AREA

NORTH AMERICAN - WESTERN

I. BERKELEY, CALIFORNIA

ADDRESS
Biomechanics Laboratory
University of California
5144 Etcheverry Hall
Berkeley, California 94720

Director: C. W. Radcliffe

Deputy: Larry W. Lamoreux, Ph.D.

I. EQUIPMENT

Biomechanical.

Treadmill: Speed range 50 - 350 cm/sec. Inclination -5^{o} to $+15^{o}$.
Special string transducers for remote sensing of angular positions, and linear positions, velocities, and accelerations of body segments.
Special self-aligning goniometers for measurement of relative angular motions at hip, knee, or ankle in 1, 2, or 3 dimensions.
Small (5g) piezo-resistive accelerometers suitable for body mounting.
Foot switches: Heel contact switches outside shoes.
Heel and toe contact switches inside shoes or on bare feet.

Walkway: Total length = 9 m. Effective length between photo detectors = 4m.
Run-in and Run-out = 2.5 m. each. Conductive walking surface available.

Physiological.

EMG: surface and indwelling electrodes.
Heart rate from electrocardiogram.
Max Plank Respirometer with manual O_2 and CO_2 analyzers.

Data Collection and Data Processing.

7 Channel Analog Instrumentation Tape Recorder.
Computer, Data General Corporation "Nova" (2.6 μs cycle time).
Data Acquisition:
16 channel, 12 bit, differential input Analog-to-Digital converter. ±10 volt input range.
4 channel digital pulse input.
48 channel static switch-closure input.
Sample rate up to 1000/s; 200/s usually used.
Data storage: 7 track IBM compatible magnetic tape.
Data processing in NOVA or, via modem or hand carried mag tape, in campus computer (CDC 6400).
Data display:
Tektronix 4013 graphic display terminal.
Access to Gerber digital plotting machine.
Data processing time from 0 to 1 hour in NOVA; possibly longer in campus computer.

II. PARAMETERS

Up to 16 analog and 4 digital simultaneously

Events: experimental error <5%. Heel and Toe Contact. Times measurable to 1 millisecond.

Motions: experimental error <5%.

Treadmill:
Absolute linear and angular positions of body segments (with string transducers) in 1, 2, or 3 dimensions.
Relative angular positions at joints (with goniometers) in 1, 2, or 3 dimensions.
Accelerations.

Walkway:
Average velocity (Photo Detectors).
Relative angular positions at joints (with goniometers and cable connection to computer).
Accelerations (with accelerometers and cable connection to computer).

Forces: experimental error <10%.
Forces and moments in prosthetic limbs.

Physiological: experimental error <20%.
Electromyograms.
Electrocardiograms.
Oxygen consumption and CO_2 production.

III. PHILOSOPHY

The objective of the Locomotion Laboratory is to obtain experimental data on walking that provide meaningful measures of gait performance and lead to a better understanding of the mechanics of normal and pathological walking. Unanswered questions in the area of gait disability have been the primary motivation for development of the laboratory which focuses on the design of prosthetic and orthotic devices and related biomechanical studies of locomotion. Current limitations in the following three phases of locomotor rehabilitation emphasize the need for improvements in our understanding of the mechanics of human walking:

1. Diagnosis: Diagnosis of a locomotor disability requires identification of those specific abnormalities in walking patterns that characterize the disability.

2. Treatment: Establishment of a treatment program requires a recognition of the causes of the abnormal motions and an awareness of the requirements for maximal restoration of lost function.

3. Evaluation: Effective rehabilitation requires the ability to determine whether a prescribed treatment has benefited the patient.
Not only are techniques for measurement needed, but knowledge is also required of the functional significance of each of the variables measured,

in order to achieve objective evaluation of the degree of disability or the effectiveness of treatment.
First and foremost, measurements must be reasonably repeatable in order to be useful at all. Laboratory measurements have shown that virtually all gait variables are influenced to some degree by walking speed. Consequently, repeatable measurements can only be obtained when speed is taken into account. Careful attention must be given to the attachment of measuring instruments to body segments.

IV. PROJECTS

The accomplishments of the laboratory include contributions to a more basic understanding of human gait, effects of gait parameters on metabolic and mechanical energy expenditure, studies of physiological and psychological problems resulting from amputation, kinematics of joint action in the normal lower extremity, interpretation of gait studies leading to design criteria for improved prosthetic components, development of modular prosthetic devices, and development of biomechanical fitting and alignment principles for all levels of lower-limb amputation.

The emphasis of the research program has changed often to reflect the current interest and abilities of the professional and technical staff as well as the needs of the Veterans Administration. During 1976 the principal research was in the areas of biomechanical studies of human locomotion and engineering design and development of devices to aid the orthopaedically disabled. A more modest effort is undertaken in research, directed toward understanding the problems associated with spinal supports.

During 1977 the major effort of the laboratory will be related to the following projects: (1) assistance to VAPC in the procurement and testing of 50 production models of the UCBL-Four Bar Polycentric Knee. (2) Development of a new Shank Axial-Rotation Unit to minimize problems of rotation instability. (3) Completion of development and documentation for the Six-Bar Knee-Disarticulation prosthesis with potential for pneumatic swing control (4) Completion of development of a new metal heel SACH foot. (5) Development of a new friction stabilized knee unit. (6) Extension of a gait dynamics project to include more subjects. (7) A collaborative effort with the University of Uppsala in the testing of clinical gait evaluation.

II. DOWNEY, CALIFORNIA

ADDRESS
Pathokinesiology Service
Professional Staff Association
Rancho Los Amigos Hospital
12808 Erickson Avenue
Downey, California 90242

Director: Jacquelin Perry, M.D.

Deputy: Daniel J. Antonelli, Ph.D.

I. EQUIPMENT

Biomechanical.

Walkway:	Total length 20 m		
	Run-in 3 m	Effective length 15 m	Run-out 6 m
	Foot switch	Gait analyzer	Accelerometer
	Strobe	Cline	Video
	Electric goniometers		

Physiological.

Oxygen consumption, dynamometer, EMG surface and indwelling electrodes

II. PARAMETERS

Recorded simultaneously
Motions: Linear: Stride length, cadence, swing, stance, velocity
Angular: Hip, Knee, ankle by electric goniometers
Physiological: EMG and energy cost

Processing: Sampling rate: 500-20,000/s
Experimental error: ± 2%
Time: 1 hour to 2 days

III. PHILOSOPHY

To contribute to improved patient care by establishing and applying quantitative techniques to more accurately define disabled performance. To determine therapeutic effectiveness of clinical measures designed to improve function and correct deformities.

IV. PROJECTS

1. Interpretation of Muscle force from Quantitated EMG.
A series of studies are underway to quantitate electromyography and to develop a mathematical model for muscle. When completed electrical output of a muscle will be able to be used to estimate muscular force output. This is estimated to be at least a five year project. Studies will be of eccentric, concentric, fixed and variable velocity contractions, damping, signal definition and mathematical model development.

Downey cont.

2. Definition of Lower Extremity Muscle Action in Stroke, Cerebral Palsy, Head Trauma, Spinal Cord Injury and Muscular Dystrophy.
On-going clinical analysis of muscle function via EMG is routinely done to aid the surgeon in his operative decisions. Studied are walking EMG's using indwelling wire electrodes.

3. Correlation of Physical Impairment with Stride Characteristics.
Pre-operative, followed by a series of post-operative studies are done on all total hip and total knee replacement arthroplasties. Gait parameters such as velocity and single limb support are collected. These parameters are compared with the Harris factors in order to find the relationship of the two testing methods.

4. Energy Cost Determination.
Oxygen consumption studies are currently being done to define the efficiency of ambulation for spinal injured paraplegics, diplegic cerebral palsied persons, bilateral BK amputees and patients with muscular dystrophy. In addition pre- and post-treatment O_2 studies are being done on rheumatoid arthritis patients undergoing endurance training and patients with cerebral palsy participating in Rolfing treatment. A modified Douglas Bag method of expired air collection is used as patients traverse a 60 meter outdoor track. Heart rate, respiratory rate, and foot contact are telemetered to recording equipment to eliminate the need for cables.

5. Evaluation of Assistive Devices.
The laboratory evaluates assistive devices to determine effectiveness in aiding the patient's gait. Currently, a study of the effectiveness of different AFO's to support the collapsing tibia (i.e. inadequate ankle plantar flexion force) is being done. Gait parameters, knee and ankle motion and forces on the braces are being studied. The effect of light-weight vs standard BK prostheses on gait efficiency is being studied by oxygen consumption and gait parameter analysis. In another study in patients with joint disease the support forces and gait patterns using various walking aids will determine the proportion of body weight being supported on the lower extremity vs that on the supporting device. Presently the assistive devices are being instrumented for force measurement.

6. Development of Single Concept Instrumentation.
Currently a gait analyzer has been developed which is small enough and inexpensive enough to be used outside of major gait laboratories. This device monitors velocity and single limb support times. Velocity is a measure of gait efficiency, while single limb support time indicates weight bearing tolerance. A significantly lower than normal single limb support time would be caused by limb pain or instability.

III. PALO ALTO, CALIFORNIA

ADDRESS
Department of Rehabilitation Engineering
Children's Hospital
Stanford University
520 Willow Road
Palo Alto, California 94304

Director: E. E. Bleck, M.D.

Deputy: Maurice A. LeBlanc, C.P.

I. EQUIPMENT

a) Biomechanical walkway: freewalking with telemetry in area of 20m x 15m, foot switches and light pattern equipment to trace the trajectory of light measuring, particularly vertical displacement, physiological EMG telemetry with surface and indwelling electrodes, straingages to record postural shift, Nova computer.

b) Oxygen consumption measuring system for children on trackway with EKG linked to Nova computer.

c) Fixed 35mm cameras, overhead and lateral projections for recording light patterns.

II. PARAMETERS

Recorded singly
Motions: Linear: Stride length, cadence, swing, stance
Spatial Relations: Body segments
Physiological: EMG and equilibrium

Processing: 7 gait cycles
Time: 3 days

III. PHILOSOPHY

The laboratory is called a "motion analysis laboratory" and is part of the Rehabilitation Engineering Center at the Children's Hospital at Stanford. The philosophy is to conduct research and development for measuring objectively components of human locomotion, with the eventual aim of making this a practical clinical tool. It is hoped, eventually, that the laboratory will be able to give a clinician a reduction of the analog data to digital form and then to graphic printout as an analysis of the gait within one hour. This digital and graphic recording would be comparable to an electrocardiogram or an electroencephalogram.

IV. PROJECTS

1. A study of the spinal cerebellar system through quantitative measurements of postural reactions and motor coordination in normal and scoliotic children. Through these studies, it may be shown that idiopathic scoliosis is a central nervous system disorder and if so, then appropriate treatment methods might be devised and objectively tested. The expected date of completion of this project is January 1978. Force-plate measurements of

posture are made and the subject's ability to compensate for the posture is measured. The system is linked to a computer for reduction of the analog data to digital form and to graphic printout. In parallel with this, electronic and electrical methods to measure vestibular function are being used.

2. An eight channel electromyographic telemetry system, developed by NASA, is being linked to a computer. Footswitches are used to record the stance and swing phases of gait and these will be linked by telemetry to the computer as well. Electromyograph and foot switch patterns will be used to study a variety of clinical problems.

3. It is planned to study the energy requirements of various handicapping conditions in children, as well as the effect of orthotics and mobility aids on the energy requirements. This will necessitate measurements of oxygen consumption, EKG, etc., all linked to the Nova computer system.

4. The group is in the process of designing a television tracking system to measure joint ranges of motion during gait and other activities, linking this with a computer program for immediate reduction of data obtained and graphic printout. The clinical implications of this are that such a system could be used as a valuable objective examination of gait abnormalities, comparable to the EKG in heart function and the EEG in cerebral function.

IV. SAN DIEGO, CALIFORNIA

ADDRESS
Gait Analysis Laboratory
Children's Health Center
8001 Frost Street
San Diego, California 92123

Director: David H. Sutherland, M.D.

Deputy: Savio Woo, Ph.D.
Lester Cooper

I. EQUIPMENT

Biomechanical.

Walkway: Total length 18 m
Run-in 4.5 m Effective length 3.6 m Run-out 9.9 m
Force plate
Cine

Physiological.

EMG surface and indwelling electrodes

II. PARAMETERS

Both limbs recorded singly or simultaneously
Motions: Linear: Stride length, cadence, swing, stance, velocity, gait width
Spatial Relations: Joints and body segments
Angular: In three planes - hip, knee, ankle, etc., but not toes

Forces: Angular Moments: All joints in three planes
Ground Reaction: Vertical, AP and ML shear, center of pressure
Joints: All - compression, tension and shear
Instant center measurement capability
Bones: None
Musculature: Tension - individual as well as group

Physiological: EMG

Processing: Manual, Motion Analyzer, Computer

Rates: 25-500 frames per second - photosonic cameras
10-5000 frames per second - Hycam camera
Force plate: 1000/s
Experimental error: 2%
Time: 2 days

III. PROJECTS

1. Gait Studies of Normal Children in Their Growing Years.
Objective: (a) To provide a reliable data base for comparison of children with gait problems to children with normal gait. The purpose for this comparison is to provide an objective base for the treatment of gait disorders in children. (b) To study a hypothesis that regular initial

heel strike in stance phase in a child denotes the development of an adult gait pattern in terms of angular rotations at the hip, knee, and ankle in the sagittal plane. When this stage in gait has been achieved, sagittal plane rotations can be compared with adult normal values. Free speed cadence, walking velocity and step length are related both to height and age and must, therefore, be compared with age related normals. Transverse rotations are closely related to walking velocity, but if normalization of velocity is achieved by free speed cadence, rotations in the child requiring the establishment of normals by age for a proper establishment of the normal pattern.

2. Gait Analysis for the Muscular Dystrophy Clinic.
   Objective: (a) To provide reliable and comprehensive gait measurements of selected children with chronic muscle disease problems. (b) To investigate the abnormalities of gait produced by progressive muscular diseases. (c) To improve brace design.

3. Kinematic Assessment of Gait in Rheumatoid Arthritis as Modified by Implant Arthoplasty.
   Objective: The specific purpose of this proposal is to evaluate the effect of joint deformities of the lower extremity in rheumatoid arthritis on the adjacent joints in the same patient.

4. The Use of Gait Analysis to Achieve Precise Alignment of Lower Extremity Prostheses.
   Objective: To provide a precise, definitive method of aligning a lower extremity prosthesis that would eliminate time-consuming trial and error methods currently in use. This method would hopefully allow prosthetic alignment to be done more efficiently and would eliminate the need for repeated adjustments of present devices based on subjective patient response and on the "educated guesses" of the prosthetist. Movement measurement determinations with graphic representation of angular rotation, velocity, step length, and a variety of other measurements, will be carried out as well as force plates determinations of the floor reaction for both right and left extremities. Simultaneous electromyograms will be obtained to supplement movement measurements and force plate data recordings. Particular use will be made of force vectors derived from the floor reaction values to quickly and accurately permit alignment of the lower extremity prosthesis on the stump in a relationship that will be dynamically correct for the unique musculoskeletal problems of the involved patient and will achieve minimal energy expenditure because of this alignment.

5. Determination of the Effect of Plantar Flexors of the Angle Upon Walking in Normal Human Subjects.
   Ongoing project.

V. SAN FRANCISCO, CALIFORNIA

ADDRESS
Shriners Hospital for Crippled Children
1701 - 19th Avenue
San Francisco, California 94122

Director: Roger A. Mann, M.D.

Deputy: John L. Hagy

I. EQUIPMENT

Biomechanical.

Walkway: Details not available
Force plate   Foot switch   Accelerometer
Cine   Video

Physiological.

Oxygen consumption.   EMG surface and indwelling electrodes.
The equipment available in the gait analysis laboratory consists of four cine-motion picture cameras capable of 500 frames per second; a force platform; accelerometers; and electromyographic equipment.

II. PARAMETERS

Recorded singly or simultaneously
Motions: Linear: Stride length, cadence, swing, stance, velocity, gait width
Spatial Relations: Joints and body segments
Angular: In three planes - all joints except subtalar and toes
Forces: Angular Moments: In three planes - hip, knee, and ankle
Ground Reaction: Vertical AP and ML shear, center of pressure and torque

Physiological: EMG, nerve conduction, and energy cost

The parameters that can be studied on each individual walk cycle are as follows:

a) Angular Data

The angular data taken from cine-cameras are:

Pelvic Tilt	Femoral Rotation
Hip Flexion-Extension	Hip Rotation
Knee Flexion-Extension	Tibial Rotation
Plantar Flexion-Dorsiflexion	Knee Joint Rotation
Pelvic Obliquity	Hip Ab-adduction
Pelvic Rotation	Foot Rotation

b) Force Data

The forces available are taken from the quartz-crystal force plate and include:

Vertical Force	Torque
Fore-Aft Shear	Center of Pressure
Medial-Lateral Shear	

Processing: Sampling rate: 500/s
Experimental error: ± 2%
Time: 1.5 hours - 1 day

The processing equipment available is an 18-bit Electronic Processors, Incorporated Model 118 Computer System. This system includes two Diablo Disk Drives for storage; Read-Write Cassette Tape Recorders; Line Printer; and a 12-bit Analog to Digital Converter and Analog Plotter.

III. PHILOSOPHY

Any research that is conducted has to apply clinically to the individual patient. Each patient run through the laboratory for analysis first has a physical examination. EMG, force-plate and angular data are then gathered. Recommendations for surgery or treatment follow from data reduction. Clinical research has a major priority.

IV. PROJECTS

Those nearing completion are entitled "The popliteus muscle and its function in normal walking", "The initiation of gait" and "The role of the posterior calf muscle in normal walking". New projects are: "A complete study on the effects of jogging on the body" and "A study of 35 scoliosis patients in relation to their abnormalities in normal walking".

VI. SEATTLE, WASHINGTON

ADDRESS

Orthopaedic Biomechanics Laboratory
Seattle VA Hospital
4435 Beacon Avenue, South
Seattle, Washington 98108

Directors: F.G. Lippert, III, M.D.
G.S. Kirkpatrick, Ph.D.

Deputy: G.A. Spolek, M.S.

I. EQUIPMENT

Biomechanical.

Walkway: Instrumentation can be used in any location and is not confined to a specific walkway
Force plate
Miniature force transducers incorporated into shoe sole and heel
Strobe Cine

Microcomputer in laboratory, use of minicomputer and large computer facilities available; 16-channels of magnetic tape and 8-channels of paper recording equipment available; equipment for accelerometer studies; x-ray microradiograph equipment in laboratory; bone torsion testing equipment in laboratory; tension/compression testing equipment available; machine shop and electronics laboratory for assembling research equipment. Prosthetic research facilities at Eklund Hall and Veterans Administration Hospital which include walkways and interface pressure monitoring devices. Forceplate, treadmill, cinematographic motion analysis system located in Department of Physical Education.

II. PARAMETERS

Limbs recorded singly
Motions: Linear: Stride, cadence, swing, stance and gait width
Spatial Relations: Joints
Angular: Sagittal and coronal planes only - all joints except hip
Forces: Angular Moments: In three planes - all joints except hip
Ground Reaction: Vertical, AP and ML shear, center of pressure
Joints: Compression, tension, and shear in hip, knee and ankle, exclusive of synergistic muscle action
Bones: Compression, tension and shear - all bones

Processing: Manual, Computer

Data can be processed in analog state or digitally
Time from collection to presentation of data: 1 day

III. PHILOSOPHY

This group is devoted to basic research into loading environments of the joints of the lower extremities, and the derivation of exact three-dimensional motion patterns between the bones of the joints.

IV. PROJECTS

1. Development of a portable shoe-mounted force-measuring device which measures floor reaction forces and three angles. A portable micro-computer system processes data to yield three forces and the torque acting on the tibia will be used with a cinematographic motion analysis system based in the University of Washington, Department of Physical Education, to calculate forces acting on all joints during gait. The system is expected to be operational in summer 1977.

2. Patellar tracking through x-ray photogrammetry. This precisely measures the three-dimensional motion of the femur, tibia and patella as the knee is flexed from 0° to 90°. The system uses stereo x-ray heads and analytical photogrammetry (University of Washington, Department of Civil Engineering). This information is needed to be able to understand the load distribution through joints during gait. It is currently operational.

VII. SEATTLE, WASHINGTON

ADDRESS
Department of Rehabilitation Medicine Research
CC 814 University Hospital
University of Washington
Seattle, Washington 98185

Director: Justus F. Lehmann, M.D.

Deputy: C. Gerald Warren

I. EQUIPMENT

Biomechanical.

Treadmill: No details given

Walkway: Total length 10 m

Run-in 4.25 m	Effective length 1.5 m	Run-out 4.25 m
Force plate	Foot switch	Accelerometer
Strobe	Cine	Video

Physiological.

Oxygen consumption   Dynamometer   EMG surface and indwelling electrodes

II. PARAMETERS

Both limbs recorded singly or simultaneously

Motions: Linear: Stride length, cadence, swing, stance, velocity, gait width
Spatial Relations: Joints and body segments
Angular: In three planes - all joints except toes

Forces: Angular Moments: In three planes for hip, knee, and ankle
Ground Reaction: Vertical, AP and ML shear, center of pressure
Joints: Compression, tension, and shear in knee and ankle
Bones: Compression, tension and shear in femur, tibia, and fibula

Physiological: EMG, nerve conduction, and energy cost

Processing: Computer

Sampling rates: 200 Hz max.
Experimental error: 2% max.

VIII. VANCOUVER, CANADA

ADDRESS
Division of Orthopaedics
Faculty of Medicine
University of British Columbia
Vancouver, British Columbia
CANADA

RESOURCE ONLY. Mr. J. Foort
No gait laboratory facilities per se.

I. PHILOSOPHY

The philosophy of this resource group is that studies of a scientific nature have two aims: (a) to increase knowledge; and (b) to help solve clinical problems. Of these, our primary aim is to obtain information about gait on particular persons, so that we can formulate better treatment or aids for rehabilitation. A specific solution may be applicable to a group of people with similar disabilities. Thus, the thrust of gait studies can be said to be clinical and to relate to disabled people with lower limb deficiencies (but eventually other joints such as arms and spine). Also, we would be quite prepared to take data of a specific type and to forward it to a "mother laboratory" for interpretation to the end that the patient would benefit either by being classified in a way that would help in the selection of a solution to his problem, or learn directly what his disabling factors were.

II. PROJECTS

A goniometric study of knee function bilaterally, on elderly arthritic patients with and without knee implants, is underway. Also, we are doing normals as a base group to educate therapists. Effects of cane use on knee function is being studied, (Which is the best hand to hold it in for a particular disability - dominant hand, etc.). The effects of shoe wedging are being studied. How do changes on the abnormal side effect the normal? (Evidence is that the normal side is sometimes more affected by changes done on the abnormal side than appear on the abnormal.) Because our efforts are clinical in nature, they are ongoing, and will shift according to the patients for which goniometric studies are most appropriate. This should lead us to studying cerebral palsy people, amputees, etc. For our studies, we now rely heavily on engineers, but increasingly will depend on therapists. Eventually we expect to pull out completely and leave use of the equipment and system to the therapists, providing only services that they might need and interpretations.