AN OVERVIEW OF THE CURRENT STATUS OF EXISTING GAIT LABORATORIES

Morris Milner, Ph.D. P.Eng.

INTRODUCTION:

In the time allocated I hope to provide an overview of existing gait laboratories and incorporate a general review of present projects, methodologies and purposes, while recognizing the chief interests and directions of existing gait laboratories. Of necessity, this will have to be a limited presentation. Limitations will be those of the information at my disposal and the interpretations I inject. At the outset, I wish to express my appreciation to the various groups and individuals to whom I appealed for information and for their readiness in forwarding material.

CONCERNS OF GAIT LABORATORIES

Different gait laboratories have differing specific goals and objectives, usually arising out of specific interests of individuals, their backgrounds, constraints imposed by, or stimuli derived from the milieus in which they function and the resources they can muster. In an attempt to integrate all of known gait laboratory endeavor, overall concerns might be delineated as follows:

1. The study of normal locomotor function in all its facets including neural aspects, muscular activities, joint and limb motions and concomitant forces acting within and upon the subject, energy consumption and distribution, and times of contact with the walkpath surface. Statistical data to delineate "normality" are required and these must take cognizance of numerous factors such as speed of walking, anthropometric data, age, and repeatability of gait. Proper understanding of normal locomotion provides an effective backdrop for dealing with pathological, diagnostic, therapeutic and training aspects pertinent to gait.

2. The study of pathological conditions with a view to gaining complete understanding of their mechanisms on the one hand, and, on the other, the generation of pertinent follow-up data to mark the progress of a patient or subject.

3. The design, development and evaluation of rehabilitative aids and techniques, prostheses and orthoses to facilitate locomotor function in cases of impairment due to pathological conditions or circumstances arising from accidents.

4. The provision of guidance in regard to patient management where surgical intervention is suggested, and follow-up to confirm the efficacy or otherwise of procedures undertaken.

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5. To develop or inspire the development of equipment and techniques to enable efficient and effective gathering of pertinent data, its processing and presentation in suitably digestible forms for the end user to take the most appropriate action.

SETTINGS

Gait laboratories are to be found in various settings. These include University departments such as Physical Education, Kinesiology, Biomechanics and Anatomy. Other settings are within hospitals or clinics where patient services, usually of a rehabilitative character, are rendered. In some instances laboratories have the fortunate advantage of being located in settings where service, education and research are of approximately equal concern. This has the obvious potential advantages of mutual, beneficial interactions between these various segments and the promotion of the effective facets of usage of gait laboratories.

MULTIDISCIPLINARY ATTACK

Because of the challenging complexity of locomotor function in both normal and pathological states, and the possible variety of approaches to dealing with problems and issues arising in regard to descriptions of conditions encountered, consequent treatment and its efficacy, many disciplines have been attracted to the field. The disciplines include medical specialists drawn from physical medicine and orthopaedics, engineers, bioengineers, kinesiologists, anatomists, physical therapists, physicists, computer engineers and scientists. Thus many locomotion laboratories are able to launch multidisciplinary attacks upon the problems they must deal with.

GENERAL

In general, gait laboratories require substantial space and necessitate the incorporation of costly, sophisticated equipment. The space requirement is to ensure an adequate walkpath, to enable several steps of a steady-state walk to be achieved. A walkpath several meters in length is required to provide for suitable lead-in and run-off lengths. Where movement information is required in several planar views including overhead, underfoot, front, back and sides, a substantial space volume is necessary. Some space can be saved by resorting to special arrangements incorporating mirrors or by the use of treadmills. The latter are generally not favored for clinical studies largely because of the management of the patient who has to adapt to an additional machine component. Provision must be made for the incorporation of data lines which may be connected to the subject for the collection of signals such as footswitch contacts, electromyographic and electrogoniometric data. (These data might be telemetered). Data can be recorded (film, videotape, fm tape recorder) or taken to a data reduction center or, as is generally preferred, immediately submitted for direct analysis by a computer system. Recognizing the vast amounts of data involved with each locomotion run, the need for computational systems is underscored. This need is further emphasized when it is appreciated that for clinical purposes, rapid data processing and display are of great value. Incorporating such systems adds to the space requirement allied with locomotion laboratories. Most modern laboratories embody computer systems. Trained staff, drawn from a variety of disciplines, are required in the various aspects of measurement and recording of gait characteristics, interpretation of data and the delineation of future areas of pursuit. Where routine clinical studies follow from fundamental studies, stringent constraints are implied in terms of the maintenance of regular, efficient service. It is probable that the most significant gait studies will emerge from laboratories closely involved with clinical problems.

METHODOLOGIES

Some methodologies have already been alluded to; major methodologies are as follows:

1. Footswitches. Fitting footwear with switches to respond to contact times of the extremities with the walking surface, enables temporal information relevant to cadence, stance and swing times to be acquired and recorded. Several footswitches distributed underfoot facilitate a rendering of the time-space sequences which occur during the stance phase. Asymmetries between body sides and sequences of stance activity reveal valuable basic gait information. Some groups have developed special techniques to enable spatial data to be acquired regarding stride lengths and foot placement characteristics. There does not appear to be a universally used system.

2. Electrogoniometry. A number of groups are utilizing electrogoniometers to measure joint angle variations under dynamic conditions. Useful design concepts have emerged to deal with problems of self-alignment. This is important since joints are not simple hinge joints and their centers of rotation vary dynamically. Fixation is usually a problem and set-up is often time-consuming. Data can be transferred to a recorder by an "umbilical cord" or telemetry.

3. Kinematic Data. Whilst electrogoniometry constitutes one form of kinematic data derivation, the more general concerns are with trajectories of selected anatomical members and the velocities and accelerations (linear and rotational) of these members. Methods of data capture range from simple stroboscopic flash photography (or light interrupted photography) through cine-photography, video data capture and special optoelectronic devices. There is enormous tedium in having to extract data from still or cine-film on a frame-by-frame basis and while there are devices available to facilitate this process by generating the converted data immediately into computer compatible formats, technology has been moving rapidly towards making available special optoelectronic devices. These enable the direct conversion of movements of illuminated markers into electrical signals which can be entered into a computer system, undergo relevant processing and then be displayed appropriately. Patterns of movement are of concern in describing various pathologies.

4. Kinetic Data. Here investigators are concerned with measurements of ground reaction forces, joint reaction forces, torques, energy imparted by muscles to limbs and the like. The most widely used device is the force-plate, which enables measurements of ground-force reactions and the locations of

instantaneous centers of pressure. Coupling these data with simultaneously acquired kinematic information leads, by applied mathematical methods, other force variables such as joint reaction forces can be determined. Energy components can also be calculated. Accelerometers attached to limbs enable components of acceleration to be derived. Signal processing can lead to velocity and spatial information.

5. Electromyographic Activity. The use of surface and indwelling fine-wire electrodes, appropriately coupled to recording equipment, enables phasic activities of muscle groups to be determined. Programmatic sequences of muscular activity can thus be elucidated.

6. Energy Consumption. By determining oxygen uptake during the course of locomotion activity it is possible to gain insights regarding overall body energy needs.

COSTS

Exclusive of staffing and building construction, a laboratory which is to have up-to-date resources for performing locomotion studies would require capital expenditures approximately as follows:

Computer System with display and hard copy capabilities	$45,000
Optoelectronic Body Tracking System	$15,000
Multichannel electromyographic equipment, amplifiers etc.	$15,000
Force-plate system	$15,000
Total	$90,000

REGISTER OF GAIT LABORATORIES

Table 1 is an updated version of data reflected in a Preliminary Register of Gait Laboratories developed in 1975 by the Committee on Prosthetics Research and Development of the National Academy of Sciences. (Further work on this particular project is anticipated under the auspices of the Rehabilitation Services Administration). Since the original material was drawn up, some laboratories have augmented their capabilities, new ones have been developed and others have redeployed their resources, but most are at least maintaining their momentum. It should be noted that the laboratories are grouped by geographical areas and are listed from North to South.

Appendix 1 updates the earlier Committee on Prosthetics Research and Development information.

CURRENT PURSUITS OF VARIOUS LABORATORIES

The philosophies of a number of gait laboratories are presented in Appendix 1, together with an indication, wherever possible, of current projects being pursued. The activities of most of the groups are well-published and a number of the laboratories produce annual reports describing their activities.

CONCLUSION

Gait laboratories encompass human resources from a diversity of disciplines, physical resources which for rapid, effective data acquisition require much of what modern technology has to offer, and they require substantial space.

e these are generally costly resources to establish and maintain, they ould be nurtured with care in order to facilitate the realization of their ll potential in the area of clinical service which, ideally, should be olidly underpinned by appropriate research endeavor and effectively promulgated r meaningful educational thrusts.

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TABLE I.

SOME GAIT LABORATORIES AND PRINCIPAL PARAMETERS AVAILABLE WITHIN THEM

PRINCIPAL PARAMETERS AVAILABLE

	LOCATION OF GAIT LABORATORIES	SIMULTANEOUS RECORDING YES	SIMULTANEOUS RECORDING NO	LINEAR AND TEMPORAL	LINEAR FORCES: GROUND REACTION	LINEAR FORCES: SKELETAL IN BONES	LINEAR FORCES: SKELETAL IN JOINTS	LINEAR FORCES: IN MUSCLES	JOINTS: SPATIAL RELATIONS	JOINTS: ANGULAR MOTION	JOINTS: ANGULAR MOMENTS	PHYSIOLOGICAL DATA: E.M.G.	PHYSIOLOGICAL DATA: NEURAL CONDITION	PHYSIOLOGICAL DATA: ENERGY COST	UPPER-LIMB DATA
N. AMERICA WEST	Los Angeles - Rancho Los Amigos H.	X		X	X	X	X		X	X	X	X	X	X	
	Palo Alto - Children's Hospital at Stanford		X	X					X			X		X	
	San Diego - Children's Health Cent.	X		X	X		X	X	X	X	X	X			
	San Francisco - Shriners Hospital for Crippled Children	X		X	X				X	X	X	X	X	X	X
	San Francisco - UC Berkeley	X		X					X	X	X	X		X	
	Seattle - VA Hospital		X	X					X	X	X				
	Seattle - University of Washington	X		X	X	X	X		X	X	X	X	X	X	
	*Vancouver - University of B.C.									X					
NORTH AMERICA CENTRAL	Iowa City - University of Iowa (i)	X		X	X			X	X	X	X	X	X		X
	- University of Iowa (ii)			X					X	X	X	X		X	
	Houston - Texas Institute for Rehabilitation and Research	X		X					X			X	X		
	Rochester - Mayo Clinic	X		X	X	X	X	X	X	X	X				
	Saskatoon - Univ. of Saskatchewan	X		X					X	X		X			
	Winnipeg - Shriners Hospitals for Crippled Children	X		X	X	X	X		X	X		X			
	Milwaukee - VA Center	X		X	X			X	X	X	X	X			
N. AMERICA EAST	Atlanta - Emory University	X		X	X			X	X	X		X	X		
	Cleveland - Case Western U. (VA)	X		X	X	X	X	X	X	X	X	X	X		
	Hamilton - Chedoke Rehab. Centre	X		X				X	X	X		X	X	X	
	New York - VA Prosthetics Center	X		X	X	X	X	X	X	X	X	X		X	
	Philadelphia - Moss Rehab. Hospital	X		X	X				X	X	X	X	X		
	Waterloo - Waterloo University	X		X	X	X	X		X	X	X	X		X	
UNITED KINGDOM	Birmingham - University of Birm.	X		X	X										
	Glasgow - University of Strathclyde	X		X	X	X	X	X	X	X	X	X			X
	London - BRADU Roehampton	X		X	X				X	X	X	X			X
	+London - Medical Research Council	X		X	X			X	X	X		X			
	Manchester - University of Man.	X			X		X	X	X	X	X				
	Oxford - University of Oxford	X		X	X				X						

* Resource Group

\+ Redeployment of resources for purposes other than gait studies

APPENDIX 1

SOME GAIT LABORATORIES IN THE U.S.A., CANADA AND THE U.K.:

Their Physical Resources and Capabilities

Data made available as of February 28, 1977

Listed alphabetically by location.

NOTE: This material is an augmentation of data drawn from a Preliminary Register of Gait Laboratories, produced by the Committee on Prosthetics Research and Development, National Research Council, National Academy of Sciences, drafted in 1975.