International Society of Biomechanics Newsletter

SUMMER ISSUE 1989 N° 35

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You should know...

VISITING SCHOLAR AWARD CENTER FOR LOCOMOTION STUDIES

The Herbert and Jean Barron Visiting Scholar's Fund will provide one award for an international scholar to conduct research for up to three months at the Center for Locomotion Studies during 1990. Award includes support for travel, stipend and research related expences while at Penn State University. Areas of interest include:

clinical applications of biomechanical techniques,
studies of the diabetic foot,
reduced gravity locomotion, and
aging related issues.

Applications will be accepted until September 1, 1989 and awardee will be notified in November. Interested candidates should submit their vita plus a brief proposal outlining research goals to: Peter R. Cavanagh, Ph.D., Professor and Director, CELOS, Penn State University, University Park, PA 16802. Telephone: 814-865-1972.

TWO FACULTY POSITIONS: ORTHOPEDICS-BIOMECHANICS-ELECTROPHYSIOLOGY/ PHYSICAL AGENTS

The Physical Therapy Program in the School of Allied Professions at the University of Wisconsin-Madison seeks TWO assistant, associate, or full professors to teach graduate and undergraduate courses in area of specialization, direct student research, advise students, conduct research, prepare grant proposals for external funding, and participate in University service activities. Minimal qualifications include graduation from an accredited program in physical therapy; earned doctorate in biomechanics, physical therapy, or related field; evidence of potential for conducting research in area of specialization; and special expertise in one or more of the following areas: orthopedic physical therapy, biomechanics, electrophysiology/physical agents. Appointments will be on an academic year (9-month) basis with a possibility of limited summer school teaching or research support. Positions are tenure-track or tenured with initial date of appointment on August 28, 1989. Salary is competitive and dependent upon qualifications of appointees. Application deadline is March 20, 1989 or until position is filled. Letter of application, vita, and three letters of reference should be sent to Millard Susman, Ph.D., Acting Dean, School of Allied Health Professions, 1080 Medical Sciences Center, University of Wisconsin-Madison, 1300 University Avenue, Madison, WI 53706, USA. THE UNIVERSITY OF WISCONSIN IS AN AFFIRMATIVE ACTION/EQUAL OPPORTUNITY EMPLOYER.

You should know...

THE VOLVO AWARD FOR CNS INJURY RESEARCH 1989

In order to encourage research aimed at injury prevention analysis and mitigation of central nervous system injuries, the Volvo Company of Göteborg, Sweden, has sponsored an award for 1989 of US $ 5.000.

Papers entering the contest must contain **original** material, not previously submitted for publication. Multiple authorship is acceptable. The manuscripts, in the English language, should be full-length, including original illustration, in a form suitable for submission as an original paper (not postgraduate thesis) to a scientific journal. One original and 5 copies of each paper in full must reach the address below **not later than June 1, 1989.**

One of the authors should be prepared to come to New Delhi, India, at his own expense, for the 9th International Congress on Neurological Surgery, October 8-13, 1989 to present the paper and to receive the award.

The board of referees will be chaired by the undersigned and will contain members chosen by the Committee of Neurotraumatology of the World Federations of Neurosurgical Societies.

Please direct all correspondence to:

Ass professor Daniel Stålhammar
Department of Neurosurgery
Sahlgren Hospital
S-413 45 Göteborg, Sweden

THE ORIGINS OF SCIENTIFIC CINEMATOGRAPHY

Prehistory - Birth - Pioneers

This film series will include original sequences of the pioneers of scientific cinematography, reconstructions and re-animations of serial photographs as well as already existing film documents on the Origins of Scientific Cinematography. New shootings, animation and other special effects are used to show the functioning of the first cine-cameras and the pioneers' special techniques.

The three parts of the series on the Origins of Scientific Cinematography are in production and will have a total running time of about 180 minutes. The films will be completed by the end of 1988.

PREHISTORY

In the middle of the 19th century scientists like FARADAY, PLATEAU, PURKYNE etc. started creating equipments enabling to show dynamic processes out of series of still pictures for motion analysis. Some of these instruments have become widely known as optical toys, as for instance thaumatrope, phenakistiscope, stroboscope, daedaleum, phorolyt, etc.

BIRTH

This film presents the technical achievements and the iconographic documents of the three most famous fathers of scientific cinematography: the astronomer JANSSEN, the photographer MUYBRIDGE and the physiologist MAREY.

PIONEERS

Starting from Muybridge's and Marey's followers up to the applications in various scientific domains, the film shows the expansion of the techniques of scientific cinematography during the last years of the 19th and the beginning of the 20th century: ANSCHÜTZ, BULL, COMANDON, DEMENY, DOYEN, OMEGNA, PFEFFER, PÖCH are only a few names of those scientists and technicians who may be called the pioneers of scientific cinematography.

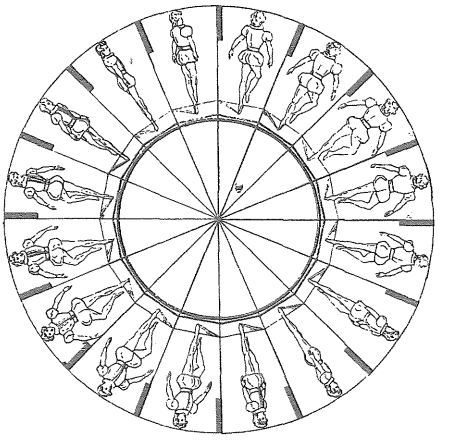
Produced by
INSTITUT FÜR DEN WISSENSCHAFTLICHEN FILM, Göttingen, F.R. Germany
Nonnenstieg 72, Telex 96 691
executive producer: Dr. Hans-Karl Galle
Int. + 49 551 - 202 101
in cooperation with
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS Audio-Visuel)
Paris, France
ISTITUTO LUCE spa
Rome, Italy

scientifique author and film director:
Virgilio Tosi

THE AUTHOR

VIRGILIO TOSI (Milan, 1925), director of scientific, cultural and teaching television programs, professor at the Centro Sperimentale di Cinematografia, Rome, state school for cinematography and television, UNESCO consultant and director of experimental researches on audiovisuals for C.N.R., Italian national scientific research centre, and RAI, Italian television network; has long been President of ISFA, International Scientific Film Association, of which he now is Vice-President; has published, among others, 'Cinematography and Scientific Research, UNESCO, Paris, 1977, 'Il cinema prima di Lumière', ERI (Italian Television's Publishing House), Rome 1984, 'How to Make Scientific Audio-Visuals for Research, Teaching, Popularization', UNESCO, Paris, 1984.

The scripts of the films are based on the historical researches by Virgilio TOSI during the last 12 years.



Laboratory Feature Center for ergonomics The university of Michigan

Part 2

(Part 1: see Newsletter n° 33, 1988)

Computer Keyboard Evaluation

In offices where large volumes of data are continually entered into or retrieved from a computer system, it is important that the keyboard operators work quickly and accurately with a minimum of discomfort. Preliminary investigations into the posture adopted in data entry have shown that the most common posture adopted in typing is such that the upper arm is abducted with the elbows away from the body, the forearms are unsupported, extended in dorsiflexion, and in ulnar deviation. These positions create static loads in the arms and shoulders, leading to unnecessary muscle strain, and operator fatigue. Unfortunately, current keyboard designs are such that, with minor variation, this is the only posture that the operator can adopt during the conduct of the task.

Data entry tasks should be designed to maintain the wrists in the same position as when the arm/hands are relaxed at the side of the body, i.e., the wrist should not be deviated from side to side, flexed towards the palm or hyper-extended towards the back of the hand.

In this project, we utilize the principles of hand and arm motion economy to design a standard QWERTY keyboard to enhance throughput and minimize fatigue.

This work is under the direction of Professor Dev Kochhar.

Study of Cumulative Trauma Disorders

Cumulative trauma disorders, such as tendonitis and carpal tunnel syndrome, are a major cause of worker suffering and lost work in many hand-intensive industries. Although repetiveness, forcefulness and posture are frequently cited causes of these disorders, acceptable exposure guidelines have not been proposed.

An epidemiological study is being performed to quantify the relative contributions of repetiveness, forcefulness and posture. The study entails in-plant analysis of jobs to quantify worker-exposure and physical examinations to quantify worker-response. The results will be used to develop work-design guidelines for controlling risk of cumulative trauma disorders.

This work is sponsored by the National Institute of Occupational Safety and Health. Principal investigators are Professors Armstrong and Fine, and Ph.D. candidate Barbara Silverstein.

Analysis of Forces and Postures in Hand-Intensive Work

Strength and posture are important performance parameters of manual work; they determine how much work can be done without adverse health effects. Special equipment and procedures are required for measurement of strength and posture because exertions and movements of the hand occur quickly.

The analysis of work posture is being approached in two ways: direct measurement and prediction. In the direct measurement approach, forces are estimated from surface electromyograms which are superimposed on a video recording of a worker doing the job. Posture is analyzed by observing the pictures or by recordings from goniometers attached to the workers joints also superimposed on the video recording. The system is controlled by a micro-computer that simultaneously records the data on a video floppy disk for further analysis.

In the predictive approach, hand forces are estimated from analysis of task attributes, such as the size and weight of the part. Force predictions are based on biomechanical theory and laboratory simulations of similar tasks. Posture predictions are based on simulations with drawing board manikins via a microcomputer-based computer-aided design program.

This work is supported by the Natural Institute for Occupational Safety and Health and Amp Inc. Principal investigators include Professor Thomas J. Armstrong, Ms. Linda Frederick, Mr. Charles Woolley and Mr. Stephen Tobey.

Hand and Arm Vibration

Exposure to vibration and low temperature impairs the sensitivity and dexterity of the hand. This impairment may be significant enough to reduce the quantity and quality of work and increase the workers' risk of developing a cumulative trauma disorder.

This work investigates the effects of occupational levels of vibration and temperature on manual work performance. Typical levels of vibration exposure associated with powered hand tools are determined from a survey in an automobile plant. The exposure then is simulated in the laboratory where the effects on hand sensitivity and force can be measured. The results will be used to recommend, if necessary, exposure guidelines.

This work is supported by the National Institute for Occupational Safety and Health and the Ford Motor Company. Principal investigators are Professors Monroe Keyserling and Thomas J. Armstrong and Mr. Robert Radwin.

Emergency Egress Studies

Although air travel is one of the safest forms of transportation, accidents still occur. Rapid egress of crash survivors is essential to protect them from possible fires and to administer

emergency medical treatments. Investigations of aircraft accidents has shown that emergency egress is a major problem in many crashes.

This work is concerned with the human requirements of emergency egress, both from the view of the occupant and the rescuer. It includes survey of egress procedures from typical commercial and business aircraft and simulation of the reach and strength requirements so that the major impediments to egress can be determined and to develop design guidelines for airframe manufactures.

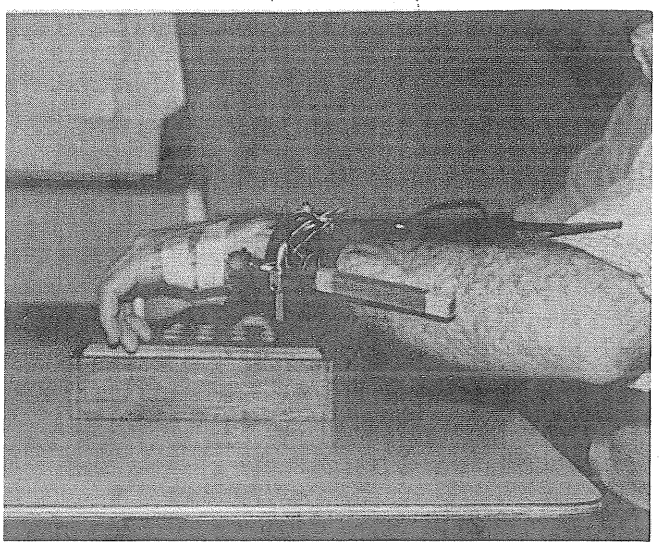
This work is supported by NASA and The University of Michigan Transportation Research Institute. Principal investigators include Professors Richard G. Snyder and Thomas J. Armstrong.

Physical Stresses from Associated Manual Work Activities

Many hand operations are performed in aircraft, automobile, data processing, electronics, medical products, meat processing, sewing and tire and rubber industries. The irregular shape of the hand and its nonlinear mechanical properties make it particularly difficult to describe these forces and their effects.

This work is connected with how objects should be designed to provide maximum control and at the stame time provide minimum stress and risk of injury. The first step of this work entails developing a biomechanical model for predicting how objects of a given size and shape distribute forces on the hand. The second step involves studies of the mechanical and physiological effects of these stresses on the hand that can be used to determine safe work limits.

This work is supported by AMP Incorporated. The principal project investigators are Professor Thomas J. Armstrong and Mr. Bryan Buchholz.



Development of a hand and wrist goniometer for field studies of hand postures in manual jobs

Evaluation of Neurotoxic Chemical Hazards

Industrial workers are often exposed to substances such as lead, mercury, solvents and pesticides which can potentially harm the health of their nervous systems in subtile yet serious ways. Because these neurotoxic substances can cause effects which include memory deficits, delayed response time, and impaired manual dexterity, sensitive tests are needed to aid in medical examinations of workers. It is important to detect impairments at an early stage when effects are reversible. Using our knowledge in ergonomics and psychology, we have developed test batteries which are used to evaluate the functional capacity which are used to evaluate the functional capacity of workers' nervous systems. Tests include measurement of sensory functions, perception, memory and psychomotor skills. We have recently completed a study of the effects of mercury exposure in industry. Results showed that our tests are very sensitive to early neurotoxic mercury effects, and have provided improved guidelines for acceptable levels of mercury exposure in industry.

We have also completed a study of several hundred workers exposed to organic solvents in painting and printing operations. In this study there was no evidence that solvents have neurotoxic effects when exposures are below current threshold limit guidelines.

The principal investigators in these studies have been Professors Gary Langolf and Larry Fine. Support has been provided by NIOSH grants and Olin Chemical Company.

Postural Analysis Methods

Awkward working postures are frequently cited as a contributing factor in the development of occupational cumulative trauma disorders. Postural stress is frequently not considered during job evaluations because existing posture analysis systems are tedious to use and time-consuming. The goal of this project is to develop a simple, computer-aided system for analyzing work posture in real time.

A PC-based system for the real time analysis of trunk and shoulder posture has been developed. Additional activities are planned to expand the capability of the system to other joints and to develop a hand-held version of the system. The results of this activity will enable ergonomists and engineers to quickly describe and analyze the postural requirement of work. The principal investigators are Professor Keyserling and Research Engineer Charles Woolley. This research is sponsored by the Ford Motor Company.

Injury Surveillance Systems Development

The ability easily and effectively identify jobs that create excessive injuries (particularly chronic musculoskeletal injuries) does not exist. This is the result of fragmented or missing computerized data bases, and the complexity of the information and statistical systems needed for such analyses.

This project is an attempt to develop a method and information system which will allow effective injury surveillance of industrial jobs. Pilot study of 450 jobs is underway to develop and evaluate the system. Three types of data are being used to construct the information system: (1) Health status data acquired from medical evaluations of workers performing a variety of jobs, (2) physical stress data acquired during ergonomic evaluations of the jobs, and (3) job assignment data which links the results of the medical evaluations to the results of the job analyses.

To date, approximately 200 workers have been medically evaluated for shoulder and back injuries, and their jobs have been videotaped and ergonomically measured. Using three different biomechanical and postural stress analysis systems the resulting data have have structured for use on a PC-based data management system.

The results of this study should provide the basis for an effective injury surveillance system, and will also provide guidance as to which jobs have excessive shoulder and back injuries and lost work days.

The work is being jointly sponsored by the Ford Motor Company and Firestore Tire and Rubber Company. Professors Lawrence Fine, Gary Herrin, and W. Monroe Keyserling, and Research Engineer Charles Woolley are the principal investigators.

A PC postural analysis method has been developed to evaluate videotapes of jobs requiring awkward work postures

Automobile Controls and Displays (MVMA, Ford)

A series of studies have been conducted by Center staff through the UM Transportation Research Institute concerning ergonomic aspects of instrument panel design. Some of the problems studied are the design of multifunction stalk controls, the development and evaluation of pictographic symbols to label controls and displays, driver understanding of warning displays, driver understanding of electronic fuel and engine gauges, and comprehension of advanced speedometers and tachometers. The results from these projects have been used to help engineers design new instrument panels.

Biomechanics of Pushing and Pulling Materials

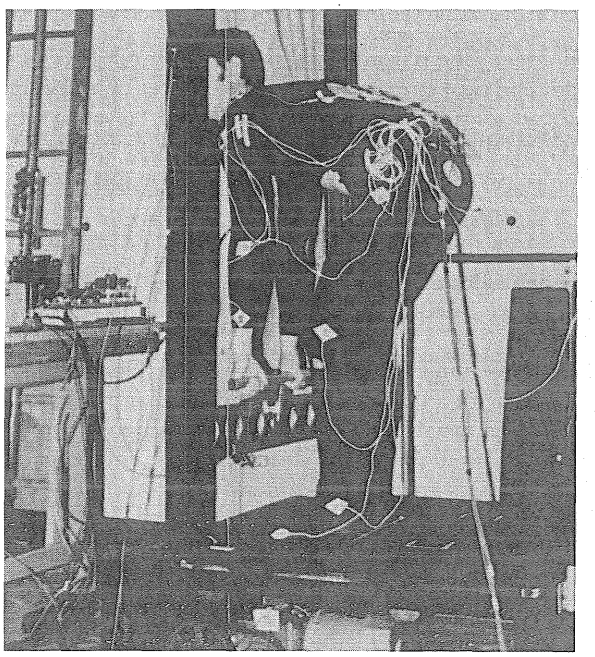
It is reported that manual pushing and pulling of materials account for approximately 20 per cent of over-exertion and slip-related injuries in industry. A three-year study sponsored by NIOSH was undertaken to develop a more fundamental understanding of how cart loads, handle positions, movement speeds, and postures affect stresses on the low back and foot slip potential. The study involved the development of a dynamic biomechanical model, which was then validated and refined by a series of laboratory studies. This has resulted in a unique model and laboratory to simulate cart pushing and pulling activities.

The project had been directed by Dr. Robert Andres with assistance of Ph.D. students Mark Redfern and Don Bloswick.

Low-Back Biomechanical Studies

Low-back pain, often chronic in nature, is a predictable end result for those workers engaged in manual exertions and activities requiring awkward postures. A series of earlier studies documented how certain work requirements overstress the lumbar spine. Recent studies have concentrated on how specific work postures assumed by individuals during load lifting can adversely affect the back. This has required modifications of our earlier static models of the lumbar back to include additional muscles and inertial loads. A dynamic lifting simulator has also been developed to assist in these studies.

The project has been directed by Dr. Chaffin with principal investigators Drs. S. Kumar (University of Alberta) and C. Anderson (Back Systems Inc.), while they were with the Center. Sponsorship was been provided by NIOSH, Owens Corning Fiberglas, Marathon Oil Foundation, AMP, and Firestone Tire and Rubber Company in the last couple of years.



Subject being studied with EMG and Selspot systems on Dynamic Lift Simulator

RESEARCH FACILITIES

The Center for Ergonomics laboratory occupies over 5000 square feet in the Industrial and Operations Engineering Building. The Center's chief facilities include specialized laboratories for biomechanics, work physiology, cumulative trauma, work measurement, and human factors research. Each of these laboratories is connected to a general-purpose laboratory computer which can control and monitor individual experiments. The facilities also include an electronics and machine shop which is equipped to construct, calibrate and maintain instrumentation and apparatus.

Human Factors Facilities

The Center is equipped to measure all facets of human perceptual, information processing, and motor performance. A major feature of the Center is a computer-controlled, multiple response facility which is used in teaching and research in a variety of human factors experiments. 'Button pressing' response stations are provided to simultaneously test up to 24 subjects. The computer-controlled devices for stimulus presentation include cathode ray tubes, techistoscopic slide projectors, a voice synthesizer, an audiometer, light panels, digital displays and other specialized devices. The equipment is currently used in experiments involving sensory threshold determination, evaluation of visual instrument designs, speech communication, masking effects of noise, human sensory judgments, information processing and short term memory.

The Centre also has an inventory of a wide variety of psychomotor tests, many of them computer-controlled. Major items include a battery of tests used to evaluate effects of worker exposure to neurotoxic substances in industry, eye movement transducer (corneal reflection and 'Stark' photoelectric types) and a television-computer tracking system for analysis of human movement patterns. Recording equipment such as FM tape recorders and strip chart recorders are available. The Center also has computer-controlled video equipment for micromotion analysis.

Equipment for environmental measurement includes light, sound, and heat stress measurement devices. These include precision sound level meters, octave and 1/3 octave band analyzers, illumination meters, Prichard type photometers, humidity sensors, anemometers, and globe thermometers.

Biomechanics and Work Physiology Facilities

The biomechanics and work physiology laboratories are equipped with a variety of equipment for anthropometric, strength and metabolic measurement. Anthropometric equipment includes mobility and strength cages, anthropometric measuring sets and a three-dimensional computer kinesiometer. A variety of instrumented strength measurement equipment includes custom-built digital force monitors, dynamometers, an eight-component force platform, a dynamic strength apparatus, and an instrumented ladder. Complete equipment also exists for analysis of electromyographic signals in conjunction with strength and muscle fatigue testing. The above-mentioned equipment represents a sampling of major terms.

In the area of work physiology, the laboratory also has complete equipment for measurement of human endurance in physically stressful environments.

ERGONOMICS AFFILIATES PROGRAM

In addition to the sponsored research projects listed in this document, there are other organizations who sponsor research through their participation in the Ergonomics Affiliates Program. This program facilitates an alliance between industrial and clinical organizations and the Center in areas of common ergonomic interest. Funds generated by this program and interaction with the Affiliates are valuable resources used to pursue research into meaningful, workplace ergonomic problem areas. For information about the Ergonomics Affiliates Program please contact Randy Raboum at the Center. Current Affiliates Program members include:

Sheller-Globe
Association of American Railroads
GenCorp
Sonoco Products Company
General Industrial Equipment Company

Computer Facilities

The central computing for the laboratory is currently based on two Hewlett-Packard 1000 mini-computers, an Apollo terminal, and 12 personal computers dedicated to experimental tasks. The computers are interfaced for laboratory and field data collection. Peripheral equipment includes analog to digital converters, graphics terminals, digital to analog converters, magnetic tape, and printers. Lines and remote terminals allow computer control to experiments in varous rooms throughout the laboratory.

For further information

Inquiries should be addressed to:

Center for Ergonomics
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1205 Beal Avenue
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The University of Michigan
Ann Arbor, Mich. 48109-2117

Telephone: (313) 763-2243

Thesis abstract corner

THE FUNCTIONAL DISABILITY AND GAIT OF SUBJECTS WITH ANTERIOR CRUCIATE LIGAMENT DEFICIENCY

by

Peter J. McNair

A thesis presented as a part requirement for the degree of Master of Physical Education of the University of Otago

Supervisor: Bob Marshall

ABSTRACT

While considerable research has been conducted on ACL deficiency few studies have examined the gait of subjects with this knee condition. Evaluation of the gait of subjects with an ACL deficient knee would provide useful information to surgeons and clinicians concerning the compensatory techniques used and provide insights into factors which are important in ACL deficient gait.

Ten subjects with unilateral ACL deficiency participated in this study. Each subject answered an extensive questionnaire outlining their knee injury and their return to sports activity. Subjects also underwent a physical examination by an orthopaedic surgeon. A bilateral limb comparison was undertaken in the following areas: Isokinetic muscle testing was carried out at joint angular velocities of 60, 180 and 300 deg/sec. Each subject was filmed while running on a treadmill at a recreational jogging pace. EMG data was collected from the vasti lateralis and biceps femoris during running while accelerations at footstrike were measured at the proximal tibia.

The questionnaire results showed ACL deficiency was associated with considerable functional disability, particularly during sports which involved pivoting, sudden stops and jumping activities. While subjects had decreased their level of sports participation they were still playing at levels where they experienced 'giving way' episodes periodically.

Physical examination revealed all subjects to have anterolateral instability.

Isokinetic muscle testing revealed a significant quadriceps deficit in the ACL deficient limb.

EMG profiles showed increased quadriceps activity during a 200 ms period centred about footstrike and this may be related to quadriceps strength deficits in the ACL deficient limbs. Earlier EMG activity was observed from the biceps femoris of the ACL deficient limbs shortly after footstrike and this was thought to occur in an effort to increase stability of the knee joint at this time.

While no statistically significant differences were observed in the angle of the knee at footstrike, the net amount of stance phase knee flexion or the tibial accelerations, it was evident there were widely diverging strategies adopted by subjects to deal with their knee condition during running.

It was concluded that even during straight line running, an activity not usually thought to affect individuals with ACL deficiency, marked compensatory techniques may be observed.

UNIVERSITY OF SALFORD

MENS NEW RULES AND LADIES JAVELIN: AERODYNAMICS, FLIGHT SIMULATION AND BIOMECHANICAL CONSIDERATIONS

by

RUSSELL J. BEST (M. Sc.)

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ABSTRACT

The javelin event, using men's old rules specifications, has been reported in the literature from various aspects including aerodynamics, biomechanics, and computer flight modelling. However, men's new rules specifications, implemented by the IAAF in 1986, and the ladies event have received scant attention. The objectives of this study were to develop a 2-dimensional computer flight simulation model for a TI Apollo ladies javelin and men's rules javelin, and to validate these models using high speed cinematography of British national javelin squad athletes.

Aerodynamics force and moment data for a range of angles of attack (b) and air speeds (v) were measured in a large working section environmental wind tunnel at the University of Salford. Findings included a constant centre of pressure location (d) 0.225 m behind the men's javelin CG (5 b 30°), but a variable location for ladies javelins (d = 1/(2.04 + 0.123b), 5 b 35°7. Aerodynamic forces and moments were found to be functions of the square of air speed to high degrees of correlation (r 0.98) with no observable Reynold's number effect for any javelin (5 v 30m/s).

A computer simulation program predicting javelin positions, angles, velocities and angular velocities at any time during flight was developed incorporating the aerodynamic data and solving the remaining simultaneous differential equations of motion numerically using a Runge-Kutta fourth order technique. Using this program it was possible to predict optimal release conditions for any athlete. Release speed was found to be overwhelmingly the most important variable influencing range, simulated optimal release angles were 6.5° higher for the men's new rules javelin compared with old specification simulation results from previous studies, optimal release pitch rates were found to be negative, and optimal release angles of attack were negative for men but positive for ladies javelins at the elite level of performance.

The men's and ladies javelin flight simulation programs were validated using comparative data from release parameter sets of real throws of known range obtained from high speed cine film (100Hz). However, validation was not possible to the degree required for use as an accurate coaching aid owing to the inappropriate rigid body javelin model used in this and previous javelin cine studies. Javelin flutter at a frequency of 22-23Hz meant that the javelin could not be expressed as a rigid body and resulted in digitizing errors which translated to 1m/s error increments in release speed, 25% errors in release pitch rate and increments of up to 8m in terms of simulated range. The range decrement associated with the change from old to new rules men's javelins was measured separately to be at least 9.85%.

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THE EFFECTS OF LANDING ON LOWER EXTREMITY FUNCTION

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ABSTRACT

The investigation of force attenuation and performance mechanisms during landings may help identify performance strategies used during the activity. The purpose of the study was to evaluate the effects of height (3), distance (3) and landing technique (3) on impact forces. In addition, the effects of selected joint kinematics on landing technique were evaluated.

Three semi-skilled male volunteers served as subjects. The experimental set-up consisted of a force platform interfaced to a laboratory computer, a high speed camera, and an adjustable height jumping tower. Three techniques were defined based upon the knee joint angle during landing: stiff (ST; greater than 110 deg), slightly flexed (SL; 75 to 110 deg) and fully flexed (FF; less than 75 deg). Subjects were filmed (100 fps) while performing three right foot landings on the force platform (500 Hz) for each combination of height (40, 60, 100 cm), distance (40, 70, 100 cm) and technique (ST, SL, FF) for a total of 81 trials. Temporal and kinetic data describing the maximum impact force value(s) and joint position and velocity data were used in the analysis.

First (F1) and second (F2) maximum vertical forces and times of occurrence of F1 and F2 (T1 and T2) were analyzed using group and single subject three-way analysis of variance (ANOVA) techniques. Single subject regression models were used to identify critical performance factors associated with the forces. A regression model was also computed to identify the most important kinematic variables related to technique.

The group ANOVA results for F1 and F2 indicated significant (p 0.05) height (H), distance (D) and technique (T) main effects and an H x T interaction, respectively. Individual subject ANOVAs produced different results with S1 exhibiting H and T main effects for F1 and F2 while results for S2 and S3 indicated confounding interactions. Group ANOVAs computed on T1 and T2 resulted in significant H x D and D effects, respectively. The within subject ANOVAs computed on T1 and T2 suggested variability of performance with none of the individual subject ANOVA results being similar to those of the group models.

The regression analyses using F1 as the dependent variable and H and D as the independent variables explained 57.6, 82.9 and 40.5% of the variance for the three subjects, respectively. The incorporation of T as an independent variable improved the predictions for S1 (81.7%) and S2 (83.3%) but not S3.

Substitution of selected kinematic variables describing ankle, knee and hip joint positions and velocities for T produced a poorer model for S1 (56.7%), a nominally improved prediction for S2 (83.4%) and a greatly improved prediction model for S3 (80.9%). Prediction of F2 from H and D resulted in 31.9, 19.7 and 10.1% explained variance, respectively. The addition of T improved all subject models (72.8, 60.4 and 59.1% explained variance) and substitution of kinematic variables for T produced models accounting for 37.7, 81.[illegible] and 88.0% explained variance for the subjects, respectively. Prediction of T from kinematic variables produced models accounting for 13.1, 74.0 and 63.1% of the variance for the three subjects.

Results of the statistical analyses suggest that different performance strategies were used by the subjects to accommodate to the demands imposed by the various landings investigated. In addition, the combined use of ANOVA and regression statistical techniques provided additional insight into the incorporated strategies and underlying mechanisms affecting the performances. The ANOVA analyses identified main and interactive effects while the regression models provided more specific information indicating respective variable contributions to performance.

VRIJE UNIVERSITEIT AMSTERDAM

Werkgroep Inspanningsfysiologie
en Gezondheidskunde

MECHANICS AND ENERGETICS OF SWIMMING

H.M. TOUSSAINT

Submitted for the fulfillment of the requirements for the degree of Doctor of Movement Science

Promotor: prof. dr. A.J. Sargeant

dr. A.P. Hollander

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Parts of the present thesis are published:
Toussaint, H.M., G. de Groot, H.H.C.M. Savelberg, K. Vervoorn, A.P. Hollander and G.J. Van Ingen Schenau. Active drag related to velocity in male and female swimmers. J. Biomechanics 21, 435-438, 1988.
Toussaint, H.M., A. Meulemans, G. de Groot, A.P. Hollander, A.W. Scheurs and K. Vervoorn. Respiratory valve for oxygen uptake measurements during swimming. Eur. J. Appl. Physiol. 56, 363-366, 1987.
Toussaint, H.M., A. Beelen, A. Rodenburg, A.J. Sargeant, G. de Groot, A.P. Hollander and G.J. van Ingen Schenau. Propelling efficiency of front crawl swimming. J. Appl. Physiol. 65, 2506-2512, 1988.

ABSTRACT

Due to the aquatic environment there are some difficulti[illegible] to overcome in the study of swimming. For instance the power output the swimmer produces is difficult to measure. Some of the power output is necessarily expended in giving water a kinetic energy change, since the propelling thrust is made against masses of water that acquire a backward momentum.

Hence the power output (Po) is apportioned between that part used to overcome drag (Pd) and that part which gives water a kinetic energy change (Pk).
Hence

$$Po = Pd + Pk \quad (1)$$

It will be obvious that the latter component Pk is rather difficult to measure. However, the apportionment of Po into Pd and Pk could be an important determinant of swimming performance. This idea is given expression in the concept of propelling efficiency ep (Toussaint et al 1983)

(2)

The measurement of the component powers of the total mechanical power produced by the swimmer was made possible by the development of the system to measure active drag (MAD-system, Hollander et al, 1986). With suitable instrumentation this system allows active drag to be directly measured for the first time.

Active drag related to velocity
The drag force on the swimmer while swimming the front crawl is related to the swimming velocity raised to the power 2.12 1 0.2 (males) or 2.28 1 0.35 (females). Most subjects (29) showed rather constant values of , but 12 subjects gave significantly (p 0.01) stronger or weaker quadratic relationships. Differences in drag force and coefficient of drag between males and females (drag at 1 m.s-1 28.9 5.1 N, 20.4 1.9 N, drag coefficient: 0.64 0.09, 0.54 0.07 respectively) are especially apparent at the lowest swimming velocity (1 m.s-1), which becomes less at higher swimming velocities.

Mechanical efficiency of swimming
Mechanical efficiency can be defined as the ratio of the power output to the power input. The power input was assessed by use of the MAD system. The estimation of power input from steady state oxygen uptake measurements does not present major problems, provided that the respiratory apparatus does not increase body drag.
A respiratory valve was developed whereby the inspiratory and expiratory tubing was arranged in-line and moulded over the swimmers head. Using the MAD system the effect on total body drag due to the addition of the respiratory apparatus was evaluated to be negligible. This apparatus was applied in the determination of mechanical efficiency in a group of male (N = 6) and female (N = 4) competitive swimmers. The mechanical efficiency ranged from 5 - 9.5%. At equal swimming speed the male competitive swimmers demonstrated a higher mechanical efficiency. However, this was due to the higher power output required by the male swimmers at a given speed. At the same power output the values for the mechanical efficiency do not differ between the male and female competitive swimmers.

Propelling efficiency of swimming
To determine the propelling efficiency of swimming it is necessary to measure Pk. This can be done by comparing at the same velocity the Pi swimming free, where Pi reflects Pd Pk, with the Pi obtained while swimming on the MAD system (Pk = 0, since the push off is made against a fixed point). For the four top class swimmers studied the propelling efficiency was found to range from 46 - 77%.
To evaluate the significance of the propelling efficiency as a performance determining factor, the ep of 6 competitive swimmers was compared to the ep of 5 triathletes. Using regression equations the data was interpolated and the groups were compared at equal rates (900 Watt) of energy expenditure. The groups did not differ in mechanical efficiency, stroke frequency, and work per stroke. There was a difference in distance per stroke (1.28 m vs 0.99 m), and mean swimming velocity (1.11 $Jm.s^{-1}$ vs 0.90 $m.s^{-1}$). The difference in swimming speed between the two groups can be explained by the fact that the competitive swimmers can use a much higher proportion of their power output to overcome drag (44 W vs 30 W). At the same time the competitive swimmers expend less power in moving water backwards (28 W 0 vs 390 W). This difference in apportionnement of the power output can be characterized as the propelling efficiency. Mean (1SD) propelling efficiency for the competitive swimmers was 62 ± 6% but only 44 ± 4% for the triathletes.
Since propelling efficiency was shown to be an important determinant of swimming performance the influence of contributing factors was considered. One of them, the artificial enlargement of the propelling surfaces of the hand, resulted at a given velocity in a decrease in energy expenditure (6%), power output (7.6%) and work per unit distance (7.5%). At the same time increases were seen in propelling efficiency (7.8%) and work per stroke (7%). The increase in distance per stroke and the decrease in stroke frequency could be explained by the increase of the propulsive area.

Future directions
It is obvious that the technique of the swimmer determines the level of propelling efficiency. However, the present method employed to determine the propelling efficiency does not relate technique to it directly. For a more thorough understanding of swimming it seems imperative to develop methods that relate the movement pattern of the swimmer to their propelling efficiency.

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Toussaint, H.M., F.C.T. van der Helm, J.R. Elzerman, A.P. Hollander, G. de Groot, and G.J. van Ingen Schenau. A power balance applied to swimming. In: A.P. Hollander, P.A. Huijing and G. de Groot (Eds.), Biomechanics and Medicine in Swimming. Champaign, IL, Human Kinetics Publishers, pp. 165-172, 1983.

International Society of Biomechanics
Working Group on Computer Simulation

1. MAIN GOALS

— joining ISB members particularly involved in computer simulation
— extensive exchange of information related to new computer simulation approaches in biomechanics (methods, software, hardware and applications)
— formulating standardized terminology of computer simulation in biomechanics

2. MAIN FORMS OF ACTIVITY

— organizing periodic satellite to ISB congresses meetings on computer simulation (the first took place in Warsaw, 1987, the second one is going to be organized by University of California at Davis, 1989)
— organizing non-periodic meetings, workshops, exhibitions dedicated for computer simulation approach in various fields of biomechanics
— establishing a standardized form of contact and information exchange by use of electronic mail between main biomechanics centers involved in computer simulation and between WGCS members
— creating ISB WGCS DMBS (Data Base Management System) for gathering all information on valuable software developed among ISB community — the access to files of WGCS DBMS would be free for all ISB members. The proposed DBMS would prevent duplicating efforts for development a given software already done in another center and would help in fair software exchange
— editing own Newsletter covering WGCS activities (at the beginning the use of one page of ISB Newsletter seems to be absolutely satisfactory)

3. WGCS FOUNDING MEMBERS

Dr. W. Bauer, University of Bremen, BRD
Dr. A. van der Bogert, University of Utrecht, Netherlands
Dr. A. Cappozzo, University 'La Sapienza', Rome, Italy
Prof. H. Hatze, University of Vienna, Austria
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WORKING GROUP ON COMPUTER SIMULATION

Dear ISB Members,

Rapid penetration of computers into all areas of biomechanics has created new possibilities for application of advanced modelling and simulation methods in our research. The programs of several last ISB congresses and related events document that this aspect of our research activity in biomechanics is flourishing and growing rapidly.
Therefore, during the last ISB Executive Council meeting our initiative creating a new working group of the ISB, the Working Group on Computer Simulation, was approved. The main purpose of the group, as stated in our Status Report below, is to integrate ISB members particularly involved in computer simulation, to improve the exchange of information related to new applications in the field, and to stimulate the development of advanced simulation methods and their use among the ISB community.
We believe that our Working Group will allow for better coordination of those members who use computer simulation as a main research tool and will allow more effective information and software exchange.
An example of our group's already on-going activity is the periodic International Symposium on Computer Simulation in Biomechanics. These symposia are organized as satellite meetings to the ISB Congresses and take the form of computer workshops with extended software demonstrations. The first Symposium was organized in Warsaw in 1987 and this year it will be held at the University of California, in Davis.
We invite all biomechanists with interest in computer simulation to join the group and the further our goal of the continuous improvement of scientific quality of biomechanical research.

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