AREA

NORTH AMERICAN - EASTERN

I. ATLANTA, GEORGIA

ADDRESS
Regional Rehabilitation Research and Training Center
Emory University School of Medicine
Atlanta, Georgia 30322

Director: Dr. J.V. Basmajian, M.D.

I. EQUIPMENT

Treadmill
14-channel recording system
Amplifiers and power supplies
16 mm Motion Analyzer
16 mm Camera
Split screen video systems
Foot switches
Goniometers
Balance platform
Indwelling or surface EMG electrodes
PDP 8/E Laboratory Computers

II. PARAMETERS

1. Both limbs singly or simultaneously. Stride length, cadence swing, stance and velocity.

2. Muscular tension, individual or muscle groups.

Analysis.

1. Computer analysis of 16 mm film or on-line analog to digital conversion of multi-channel EMG.

2. Computer analysis of balance in 3 components of force and location of point of force application.

Usage
Gait training

Kinesiology Laboratory: Size 24' x 47'

II. BOSTON, MASSACHUSETTS

ADDRESS
Gait Analysis Laboratory
Children's Hospital Medical Center
300 Longwood Avenue
Boston, Massachusetts 02115

Director: Sheldon R. Simon, M.D.

Deputy: Joseph Mansour, Ph.D.

I. EQUIPMENT

PDP 11/34; PDP 11/10
RK05 Disks (2)
DEC Tape system
Teletype
LPS
Tektronix 4014 Graphic Display Terminal
4631 Hard Copy Unit

Data Acquisition.

Walkway - Total length = 14 meters.
Run-in - 3.3m Effective length 2.6m Run-out 8m
Width 8 m
Cine - Frontal, Sagittal Plane (2)
Accelerometers
Force Plate (2)
Acoustic Foot Strike Indicators

Physiological.

EMG urface & indwelling electrodes.

II. PARAMETERS

All limbs recorded singly or simultaneously
Kinematic: linear-stride length, cadence, swing stance, velocity, base of support
Spatial relation - body segments
(upper and lower extremities and trunk)
Angular displacements, velocities, and accelerations of all joints and limb segments

Forces: Angular moments: In three planes for hip, knee and ankle.
Ground reaction - vertical, fore-aft, medial-lateral, center of pressure, torque.
Joints - compression, tension, shear in hip, knee and ankle-exclusive of synergistic muscle action.
Bone - compression, tension shear-lower extremity

Boston cont.

Processing:

a) EMG - Force Plate data-directly computer stored in line via 16 channel 12 bits differential input Analog-to-Digital Converter ± 5 volt input range.
Sample Rate: 500 Hz/channel with simultaneous computer recording, 16 channels.
Experimental Error - Force Plate 3%
Data acquired, processed, presented - 2 minutes

b) Motion-Semi-automatic system with film coordinates recorded and transferred via Vanguard Motion Analyzer and digitization system with GRAF PEN under computer hardware and software control.
Experimental Error - 3% 3-D coordinate location
Data acquired, processed, presented (1 hour + 1 day for film developing)

Software Programs:

1. EMG - Force plate on line data acquisition with high degree of flexibility for various clinical demands.

2. Motor acquisition from film with flexibility for single to multiple limb segments for man or animal, recorded in the laboratory or in the field.

Data Storage and Processing and Display Dual:

1. Equipment - track, magnetic tape, Tektronix 4014 Graphic Display Terminal, 4631 Hard Copy Unit
Software Program-Processing
-motion-parallex correction and absolute 3-D coordinate determination with interpolation of obscured points.

2. Digital filtering and calculation of linear and angular displacement, velocity and acceleration of designated anatomical markers, segments or center of gravity.

3. Energy of body segments of lower limbs determined about all 3 axes.

4. Linear and angular momentum.

EMG force plate - Digital Filtering via fast fourier transformation
computer graphics - variety of curve plotting routines and stick diagrams.

III. PHILOSOPHY

The long term goal of the Gait Analysis Laboratory at Children's Hospital Medical Center is to incorporate knowledge of bioengineering and neurophysiological practices in the performance of clinical research on patients with various gait abnormalities. Objective, comprehensive information on the pathological gait patterns of handicapped individuals - with emphasis on childhood disabilities - for the evaluation and improvement of their ambulatory status, is planned.

Specifically, the laboratory's objectives are: (1) the testing of new scientific principles and technological advances in a clinical setting and assisting in their development for clinical utilization, (2) the development of diagnostic procedures (using biomechanical parameters) by which the identification of significant pathodynamic features of the gait patterns of handicapped children may be ascertained, (3) the evaluation and efficacy of various existing treatment programs such as physical therapy, surgery, orthoses and prosthetic apparel and the utilization of biofeedback devices, (4) the appropriateness of the timing and selection of the various treatment modalities, and (5) the evaluation of new treatment modalities developed to improve pathological gait patterns of the handicapped child.

IV. PROJECTS

Since its inception approximately two and one half years ago, the Gait Analysis Laboratory has been involved in developing new systems and improving existing systems to measure and process simultaneously all the major parameters of gait. This includes muscle group activity, motion of all limb segments and the external body force as manifested by the foot-floor reaction force. The system was designed to facilitate rapid and accurate acquisition of data with a minimum of effort. A data storage system was developed whose characteristics lend themselves toward a flexible modality of utilization of each of the three measured and stored parameters; independent modes of utilization or in combinations of data displayed in various modes. The latter is particularly valuable in establishing communication between the engineer scientist and the clinician.

In order to assess the clinical applicability and to anticipate possible difficulties in examining and evaluating the pathological gait patterns seen in handicapped individuals, two pilot clinical studies - the gait patterns of normal children between the ages of two and five and the specific pathological gait existing in children with cerebral palsy and genu recurvatum - were undertaken and completed. The former group of patients provided a baseline for assessing our techniques and the equipment when used on a subject group with highly variable gaits and limited attention spans. The second group provided an additional source for evaluating errors and problems in a group of patients having limited ambulation potential. The results of these studies in terms of both the development of the laboratory system and the clinical relevance of such a system assured us that the gait analysis system as currently being developed is a clinically feasible data acquisition and processing system and can readily and accurately handle almost any type of pathological gait problem needing investigation. Work to date has provided leads as to which biomechanical parameters presently measured might be clinically significant.

On the basis of the results of past year's work, studies proposed for the forthcoming year include: (1) An expansion of the population of patients with cerebral palsy having genu recurvatum to determine if preliminary results previously noted are confirmed. The application of recently developed software programs of engineering principles (i.e. limb segment energy changes) to the population group in order to determine their clinical significance. (2) The study of the dynamics of the body's center

Boston cont.

of mass in a group of patients with scoliosis to determine the dynamic function of conservative measures in the correction of this deformity. (3) A clinical study pre- and post-treatment of a group of cerebral palsy patients who have dynamic equinus to determine what the effect of specific abnormality and its treatment has upon the overall ability and quality of the gait pattern seen. (4) The further development and incorporation into the system of additional computer programs to derive and calculate gait parameters which can be derived from measured kinesiological data and foot-floor reaction forces. (5) The further development of the data acquisition and handling system to incorporate 16 additional channels of force-plate and EMG date. (6) The clinical field testing of new technological advances and devices as it is requested of us and the devices become available, specifically the testing of biofeedback devices of a limb load monitor.

III. CLEVELAND, OHIO

ADDRESS
Electronic Gait Laboratory
Case Western Reserve University
Veterans Administration Hospital
10701 East Boulevard
Cleveland, Ohio 44106

Director: Ernest B. Marsolais, M.D., Ph.D.

I. EQUIPMENT

Biomechanical.

Walkway: Total length 10.0 m
Run-in 3.0 m Effective length 4.0 m Run-out 3.0 m
Automated 3-D strobe Video (Sel-spot)

Physiological.

EMG surface and indwelling electrodes

II. PARAMETERS

Both limbs recorded simultaneously
Motions: Linear: Stride length, cadence, swing and stance, velocity, gait width
Spatial Relations: Joints and body segments
Angular: Hip, knee, ankle, foot in three planes
Forces: Angular Moments: Hip and knee only at present in three planes
Ground Reaction: Vertical, AP and ML shear, center of pressure
Joints: Hip and knee only - compression and tension
Bones: Compression, tension, shear, in pelvis, femur, tibia, and fibula
Muscular Tension: Individual muscles and major groups.

Physiological: EMG, nerve conduction

Processing

Sample rates: 1,400/min.
Experimental error: ± 15%
Time: up to 7 days

III. PHILOSOPHY

It is the philosophy of our group that locomotion studies must provide information to help in clinical care of the patient. In order to do this:

a) Laboratory must be reasonably accessible.
b) Procedure must be relatively rapid and reporting must be relatively rapid.
c) The material must be presented in a fashion that it can be easily understood and utilized by the clinician.

Cleveland cont.

IV. PROJECTS

At present we are working on the following projects:

a) Development of a computerized clinical foot contact laboratory. This is in operation at the present time.
b) Development of computerized Selspot Laboratory. This laboratory will provide complete dynamic information including the kinetics and kinematics. It is hoped that this will be available for clinical use within six months. The laboratory will allow estimates of forces in the hip joint and knee joint, and eventually also the ankle.
c) Comparison of the Neural Muscular Assist with the Double Upright, AFO, the VAPC Clip, the Engen AFO, the FEPB and no brace at all in the treatment of the drop foot patient. This study will be completed in approximately another two months. This study evaluates use of an implanted electrical stimulation brace on a significant number of patients.
d) Feasibility study on use of electrical stimulation to augment hip control in the hemiplegic and hemiparetic. This is the first step in our effort to utilize electrical stimulation for synthetic gait in the paraplegic.
e) Evaluation of implanted instrumented total hip and total knees. These will telemeter loading information to the laboratory in conjunction with our routine gait analysis. It is hoped that these will provide essential design information.
f) Feasibility of use electrical stimulation in treatment of the cerebral palsy patient.

IV. GUELPH, CANADA

ADDRESS
Biomechanics Unit
Department of Human Kinetics
University of Guelph
Guelph, Ontario
CANADA

Director: Dr. J. Brooke
Prof. J. Charteris

I. PHILOSOPHY

The department has general interest in human biology, and human gait if of focal concern to it.

II. PROJECTS

Projects underway include the development and use of a technology to pursue kinematic (cyclographic) analyses of gait patterns. Our interests in this regard center on normative perspective; differences in pattern which may be attributable to ontogenetic features, sexual dimorphism etc. Presently we are conducting research into treadmill versus overground gait patterns at selected relative speeds, and are also investigating the process of habituation to treadmill walking.

We use a PDP Lab-8E minicomputer, interfaced with Tektronix CRT and a sonic digitizer (DEK). 16 mm film is made (processing delay 1-2 days) and projected from behind onto the digitizer plate. Requisite software has been developed in-hour for data-entry and processing according to the theory first enunciated by Grieve, and using a methodology not essentially dissimilar to that of Milner.

Additionally we have constructed a plexiglass walkway, after the model of Ducroquet, which permits multi-planar viewing/filming, and are in the process of developing footswitch technology for analysis of the temporal aspects of gait in projects such as listed above. An expert in this technology is joining our faculty imminently and will doubtless pursue this form of work.

V. HAMILTON, CANADA

ADDRESS
Locomotion Laboratory
Chedoke Rehabilitation Center
(Teaching Unit of McMaster University)
Hamilton, Ontario
CANADA

Director: Dr. Morris Milner, Ph.D.

Deputy: Dr. H. de Bruin

I. EQUIPMENT

Biomechanical.

Special self-aligning electrogoniometers for measurement of relative angular motions at hip, knee and ankle.

Heel and toe contact switches attachable to footwear.

Grass force transducers

Walkway: Total length 13 meters, run-in and run out ± 2 meters each.

Physiological.

EMG: Surface and indwelling electrodes, O_2 consumption.

Digitimer Equipment for electrostimulation:

4030 Timer Unit
2 x 2533 Isolators
1 x 3072 Stimulator Unit

Data Collection and Processing:

A stroboscopic flash photography system is available for collecting stick diagrams. These data can be fed to a CDC 6400 system by the use of a digitizer system. Appropriate programs for data management are available.

Selspot system for 3-D tracking has just recently been acquired. It is expected to implement this shortly.

Computer System:

On-line PDP 11/10 faculty incorporating 28k Core, RK11 Disk, Dec Tape system, Teletype with paper tape reader and punch, LPS system (8 A/D channels and 2 D/A), Tektronix 4006-1 Computer Display Terminal with 4631 Hard-Copy Unit.

Processing times: Virtually all on-line interactive processing.

Recorders:

1x Honeywell 1858 CRT Visicorder
Potential for 18-channels
Present capacity 8-channels

2 x Tektronix 7613 Storage Oscilloscopes

II. PARAMETERS

8 Analog channels and 2 Digital Channels simultaneously

Motions: Linear, stride length, cadence, swing, stance

Spatial Relations; body segments, angular variations in sagittal plane.

EMG - raw and average envelopes.

III. PHILOSOPHY

The Laboratory is concerned with locomotor function particularly as it relates to pathological conditions. It is considered essential to embody a team approach to studies of human locomotion in order to provide clinical relevance to research and developmental pursuits. The team is comprised of physiatrists, physiotherapists, bioengineers, electronic and mechanical technologists. Special attention is directed to the generation of "clinically digestible" displays of information utilizing appropriate computational facilities.

IV. PROJECTS

1. Follow-up of patients undergoing knee-joint replacements using angle-angle displays (Expected date of completion 1978)

2. Elucidation of key factors in hemiplegic gait. (Pending funding, date of completion 1979)

3. Multifactorial analysis of lower limb amputee gait using computer-generated displays. (Expected date of completion 1978)

4. Fundamental studies on functional electrostimulation of skeletal muscle to facilitate locomotion in cases of paralysis. (Continuing study)

5. The development of a charge-coupled device (CCD) sensor camera system for on-line tracking of body motions. (Expected date of completion - 1978)

VI. NEW YORK, NEW YORK

ADDRESS
Advanced Systems Laboratories
Bioengineering Research Service
Veterans Administration Prosthetics Center
252 Seventh Avenue
New York, New York 10001

Director: Anthony Staros

Asst. Director: Edward Peizer, Ph.D.

Projects Manager: Carl Mason

I. EQUIPMENT

Biomechanical.

Treadmill: 1-6 mph

Walkway: Total length 15 1/4 m

Run-in 4.0 m	Effective length 7.3 m		Run-out 4.0 m
Force plate	Foot switch	Elgons	Accelerometer
Barograph			
Cine	Video	Static and gliding cyclograph	

Physiological.

Oxygen consumption	Dynamometer	EMG surface electrodes

II. PARAMETERS

Each limb singly

Motions: Linear: Stride length, cadence, swing and stance, velocity, gait width
Spatial Relations: Joints and body segments
Angular: Sagittal and coronal planes only - all joints

Forces: Angular Moments: Sagittal and coronal only - all joints
Ground Reaction: Vertical, AP and ML shear, center of pressure
Joints: Compression, tension, and shear in all
Bone: Compression, tension, and shear in all
Muscular Tension: In individual and muscle groups

Physiological: EMG, energy cost

Processing - Manual

Time: 8 weeks

VII. PHILADELPHIA, PENNSYLVANIA

ADDRESS
Krusen Center for Research and Engineering
Temple University
Moss Rehabilitation Hospital
12th Street and Tabor Road
Philadelphia, Pennsylvania 19141

Director: Richard M. Herman, M.D.
Deputy: F. Ray Finley

I. EQUIPMENT

Biomechanical.

Walkway: Total length 13.0 m
Run-in 5.0 m — Effective length 2.0 m — Run-out 5.0 m
Force plate — Foot switch — Elgons
Force transducer
Cine — Ultrasound

Physiological.

EMG surface electrodes — Equilibrium

II. PARAMETERS

Recorded singly or simultaneously
Motions: Linear: Stride length, cadence, swing and stance, velocity, gait width
Spatial Relations: Joints
Angular: Hip, knee, ankle, sagittal plane, hip, subtalar, coronal
Forces: Angular Moments: Knee and ankle, three planes - stance only
Ground Reaction: Vertical, AP and ML shear, center of pressure

Physiological: EMG, nerve conduction

Processing: Manual, Computer

Sampling rate: up to 200/s
Experimental error: 10%
Time: 1/2 hour

III. PHILOSOPHY

Develop a facility and the expertise to conduct a balance of research, development, evaluation and clinical services directed toward increasing the independent mobility of the neuromusculoskeletally impaired.

a) Engineering: to develop tests and measures, design devices, and apply engineering principles in the rehabilitation process.

b) Clinical: to develop an integrated, multidisciplinary consulting group approach devoted to problems of the disabled, evaluate new devices and treatment techniques, and provide clinical training of health personnel in the utilization of advanced instrumentation and techniques.

Philadelphia cont.

c) Biological: to develop concepts of neural control of locomotion and to study role of eye-head-neck coordination in the control system.

IV. PROJECTS

a) Force Line Visualization. Employ a force plate, a cathode ray tube, an optical beam splitter, and necessary electronics to display the ground reaction force vector superimposed upon the image of the subject or patient. The purposes are to provide a teaching tool, an aid for the prosthetist/orthotist in making more precise and reliable judgements about proper alignment, and an aid for surgeons and physicians in assessing patients before and after surgery or other treatment.

b) Accelerometry: Ambulation Energy Meter. Employ triaxial accelerometer at lumbar area together with small stationary microprocessor and miniature tape printer to render an objective, permanent record of performance. Principle demonstrated in literature, but has not been previously reduced to practice. The output is a measure of energy expended against the external environment and is expected to discriminate among severity of disability and differentiate among treatments. Expected completion 1980.

c) Knee Mechanics and Orthotics. Assess various knee orthoses designed to enhance the medial-lateral alignment and/or stability. Expected completion 1979.

c) Therapeutic Applications of Phase-Dependent Reflex Reversals. Investigate the effect of somatosensory input on spinal cord integration during locomotion. Electrically stimulate superficial sensory nerves of cutaneous tissues to elicit or facilitate functional muscle synergies during walking in patients with central nervous system dysfunction. Results should further concepts of motor control and of rationale for future treatment.

e) Ultra-low Mass Prostheses. The advent of sheet polypropylene and vacuum-forming techniques makes it possible to provide lower-limb prostheses that weigh up to 60 percent less than conventional limbs (B/K: 24 oz. versus 64 oz.). The effect of light weight prostheses on locomotion performance will be evaluated. Expected completion 1978.

f) Clinical Classification and Functional Prediction. A Study of the Stroke Population: to clinically assess status in relation to general medical, demographic and function sets. Analyze gait performance to determine responsiveness to selected treatment. Search for predictors expressive of function on a basis closely identified with the nervous system. Expected completion 1978.

VIII. TORONTO, CANADA

ADDRESS
Amputee Research Center
Department of Orthopaedic Surgery
University of Toronto
West Park Hospital
Toronto, Ontario
CANADA

Directors: J.P. Kostuik, M.D., F.R.C.S.
G.R. Fernie, Ph.D., P. Eng.

I. EQUIPMENT

5 different gait deviations can be recorded using specially designed portable electronic instruments.

Displacement transducer system to measure postural sway.

Foot switch, counter and read-out devices to record the number of steps taken with a prosthesis over an extended period of time.

II. PARAMETERS

Postural sway: length of the locus in unit time, pattern of sway.

Gait deviations: control of the knee joint in A/K prostheses, limb load, forward trunk bending, lateral trunk bending, stride length.

Activity: daily count of the number of steps taken whilst in hospital, count over an extended period of time of up to 1 year.

Processing:

Present computer facilities are based on a Tektronix 4051 minicomputer, 32K core, 2 tape decks, hard copy unit, joy stick, graph plotter, multiplexer, digital volt meter and interface.

Data stored digitally. Presentation of data follows collection almost instantly.

IX. WATERLOO, CANADA

ADDRESS
Gait Laboratory
Department of Kinesiology
Waterloo University
Waterloo, Ontario
CANADA

Director: D.A. Winter, Ph.D., P.Eng.

Research Assistants: J. Cairns, B.Sc.
J. Pezzack, M.Sc.

I. ENGINEERING

Walkway: 32' x 4' x 1' high, with force plate in middle
Tracking cart with guide track at 12 ft. distance, TV and cine camera
6 channel biotelemetry system, with EMG, EKG, footswitches
Video tape recorder, 8 channel pen recorder, 10 channel storage scope,
8 channel instrumentation tape recorder
Master synchronization system for cine, telemetry and force plate

Conversion and Computing Facilities.

8 channel A/D to NOVA 1200 for EMG, force plate, etc.
Film coordinates converted via a NUMONICS film analyzer to NOVA 1200
All data transferred to IBM 370/158 or IBM 360/175

Software Programs - Saggital Plane only at present

Parallax correction and absolute coordinate determination
Digital filtering and calculation of linear and angular displacement, velocity and acceleration of any marker, segment or center of gravity
Energy of body segments, total body, energy changes during stride
Muscle moments, joint reaction forces
Linear or angular momentum, force impulse
Flow of mechanical power from muscles, across joints, etc.
Computer graphics - curve plotting, stick diagrams

III. PHILOSOPHY

Because our research is being conducted in a university environment in the Department of Kinesiology much of our directions are being influenced by interactions with our motor learning and exercise physiology groups. As such, gait is considered as one aspect of human movement on which we study normal and pathological movement. The major emphasis is therefore aimed at a better understanding of the mechanisms of normal and abnormal gait. We are not, at present, involved in routine clinical assessments; rather, our assessments of pathological gait are on a case study basis aimed at developing techniques and understanding mechanisms.

IV. PROJECTS

a) Mechanisms of Stability in Gait - cine, force plate and EMG. The interactive role of muscle activity at the hip, knee and ankle during weight acceptance is being investigated. Initial evidence is that a pre-programmed pattern results, and once this pattern has been validated the

ariance of this pattern will be examined in pathological gait (total knee replacements, hemiplegia, cerebral palsy). M.Sc. project - expected completion of study on normal - June 1977.

Generation, Absorption and Flow of Mechanical Power in Normal Gait - cine and force plate. The mechanical power generated and absorbed (-ve work) by the muscles at the hip, knee and ankle are being analyzed in detail during stance and swing, along with the intersegment flow of power across joints. A complete accounting can be made of the power flows at both distal and proximal ends of each segment, and then compared with the rate of change of energy of each segment. The basic information derived from these analyses will give a better indication of the role of each muscle group and also show basic patterns that may give further insight into the neuromuscular integration. Similar patterns will be analyzed in pathological gait. M.Sc. project - expected completion - April 1977.

Mechanical Energy of Walking as Cadence - cine only. A basic kinetic study is being done to test the hypothesis that we walk more efficiently at our natural cadence than at slower or faster speeds. The kinetic and potential energies of each segment are calculated, and the sum of all segment energies (total body energy) determined for each point in time. From this curve, the sum of the absolute energy changes is calculated over 1 stride to yield the mechanical energy requirements per unit distance walked. This will be compared for eight normal subjects at each of three walking speeds. Completion date - April 1977.

Case Studies of Cerebral Palsy Gait - cine and EMG. Assessments are being conducted on a population of cerebral palsy patients on a case study basis. Each case will be documented as to evident abnormalities in movement and EMG patterns. Pre- and post-surgery and therapy assessments will assist the surgeon and therapist in their planning and final assessment of their procedures.

X. WESTON, CANADA

ADDRESS
Amputee Research Center
Buttonwood Avenue
Box 4
Weston, Ontario
CANADA, M9N 3M6

Director: J.P. Kostuik, M.D.
G.R. Fernie, Ph.D.

The research at the center is largely concerned with the problems of the lower limb amputee. Concentration of effort is on the selection of the amputation site, problems of swelling and shrinkage in amputation stumps, problems of training elderly amputees to manage their prostheses safely.

The center had adopted the approach of fitting minature electronic sensors and counters to the patients to provide a record of the number of serious gait deviations made over a period of time.