testing of two implants commonly used at Gartnavel General Hospital, Glasgow. Strain-gaged Richards Sliding Screws have been implanted in fresh pairs of specimens and loaded under known geometrical conditions. Of each pair of bones, one screw was implanted normally while the other was implanted and subsequently surrounded with methyl-methacrylate bone cement in order to increase the support provided to the femoral head. The results

show interesting load sharing between bone and implant, with a significant increase in support provided by the cement. X-ray measurements have been taken to estimate the degree of osteoporosis present in the specimens.

A second series of tests is being initiated using KY nails and adopting the same experimental method. The results of both series will be compared to the clinical results of many years of surgery using these implants ■

#### STRATHCLYDE

#### **EFFECTIVENESS OF OLECRANON FRACTURE REPAIR TECHNIQUES**

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University of Strathclyde  
Bioengineering Unit  
Wolfson Centre  
106 Rottenrow, Glasgow G4 ONW

The use of bone screws and other techniques to effect the repair of fractures of the olecranon is being studied. Mechanical testing is underway of intramedullary screws, coronoid screws, and the posterior band-wire technique. Both human and plastic ulnae are being tested, and it is planned to model the plastic bone/implant assembly in order to validate the results obtained from the human bone tests.

The results of the mechanical analysis will be compared to the clinical experience of the three procedures performed at the Western Infirmary, Glasgow ■

#### STRATHCLYDE

#### **THE BONE-CARTILAGE INTERFACE**

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Bioengineering Unit  
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Examination of surgically removed femoral heads is being made by histological, histochemical, scanning electron microscopy, and stereological techniques. The studies are aimed at determining the significance of the bone-cartilage interface in terms of its structural, mechanical, and nutritional parameters. Previous studies have indicated the possible consequences of the structural form of calcified cartilage at the interface in terms of a partial barrier to the diffusion of nutrients. Development of microprocessor-based equipment is aiding research.

Studies on pathological tissue will lead to further interpretation of the role of the bone-cartilage interface in relation to degenerative disease ■

#### STRATHCLYDE

#### **MODULAR BONE REPLACEMENT PROSTHESES**

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Bioengineering Unit  
Wolfson Centre  
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Re-section of bone, often with adjuvant chemotherapy, is now a recognized treatment of certain bone tumors. If the whole bone is not replaced, the surgeon cannot alter the length of re-section except by ordering more than one prosthesis. This is a wasteful and expensive procedure. A modular design system that can be assembled during the operation would give the surgeon flexibility and also reduce the time from diagnosis to treatment.

At present, methods of joining components are being assessed. It is hoped to produce designs for the femur, tibia, and humerus, and eventually to examine possibilities for the acetabulum and glenoid ■

# LOWER LIMB GENERAL

RORRC (CANADA)

## A NEW GONIOMETER FOR PHYSIOTHERAPY

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Measurements of joint angles using conventional goniometers suffer from intertester and intratester variations, which result in errors and uncertainties when clinicians monitor a patient's progress or perform cross-patient comparisons. The major source of error appears to be in the estimation of the centre of rotation of the joint and in the placing of the goniometer's centre over this point. To overcome the problem of placement, we have designed a new goniometer that can accurately measure a joint angle without requiring an estimate of the joint's centre of rotation. This is achieved by making use of the parallelogram principle. As this double exposure shows, the pointer remains parallel to the rotating arm, even if the arm is displaced sideways. Thus, the measured value is always the angle between the two goniometer arms (in the plane of rotation). This greatly facilitates the measurement of joint angles, by giving extra freedom of movement and adjustment to the arms of the goniometer.

To use the goniometer, the clinician places the arms along the axes of the patient's limb segments. The angle between the two limb segments can then be measured accurately, regardless of the position of the centre of rotation of the joint in respect to the goniometer. If the limbs are in two different parallel planes (for example, if one limb segment is bulkier than the other as can happen in the measurement of hip angles), the parallelogram can accommodate this without any resulting error. Angles in two different intersecting planes, such as those encountered in ankle inversion/eversion, can also be measured as long as the axis of the goniometer is placed parallel to the axis of rotation (see Figure 1).

The construction of the new goniometer is very straightforward. It is a modification of commercial model, which is modified by removing part of the rotating arm and inserting a parallelogram. The parallelogram can be manufactured in any machine shop in a few hours, using readily available materials.

The goniometer was designed and constructed by Rehabilitation Engineering and was evaluated by Physiotherapy ■



**FIGURE 1**

Use of goniometer to measure ankle inversion/eversion.

RORRC (CANADA)

## A PRESSURE-MEASURING DEVICE FOR PAIN ASSESSMENT

Royal Ottawa Regional Rehabilitation Centre  
505 Smyth Rd., Ottawa, Ontario, K1H 8M2, Canada

It is often useful to compare sensitivity to pressure at different locations on the body. Physicians generally do this by pressing on different sites with their fingers. This type of qualitative assessment can be improved upon by using a device which gives a direct reading of the applied pressure. A number of such devices, both mechanical and electromechanical, have been constructed in various centres. Our device is completely mechanical. Pressure is applied through a 1-cm<sup>2</sup> plastic disc attached to a coiled compression spring. A magnetic pointer follows the displacement of the spring and gives a reading of

applied force, in newtons. The scale on the current model reads up to 20 newtons of force. The range of force can be changed simply by changing the compression spring and making a new calibrated scale.

This pressure-measuring device is used routinely in the investigation of acute neck sprain injuries and other painful conditions ■

#### DERBY O&DRC (GT. BRITAIN)

### **SOME MECHANICAL AND RADIOGRAPHIC PROPERTIES OF BANDAGE-FORM SPLINTING MATERIALS**

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There has been recently a rapid increase in the number of bandage forms of splinting materials available commercially as a substitute for plaster of paris (POP). Much work in the past has been carried out on the property of POP and some of its early competitors, but comparatively little regarding the more recent products. It was decided that six new products be compared with POP in a variety of tests designed to provide useful comparative data. The products chosen were: Scotchcast, Scotchflex, Baycast, Hexcelite, Gypsona (POP), Crystona, and Zoroc.

The tests carried out were:

1. Three and four point bending of the materials;
2. Exothermic heat production under six layers of bandage;
3. X-ray studies;
4. Fatigue studies; and
5. Compression of cylinders.

Full details of the geometry of the various test rigs and experimental conditions can be found in the following:

Pratt, D.J. et al. 1983. Some comparative properties of splintage materials. Presented at the conference "Biomechanical Measurement in Orthopaedic Practice" 14th and 15th April, Oxford, England. To be published in the conference proceedings.

Here it is more appropriate to briefly outline the results obtained from this preliminary study, bearing in mind that it is still continuing.

Of all the splinting applications of these new materials the requirements of the walking cast are the most demanding. An orthopaedic walking cast should have the following criteria satisfied if it is to be successful: (i) high strength-to-weight ratio, (ii) water resistance, (iii) ease of application, (iv) high

fatigue life, (v) high radiolucency, and (vi) cost-effectiveness. If all the products are examined in the light of these criteria then the following conclusions are possible:

1. The highest strength-to-weight ratio, in terms of three and four point bending and compression of cylinders, is found in Scotchcast.

2. All the materials, except Gypsona and Zoroc, are water resistant.

3. Ease of application is a subjective property but Gypsona, Zoroc, and Crystona seem to be the easiest, perhaps due to their similar application technique. The least popular product on this point was Baycast.

4. Both Scotchcast and Scotchflex have high fatigue lives, much higher than the POP like materials with Baycast in the middle.

5. Baycast has by far the highest radiolucency with Scotchcast the highest of the remaining products. It is unlikely, however, that any of the products would cause difficulty with their radiolucency.

6. The cost effectiveness of products such as these is very difficult to assess. If, by using a product, the time spent on cast repairing and the time spent in hospital can both be reduced, then a net saving should result. However, due to the way in which the accounting is performed within the National Health Service, this is not seen to be the case. It still seems to be the case of finding the cheapest product to do the job ■

## LOWER LIMB PROSTHETICS GAIT ANALYSIS

RORRC (CANADA)

### **GAIT LABORATORY**

Royal Ottawa Regional Rehabilitation Centre  
505 Smyth Rd., Ottawa, Ontario, K1H 8M2, Canada

The gait laboratory at the Royal Ottawa Regional Rehabilitation Centre is located in Rehabilitation Engineering. The purpose of the gait laboratory is, primarily, to provide a clinical gait analysis service to clinicians in the Centre and, secondarily, to per-

form research. The emphasis on clinical gait analysis necessitated the streamlining of measurement and reporting techniques so that a large number of patients could be seen. The gait laboratory and the analysis procedures will be discussed in the following paragraphs.

The gait laboratory contains a walkway 10 metres long and 5 metres wide. A force plate (A.M.T.I.) is concealed in the centre of the walkway, for the measurement of three-dimensional forces and moments during a step. The force plate is embedded in the concrete floor, thus eliminating the necessity of using a raised platform. Two video cameras obtain frontal and sagittal views of the patient during gait. Two infra-red beams measure the instants when the patient crosses two specific locations on the walkway, giving the appropriate timing and velocity data.

The patient is instrumented with Lamoreaux-type goniometers which measure angles of hip, knee, and ankle, bilaterally, in the sagittal plane. Foot switches record the times of heel contact, foot flat, heel off, and toe off. In addition, up to six channels of EMG can be measured.

**Data processing** — All of the data collected in the gait laboratory are fed to a PDP 11/34 computer with a 16-channel analog-to-digital converter. Immediate plots can be made of goniometer data, foot switch data, EMG data, and force plate data, with time as the independent variable. Off-line processing, done immediately after the gait analysis, produces the following additional data:

1. Goniometer and EMG data with percent stride as the independent variable.
2. A comparison of the patient's data and normal (averaged) data, on the same hard copy, with percent stride as the independent variable.
3. Temporal/spatial parameters: cadence, velocity, step length, stride length, stance time, swing time, double support time, and angular range of motion.

The step base is measured from the video record using a scale on the floor of the walkway.

**Procedures for clinical gait analysis** — An initial videotaping is made of the patient's ambulation, prior to applying the instrumentation. The patient is then instrumented with six electrogoniometers for bilateral assessment of hip, knee, and ankle joint angles. Foot switches are fixed to the soles of each shoe. Up to six pairs of EMG electrodes can be placed on the patient's leg muscles. When required, the force plate can be used to measure the three-dimensional forces and moments of stepping. Generally, two runs are performed for each specific evaluation to ensure consistency of the recordings.

The written reporting procedures are in two stages:

1. Initially, a brief documentation of the results is made using a "quick gait analysis" form. This form

was designed to provide rapid feedback (within 2 days) to the patient's attending clinician, in order to plan further treatment.

2. A more comprehensive interpretation of the results is made on a form entitled: "report on gait analysis". This latter report is then placed on the patient's medical chart.

The Gait Laboratory is operated by Rehabilitation Engineering and Physiotherapy staff, in association with psychiatrists and other clinicians ■

RORRC (CANADA)

### JOINT POSITION TRAINER

Royal Ottawa Regional Rehabilitation Centre  
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This device was designed for use in physiotherapy to train stroke patients to achieve appropriate movement at the knee while walking. The knee angle is measured using a Lamoreaux-type electrogoniometer. Two thresholds can be selected, one for knee extension and the other for knee flexion. Reaching or exceeding the extension threshold will result in a high-pitched audio tone. Reaching or exceeding the flexion threshold will result in a low-pitched tone. No tone sounds if the knee angle is in between the two thresholds. As the patient progresses, the thresholds can be set wider apart until the desired range of motion is obtained.

The joint position trainer can be used with limbs other than the knee and for patients other than stroke patients ■

# LOWER LIMB PROSTHETICS MISCELLANEOUS

## IMA (ARGENTINA)

### BIOMECHANICS RESEARCH AND DEVELOPMENT AT IMA

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It is one of the main goals of the present report to describe the IMA crutch which attempts to "accompany" the human body in a more active manner by providing:

1. Deformable underarm support;
2. Deformable handgrip;
3. Full contact between crutch tip and ground for any position of the crutch by means of a self-aligning bearing (the possibility of sliding accidents is then greatly reduced);
4. A geometric change when modifying the position from standing to sitting and viceversa.

On the other hand, it has been possible to introduce certain basic modifications on forearm crutches and canes and special care has been taken in the design of walking-aids for handicapped children.

The authors have developed these elements in accordance with present and future needs, and technical and social possibilities of a developing country like Argentina. With regards to research and development in the rehabilitation engineering field in South America it may be worthwhile to recall that data presented at the Second World Congress of ISPO in 1977 showed all of South America as having no rehabilitation engineering R&D centers at all (the total number in the world was put at 561, of which North America had 267, Europe 233, Africa 4, Asia 36, and Australia 21).

**Retractable, anti-shock, non-sliding "IMA" crutches and further developments** — Since 1981 a special program dealing with elements for disabled children is in progress at the "Instituto". These elements are: underarm crutches, forearm crutches, canes, etc.

The fact that in all cases the ratio weight/resistance has been minimized must be emphasized. The metal used has been standard aluminum in practically all

situations. Obviously, the weight/resistance parameter may be improved considerably if alloys of better quality are used.

**Description of the "IMA" crutches** — This orthotic device presents several attractive features from an overall mechanics-functional viewpoint.

1. It is retractile (adaptable to several lengths, easy to transport when not in use, etc.);
2. The armpit support and the crutch handle are flexible, internally damped and anatomic in shape (acts like a shock-absorber under the impact induced even in normal walking);
3. The "ground structural element" which consists in the tip which is mounted on a self-aligning spherical bearing (the possibility of a sliding accident is greatly decreased by means of this device), and
4. When the person sits, he adapts the full length of the crutches to a convenient length. A system of springs is then compressed, but when the person stands up, the springs recover the initial length.

**Angle-adjustable forearm "IMA" crutches** — Stated in terms of engineering design requirements, the improvements obtained with the "IMA" forearm crutches are:

1. Arm supports: deformable and of conical shape;
2. Angle-adjustable handgrips and cuffs in order to accommodate to the disabled actual needs;
3. Crutch handle with deformable upper portion; and
4. Tip mounted on a self-aligning spherical bearing. Each crutch weighs 1.00 Kg.

**"IMA" Canes** — Useful discussions with physicians and disabled persons lead to the idea of developing a new type of cane with the following characteristics:

1. Handle with deformable upper portion;
2. Continuously varying length (it can accommodate to practically any person: short or small);
3. Non-sliding tip (mounted on a self-aligning spherical bearing).

It is important to emphasize the fact that the "IMA" cane weighs 0.375 kg.

**Elements developed for disabled children** — Following the criteria previously established for orthotic devices for adults, underarm crutches, forearm crutches, and canes were developed for disabled children.

Each forearm crutch weighs 300 g and the length may be varied from 40 to 65 cm, while this length variation goes from 65 to 95 cm in the case of underarm crutches.

A rather unique concept has been developed in the design and construction of the child crutch. It was developed for the special situation of a 6-year-old child who uses crutches when performing activities

outside his home. However, when walking inside his house, he feels safe walking with a cane. By pressing a button and applying compression the disabled child can convert the crutch into a cane.

A "karting" type vehicle for disabled children was developed at the Instituto de Mecanica Aplicada. Its conception is based, fundamentally, in the design of the "Caster Cart" developed at the Ontario Crippled Children's Centre (Toronto-Canada).

A multipurpose walker, child and junior size, which has been developed at IMA possesses the following features:

1. As a deambulator, it offers parallel bars, crutches, and a balance ring.

2. For transportation purpose, it serves as a transport chair, and

3. For feeding and schooling purposes, it provides a removable tray and a seat.

The material is aluminum; total weight including all accessories is 22 lb (this fact constitutes a definite advantage, considering the much larger weight of foreign walkers known in Argentina). Since the dimensions can be adjusted easily, it can be used for ages varying from 6-year-old children to 14-year-old teenagers, according to the experience obtained at IMA ■

## UPPER LIMB GENERAL

RORRC (CANADA)

### EMG BIOFEEDBACK

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A two-channel EMG biofeedback system was designed and constructed by Rehabilitation Engineering for use by therapists in patient re-education and for the performance of research. This biofeedback system can measure the full frequency spectrum of the EMG signal. Most of the EMG frequency spectrum lies in the range of 20 to 100 Hz, a range which is eliminated in many commercial EMG biofeedback systems. The fact that changes in EMG due to neuromuscular regeneration, or due to muscle fatigue, occur in lower half of the spectrum further empha-

sizes the importance of providing biofeedback in this range.

Our EMG biofeedback system consists of the following:

1. A two-channel TECA EMG system with AA6 Mk III amplifiers.

2. A two-channel oscilloscope.

3. A two-channel high-fidelity audio system.

4. Two digital displays showing integrated full-wave rectified EMG with integration periods variable from 1 second to 60 seconds.

The TECA amplifiers contain remote preamplifiers which are placed close to the patient, thus enabling short electrode leads to be used. The oscilloscope is required because the wide bandwidth used increases the risk of picking up interference due to power lines, movement artifact, etc. The oscilloscope can be used to distinguish between EMG signals and interference signals. If interference signals are observed, appropriate steps can be taken to eliminate them. The high-fidelity audio system is used for direct feedback of the raw EMG signals. It is also useful in detecting certain types of high frequency noise, such as that caused by electrode leads rubbing on the skin.

The EMG biofeedback unit is used in the centre by physiotherapists, occupational therapists, and psychologists, for muscle re-education and for relaxation therapy ■

RORRC (CANADA)

### A WRIST GONIOMETER

Royal Ottawa Regional Rehabilitation Centre  
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Physiotherapists often need accurate measures of wrist flexion and extension when training patients with peripheral neuropathies or with stroke. The goniometer uses a Lamoreux-type parallelogram with specially designed support to prevent it from collapsing. Connected to a pen recorder, it accurately displays wrist angle and range of motion.

Other applications of the goniometer include audio and visual biofeedback for training wrist control and for increasing wrist range of motion.

The goniometer can be adapted for other joints, such as the elbow, by changing the attachments to fit the different limbs. To ensure accurate measurements, care must be taken that the goniometer is in the plane of movement ■

STRATHCLYDE**A STUDY OF DYNAMIC FUNCTION IN THE RHEUMATOID HAND**

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Rheumatoid arthritis is a common disease, affecting 2 percent of the population in Britain. One of the areas frequently affected is the small joints of the hand, where a gradual deterioration of function takes place. The development of the deformities is not clearly understood, and it is not possible to forecast the pattern of deformity by methods of assessment currently in use. It is believed that a more thorough knowledge of mechanical factors involved in the movements of the rheumatoid hand during the early stages of the disease will allow for better understanding of the factors leading to the development of deformities in the later stages. This will allow improved treatment incorporating the provision of orthoses, technical aids, and advice on methods of joint protection/preservation. In this project, the coordinated joint motions and loads developed during function of the rheumatoid hand are being measured and studied. An evaluation of the treatment and advice relating to the theories of joint preservation/protection is being carried out ■

more effective and safer coaching schedules.

The practical experimental work in the research involves the acquisition of cine film and force transducer data during performance of 'kip actions' on the horizontal bar, parallel bars, rings, and in floor exercise. In order for this to be possible, it has been necessary to install the gymnastic apparatus in the Biomechanics Laboratory at the University of Strathclyde.

Strain-gage force transducers have been designed to form an integral part of the parallel bars and ring apparatus. Strain gages have been applied directly to the horizontal steel cross bar, and forces were measured during floor exercise skills, using two force plates installed in the laboratory.

The performances were filmed by two cine cameras in order to obtain three-dimensional spacial information relating to the movements. Computer programs manipulate the film and force-transducer data to aid in the final analysis of the resultant forces transmitted between the segments of the performer's limbs together with the moments ■

STRATHCLYDE**UPPER LIMB LOAD ACTIONS DURING CERTAIN ACTIVITIES IN MEN'S OLYMPIC GYMNASTICS**

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It is the aim of this project to determine, in mechanical terms, the interactive movement patterns and the corresponding forces during the performance of skills within the skill classification of 'kip actions.' This includes assessment of the timing and direction of application of forces by the gymnast in relation to instantaneous positions during the performance of skills. Once this has been determined for individual skills, it will be possible to establish biomechanical principles for the classification of all skills in order of difficulty within the category; hence, providing