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JANUARY 1978

FORCE PLATFORM GROUP

INTERNATIONAL SOCIETY OF BIOMECHANICS

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(The Newsletter is circulated free to members of the Force Platform Group. Membership enquiries to the Secretary).

Contents

	Page
The Force Platform Group of the ISB	3
Editor's Note	4
Secretary's Report for General Meeting, July 1977	6
Minutes of Biennial General Meeting of FPG	9

Original Papers

The Application of Posturography in Neurology Ch. Njiokiktjien	12
The Force Platform in Basic and Applied Biomechanics : UCLA Projects Roland F. Zernicke	22
The Use of Several Force Platforms to Obtain Human Kinetic Data Micheline Gagnon	27

Technical Notes

Amtech-Cook Model No. OR6-2 Multi-Component Force and Torque Measuring Platform	35
Kistler Type 9281A11 Multicomponent Measuring Platform for Biomechanics and Industry	37
Subscription forms	40, 41

The Force Platform Group of the ISB

The Group first formed in 1973 at the Fourth International Seminar on Biomechanics at the Pennsylvania State University, U.S.A., with an ad hoc committee of Peter Cavanagh (U.S.A.) and Don Grieve (England). Howard Payne (England) became 'catalogue editor' and produced two editions of "A catalogue of force platforms used in biomechanics research".

Since January 1976 the Force Platform Group (FPG) has produced a biannual newsletter for which FPG members are asked to pay a US $5 subscription to cover production costs and mailing.

The biannual newsletter was initiated with the following objectives:-

(a) To provide a bibliographic service to Group members on a regular basis.

(b) To publish original articles on topics related to force measurement in human biomechanics.

(c) To provide a forum for questions and answers on related subjects.

In this 'Message' in the Newsletter No. 1 the Chairperson urged: "Firstly, please let the editor of the newsletter have any ideas that you might generate concerning material to be included in future editions. The newsletter is a far stronger means of communication than one meeting of the Group every two years, and in such a small group, we shall need input from almost every member. Secondly, if you are aware of force platform users who are not members of our group, please encourage them to get in touch with us so that we can benefit from their input."

Editor's Note

The role of a newsletter in serving the needs of the group members appears to be a changing one. Following the inception of the Force Platform Group (FPG) in 1975, Howard Payne produced 2 editions of "A Catalogue of Force Platforms in Biomechanics Research". Subsequently, a register of force platform users, a force platform bibliography, a register of gait laboratories, and several articles on the design and use of force platforms have been published in the FPG "Newsletter".

At the July 1977 meeting of the FPG during the Sixth International Congress of Biomechanics, it was decided that the Newsletter should contain less on the technical aspects of force platforms with more space being devoted to the studies being done with force platforms. Thus, force platform designs or improvements will be published, in brief, as technical notes, further details of which may be obtained from the authors.

Studies submitted for publication in the Newsletter should be submitted in a form suitable for publication, with a maximum of 8 pages typed double space and art work as black on white line drawings or photographic prints of black on white drawings of $3^{1}/2$" x 5" size.

Details concerning (1) the problem, (2) the platform, (3) the peripherals, and (4) how the platform can aid in solving the problem, would be appropriate for submission. Editorial changes will be minimal and should not require correspondence between the author and editor before publication. The deadline for submission will be December 1 and June 1 for the January and July Newsletters respectively.

Please send details of any new publications suitable for inclusion in the Force Platform Bibliography to me at my Australian address (P1 of this Newsletter). The bibliography update will be included in the July Newsletter.

Finally, to those persons who have contributed to this Newsletter, thank you.

Barry D. Wilson

Force Platform Group

International Society of Biomechanics

Secretary's Report for General Meeting, July 1977

Membership

Paid	up	members	in	1976	65
"	"	"	"	1977	53

1977 paid up members consisted of 36 members from 1976 plus 17 new members.

Newsletters

Four Newsletters have been sent out since the last General Meeting in 1975. The circulation has varied, but to illustrate the present situation, the circulation for Newsletter No. 4 for July 1977 was as follows:-

No. 4 was sent to everyone on the mailing list irrespective of whether they had paid their subscriptions or not. So in addition to the 53 paid up members, copies were sent to 4 contributors to the Catalogue who had not communicated since that publication, a further 19 courtesy copies were sent to libraries and persons who had made enquiries about the Force Platform Group, and 29 copies went to 1976 members who had not paid their subscriptions for 1977.

It was decided not to take any decision on the mailing list until this question could be discussed at the General Meeting.

Wherever possible serious enquiries from outside the mailing list have been answered with back numbers of the Newsletter, and this practice has resulted in several new members joining the Group. Copies of Newsletter Nos. 1 and 2 are now exhausted. 20 copies each of Newsletter Nos. 3 and 4 are still in stock.

Finance

Please see separate balance sheets. One year subscriptions and cheques in foreign (to the Secretary) currency are most uneconomical, since the cost of processing foreign cheques is very high. It is suggested that subscriptions be paid in two year units and that the currency is that of the secretary's country, all costs of conversion being borne by the subscribing members.

Conclusion

Your secretary is of the opinion that the Force Platform Group is a viable and successful association, both in informing members of developments in the field and in assisting new researchers.

A.H. Payne

F.P.G. Income and Expenditure Account

for year ending July 1977

(covering issues of Newsletters 3 and 4)

Income	£	Expenditure	£
Membership subscriptions net of currency exchange charges and bank commission	152-79	Printing of Newsletter No. 3	69-15
		Postal charges for Newsletter No. 3	12-70
		Printing of Newsletter No. 4	50-60
Carried forward from year ending August 1976	27-18	Postal charges for Newsletter No. 4	18-36
		Bank charges	2-72
			153-53
		Balance, being excess of income over expenditure	26-44
	179-97		179-97

Notes

(1) Exchange rates have fluctuated around the value of £1 ≡ US $ 1-72

(2) The F.P.G. has a bank account in the U.S.A. containing approximately US $ 10

A.H.P.

Force Platform Group

International Society of Biomechanics

Minutes of Biennial General Meeting 12.15 pm. 12 July 1977

Copenhagen, Denmark

Present:

M. Gagnon	CAN
G. Gautschi	SWI
R. Rozendal	HOL
A. Lephart	AUS
J. Baumann	SWI
P. Cavanagh	USA
R. Gregor	USA
J. Hudson	USA
N. Pike	USA
K. Nicol	GER
A. Connan	FRA
L. Petersen	DEN
K. Bertelsen	DEN
H. Kingsbury	USA
H. Lamb	CAN
J. Walton	USA
P. Stothart	CAN
C. Richardson	USA
D. Kelly	USA
W. Schroder	GER
L. Delmez	BEL
R. Spooner	USA
H. Gros	CAN
B. Roy	CAN
J. Paul	GBR
H. Payne	GBR
B. Nigg	SWI

1. **Minutes of Biennial General Meeting 2nd July 1975**

   Accepted

2. **Matters arising from minutes**

   Carried forward to items 4 and 6

3. **Secretary's Report**

The Secretary reported on membership and subscriptions and raised the question of members who were in arrears with dues. No resolution was passed and it was left to the Committee to make a decision.

Balance sheets for 1976 and 1977 were presented and accepted.

The Chairperson thanked the Secretary and pointed out that the small sum in credit balance was due largely to the "hidden subsidy" of free clerical services provided by the University of Birmingham.

4. Chairperson's Report

The Chairperson reported on discussions he had had with the officers of the International Society of Biomechanics concerning financial support. There was the problem of aiding a group which included many non-members of the I.S.B. and further discussions were necessary to work out a suitable solution.

The Chairperson raised the question of changing the name of the Group and a long debate followed. Finally a proposal to keep the title as it was was put to the meeting and accepted by 12 votes to 6 with 10 abstensions.

The Chairperson asked for members' views on the form that the Group should take and how the material in the Newsletters could be improved. The general feeling of the meeting was that reports on the technical aspects of force platforms should be limited and that more space should be devoted to work done with force platforms. Members were asked to send copies of published papers to the editor who would then include abstracts in Newsletters.

Election of Officers

The following were elected (subject to their acceptance)

Chairman Howard Payne

Secretary/Treasurer/Editor/Bibliographer Barry Wilson

Bibliographers Klaus Nicol (German)
Alain Connan (French)
Peter Francis (English)
Vladimir Zatziorsky (Russian)

Technical Liaison Officer Bob Spooner

Howard Payne proposed a vote of thanks to the outgoing Chairperson, Peter Cavanagh, for the work he had done over the past five years to ensure the existence of the Force Platform Group.

This was accepted unanimously.

The meeting closed at 1 pm.

A.H. Payne

The Application of Posturography in Neurology

By

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Amsterdam,
Holland

Introduction

Postural equilibrium is a complex nervous function which might be disturbed by many neurological disorders. The process of equilibrium can be studied by observing the behaviour of the standing patient amongst others, which has been done in fact by neurologists since Romberg in 1846 drew attention to the effect of eye closure on the standing tabetic patient (1). After Romberg, methodological and technical thinking raised the advantages of objective examination methods. Consequently in several laboratories the recording of postural behaviour - posturography - has been developed, but until now the application has been restricted to very few neurological clinics for two reasons. Firstly, the advantages of differential diagnosis are not great enough for the clinician who has the disposal of other methods. Secondly, there are methodological difficulties. Although it has long been clinical custom to differentiate between various types of ataxia we are still dealing with a clinical and therefore little-quantified symptom. Quantification of symptoms in neurology is a procedure more and more accepted: reflex intensity, conduction times, muscular changes, eye movements, sensory phenomena and vascular symptoms can be objectified. Ataxia can be quantified only under conditions in which measurements may be made. The orthostatic stability of the standing individual is suitable par excellence for this purpose, but gives only a limited impression of the postural mechanisms which could be involved. Moreover the use of the force platform does not enable us to study the postural behaviour of all body parts separately which further reduces the differential power of this kind of examination.

Methods

The apparatus we use is a stabilometer - or statokinesimeter according to the French literature. Many other names are encountered - stabilograph, ataxiameter, ataxiagraph, statometer, staticometer and statokinescope.

The apparatus consists of a platform, which measures vertical forces only and transmits them in terms of voltage to an amplifier, connected with an oscilloscope, a plotting unit and an instrumentation recorder. The oscilloscope shows the 2-dimensional displacement of the center of gravity which is called a statokinesigram (SKG). The plotting unit writes the phenomena on a time base in two directions separately : anteroposterior (AP) and medial-lateral (ML). This is the stabilogram (SBG. The stabilogram is also recorded on two channels of an instrumentation recorder for off line analysis by the computer (PDP8).

The force platform consists of a stiff wooden plate of 20 mm thickness firmly attached to T-shaped steel frame. To this frame 3 strain gauges are fixed, which enable the measurements of pressure differences in AP and ML directions. The 3 point method does not enable the measurement of horizontal forces. The support on the ground consists of 3 roller bearings, one on each end of the T-frame, in order to avoid friction in horizontal direction between the platform and the floor. This friction is theoretically possible, in practice very small. In many articles - not only ours - the authors state that their platform records the position of the vertical projection of the body's center of gravity within the plane of support. This is only accurate for the static condition. In the dynamic condition the platform measures vertical forces entailing also acceleration components and this increases with increasing frequencies. This has been rightly criticized by Thomas and Whitney (2).

The data on which we rely mostly for clinical use are :

(a) visual inspection of the SBG, looking at regularity, frequencies in both directions and antero, postero - and lateropulsion and the relation between AP and ML. The visual inspection is still superior to the computerised data analysis. The relationship between AP and ML can also be studied by doing cross correlation, which may show phenomena not visible through inspection of the SBG.

(b) The mean amplitude in both directions is calculated by the computer, but this can be done by a simple electronic integrator as well. The mean position of the center of gravity with respect to the center of the plane of support is also calculated. The computer calculates other parameters such as the amplitude $\bar{r}$, which is the distance between the position of the center of gravity and the average position of the center of the plane of support, measured about every 40 msec. and averaged. The reader is referred to another publication (3) for further information about the program.

Applications

1. Before the clinical application was introduced, we did some work on the physiology of posture and we were able to show amongst others that:

   - the line of gravity of most people is situated asymmetrical and mostly to the right of the center of support;
   - the anteroposterior amplitude of movement of the line of gravity is about 1.5 times greater than the lateral one;
   - closure of the eyes changes frequencies, changes the relationship between AP and ML and does increase the amplitudes in both directions in a predictable manner;
   - the results of Romberg's test are different in different visual circumstances;
   - there are at least two clearly visible frequency spectra, a slow one at about 0.2 - 0.5 Hz and a higher one at about 1 - 2 Hz. The slower one is not visible in all people with the eyes open and is sometimes hardly seen at all, but becomes more visible, if the eyes are closed. This frequency is also enhanced by galvanic stimulation of the labyrinth (4) and all

kinds of visual destabilisation (5,6,7,8,9,10). This frequency-band seems to be a resonance frequency of the body and has probably a central vestibular origin. The higher frequencies of 1 - 2 Hz have possibly a peripheral proprioceptive origin.

- each subject has his own postural regulation, the SBG is recognisable and the amplitudes have their own level, just as e.g. in blood pressure.

2. A problem still not solved is the definition of a normal posture or a normal SBG. At present, we have to rely on quantitative norms of several parameters and mainly visual inspection of the SBG. A useful pattern recognition program for computer analysis is not yet available.

Actually the visual inspection of the SBG allows us - grossly - to differentiate between peripheral (Proprioceptive) and more centrally localised affections.

We also can say something about lateralisation of a process. We can differentiate these organic processes from functional or so called psychogenic disturbances (11). Aggashyan et al. (12) found that the 0.7 - 1.2 Hz band was enhanced in patients with peripheral deafferentation. It is also our experience that rapid frequencies of irregular nature and superimposed on slower movements indicate a peripheral process (polyneuropathy cord disease such as tabes dorsalis and cervical myelopathy).

In central processes - brain stem and cerebellum - one sees slower frequencies of 0.2 - 0.5 Hz. This is corroborated by de Wit (13) and Tokita (14), while Cernacek (15) found frequencies of 0.5 - 1.2 Hz after closure of the eyes in patients with central vestibular disturbances with a vascular cause. The feature of the SBG of patients with cerebellar atrophy - mainly seen in alcoholics - has pathognomonic characteristics, namely the occurence of a 3 Hz tremor superimposed on slower movements in AP directions (16). Pneumencephalographic examination could several times confirm this diagnosis. Another important characteristic in patients is the difference between the amplitudes with the eyes open and the eyes closed, the Romberg sign. Van Parijs studied this in healthy and pathologic subjects and expressed this difference in a quotient (17). He showed too, that this method differentiated peripheral from central disturbances (18).

3. Stabilography has other applications, such as the study of the actions of pharmacological substances and neurological functions. In a pilot study with van Parijs we were able to show that the serum level of the anti-epileptic drug carbamazepine was correlated with the amplitude of the postural sway. In another study with Folkerts (19) we could show the action of L-DOPA on the postural regulation of Parkinson patients.

It is particularly useful to follow patients longitudinally. We followed several patients whose posture was not quite normal and who turned out to develop later a pathologic process such as a brain tumor. In these cases stabilography proves to be a very sensitive method for the detection of slight disturbances. We followed 2 patients with a pontic tumor and 3 patients with a cerebellar medulloblastoma after surgical or radiological treatment. In these cases disequilibrium was a nuclear symptom. The recovery after treatment can be objectified and relapses can be noticed early (20).

Although the individual recording cannot always solve a clinical problem, the study of clinically subdivided groups, such as Parkinsonians, epileptics, can deliver useful information. In 1975 (20) we studied learning disabled children in whom we could show that their so called equilibrium problems were correlated with hyperkinesia and choreiform motor unrest. The SBG's did not resemble SBG's seen in cerebellar affections.

Actually the stabilography cannot yet be used as a routine examination method, but it is for the clinician an objective and simple tool - even without a computer available - to study the postural regulation in patients and to follow them.

For extensive information about the application of posturography in several fields the reader is referred to the Proceedings of the Symposia of the International Society of Posturography (21).

References

1. Romberg M.H. A manual of the nervous diseases of man (1853). London Sydemham Soc. 2;395-401. 1846 German edition.

2. Thomas D.P. & Whitney R.J. Postural movements during normal standing in man J. Anat. (London) 1959, 93; 524-539.

3. Njiokiktjien Ch. & de Rijke W. The recording of Romberg's test and its application in neurology. Agressologie 1972, 13 C; 1-7.

4. Njiokiktjien Ch. The influence of vision on the vestibulospinal reflex. Agressologie 1972, 13 C: 91-94.

5. Njiokiktjien Ch. & Folkerts J.F. Displacement of the body's center of gravity at galvanic stimulation of the labyrinth. 1971, Conf. Neur. 33:46.

6. Leroux J. et al. Etudes spectrales des deplacements spontanee antero posterieurs et lateraux du centre de gravite de l'homme. Agressologie 1973, 14 C 57-63.

7. Bles W. & de Wit G. Study of the effects of optic stimuli on standing. Agressologie 1976, 17 C; 1-7.

8. Dichgans J. et al. Postural sway in normals and atactic patients: analysis of the stabilising and destabilising effects of vision. Agressologie 1976, 17 C; 15-25.

9. Oblak B. et al. Computer analysis of the correlation between visual stimulation, ocular movements and stabilograms. Agressologie 1976, 17 C; 11-15.

10. Lestienne et al. Effets posturaux induits par une scene visuelle en mouvement lineaire. Agressologie 1976, 17 C: 37-47.

11. Njiokiktjien Ch. The influence of an auditory task on Romberg's test in healthy people and neurological patients. Agressologie 1973, 14 D: 11-19.

12. Aggashyan R.V. et al. Changes in spectral and correlation characteristics of human stabilograms at muscle afferentiation disturbance. Agressologie 1973, 14 D: 5-11.

13. de Wit G. The stabilometry as an auxiliary in investigations of patients with vestibular disturbances. Agressologie 1973, 14 D: 27-31.

14. Tokita T. et al. Correlation analysis of the body sway in standing posture. Agressologie 1976, 17 B: 7-15.

15. Cernacek J. et al. Stabilographic findings in central vestibular disturbances. Agressologie 1973, 14 D: 21-27.

16. Silfverskjold P.B. Romberg's test in the cerebellar syndrome occurring in chronic alcoholism (1969) Brain 41: 332-343.

17. van Parijs J.A.P. Romberg's sign expressed in a quotient. I. Agressologie 1976, 17 B, 95-100.

18. Njiokiktjien Ch. & van Parijs J.A.P. Romberg's sign expressed in a quotient. II. Agressologie 1976, 17 D; 19-25.

19. Folkerts J.F. et al. The influence of L-Dopa on the postural regulation of Parkinson patients. Agressologie 1972, 13 C: 19-24.

20. Njiokiktjien Ch. et al. Stabilography as a diagnostic tool in child neurology. Agressologie 1976, 17 D; 41-49.

21. Agressologie 1972, numbers B & C. (proceedings I Symp. International Soc. of Posturography).

1973, numbers B, C & D (proceedings II Symp. Int. Society of Posturography).

1975, number A & D.

1976, number A, B, C, & D (proceedings III Symp. Int. Society of Posturography), edited by Masson 120, Bd. St. Germain, Paris, France.

The Force Platform in Basic and Applied Biomechanics : UCLA Projects

By

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The Biomechanics Laboratory at the UCLA Department of Kinesiology originated in 1975. Since its inception, the laboratory has acquired space and equipment to conduct research in both the basic and applied aspects of biomechanics. In the following, two of our projects are briefly described to illustrate the manner in which a force platform and its peripherals are used in the research. Rather than emphasizing the specific equipment configurations in this discussion, the aims and the objectives of the research will be highlighted (a selected list of equipment in the laboratory is found in the Appendix).

One project being conducted in the Kinesiology Department is a collaboration between researchers in the Neuromuscular Research Lab (V.R. Edgerton and J.L. Smith) and the Biomechanics Lab (R.F. Zernicke). The project is supported by the National Institutes of Health, and the general title is "Significance of Muscle Fiber Types". The long range goal, simply stated, is to determine how gross structure, fiber type composition and whole-muscle mechanics affect recruitment during various movements. Specifically, a series of projects are planned to study the recruitment of synergistic skeletal muscles, classified primarily as fast or slow, required to produce forelimb and hind limb movements of varying velocity and force using cats as subjects. To this end, the kinetics and kinematics of selected joints (ankle, knee, elbow) will be described for locomotion, jumping, landing and novel non-supportive movements, e.g., swimming and limb shaking and recruitment patterns during these movements and the dynamic properties of selected slow and fast synergists of these three joints will be compared. Also, the recruitment of slow and fast muscles will be studied during peripheral and central pertubations of fatigue, muscle isolation, joint immobilization and spinalization. It is anticipated that from these studies our knowledge of the role of fast and slow muscles, which differ dramatically in their metabolic and mechanical properties, will be increased, and that we will gain further understanding of the selective recruitment of motor units to affect efficient and effective movements under normal conditions.

Integration of biomechanical and neurophysiological data will play a key role in the project. Kinematic data will be synchronized with kinetic and EMG data. While a cat is walking, trotting, galloping or jumping, either the camera or SELSPOT system will record the kinematics of the motion; the kinetics will evolve from force platform and rigid-body dynamics. An example of a portion of the project which uses the force platform is where the cat is taught to jump from the force platform to a variable height platform (see Fig 1). The cat straddles the edge of platform with its hind limbs as it jumps to the

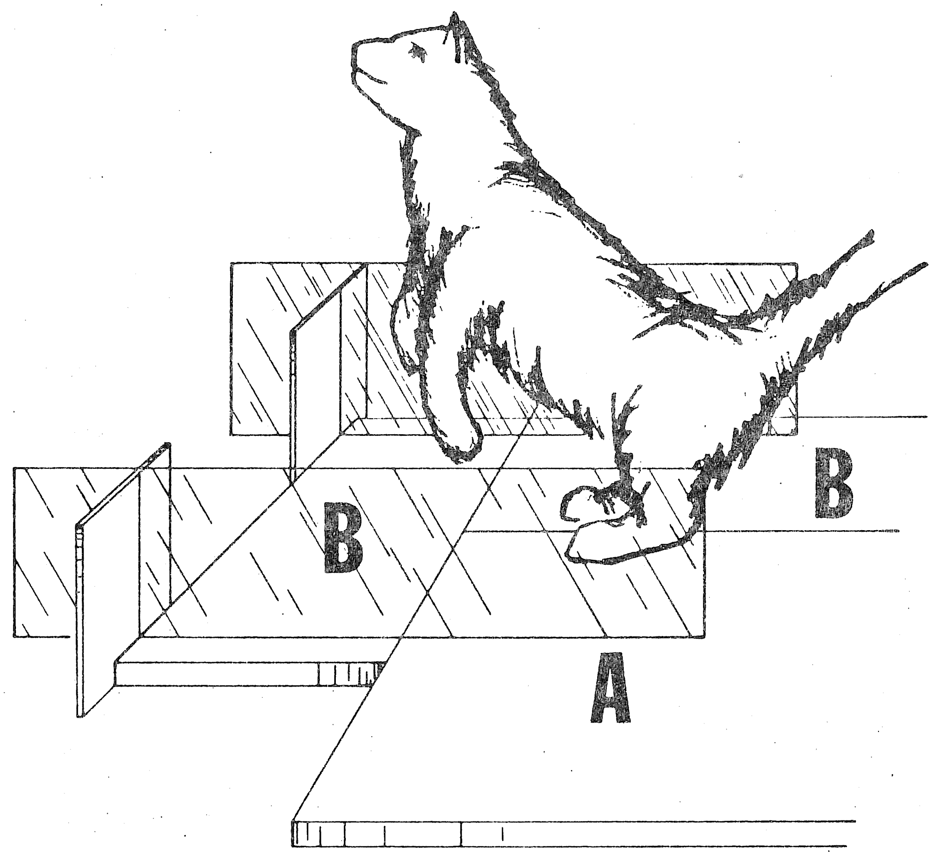

Figure 1. Cat jumping to upper platform (not pictured), 46 cm high. The chronically electroded hind limb (left) is exerting force on the force platform (A) while the right hind paw is supported by a wooden platform (B) placed next to the force plate. EMG and force data is recorded on FM tape along with coding lights which also appear on the 16 mm film. Plexiglass panels have been placed along side the cat to guide the animal's take-off position.

upper platform. The height of the second platform is 46 cm, 75 cm, or 110 cm above the force plate. Kinematic, kinetic and EMG data (medial gastrocnemius and soleus) are recorded with each jump.

A second project being conducted at UCLA includes a collaboration between the Biomechanics Lab and the Child Amputee Prosthetic Project (Yoshio Setuguchi, M.D. Director) associated with the UCLA Institute for Rehabilitation and Chronic Diseases. Quantification of locomotion and postural characteristics of amputee children and normal children is one of the major aims of the project. Three groups of children will be included in the study : (1) "above-the-knee" amputees (proximal femoral focal deficiencies, hip disarticulations, and above-knee amputees), (2) below knee amputees (unilateral and bilateral), and (3) normal children. The force platform will be used in conjunction with film, to record (1) upright stance and equilibrium measures (center of pressure), (2) slow, normal, and fast gait (reaction forces and center of pressure), (3) ascending and descending stairs (for normals and below-knee amputees). Stride characteristics including footprint angles, stride lengths and widths will also be collected. Physiological efficiency and mechanical efficiency of locomotion will also be examined during treadmill walking. One subproject will involve the comparison of the SACH (Solid Ankle Cushioned Heel) foot and the CAPP (Child Amputee Prosthetics Project) foot for above-knee amputees. Little biomechanical information is available for the <u>child</u> amputee; it is anticipated that the collaboration between CAPP and the Biomechanics Lab will result in useful quantitative information for prosthesis alignment and evaluation for children and possible modifications and suggestions for child lower extremity prostheses.

APPENDIX - SELECTED LIST OF EQUIPMENT USED FOR THE UCLA BIOMECHANICS PROJECTS

Kistler force platform (9261A) mounted in 40 ft walkway flush with the top of the walkway, Photosonics IP high speed camera, Hewlett-Packard (HP) 21 MX minicomputer with dual disc storage, HP(x,y) plotter, HP 8-channel FM tape recorder, SELSPOT system, APPLE-1 microcomputer with video terminal and Graf Pen as time-sharing terminal to HP 21 MX, Tektronix Graphics terminal and printing terminal with HP 21 MX, 9830 HP calculator and HP 9864 digitizer coordinated with a Vanguard S-2 stand and Vanguard 16 mm motorized film transport (M-16C), polygraphs and oscilloscopes, animal and human treadmills and EMG telemetry equipment.

The Use of Several Force Platforms to Obtain Human Kinetic Data

By

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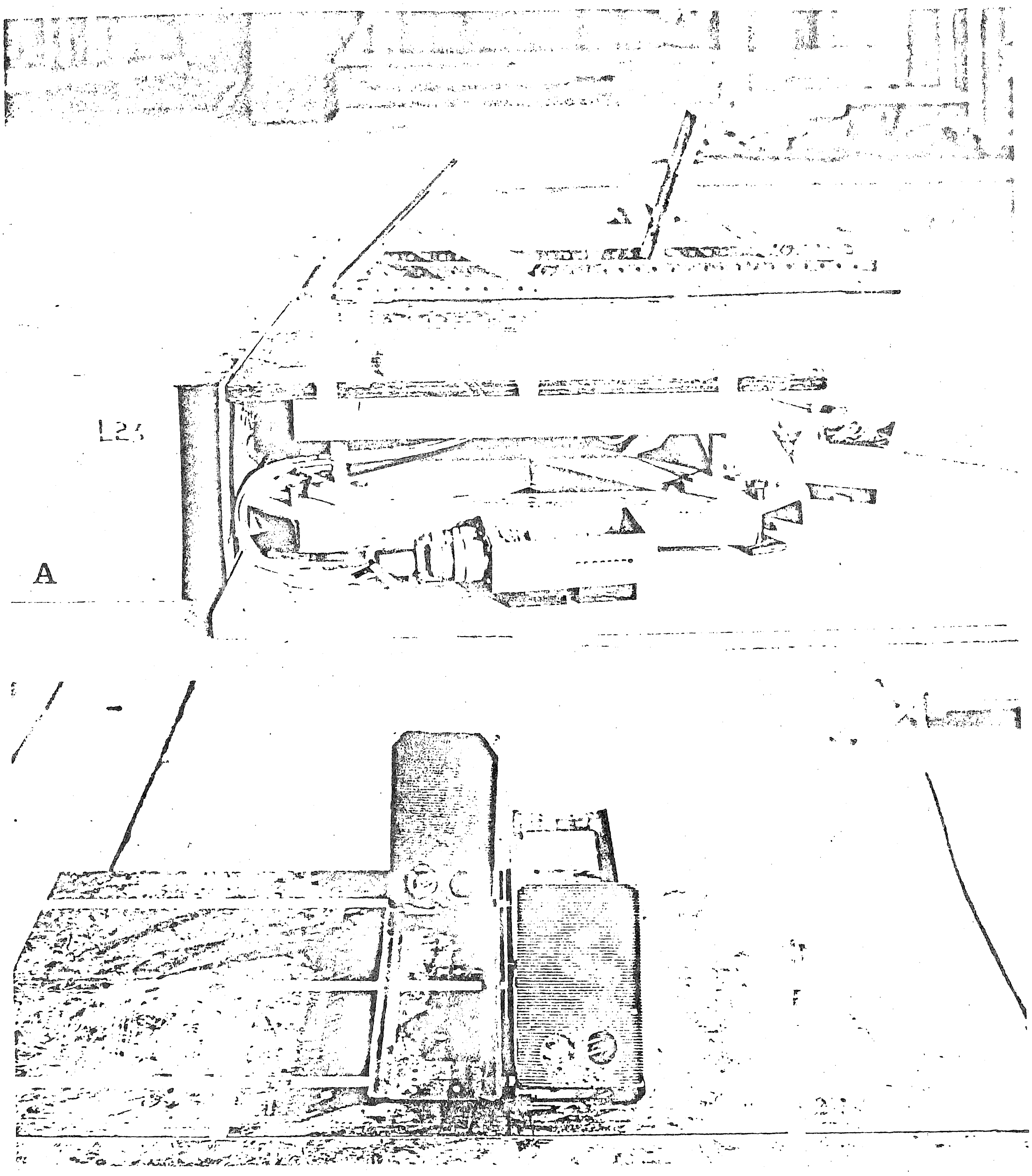
Two force platforms were designed at the University of Montreal to allow the measurements of the simultaneous forces applied by each foot during the motions associated with the sprint start. The characteristics of the force platforms, the procedures adopted in the calibration of forces and a discussion about the applications related to the use of the platforms are presented in this paper.

Characteristics

The force platforms were designed to be adjustable in height from 20 to 30 centimeters to fit the height of an elevated running platform (Figure 1). Each force platform had a mass of 30 Kg and dimensions of 66 x 66 cm. A steel base in the shape of a cross was used to encase the four supports on which the strain gauges were cemented. Four open sections of the base contained screws for adjusting the height of the platform. The screws rested on four rubber covered metal plates that were in contact with the ground surface. The four supports of the platform were fixed on the steel base at their inferior part and on an aluminum frame at their superior part. Over the aluminum frame was a hardwood floor to which the metal frame of the starting block could be riveted. On this floor, some horizontal lines were drawn directly



B

Figure 1. Lateral (A) and frontal (B) views of the force platforms

over the front and rear supports of the platforms to identify the location of the vertical forces and to determine subsequently the moments of forces applied by the sprinter about a frontal-horizontal axis passing through the subject's center of gravity (See Figure 1).

The electrical strain gauges were positioned on the supports in such a way that only deformation along a given axis was registered. A given horizontal force in X or in Y produced a flexion in the supports while a vertical force in Z produced a pure compression in the supports. The mechanical assembly of the strain gauges was used with an electrical assembly which allowed the measurement of a force in magnitude and direction along the three axes. The mechanical deformations of the gauges were therefore translated into electrical impulses by low voltage output transducers and were electronically amplified before being output on the oscillographic paper.

To measure the moments of forces around a frontal-horizontal axis passing through the sprinter's center of gravity, it was necessary to determine the line of action of the resulting vertical force. For this purpose, the vertical force was separated into those signals coming from the front part of the platform, F_{z_f} (vertical front force), and into those signals coming from the rear part of the platform, F_{z_r} (vertical rear force). The electrical signals of the strain gauges could be processed in such a way that several independent forces on the two force platforms could be added together. It was also possible to separate a total force applied along a given axis into its components applied on one given support or combination of supports. Moreover, the total area under any force-time (impulse) curve or the consecutive partial areas constituting the force-time curve were determined directly and easily by the use of integrators incorporated into the electrical assembly.

The maximum force that could be applied in the vertical direction, Z, was 4500 N while the maximum horizontal force, in X and Y, could not exceed 1800 N. These limits were well above the normal values expected in the present investigation. The damping factor of the force platform was 0.15 and the magnitude of the critical frequency was of the order of 200 Hz. This resonant frequency cannot be found in human movements. However, vibrations of very low amplitude were eliminated by a filter positioned in the electrical assembly.

Calibration

Laboratory tests were made to verify the independence of the forces applied along the three axes and the linearity of these forces. The calibration of each force platform was accomplished by statically loading known weights upon the force platform in the two horizontal directions and in the vertical direction, at the front part, Z_f, and the rear part, Z_r, of the platform. The horizontal axes were loaded from 0 to 125 pounds in 25 pound increments while the vertical axes were loaded from 0 to 200 pounds, in 25 pound increments. One force at a time was produced and verification made of null signals in the other axes. These signals were recorded from the electrical assembly of the gauges connected to a numerical voltmeter. The results showed that the two horizontal and the two vertical systems were linear for the range of forces investigated.

From these results, it was also possible to determine the degree of interaction of a force acting only through one axis upon the other axes. The results indicated that little interaction accurred between the different axes. Calibration curves were drawn which related the measurements of electrical signals, in millivolts, from the amplifiers, to the forces, in pounds, exerted on the main axis of force application and on the other axes. The coefficients of interaction were determined by the slope of these linear systems. The equations relating the output on the voltmeter to the force applied on each axis and its interaction on the other axes are presented for the two force platforms.

Force platform 1

Voltmeter output (millivolts) = Forces on each axis (pounds)

$$V_x = 8.46\ F_x - 0.12\ F_y + 0.13\ F_{z_r} - 0.08\ F_{z_f}$$

$$V_y = -0.23\ F_x + 8.45\ F_y - 0.10\ F_{z_r} + 0.33\ F_{z_f}$$

$$V_{z_r} = -0.10\ F_x - 1.80\ F_y + 8.25\ F_{z_r} + 0.26\ F_{z_f}$$

$$V_{z_f} = 1.09\ F_x + 1.55\ F_y + 0.21\ F_{z_r} + 8.36\ F_{z_f}$$

Force platform 2

Voltimeter output (millivolts) = Forces on each axis (pounds)

$$V_x = 8.78\ F_x + 0.31\ F_y + 0.13\ F_{z_r} - 0.06\ F_{z_f}$$

$$V_y = 0.11\ F_x + 8.51\ F_y - 0.18\ F_{z_r} + 0.13\ F_{z_f}$$

$$V_{z_r} = 0.47\ F_x - 1.85\ F_y + 6.06\ F_{z_r} + 2.37\ F_{z_f}$$

$$V_{z_f} = -0.03\ F_x + 1.13\ F_y + 2.61\ F_{z_r} + 6.32\ F_{z_f}$$

When a force is exerted on a given axis, the coefficients of interaction on the other axes should theoretically approach the value zero. From the observation of the coefficients, it was apparent that all coefficients of interaction were approaching the value zero, with exception of the vertical forces applied on the front and rear parts of platform 2 that were observed to interact with one another. Therefore, matrix calculus was used to estimate these forces.

It was further necessary to estimate the percentage of error made in the measurements of forces. This force effectively recorded on the given axis was compared to the true value of force that was applied on that axis and the percentage of error was calculated. The results indicated that an overall error of ± 0.5 percent was applicable to the horizontal and vertical forces on the force platform . For the force platform 2, an overall error of ± 1 percent was computed for the horizontal forces while the error was estimated to be as much as ± 5 percent for the two vertical axes, Z_f and Z_r, because of the interaction observed between these two axes. This interaction was attributed to a mechanical error in attaching the gauges to the surface of the supports.

Applications

The present study was undertaken to compare with cinematographic techniques and two force platforms three positions of the standing start and the preferred position of the kneeling start in female sprinters of differing ability. The pushing phase of the sprint start was characterized by the combined actions of the feet on two starting blocks. Consequently, the forces applied horizontally by each foot were measured independently during the course of motion. These force-time curves were integrated and therefore the linear momentum provided by the actions of each foot as well as the relative contribution of the actions of the foot on the rear block to the development of the total linear momentum were obtained.

The total forces exerted in the horizontal direction were also determined. These curves were integrated along small discrete time intervals and the velocity and acceleration curves associated with a specific starting technique or a specified level of sprinting ability could be represented. Another aspect in this study consisted in the determination of the point of application of forces to further assess the angular momenta applied around the sprinter's center of gravity throughout the starting motions. The location of forces applied vertically was accomplished through the separation of forces on the rear and front part of the platforms. The sprinter's center of gravity was cinematographically determined and the lever arms of the horizontal and vertical forces about the center of gravity was obtained in the same manner.

The detailed analysis of the impulse phase on the starting blocks provided the researcher with data of a very informative nature with regard to the efficiency of the starting techniques (Gagnon, 1976) and allowed the determination of these parameters which distinguished the good and poor performers (Gagnon, 1977).

References

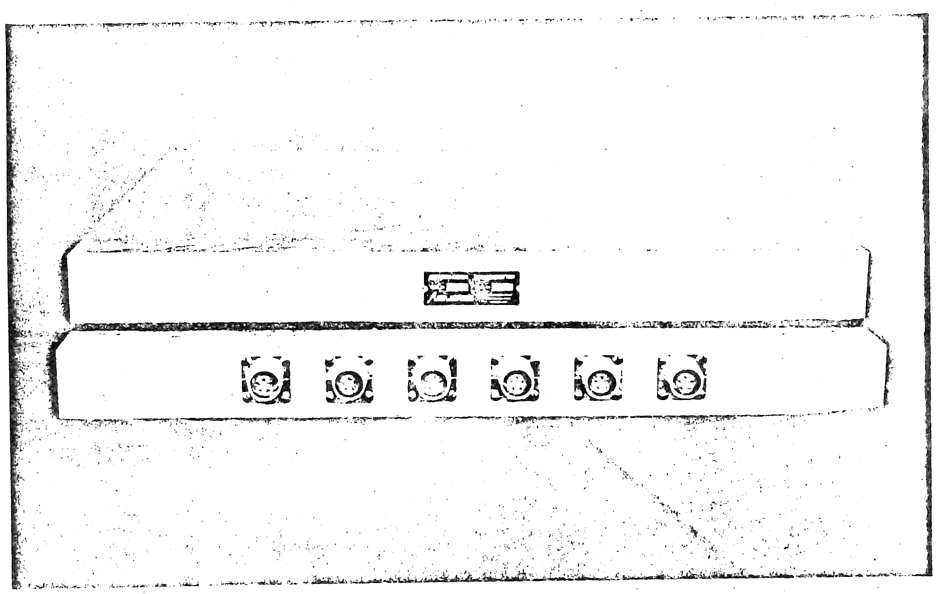
Gagnon, M. 1976. Biomechanical comparison of the standing and kneeling sprint starts. Proceedings of the International Congress of Physical activity Sciences. Series on Physical Activity and Human Well-Being. Biomechanics of Sports and Kinanthropometry, Monograph Four. Landry, F. and W.A.R. Orban (eds). (in press).

Gagnon, M. 1977. A kinetic analysis of the kneeling and the standing starts in female sprinters of different ability. Paper presented at the VIth International Congress of Biomechanics, Copenhagen.

Gagnon, M. 1977. A kinematic analysis of the kneeling and the standing starts in female sprinters of different ability. Canadian Journal of Applied Sport Sciences, September, vol. 2, no. 2, pp. 57-61.

Amtech-Cook Model No. OR6-2 Multi-Component Force and Torque Measuring Platform

The Model OR6-2 multi-component force/torque platform measures forces and torques about three orthogonal axes, giving six outputs. The two torques about the horizontal plane may be used to determine the point of application of the three orthogonal forces and the torque about the vertical axis.



The platform has a capacity for static and dynamic loads of up to 500 lbs of force and 4000 in-lbs of torque on each channel (plus 25% overload). Load sensing is by bonded foil strain-gages attached to strain rings specially designed for minimal cross-talk between channels (less than 1%) and for high sensitivity, high natural frequency, and high stiffness. The platform measures 20" x 20" x 3", with a measuring surface of 20" x 20". Specially designed units are available upon request.

Amtech-Cook dynamometers have a proven record of quality and reliability for over 20 years. Strain gages are selected for durability and sensitivity under adverse conditions. All dynamometers are individually calibrated and are warranteed for one year. The dynamometers can be used with standard strain-gage excitation/amplification and readout equipment, or can be supplied as a complete system.

For additional information please contact Dr. Walter D. Syniuta, Amtech Incorporated, 141 California Street, Newton, Massachusetts, 02158, 617-965-3660.

Kistler Type 9281A11

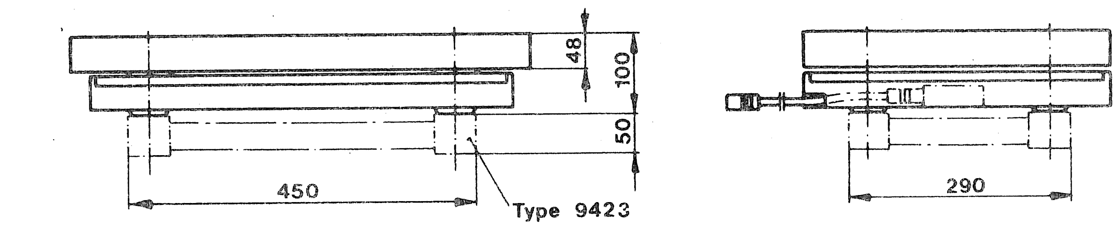
Multicomponent Measuring Platform for Biomechanics and Industry

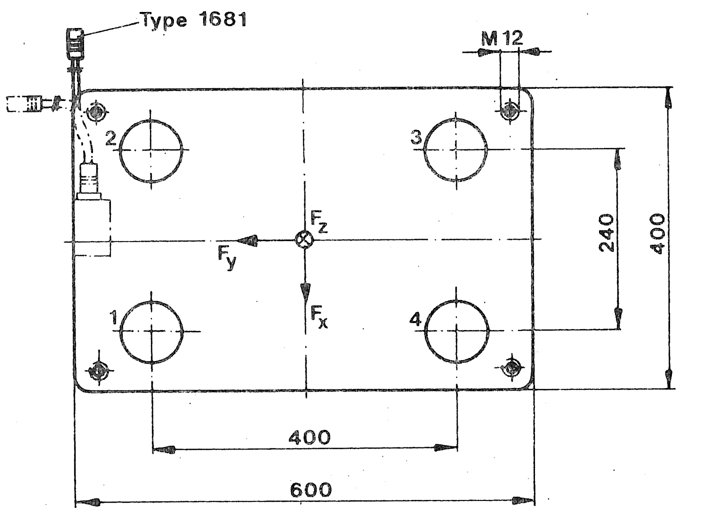
These technical specifications are published by courtesy of Kristal Instrument Corporation, subsidiary of Kistler Instruments AG of Winterthur, Switzerland

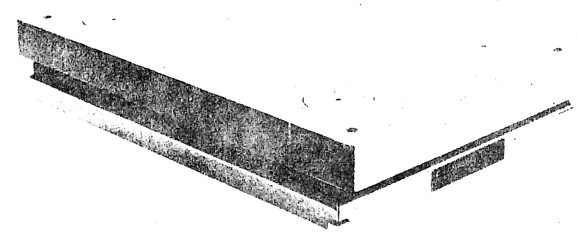
Tentative Data

Quartz Multicomponent Measuring Platform for measuring the 3 orthogonal components of any force acting on it. The coordinates of the instantaneous point of force application and the torque with respect to an axis normal to the platform. Wide measuring range, high natural frequency.

Ranges: F_x, F_y each	kN	–10 ... 10
F_z	kN	–10 ... 20
Overload: F_x, F_y each	kN	–15/15
F_z	kN	–15/30
Threshold	mN	<20
Sensitivities: F_x, F_y each	pC/N	–8
F_z	pC/N	–3,8
Variation of sensitivities within surface of top plate	%	≤±1
Linearity	%FSO	≤±0,5
Hysteresis	%FSO	≤0,5
Cross talk: $F_x \rightleftarrows F_y$, $F_z \to F_{x,y}$	%	≤±1
$F_{x,y} \to F_z$	%	≤±2
Natural frequency	kHz	>1
Insulation resistance	TΩ	>10
Operating temperature range	°C	–20 ... 70
Connector for cable	Type	1681A...
Tightening torque for M12 mounting bolts	Nm	90
Weight	kg	41







Description

The measuring platform consists of a base frame onto which four 3-component force transducers are mounted under high prestress. An interchangeable top plate is then mounted on the four transducers.

The standard version Type 9281A11 has a solid aluminium top plate. Steel top plates, with or without T-slots, are available also.

The output signals are available from a 9-pole connector. The instrument is rustproof and splashwater proof.

Examples of Applications

1. Biomechanics : Gait analysis, animal studies
2. Sport : Studies of movements, training
3. Orthopedics : Rehabilitation, fitting of prosthesis
4. Neurology : Posturography, microvibrations
5. Industry : Wheel forces in vehicle research

Mounting

The platform can be fixed with four M12-bolts on a mounting frame Type 9423 or a rigid and flat steel plate. The mounting frame Type 9423 is especially suitable for being grouted into a concrete base and has to be ordered separately.

Electronics

With the electronic units Types 9805 and 9851 the three components F_x, F_y and F_z as well as the instantaneous point of application of the acting force as well as the torque M_z can be determined (see data sheets 10.9805 and 10.9851). The platform is connected with a 8-pole cable Type 1681A5 (5 m long, other lengths available).

The Force Platform Group

International Society of Biomechanics

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