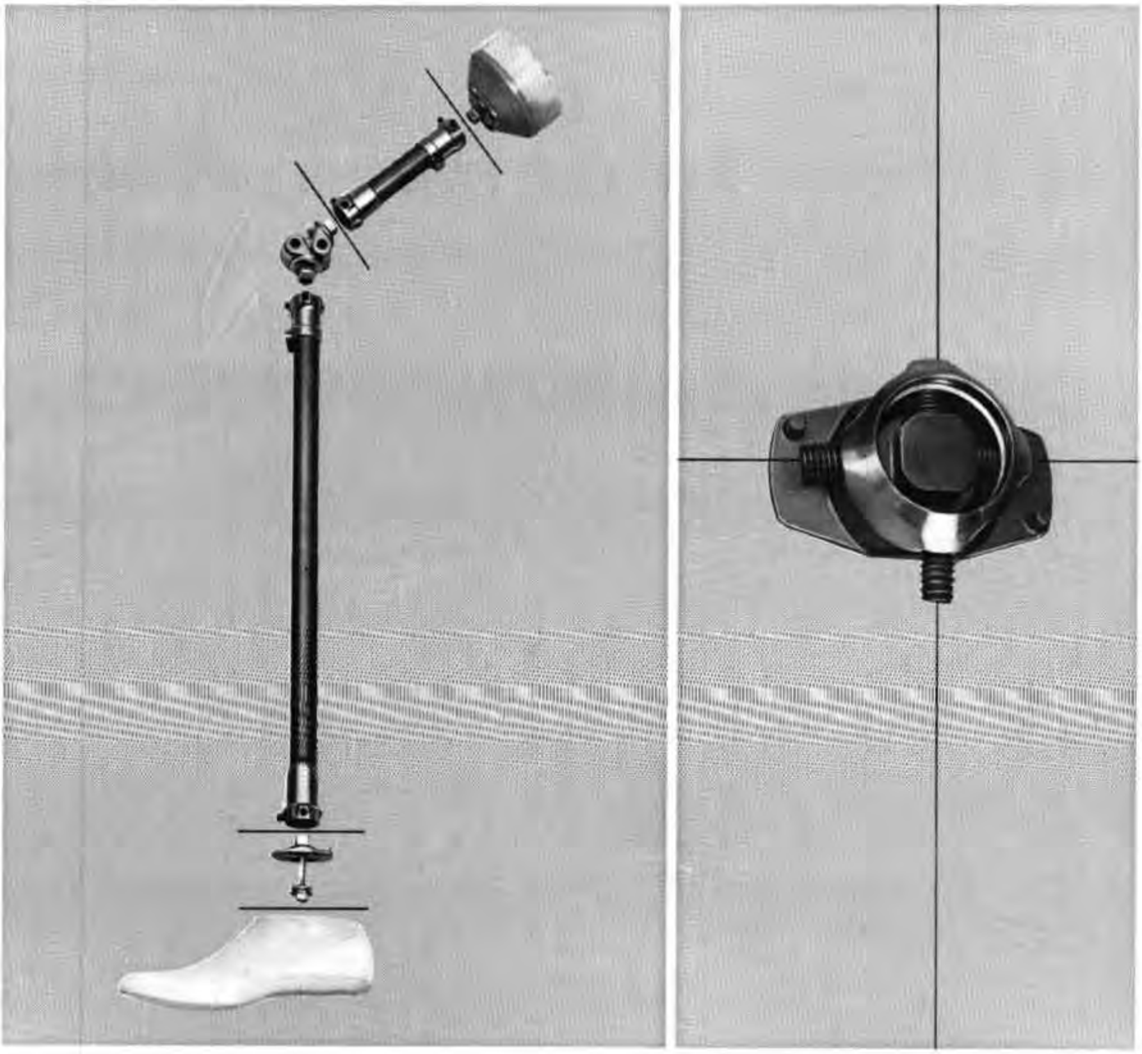
The Journal of the International Society
for Prosthetics and Orthotics

Prosthetics and Orthotics International

December 1977, Vol. 1, No. 3



Prosthetics and Orthotics International

Prosthetics and Orthotics International is published three times yearly by the International Society for Prosthetics and Orthotics (ISPO), PO Box 42, DK-2900, Hellerup, Denmark. Subscription rate is $14 (U.S.) per annum, single numbers $5 (U.S.). The journal is provided free to Members of ISPO. The subscription rate for Associate Members is $7 (U.S.) per annum. Remittances should be made payable to ISPO.

Editorial correspondence, advertisement bookings and enquiries should be directed to Prosthetics and Orthotics International, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG, Scotland (Tel:. 041-552 4049).

ISSN 0309–3646

Produced by the National Centre for Training and Education in Prosthetics and Orthotics, Glasgow.

Printed by David J. Clark Limited, Glasgow.

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Editorial

The President

We must all congratulate the United States National Member Society on their performance in hosting our Second World Assembly and Congress. Despite a difficult financial climate and the distances involved for most of our membership many made obvious sacrifices to come and learn, some to contribute and all to renew friendships and exchange experiences. The scientific programme was comprehensive and of high quality. The instructional courses were very well attended and much appreciated; they have clearly come to stay. Congratulations to Anthony Staros, Sidney Fishman, Howard Thranhardt and their hard working colleagues!

The dust has settled and we must now rouse ourselves from the inevitable let down which follows great events. We constitute a Society which exists not only to meet every three years. We have clear objectives embodied in our constitution and reflected in our Society's structure. Our broad purpose is to help the disabled of the world and the disabled will not be too impressed by their vision of a thousand-odd people cavorting and disporting themselves in the fleshpots of New York, however well they have been successful in informing each other to the patient's ultimate benefit. What will engage their interest will be hard news such as the foundation of a new Technical Committee of the International Standards Organization which will ensure proper standards for the equipment their disability demands. In our efforts we must seek to drive towards an end product either in the form of publication of the useful information or towards methods of operation and collaboration which will ensure direct benefits for our patients. These efforts must reflect needs and priorities and in prosecuting them we should be sensitive to the responsibilities of the United Nations and the World Health Organization and work hand in hand with them in their endeavours.

The contributions to our meeting in New York by Bradford Morse and Ms. Sipila are significant pointers to the way we must go and the pitfalls we must avoid.

You, the members, have responsibilities not only to your National Member Societies but also to the international field by the very fact of your membership. Nevertheless you will be more effective by operating through your National Member Society; fostering the objectives of our Society, stimulating your membership to hold scientific meetings and instructional courses, contributing your ideas, offering to help in international projects and persuading your colleagues to similar efforts. You can, for example, help in a simple and practical way by persuading university, college and hospital libraries to subscribe to "Prosthetics and Orthotics International". Descriptions of your activities, problems and aspirations reported to the Secretariat regularly can be of enormous benefit to the Executive Board in making decisions, promoting activities and in guiding the Society. If you have an idea or problem which seems to be directly within the responsibility of a particular standing committee, write direct to the relevant chairman and send a copy to the Secretariat.

The Standing Committees are presently planning their programme of work and we hope to make appropriate statements of projects in the next number of this Journal. Suggestions and critiques either before or after their plans are announced will be welcome. Two of the new Standing Committees will be meeting shortly. First the Protocol Committee will be discussing the operation of the Society and recommending to the Executive Board guidelines on which they can base their work. It will have a continuing responsibility and will encompass such matters as constitutional interpretation and reform. Your observations, comments and suggestions will be given serious consideration by the Committee. The second of these Committees—the Conference Committee—has a responsibility to create a protocol for the conduct of all ISPO Conferences. The protocol they will recommend to the Executive Board will lay down requirements for the conduct of our triennial Congresses and offer guidance to those responsible for regional and national conferences. As a standing committee the members will individually and collectively always be available for advice and help.

Our next general assembly and congress will be held in the Netherlands subject to satisfactory arrangements being made. Our Dutch friends will have a major task on their hands in preparing for what we believe will be bigger and better than our previous efforts. All members should give them support by making as firm a committment as they can to come to Holland in 1980. We should all now prepare by organizing our work studies and researches so that we can make useful contributions to the Congress. We will certainly expect many contributions on clinical, technical and scientific subjects of importance but it would be extremely valuable if national member societies were to make epidemiological studies of the various disability categories in their respective countries and regions. National statistics are not always reliable and even small studies, if meticulously conducted, will test the validity of existing statistics and prove of enormous value to the international agencies in their planning. We seek, in fact, an updating of the Les Diablerets report.

Finally I wish to congratulate John Hughes, Norman Jacobs and Ron Donovan and their editorial group on their eminently successful efforts in producing our Journal. Make it your responsibility to help them in their endeavour by sending in contributions.

George Murdoch.

The Past President

The second ISPO World Congress truly confirmed the viability of our multi-disciplinary community. Upon retiring from the chair, it is with feelings of pleasure and gratitude that I am reviewing the development of our programme with regard to its global expansion and with regard to advances in education and research.

The activities have been demanding indeed and the problems we are facing present a challenge to our Society in years to come. Millions of physically disabled remain without even basic opportunities for medical and technical care and rehabilitation. Competent staff is in short supply or non-existent in large areas. This is also true in the old world where there remain many unsolved problems or situations in need of improvement.

Our Society has a unique potential armed, as it is, with the highest competence and dedication.

I wish our new President and our new Board a fruitful period with progress and with successful effort. Negligence, outdated traditions, customs, regulations and other hurdles must be crossed. The investments by national and private funds must be properly co-ordinated and adjusted to regional needs and social conditions.

The after effects of the educational procedures which have been applied in the developing countries have not been properly assessed. Our Society is co-operating with the United Nations and Danida in planning a seminar to analyse this important problem. The Clearing House for assistance programmes, operated in collaboration with the United Nations Rehabilitation Office, should be restored and strengthened. Co-operation with the World Health Organization is mandatory to our efforts. Liaison with other organizations with allied objectives, e.g. SICOT and World Orthopaedic Concern may also prove beneficial for our progress.

In spite of some frustration in the past, it is my belief that we find ourselves in an excellent position for further movement. Our basic concept, the team approach, has proven its validity and with faithful support by the membership ISPO will in the future provide better services to more people.

Knud Jansen

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Congress Report

ANTHONY STAROS
Congress President

and

SIDNEY FISHMAN
Programme Chairman

The Committee responsible for organizing the Second World Congress of the International Society for Prosthetics and Orthotics (ISPO) has been most gratified by the response of the membership. Many complimentary comments have been received and an analysis of the registration figures indicates that more than 1000 attendees from over 40 countries, representing all of the major population areas in the world, convened in New York City last May. In fact we believe that the 1977 New York Congress marked the coming of age of the International Society for Prosthetics and Orthotics as an internationally recognized professional society.

Until the formation of ISPO, individuals professionally concerned with prosthetic and orthotic provision for the disabled had no broadly based, interdisciplinary, international forum available for comprehensive discussion and debate. Although meetings of related groups (Orthopaedic Surgery, Rehabilitation Medicine, Physical and Occupational Therapy, etc.) often devoted small portions of their programme to prosthetic and orthotic matters, full attention to pertinent subject matter and issues was never possible in these meetings.

The remarkably broad scope and diversity of ongoing research, clinical, and educational activities was evidenced by the programming in our Congress of 175 acceptable papers and five symposia covering the broad spectrum of prosthetics and orthotics and rehabilitation engineering. In addition to these submitted papers, the plenary sessions offered 30 invited lectures by leading international authorities who provided an up-to-the-minute overview of all aspects of our field.

As an innovation, an extensive programme of 41 instructional courses, ranging in length from two hours to five days, devoted to various topics of interest was offered and was most favourably received. An instructional course faculty of 70 prominent members provided the highest order of technical knowledge to more than 1650 individual course registrants, who were particularly enthused by the detailed, explicit coverage of the many technical topics which were available.

The participants carried away many facts and ideas which could be of immediate benefit to their patients.

The editors of "Prosthetics and Orthotics International" will devote future issues to the publication of selected papers from the Congress. In this way the most important contributions from the Congress will be made part of the professional literature of prosthetics and orthotics and thus available for detailed study on a permanent basis.

An undertaking of the size and complexity of 1977 Congress could not have been implemented without the devoted assistance of numerous talented colleagues throughout the world—their number being too great to list individually. However, we wish to recognize and express our heartfelt thanks and appreciation to all of these associates—and especially to Messrs. Baumgartner, Bähler, and Murdoch who provided us with an excellent model in our First ISPO Congress in Montreux, Switzerland in 1974. A special thank you is offered to our Past President Knud Jansen, who gave us very helpful guidance as the countdown for May 1977 in New York was underway.

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Second Triennial Assembly, 1977

JOHN HUGHES

Honorary Secretary ISPO

The Second Triennial Assembly of the International Society for Prosthetics and Orthotics was held on May 30th, 1977, in New York, U.S.A., at the time of the Second World Congress. The Assembly was opened by the retiring President, Dr. Knud Jansen.

National Representatives were welcomed and introduced from Australia, Belgium, Canada, Denmark, Egypt, West Germany, Israel, India, Japan, Netherlands, Norway, Sweden, Switzerland, United Kingdom and United States of America.

Reports from the Standing Committees of the Society were presented and are summarised following this report.

Dr. Jansen introduced the new Executive Board which had been elected by the International Committee at its meeting on 28th May. The Officers are:

President:	Professor George Murdoch, U.K.
Vice-Presidents:	Mr. Anthony Staros, U.S.A. (President Elect)
	Professor Ernst Marquardt, West Germany
	Mr. Cor Beyer, Netherlands
Fellows:	Mr. Bo Klasson, Sweden
	Dr. H. Ogishima, Japan
	Mr. J. A. Pentland, Canada
	Mr. H. Schmidl, Italy
Hon. Secretary:	Mr. J. Hughes, U.K.
Hon. Treasurer:	Mr. E. Lyquist, Denmark

Professor Murdoch assumed the chair and closed the Assembly with the announcement that the Third World Congress and Assembly would take place in the Netherlands in 1980.

Messages from the new and retiring Presidents form the Editorial in this issue of the Journal.

Standing Committees

Membership

Dr. McKenzie reported on the work of the Membership Committee. It had been approved by the Executive Board that in future the committee would consist of a Chairman, a Vice-Chairman and two other Fellows.

The current membership situation was:

Members and Associate Members	1169
Fellows	64
Sponsor Members	9
Affiliated Societies	5
Libraries	25
Countries represented	60

The total membership had increased by about 10% since 1974.

He congratulated those active National Member Societies which were showing steady growth. He reminded those Societies which had not already done so of the requirement to submit their formal National Constitution.

He referred to the activities of the Ad Hoc Committee on Therapists under the chairmanship of Joan Edelstein. This group would continue its work in the coming triennium.

Education

The main activities of this committee during the previous year had been centred round the preparation of the Congress.

Professor Fishman referred to the variability of the curricula of different schools and the resulting standards of education. It was proposed to hold a workshop to develop more detailed curricula which might lead to an internationally accepted standard and thence to international accreditation. It was hoped to attract funds for this.

The committee remained willing to assist in organising courses in the developing countries. A course was planned sponsored by the Danish Overseas Aid Agency (Danida) on the evaluation of teaching methods in this field.

Evaluation

A previous intention to combine this committee with the Research Committee had been reversed by the Executive Board. Although the committee had not been active there was now intergovernmental interest in establishing an evaluation programme under the auspices of ISPO.

Finance

Dr. Kjølbye presented information on the budget for 1977. A substantial part of the current allocation was to the new journal. It was hoped that eventually through advertising and increased subscription however "Prosthetics and Orthotics International" would become self-supporting.

Publications

Andre Bahler, as Interim Chairman, reported that emphasis was now being placed on developing the new journal. Within the format of this an internal ISPO News Section would be developed. He particularly invited the Executive Board, Chairmen of Standing Committees and National Member Societies to pass information about their activities on to the Publications Committee. National Committees were also invited to nominate correspondents and to stimulate members to write articles for the journal and to inform the Publications Committee of other material which was potentially suitable for publication. It was hoped that in the future Guest Editors would be invited to produce material for symposium issues of "Prosthetics and Orthotics International". The Committee intended to establish a roster of referees for the assessment of submitted papers. It was hoped that it would prove possible to translate summaries of all articles and internal news. Ways of achieving this were currently being investigated.

Research

George Murdoch reported on behalf of the Research Committee. This committee had not been as fruitful as hoped due to the resignation of the Chairman, Colin McLaurin and illness of the Interim Chairman, Fedde Germans, who had subsequently been appointed. However, several projects previously initiated had developed. The Design Criterion Sub-Committee's work had resulted in the formation of a new technical committee of the ISO. The Standards meeting to be held in Philadelphia would also further its objectives.

The fine work on Nomenclature and Classification in Congenital Limb Deficiency under the Chairmanship of the late Hector Kay had not advanced beyond the publication of the ISPO System in several journals. However, it was apparent that several centres around the world were using the system routinely and there is every hope that the work can be revived under a new chairman and with the co-operation of WHO. It will be necessary to increase the membership to include representatives from, for example, France, Japan, Spain and Italy.

Because of the disbanding of the Committee on Prosthetic Research and Development, it had not been possible to continue development of the Information Retrieval System. All copies of the first and second issues of the catalogue had been sold, but work was continuing on the third edition.

A Workshop on the Deformed Foot, which had been sponsored by the Swedish Government was held in Stockholm in March and a report would be available.

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The international organizations—United Nations

Ms. H. SIPILA

Assistant Secretary-General for Social Development and Humanitarian Affairs

Opening Plenary Session of the Second World Congress of the International Society for Prosthetics and Orthotics, 28 May 1977, New York City.

It is a great pleasure for me to speak on behalf of the United Nations at this opening session of the Second World Congress of your organization. Your Congress takes place at a time when it appears that the Member Governments of the United Nations are giving increased attention to the problems that disabled persons are facing in the communities in which they live. The Governments are also showing signs of willingness to take action in order to solve those problems.

I base this assumption on the fact that in the last two sessions of the United Nations General Assembly, in 1975 and 1976, the representatives of Member Governments have adopted important resolutions concerning disabled persons. In 1975 the Assembly proclaimed the Declaration on the Rights of Disabled Persons and in 1976 it proclaimed the year 1981 as International Year for Disabled Persons.

We fully recognize that these actions alone do not render the life of disabled persons any better than it has been. But I am convinced that with the efforts which the United Nations, its specialized agencies concerned and a great number of non-governmental organizations are presently undertaking and, it is hoped, will undertake in order to implement those resolutions, at least some improvements are bound to take place. I am referring, in particular, to conditions in developing countries, in many of which rehabilitation services, including the provision of orthotic and prosthetic appliances, are still extremely limited and reach but a minor part of the disabled population.

I believe it is widely recognized that for many physically disabled persons, the provision of an orthotic or prosthetic appliance is one of the most important elements of the total rehabilitation process. For many of them, such appliances, provided they are well fitting and made to meet each one's specific needs, may restore their mobility and enable them to look for a proper place in the community. I do not claim any specific knowledge of this field but it is obvious even for a lay person how important a phase the regaining of mobility is. Accordingly, the work that is done to make this happen, that is the design, preparation, production and fitting of orthotic and prosthetic appliances as well as all the other related work, must be of equal importance.

The United Nations has been involved during the past 25 years or so with the development of orthotic/prosthetic services although the limited resources that have been available to us for this purpose have kept that involvement at a much lower level than we in the Secretariat would have wished it to be. In this effort, we have enjoyed the technical support and co-operation of your organization as well as its predecessor, the International Committee on Prosthetics and Orthotics and I only wish that close co-operation between our organizations will be maintained in the future. As you will hear more of our specific activities in this field later during your Congress I will not go into details now.

Instead, I should like to use this opportunity to draw your attention to some of the issues of more general nature related to technical assistance activities. As you may know, the United Nations social and economic activities, including those in the field of orthotics and prosthetics, are mainly aimed at assisting the developing countries to meet the basic needs of their populations. Within this framework efforts are also being made to help Governments to establish and improve the services rendered for disabled persons. It is well known that despite all the efforts that have been made by the international community, multilaterally and bilaterally, in the social and economic fields in general, the fact remains that the gap in standards of living between the industrial and the developing countries is continuously broadening. Obviously the same applies to the levels of service to disabled persons in these two groups of countries. It has become obvious that some of the methods used in the past in assisting developing countries may not have been the right ones and that what is found to be good and desirable in this and other industrialized countries may not be relevant to the conditions in many of the developing countries.

In recent years, the United Nations and the specialized agencies concerned (ILO, WHO and UNESCO) as well as some of the interested non-governmental organizations have been re-evaluating these past efforts of assisting developing countries in the field of rehabilitation. It has been recognized that the necessary resources simply are not available to help most of the developing countries establish the same kind of rehabilitation programmes that have been created during the last 30 years in industrialized countries and that require a considerable number of highly specialized personnel, sophisticated equipment and expensive institutions. It has been suggested that alternative ways should be sought for rehabilitating disabled persons in developing countries which those countries could afford and manage and which would be relevant to their needs and resources.

This applies also to the provision of assistance to orthotic/prosthetic services. Some of these services which have been established during the past 20 years with the help of foreign assistance obviously are functioning well and providing the services that are expected from them. Other efforts may have been less successful and, no doubt, complete failures can also be found. It would be useful, I believe, to carry out a thorough evaluation of some of the past technical assistance projects in this field in order to determine whether the advice that has been rendered has been relevant to the needs and resources of the countries concerned, whether the advice has been heeded and, if so, with what results. Maybe, this body or your organization should give specific attention to this matter and help us, as well as other organizations that provide technical assistance in this field to design the most appropriate methods for this assistance—methods that would result in the establishment of services covering the maximum number of disabled persons that need those services at the lowest possible expense.

I have been speaking to you about the relationship of orthotic/prosthetic questions to the work of the United Nations Centre for Social Development and Humanitarian Affairs where rehabilitation matters, among other social issues, are a regular part of our work. You may also be interested in knowing about the United Nations activities concerning the application of advances of science and technology in the developing countries. A major United Nations conference on this subject will be organized in 1979 to explore how science and technology can contribute to the economic and social development of developing countries. It will seek, among other things, concrete decisions on ways of applying science and technology in establishing a new international economic order. I would assume that some of the principles to be discussed in this conference may be of particular interest to your organization and to your membership and that you might want to find out whether the question of transferring the benefits of technological advances in orthotics and prosthetics to developing countries could be related to the subjects to be dealt with within the framework of the United Nations activities in science and technology. In the Centre for Social Development and Humanitarian Affairs, we deal with social aspects of rehabilitation as well as of orthotics and prosthetics. Technological and scientific questions are handled by the Office for Science and Technology of the United Nations Department of Economic and Social Affairs.

Finally, I should like to use this opportunity of expressing our heartfelt thanks to your organization for the co-operation and technical advice extended to us in connection with several United Nations training courses and urge you to give special attention to the goals and objectives of the International Year for Disabled Persons 1981 in your work programmes for the next few years.

Prosthetics and Orthotics International, 1977, 1, 140–144

The international organizations—United Nations

BRADFORD MORSE

Rehabilitation International Luncheon, 31 *May*, 1977

I am very pleased to join with you today and to have an opportunity to discuss the role of United Nations organizations in the field of prosthetics and orthotics and, more generally, of the rehabilitation of disabled persons. As a former Deputy Administrator of the United States Veterans Administration I have had some direct working responsibility for the welfare of disabled persons. I know just a little of your marvellous work and I have seen too much of the desperate plight of handicapped people in the developing countries not to believe that we in the United Nations development system must intensify our efforts in all possible ways to help those hundreds of millions of people.

In the widest and longer-term context, our efforts of course must be preventive—the very process of integrated and co-ordinated development is one that seeks to eradicate the *causes* of many forms of disability. Thus, for example, the United Nations Development Programme is working with the World Health Organization and the World Bank, and many bilateral donors, in seven African countries both to eradicate the tiny blackfly that produces onchocerciasis — river blindness—and to build up an integrated development programme for the entire area as it becomes safe for human settlement. In the same way, UNDP and WHO have launched a major new attack on the six great tropical diseases that kill, debilitate and disable millions of people. Our work in the drive to increase production of nutritious food in the developing countries, including applied research in plant genetics to breed into grain crops for a higher nutritional value, will also serve to cut back nutritional causes of disablement. A new concentration on problems of providing safe water for every village in the world by 1990, one of the goals set by the recent United Nations Water Conference, will yet again progressively reduce causes of the effects which you who are specialists in rehabilitation must cope with.

But I am fully aware that all these massive longer-term development efforts do not reach to the hundreds of millions who are already disabled, or day by day are being born with handicaps, or are becoming afflicted as children and adults. Let me therefore shorten the perspective, and try to give you a brief overview of United Nations work more directly in rehabilitation. Under the Administrative Committee on Co-ordination, which is chaired by the United Nations Secretary General, I believe that we are moving towards a more concerted inter-agency effort among the agencies concerned with the disabled. These, as you know, are the United Nations Social Development Division; the World Health Organization; the International Labour Office especially in respect of Vocational Rehabilitation; UNESCO which deals with special education for the handicapped; UNICEF which works in the maternal, infant, and childhood areas; and the High Commission for Refugees which must care for handicapped refugees.

At a special meeting of these agencies in 1975, a "New Concept" was agreed, incorporating a set of objectives, aims and basic principles. I believe these are important as the foundation for a strategy and, not least, for an approach to the disabled in developing countries that can at least begin to overcome the terrible difficulty of scarce financial resources and the paramount importance of finding cost-beneficial arguments for development planners. Let me quote to you some of the key points in this New Concept:

" (a) the main objective of the programme should be to reduce the problems arising from disability for the disabled person himself, for his immediate surroundings, and for the community, utilizing all possible preventive and curative measures, or measures that might wholly or partly reverse an already present disability, or delay its progress. The action taken should not only be directed towards the individual but also towards factors in his surroundings or in the society at large;

(b) the programme should be directed towards vulnerable groups in the developing world with a high risk of disability and persons whose disability could be expected to be preventable or with whom a rehabilitative intervention was likely to be successful;

(c) the principal aim of these measures should be the integration of the disabled into community life (through such activities as the restoration of the disabled person's mental and physical abilities and capacities, mobility and orientation, self-care independence, necessary education and training, improved chances for gainful employment or other economic activity and elimination of physical barriers and prejudices and discriminatory attitudes which may form an obstacle to that integration);

(d) the programme should contain provisions for effective prevention of disabilities and for community involvement and participation (including the participation of disabled persons themselves in decisions affecting them);

- —it should emphasize the need for avoiding expensive institutional facilities and instead promote development of low-cost high-yield services;
- —it should, furthermore, underline the need for effective co-ordination of efforts at all levels (international, regional, national, local);
- —integration of disability prevention and rehabilitation services into national development plans should take place through the national programming process which would define national priorities and necessary measures and means for implementation;

(e) mechanisms should be established by which interested governments could be informed and advised, requisite national will and local interest assessed and the possibility of implementing on a long-term basis a series of comprehensive disability prevention/rehabilitation projects evaluated."

There are points within these objectives to which I will wish to return in a moment, because they closely relate to what my own responsibility, for the United Nations Development Programme, may involve in intensified efforts of collaboration with you. But first, let me give you a quick sketch of UNDP itself, and how we work.

UNDP is engaged in programming, co-ordination, financing, monitoring, delivery and evaluation of some 8,000 projects in technical development co-operation in 149 countries and territories across the world. Its annual volume of expenditure now exceeds one billion dollars, almost half from UNDP resources voluntarily contributed by governments and the balance from the direct counterpart contributions of developing country governments to support these projects.

The projects cover virtually every economic, social and technological activity one can conceive, and they vary in size and duration from the provision of perhaps one international expert for three or six months, to large-scale efforts involving teams of experts, equipment, and fellowships extending for several years and costing a million or more dollars for each such project. As of last year, UNDP was supporting over 500 projects in Health fields, and another 400 in social welfare.

The Programme is operated through some 25 technical agencies, and in each developing country the work is led and co-ordinated by our UNDP Resident Representative and staff—we have thus a network of some 100 field offices in the developing countries for this vital purpose.

Now it is crucial to understand how the use of UNDP resources is determined, because in this there is a most important factor relating to the extent of our work for disabled persons. UNDP's financial resources are massively decentralized. They are largely divided by our Governing Council into five-year "Indicative Planning Figures" for each developing country. Each government, working with the Resident Representative and his or her team, identifies its priorities for use of these funds, and draws up its "country programme" and the projects from which the programme is synthesized. On the United Nations side, the Resident Representative is responsible for the effective co-ordination of this work among the specialized agencies and for helping the government, to the extent it chooses, in its co-ordination of external assistance from other sources. The Resident Representative is responsible for ensuring that each UNDP-supported project has relevant and realistic objectives, adequate supporting infrastructure, an effective and rational timetable of activities, and the capacity for steady growth and productivity after UNDP involvement has been completed. The Resident Representative has financial authority to approve, on the spot, any project up to a cost of $400,000.

At once, then, you will understand that the decision, for each developing country, as to what priority to accord rehabilitation and services for disabled people in the use of its assigned share of UNDP funds, is a decision made *by its government*. In the vast majority of cases, this decision-making is carried out on a partnership basis with our Resident Representative, who can obviously suggest areas of investment for the Government to consider. But at the end of the day it is the Government's choice and it is no secret to those working in rehabilitation that, to date, those choices accord very low priority to the disabled.

Last year, our recorded country-level expenditures *directly* in rehabilitation of the disabled with the ILO, for example—including ILO-executed projects dealing with prosthetics and orthotics—came to some $850,000 world-wide in some 15 projects. There were, of course, other projects through UNESCO and other agencies, but at the country levels, the total *direct* application of UNDP funds for services to the disabled remains very small.

We have, of course, moved ahead to a limited extent at the level above individual country activity. As you may know, and I am very pleased about this, UNDP is supporting the opening two-year phase of the new International Institute for Rehabilitation in Developing Countries, which is hosted by Iran at Teheran, and which will draw upon WHO's Regional Training Centre, also located at Teheran. The Institute is to provide assistance to developing countries in the establishment and development of disability prevention and rehabilitation services at low cost. UNDP's assistance amounts to $237,000 over 1977 and 1978; the Government of Iran's contribution is estimated at 3.9 million Rials. This is undoubtedly one important step forward.

Another new initiative by the Development Programme should also yield a steadily widening impact at the country levels. As part of a major new effort to help Governments and our Resident Representatives to focus the planning of UNDP activity in co-ordinated ways, we are issuing what we call Technical Advisory Notes—reasonably short papers that pose key questions for planners in a given sector or sub-sector of development, but that particularly seek also to help planners to "see over the sectoral fence" as it were, and identify the elements in a given objective that will require multi-sectoral and well co-ordinated effort. I am very glad to be able to tell you that UNDP, with the specialized agencies I have mentioned that work in the field of rehabilitation, is now actively discussing the preparation of such Notes in the field of Rehabilitation of the Disabled. The discussions are also involving the Council of World Organizations Interested in The Handicapped whose chairman, as you know, is Norman Acton, Secretary General of Rehabilitation International.

It is in these critical areas of communicating the needs—*and the potential contributions*—of the disabled to our national and international planners, that I would like to make a few suggestions to you. Firstly, I am deeply concerned lest we allow the impression to persist that facilities, services and opportunities for handicapped people are solely the concern of two or three sectors and ministries; and that development benefiting the handicapped always takes the form of separate projects, so labelled. The specialized projects, not least those in prosthetics, are of course absolutely vital. But we must surely find better ways to demonstrate to planners that for many handicapped people a range of quite simple environmental adjustments and of community service opportunities could be *programmed into* a far wider spectrum of projects, and without special high costs.

Let me turn next to the technology of rehabilitation. And here, I hope that none of you will take offence if I suggest an analogy with a problem I am grappling with every day—that the unit-cost of foreign expertise which, in the United Nations system, has to date necessarily been based on the costs of an expert from the richer countries, is steadily pricing itself out of feasibility for developing countries. Has not the unit-cost of prosthetics, based on the technology of rehabilitation in the industrialized countries, followed a quite similar curve?

Yet at the very other end of the scale, wherever I have gone in the developing countries, I have seen on all sides examples of crude, self-designed physical aids in use by handicapped people, in city streets and village lanes, that have made me wonder again and again. And we know in UNDP—indeed we will be re-doubling our efforts from what we already know—that the resources of indigenous technology, suitable for conditions in developing countries, have scarcely begun to be tapped as yet for organized development work in many sectors. I claim absolutely no expertise in this area and I do know that the science of prosthetics is one of the most wonderful, intricate, and ingenious accomplishments. But has enough been done to search out *intermediate* technology in this so terribly important aspect of rehabilitation? Both in terms of the materials and of the degree of complexity of design—even the range of manual and perambulatory achievement—is it possible that the technology of rehabilitation can be made more appropriate to the resources of developing countries?

Attitudes in the developing countries are changing about this entire subject. Authorities have become profoundly aware in more and more fields and sectors that the wholesale importation, and total reliance upon technology models from industrialized countries is dangerous. The training of technicians in the design and use of technology based on the industrialized countries' capacity to pay for high-cost materials and manufacture is more and more seen as training that may train a technician almost out of usefulness in his or her own country. And so I pose the question in a deliberately dramatic form: what price the prosthetics workshop in a developing country that is dependent upon aluminium materials which the country does not manufacture and cannot afford to import—when in the streets outside there are moving miracles of ingenuity among the handicapped themselves, and in the country as a whole there may be indigenous raw materials which certainly could not replace aluminium but might indeed be better than nothing at all for more generations of disabled people?

I hope that it would be possible to plan for human settlements, rural and urban, in which there could be small workshops, staffed largely by handicapped people themselves, producing at least a range of more simple prosthetic equipment based upon inventories of minimal needs that could be met, and drawing upon all the ingenuity which re-oriented technicians could seek out in their own country among its raw materials. I admit quite freely that this vision is based, not on specialized knowledge of this miraculous technology, but on sheer confidence that it cannot be beyond the gifts of inspired men and women to achieve in this field in less costly ways what people in the developing countries have long ago achieved and are now resuming—technology that springs from their own circumstances, their own resources, their own adversity-driven inspirations.

As you may know, the United Nations Development Programme has been given the responsibility of launching a special system for Technical Co-operation between Developing Countries. This is a programme to try to accelerate the exchange of wisdom and expertise in development between the developing countries themselves because their circumstances and their massive accumulated experience may so often be inter-changeable. We are developing a data bank and information referral system for this technical co-operation, and I most certainly want to ensure that it includes any and all work and expertise in these rehabilitation technologies. Here again is surely an opportunity for international action within our existing resources.

Finally, there is a resource for development which, however paradoxical and obvious it is when once stated, we have only begun to understand and to tap—the treasure of human will, of community-wide motivation, of organized self-help in non-governmental organizations in the developing countries. It is an enormous subject, immensely rich in its potential. Let me single out only one basic suggestion related to improving the quality of life for handicapped persons in human settlement work.

The developing countries are increasingly evolving new echelons and cadres of para- or auxiliary workers in many sectors. Year by year, the re-structuring of professional, technical and administrative human resources is identifying these roles as distinct needs in development that do not rely on imported models. What are the implications for handicapped people in the developing countries? In the low-cost training, by non-governmental rehabilitation agencies, of hundreds of selected handicapped persons as auxiliary teachers of handicapped children both in ordinary schools and in village and slum centres for necessarily sheltered children? In the training of handicapped para-medical aides to nurses and midwives, to reinforce their reach to handicapped people? And the same in vocational training?

In these areas, too, I hope that the United Nations Development Programme will be able to help, not necessarily with direct financial resources for the reasons I have mentioned, but through our special new policy of seeking far more dynamic collaboration with non-governmental organizations in the developing countries and thus meshing together their resources with ours.

I hope that in this inevitably sketchy overview, I may have given those of you who spend your lives working for the disabled some measure of increased hope and some ideas as to how we can work together more closely. You have my pledge that I am deeply aware how far we have to go to give full meaning to our own United Nations Declaration on the Rights of the Disabled. If we work together; if specialists in rehabilitation can find new means to engage the understanding of development planners; if there are as yet un-tapped aspects of the new science of appropriate technology that can advance the use of prosthetics in desperately poor countries, then surely we can move ahead.

The international organizations—Rehabilitation International

NORMAN ACTON

Rehabilitation International Luncheon, 31st May, 1977

I have been asked to speak to you about Rehabilitation International, and especially its programme activities directly related to prosthetics and orthotics. I am going to take the liberty of expanding that subject a bit, not because I could not quickly fill the time at my disposal with what Rehabilitation International is doing, but for two other reasons.

I hope that most of you already know, at least in a general way, what Rehabilitation International is and does. You know that for financial and other reasons we have an extremely modest technical assistance programme, and consequently do not give our major attention to direct help of that kind. We do operate a major programme for the exchange of information with the bases of activity in Heidelberg and in Mexico City for the Spanish language countries, as well as in Stockholm where ICTA, our International Commission on Technical Aids, Housing and Transportation, distributes material relevant to those subjects. We do include in these distribution mechanisms information of direct relevance to those who are working in the fields of prosthetics and orthotics, and the subjects, of course, are always important ones in our World Congresses, Regional, and other meetings.

Perhaps one of the most important credentials of Rehabilitation International in this particular audience is the fact that it has been the mother and father of the International Society for Prosthetics and Orthotics. As you know, ISPO started as a Technical Committee within Rehabilitation International, and its eventual separation as an independent organization was planned and carried out as a progressive step with the agreement of both parties, and in a spirit of complete friendship and co-operation. ISPO remains an international member of Rehabilitation International and the co-operation continues in both spirit and reality.

My second reason for broadening the subject assigned to me is that I would like to take the opportunity of having you gathered in one audience to suggest some avenues of larger co-operation that are open to all of us that are working in this field. In this connection, I would like immediately to emphasize that we are in the presence of a pattern of opportunities that should be a major challenge to all of us who are interested in expanding the impact of international effort and the depth of its consequences in the various countries around the world.

We are entering the final years of the Decade of Rehabilitation, which was proclaimed for the 1970s by Rehabilitation International. The Decade will culminate in the 14th World Congress, to be held in Winnipeg, Canada, June 22–27, 1980. The time between now and then will be occupied by various regional and other specialized conferences and seminars, all dealing with the major themes that have been chosen for the 14th World Congress.

These themes have been selected following a survey of individuals and organizations in all parts of the world to learn what are the major preoccupations of people working in rehabilitation activities. They are as follows: the prevention of disability, the integration of disabled persons into the community, the participation of disabled persons in the rehabilitation process, and the improvement of professional care and services. We are developing a comprehensive programme for the 14th World Congress which will include attention to each of these subjects as well as to the larger principles which bind them together in the rehabilitation process.

A large number of individuals and organizations have been involved in the selection of these themes, and even larger numbers will be involved in the various preparatory conferences and other activities leading up to the 14th World Congress. The objective of all of this is to engage as many people and organizations as possible in thinking that will produce a "Charter for the 1980s". That is, a statement of principles and objectives upon which there is wide international agreement, and which can guide the further development of our collective effort during the next decade. This would be accompanied by a set of more specific recommendations capable of being implemented at the national level, making allowances for the varying stages of development in different areas and regions of the world.

As you have heard, the United Nations General Assembly has proclaimed 1981 the International Year for Disabled Persons. We are engaged with the United Nations Secretariat in a very close co-ordination of planning so that the preparatory work for the Rehabilitation International 1980 Congress will serve also to prepare the way for the International Year in 1981. The "Charter for the 80s" and the special recommendations which we hope will emerge from our preparatory process and Congress can be the basis for regional and national action during the International Year in 1981. We are discussing with the U.N. the possibility that the draft texts of these documents would be prepared by experts chosen not only by Rehabilitation International, but by the United Nations and other co-operating organizations, such as ISPO.

During the first seven years of the Decade of Rehabilitation we have achieved successes in some areas, and there remains much to be done in others. I regard our work in the pursuit of the first three objectives of the Decade as having lead to significant developments. These were to increase public awareness of the problem of disability and the fact that something can be done about it, to encourage governments to give a higher priority to services for disability prevention and rehabilitation, and to provide or stimulate the provision of information, guidance, and advice needed for the development of rehabilitation services. In each of these areas, there has been significant progress during recent years and, while I certainly would not attempt to claim credit for all of that for Rehabilitation International and its Decade of Rehabilitation, we can show that a number of these significant developments are based on the knowledge, the contacts and the stimulation resulting from the Decade Programme.

The other two objectives of the Decade were, first, to encourage an increase in the volume of training opportunities for personnel needed in the rehabilitation field, and to expand the concepts of training to deal more effectively with today's reality; and, second, to develop simpler and less expensive methods of providing needed rehabilitation services. In my opinion, it is in these last two areas that high priority attention needs to be given, not only during the balance of the Decade of Rehabilitation, but in our plans for the future. We have seen in many different ways the statistical and other data which makes it evident that traditional methods are not coming to grips with the volume of disability around the world, and it was Rehabilitation International's privilege to introduce in 1969 the estimates upon which much of our global thinking since that time has been based. You recall the figures we announced at that time, 450 million disabled persons in the world, 300 million of them in need of services that were not available to them. We may now estimate that there has been an addition of approximately 3 million disabled persons to that total each year, and I think none of us would pretend that we have been able to develop additional services to deal with that increase, or with the 300 million deficit with which we started the Decade.

I am, however, jumping ahead of the story, since the "Charter for the 80s" and the recommendations for activity in the future will emerge from the process I have described. I hope you will agree that if we all join in these co-ordinated events in the preparation for and in the actual activities of the 14th World Rehabilitation Congress and the International Year for Disabled Persons, we will succeed in generating a new level of understanding of our problems and our needs, and new levels of support for the kinds of activity we are all seeking to develop.

Prosthetics and Orthotics International, 1977, 1, 146–160

THE KNUD JANSEN LECTURE

Above-knee prosthetics

C. W. RADCLIFFE

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Introduction

In any discussion of the development of technology as applied to the rehabilitation of the above-the-knee amputee, we must first acknowledge the many contributions of European pioneers in this field.

In Europe the needs resulting from World War I resulted in greatly accelerated research and development in the field of prosthetics technology during the next three decades. This research included scientific studies of the biomechanics of human walking, alignment principles, and methods of fitting for above-knee prostheses. Notable examples were the work of Braune and Fischer on human gait, and the publications of Dr. Schede and others on scientific principles of fitting and alignment. The list of German and Austrian contributors to prosthetic technology is long and distinguished. Their literature and professional meetings have always included a series of lively discussions between proponents of different construction systems and prosthetic component designs.

In 1946 a U.S. Army Commission under the direction of Col. L. T. Peterson made a study of European prosthetics technology. They were particularly impressed with the work of Haberman and Schneider in Germany. A major recommendation of this commission was for the introduction of the so-called "suction socket" for the above-knee amputee into American prosthetic practice. Responsibility for supervision of this programme was delegated to the University of California at Berkeley and a series of schools and clinical trials were successful in introducing this new fitting technique into the United States during the 1946-1948 period.

In 1949 a second group led by Dr. V. T. Inman and Professor H. D. Eberhart visited Europe for another critical comparison of European and American practice, particularly in the area of lower limb prosthetic components and fitting and alignment principles. They were intrigued with the results obtained by Striede in Austria using the quadrilateral suction socket shape. They also described and catalogued a large number of physiological, linkage, and friction brake knee designs, alignment devices and other fitting aids. Among others, the condylar designs of Striede, Lang, Röck, and Haberman were studied and evaluated as well as the brake type designs of the Kleinkathöfer and Jüpa knees and the four-bar linkage design of Lammers. In addition, they observed the alignment principles and adjustable "walking machine" prosthesis of Schneider and other alignment systems such as those used by Haberman in Frankfurt, and others.

Upon the return of the Inman-Eberhart group, a series of clinical trials of devices and principles observed in Europe were undertaken at Berkeley in an effort to evaluate their potential for improvement of the comfort and function of the suction socket above-knee prosthesis as it was then being fitted in the United States. An extensive review of the German literature revealed a wealth of information but no universally recognized and accepted set of biomechanical principles which could guide the prosthetist in selecting components and methods for fitting the above-knee prosthesis. A number of different socket shapes were in use in Europe as well as considerable variety in the devices, materials and methods of fitting and alignment.

As a result of evaluations subsequent to the 1949 European trip, the following items were selected for more extensive study at Berkeley.

(1) The quadrilateral ischial bearing socket shape as fitted by Striede in Austria.
(2) The benefits of polycentric knee constructions; in particular, the Striede, Röck, and Lang knees from Germany.
(3) The use of adjustable prostheses for walking

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trials and dynamic alignment adjustments as used by Schneider in Germany.

(4) Biomechanical principles of fitting and alignment of the suction socket above-knee prosthesis.

In addition to the above, the Inman-Eberhart report noted the generally poor swing phase control in both American and European prostheses and proposed an additional project.

(5) The development of improved swing control devices which would simulate quadriceps and hamstring muscle action about a normal knee and allow walking over an increased range of walking speeds.

During the period 1949-55, the research staff at the Biomechanics Laboratory continued their evaluation of the German technology and developed what was considered a rational biomechanical basis for fitting the carved willow wood suction socket. An alignment system using the "AK adjustable leg" and the "AK alignment duplication jig" was developed and tested with the co-operation of prominent American prosthetists, notably Trautman in Minneapolis, Haddon in Denver, and Thranhardt in Atlanta.

This information was organized in the form of a syllabus for the first "pilot school in above-knee prosthetics" held in August 1955 for the purpose of training future instructors for the new prosthetics education programmes then being developed at New York University and the University of California at Los Angeles. This material later became the basis for the *Manual of Above-Knee Prosthetics* edited by M. H. Anderson and R. E. Sollars and published January 1, 1957.

One of the major benefits of the 1955 technology was the introduction of a uniform and scientific terminology which enhanced the ability of members of the prosthetic clinic teams to communicate with each other in solving the various problems associated with amputee rehabilitation. The new education programmes in above-knee prosthetics were one step toward the eventual certification and improved professional education of American prosthetists.

The period 1955-60 saw the introduction of thermosetting laminating resins into lower limb prosthetics technology: first as a substitute for rawhide in the reinforcement of wooden prostheses, later as the basic material for plastic sockets moulded over plaster models of the stump. The remarkable success of the laminated plastic socket used with the patellar-tendon-bearing below-knee prosthesis led to the use of similar techniques with above-knee sockets. The adjustable brims developed at Berkeley and the fitting stand developed by VAPC in New York City, both of which appeared in the early sixties, were designed to aid in the plaster wrap casting of the above-knee stump. These new tools made the "total contact" AK suction socket possible and helped to solve the problems of distal stump oedema often experienced with "open-end" carved willow wood sockets.

Studies of the kinematics of various European polycentric, physiological, and brake-type knee constructions indicated a general confusion as to the function, amputee benefits, and prescription criteria for such devices.

It was clear that a comprehensive theory which could relate the functional characteristics of such devices to their alignment and the needs of the amputee was required. It was hoped that studies of this type would show the relationship between the physical capabilities of the amputee, the functional characteristics of the device, and the manner in which the prosthesis was used in walking. It became clear that it was instructive to discuss above-knee prosthetics in a somewhat different manner than had been typical in the past. It was typical in the pre-1950 era to discuss fitting and alignment of the above-knee prosthesis as almost separate problems in three areas:

(1) socket shape and fitting methods
(2) alignment for stability and swing through
(3) selection of components.

Eventually, a somewhat different and hopefully more logical approach evolved as given below. We will first discuss the functional characteristics of certain classes of prosthetic knee designs and relate their function to alignment principles. The use of a certain class of knee mechanism plus the need to balance the body weight above the prosthesis during the stance phase creates a varying pattern of biomechanical pressures between stump and socket. These pressure patterns can be anticipated and influence the basic socket design. The most difficult part of the entire process is the fitting of the socket to the individual anatomical characteristics of the amputee. Here the skillful prosthetist will "shape" the socket to achieve a comfortable accommodation of the required biomechanical forces and pressures. In the actual fitting, the casting of the stump and shaping and adjustment of the socket are often the first steps in the procedure. However, the successful fitting also must include careful planning of the complete procedure including the influence of components and alignment on the type of socket fitting to be achieved.

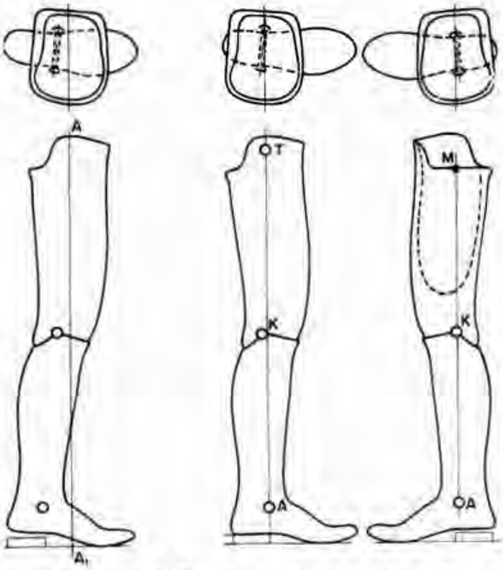
Classification of prosthetic knee mechanisms

A large number of different knee mechanisms have either been invented or developed as research studies, and many are available commercially for fitting to the above-knee amputee. The potential user often has great difficulty in evaluating the claims of the developer as to the benefits to be derived from the special features of a particular device. When a particular mechanism is considered in terms of its basic functional elements it is often possible to catalogue the device as a member of a certain class. There will, of course, be differences in construction, weight, durability, and even the degree to which a particular device approaches the optimal functional behaviour expected of a device of that class. In this discussion we will classify knee mechanisms in terms of (1) their special features which are related to enhancing knee stability, i.e., safety against collapse of the knee during the stance phase, and (2) the type of mechanism employed to control the flexion of the knee during the swing phase of walking.

Bench alignment systems

The basic means employed in many above-knee prostheses to achieve knee stability is to align the knee axis in a location such that the load carried by the weight-bearing prostheses always passes ahead of the knee axis and forces the prosthetic knee against a mechanical stop in the fully extended position. This simple principle is employed in all above-knee prostheses regardless of other means used to achieve stability and will be referred to as *alignment stability* in the following discussion.

Alignment stability is often ensured by a process which has become known as *bench alignment*. Two somewhat different philosophies for bench alignment have been proposed. In Germany the prosthesis is often assembled in a fixture using a plumb line viewed from the lateral side which passes downward from the centre of the socket brim through a point on the bisector of the length of the foot as shown in Figure 1. The trochanter is sometimes used as the upper reference point. To achieve what may be described as a rolling action of the hip over the foot the heel of the foot is elevated slightly in the reference position. The bench alignment diagram displays the prosthesis in a position corresponding to the point where the amputee would begin to roll over the ball of the foot in walking, i.e., in a position where the hip joint is close to the highest point in its trajectory. The clearance under the heel is often called a "safety factor". An increased clearance results in a more rapid transfer of weight to the ball of the foot and improves knee stability at heel contact.



Figs. 1, 2 and 3. Bench alignment systems. Fig. 1 (left) German, fig. 2 (centre) TKA reference, fig. 3 (right) MKA reference.

The position of the knee axis relative to the vertical reference line is dictated by the combination of knee kinematics and friction brake action inherent in a particular mechanism and very definite rules have been established for different combinations of knee and foot designs.

In the United States a similar plumb line reference system has been used which has the trochanter as the upper reference point and which locates the ankle joint directly under the trochanter as shown in Figure 2. Rules have been established for locating the knee joint on or behind this reference line which has been called the TKA line. In the American system the heel is shown in contact with the floor in the reference position. This system has evolved because of the need to have a convenient way to check bench alignment prior to walking trials with adjustable devices without the need for special holding or limb assembly fixtures as are common to some European systems.

The American system may result in a prosthesis which is somewhat longer than a similar prosthesis if the pelvis level is checked with the limb in the alignment reference position.

As the American prosthesis rotates forward over the ball of the foot toward the German reference position, it is clear that the heel would rise from the floor and the hip joint would be elevated slightly. This explains in part the controversy which often occurs between the American prosthetist who prefers to construct the prosthesis shortened a few millimetres to make it easier for the amputee to walk and the physician who insists on a level pelvis with the prosthesis in the alignment reference position.

Errors in both systems can result when the trochanter is used as the upper reference point. It requires that the alignment be checked with the amputee wearing the prosthesis and precise location of the point of contact of the head of the trochanter against the lateral brim of the socket is often difficult.

The reference line shown in Figure 3 is suggested as an alternative which is particularly well suited to the fitting of the quadrilateral socket shape. The upper reference point is established at the bisector of the interior medial wall of the socket. In the modified American system the new reference line becomes the MKA line and the knee joint is located on the medial aspect of the prosthesis rather than the lateral side as with the use of the TKA line.

When using the TKA line, the knee axis is located on the lateral side of the prosthesis and for a typical prosthesis the knee axis is located approximately 6 mm (¼″) posterior to the TKA line.

The knee axis is typically aligned in 5 degrees external rotation, as necessary to prevent lateral movement (whip) of the foot in the swing phase. The medial end of the knee axis is forward of the lateral end by approximately 6 mm. Therefore, when using the MKA reference line along the medial aspect of the prosthesis, the knee axis can be located directly on the MKA line for a typical active above-knee amputee with medium to long stump.

The usefulness of the German air space under the heel is also acknowledged and where greater knee security is desired, the use of increased heel rise in the prosthetic foot is encouraged.

A spacer under the heel 6 to 10 mm thick at the time of bench alignment will give the amputee greatly increased knee security at heel contact. The prosthesis will not have its length increased with this procedure since the distance to the ball of the foot remains the same.

Polycentric knee mechanisms

Alignment stability can be enhanced through the use of polycentric knee mechanisms. A polycentric knee mechanism is any device where the instantaneous centre of rotation of the knee changes its position as the knee flexion angle increases or decreases. Kinematically all polycentric devices, where stability is controlled by the location of the instantaneous centre of rotation (the instant centre), are of the same class. However, there is an infinite variety of kinematic arrangements possible, each with its own special functional characteristics. The following discussion is an attempt to explain the behaviour of such devices assuming, in the beginning, that there is no brake-type friction acting simultaneously as part of the function of a particular device.

There are several ways that polycentric motion between the thigh piece and shank can be created in a knee mechanism.

Figure 4 displays schematically most of the polycentric prosthetic knee mechanisms that have been used to date. In each diagram the point I represents the instantaneous centre of rotation of the thigh piece or knee block with respect to the fixed shank with the knee in full extension. In many cases, it has been possible to locate the point I in exactly the same position when the knee is fully extended.

Case A represents the double-skid mechanism often used for so-called "physiological" knee mechanisms. In this case the shape of the upper condylar surface determines the manner in which the instant centre changes its location with knee flexion. Point I is located at the intersection of the two lines which are perpendicular to the surfaces in contact at the two skid points.

Case B is a simple variation where one skid point has been replaced by a pivoted slider.

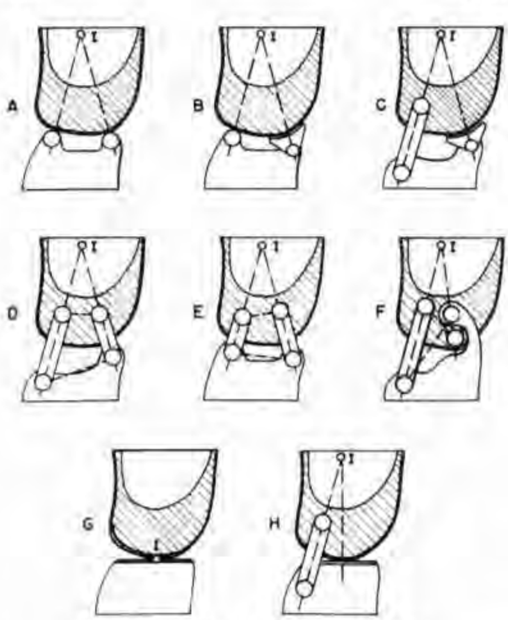


Fig. 4. Polycentric knee mechanisms.

Point I is again located by two lines, one of which passes through the slider pivot perpendicular to the upper condylar surface.

In case C the rear skid point has been replaced by a two-joint link and the centre line of the posterior link becomes one of the lines required to locate point I.

Cases D and E are four-bar linkages with the same instant centre I but obviously different flexion characteristics. The knee block and shank structure form the second pair of "bars" as shown by dotted lines.

Case F is also a four-bar linkage. The upper pivot of the anterior two-joint link is attached to the shank in this case.

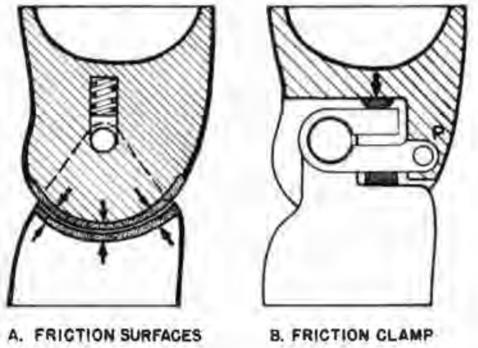
Case G represents a design involving pure rolling rather than a skidding action. In devices of this type, the instant centre I is always at the point of rolling contact.

Case H is also somewhat different. The posterior two-joint link acts in the same manner as in the four-bar linkage. The anterior guidance is provided by the skidding of the surface of knee block along a flat surface attached to the shank. Since the shank surface is flat and horizontal, the line which locates I is always perpendicular to the shank surface at the point of contact.

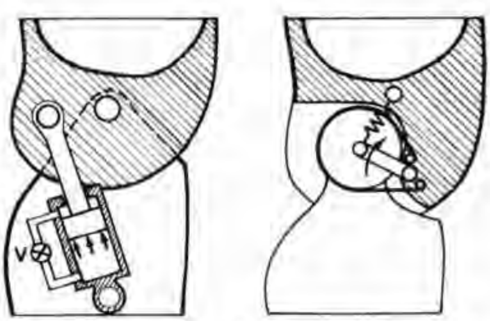
Brake knee mechanisms

The second basic way of enhancing knee stability is through the incorporation of devices which resist the tendency of the knee to flex or collapse under load by the creation of a braking action which either locks or resists a tendency of the knee joint to flex during the stance phase. There have been many designs proposed over the years which provide for braking action of this type. Figure 5 illustrates a few types which have been produced commercially. In Figure 5A the braking effect is due to friction developed between mating cylindrical surfaces on the knee block and shank. The surfaces are separated by a spring which is compressed as load is transferred to the prosthesis and allows the friction surfaces to contact. The magnitude of the friction is influenced by the surface materials, spring stiffness, and other geometrical parameters. It should be noted that friction can also be present in the mechanisms shown in Figures 4A, 4B, 4C and 4H and often is a major functional feature in such arrangements.

Figure 5B illustrates a friction clamp which is actuated by a posterior rotation of the knee block about point P. The resulting pressure on



A. FRICTION SURFACES B. FRICTION CLAMP



C. HYDRAULIC CYLINDER D. DIFFERENTIAL BAND BRAKE

Fig. 5. Brake type knee mechanisms.

the clamp creates friction on the knee bolt which is rigidly attached to the shank.

Figure 5C shows a hydraulic cylinder with a passage for fluid to flow between upper and lower chambers. The valve V can be closed by a variety of mechanisms not shown which prevents the knee from flexing under load. A controlled rate of flexion under load is possible if a small amount of fluid is allowed to flow through the closed valve.

Figure 5D shows a friction brake of the differential band brake type. Load on the prosthesis causes the pivoted arm to rotate upward against the compression spring. This relative motion increases the tension in the band wrapped around a cylinder attached to the shank. The sensitivity of the device in generating a friction brake moment is determined by the setting of the spring.

Voluntary control of knee stability

The brake knee mechanisms shown in Figure 5 provide what might be called automatic control of knee stability. When operating properly, the brake friction is created automatically each time the prosthesis assumes its weight bearing function.

The brake action is generally beneficial in level walking, particularly on rough surfaces. In some cases there may be difficulty in flexing the knee at the end of stance phase when walking on slopes and stairs.

Biomechanics of polycentric knee mechanisms*

A linkage knee offers improved function for the amputee because it is *polycentric*. As the knee flexes, the apparent or instantaneous centre of rotation between the thigh and shank changes in a manner which improves the stability characteristics of the knee and also allows an increased range of knee flexion. Swing control devices can be added to the basic mechanism.

The characteristics of any prosthetic knee are best described in terms of the relationship between four factors: (1) the instant centre of thigh-shank rotation, (2) the load line, (3) the brake moment or torque generated by the prosthetic knee, and (4) the hip moment which can be supplied voluntarily by the amputee.

Figure 6 illustrates a simple but important principle of mechanics. The combination of a force P plus moment M as shown in Figure 6a is equivalent to the single force Q offset a distance d as shown in Figure 6b. We see that Q is equal to P and that the distance d is calculated by noting that $Q\,d = M$. Hence

$$d = \frac{M}{Q} = \frac{M}{P} \qquad (1)$$

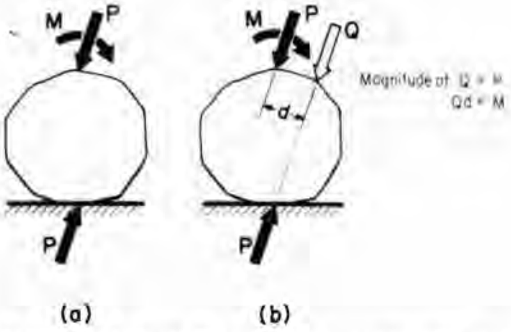


Fig. 6. Single force Q equivalent to combined force P and moment M.

Using this principle we see that the position of the load line at heel contact or at toe off may be related to the load P carried through the hip joint and the hip moment M_H exerted by the amputee, either in flexion or extension. An extension moment moves the load line ahead of the hip, a flexion moment moves it behind. Figure 7 shows a hypothetical situation where in Figure 7a the amputee is exerting a hip extension moment to maintain knee stability at heel contact. Figure 7c shows the situation where the amputee is exerting a hip flexion moment in an attempt to flex the prosthetic knee while the prosthesis is continuing to support the body weight. These two diagrams are combined in Figure 7b and drawn relative to a fixed reference position of the limb.

In Figure 7a we note that the prosthetic knee will be stable at the critical instant of heel contact whenever the knee centre is aligned behind the line PQ. In Figure 7c it is apparent that the knee can be flexed voluntarily under load if the knee centre is located ahead of the line P^1Q^1. In Figure 7b the two zones E and F when superimposed define a common region S, the *zone of voluntary stability*. For the hypothetical amputee of Figure 7 the zone S would

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*Excerpted from "Polycentric Linkages as Prosthetic Knee Mechanisms for the Through-Knee Amputee", ISPO, Montreux, October 1974.

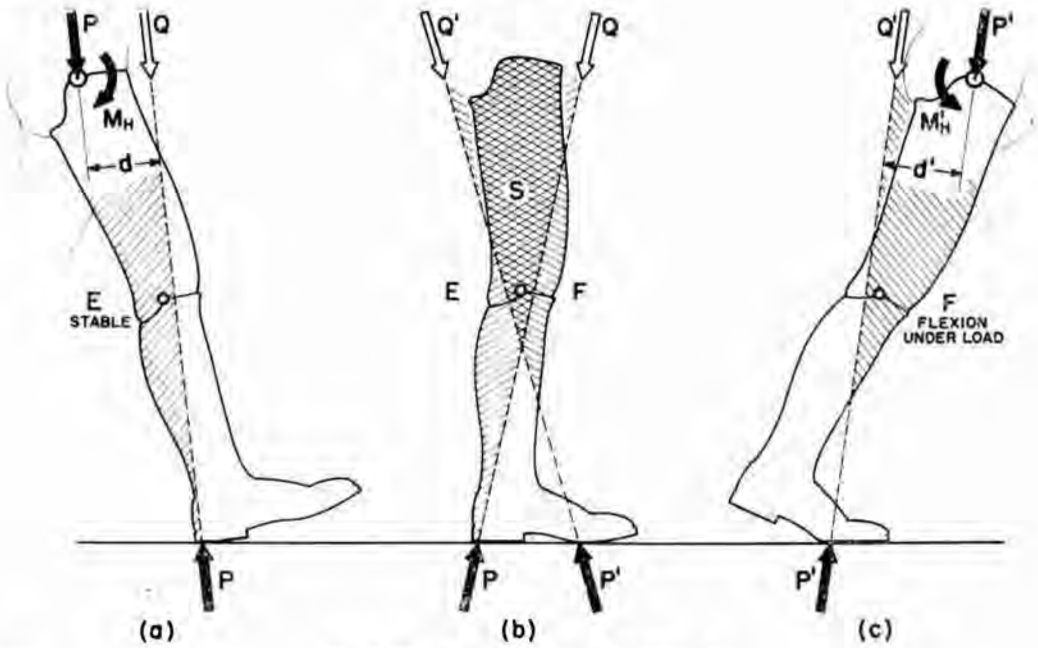


Fig. 7. The zone of voluntary stability, S.

allow considerable variation in the alignment of the prosthetic knee joint while maintaining stability at heel contact and ease of knee flexion during push-off.

Figure 8 illustrates a more typical situation where the amputee either has reduced hip moment capabilities or prefers to use his hip musculature at less than maximum strength under ordinary conditions. In this case the zone of voluntary stability is dramatically reduced. Under these conditions the prosthetist fitting a single axis prosthetic knee joint must align the knee joint with its centre behind line PQ in order to ensure knee stability at heel contact. Such a location is also well behind line P'Q' and outside of the desirable region F. The result is a stable knee at heel contact but a knee which is difficult to flex under load at push-off. Voluntary knee flexion is important in achieving an aesthetic and energy saving gait.

As Figures 7b and 8 indicate, the ability of the amputee to control knee stability is influenced by the height of the instant centre of knee rotation above the floor. A high knee centre provides improved leverage for voluntary control of knee stability. Single axis knees provide little or no opportunity to make practical use of this fact because any significant change in the vertical position of the knee joint is cosmetically unacceptable. The polycentric knee can be designed with the initial instantaneous centre of rotation located above the usual knee joint and well within the zone of voluntary stability, S. The prosthetist then has the option of emphasizing either stability at heel contact or ease of knee flexion by appropriate alignment of the knee mechanism within the prosthesis.

The interrelation of all factors, including the effect of a friction brake moment M_K developed by the knee joint, is given by the knee stability equation

$$M_H = \frac{L}{h}(Pd - M_K) \qquad (2)$$

where, as shown in Figure 9,

M_H = the muscle moment about the hip joint on the amputated side required to maintain the weight-bearing knee in a stable flexed position.

M_K = the knee moment created by mechanical or hydraulic friction in a "brake" type design ($M_K = O$ in the UC-BL four-bar knee).

L = the total length of the prosthesis from the hip to the bottom of the heel.

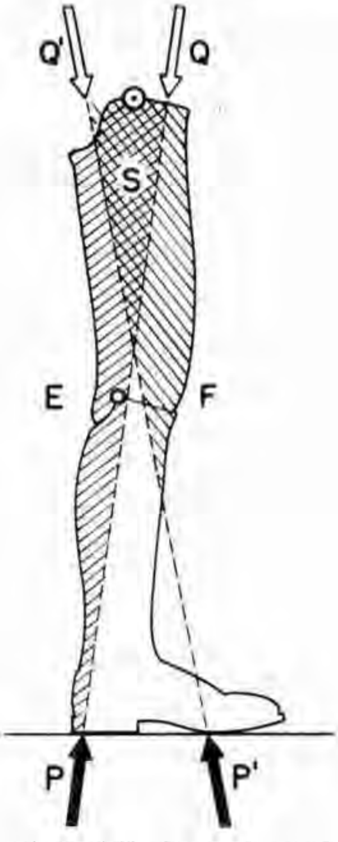


Fig. 8. Typical stability diagram for an above-knee amputee.

- P = the load carried along the long axis of the leg.
- h = the vertical height of the instantaneous centre of knee rotation measured from the bottom of the heel.
- d = the distance forward from the hip/heel line to the instantaneous centre of knee rotation.

Knee stability is influenced by three independently variable parameters: M_K d, and h in equation (2). For a given kinematic arrangement it is obvious that the required M_H can be reduced to zero if the mechanism is capable of developing a brake moment:

$$M_K = Pd \qquad (3)$$

This principle has been exploited successfully in a wide variety of *friction-stabilized* knee brake mechanisms. It should be recognized that the friction which resists flexion to provide knee stability at the beginning of stance phase will interfere with knee flexion near the end of the stance phase. As the amputee attempts to flex the knee, the negative sign in equation (2) becomes positive because the friction moment is acting in the opposite direction, and the hip moment required to initiate knee flexion is *increased* as compared with a *non-brake* mechanism.

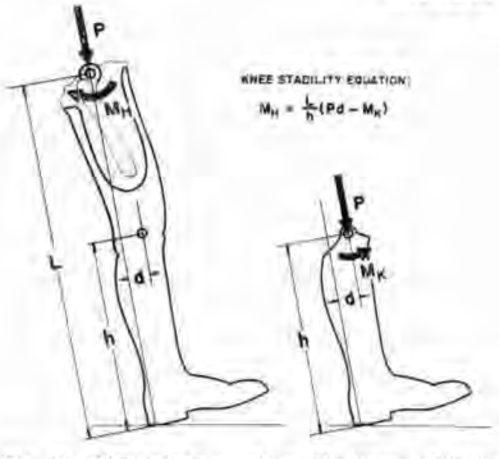


Fig. 9. Dimensions used in the knee stability equation.

The parameter d in equation (2) governs the so-called *alignment stability*.

It is possible to reduce the variable d to zero by aligning the prosthesis in such a manner that the knee centre lies on the hip/heel line. With such an alignment, a muscle moment about the hip would not be required to maintain knee stability at heel contact. Unfortunately, however, such an alignment is not satisfactory because it provides too much stability later in the stance phase when weight is borne on the forefoot, thereby interfering with desirable flexing of the knee just prior to toe off.

The third parameter h in equation (2), in combination with dimension d, provides what may be described as kinematic stability, as discussed below.

The kinematic characteristics of a polycentric linkage are determined by the length and arrangement of its links. An infinite variety of arrangements is possible.

One measure of the functional characteristics attained with a particular linkage is a plot of the successive locations of the relative centre of rotation of the socket with respect to the shank as a function of the knee angle, as shown in Figure 10 for the University of California four-bar linkage above-knee prosthesis. A larger value for h and/or a smaller value for d at a particular angle of knee flexion will result in a smaller hip moment required to maintain knee security. However, during knee flexion a large h also results in a cosmetically undesirable forward translation of the knee block in the region of the anatomic knee centre. The knee centre must eventually move downward with knee flexion or the knee will not bend in the proper place during sitting. It is desirable to maintain a large value of h and thereby keep the knee centre high over the first 10 degrees of knee flexion in order to help the amputee recover from a stumble or other situation when knee stability is accidentally disturbed. The linkage shown in Figure 10 has been selected as a compromise which tends to maximize the desired functional benefits of the linkage while minimizing the cosmetic problems due to translation of the knee block. The kinematics of the UC-BL four-bar linkage has been found to be useful to a wide variety of young male amputees, including one bilateral above-knee amputee, over periods of use ranging up to 25 years.

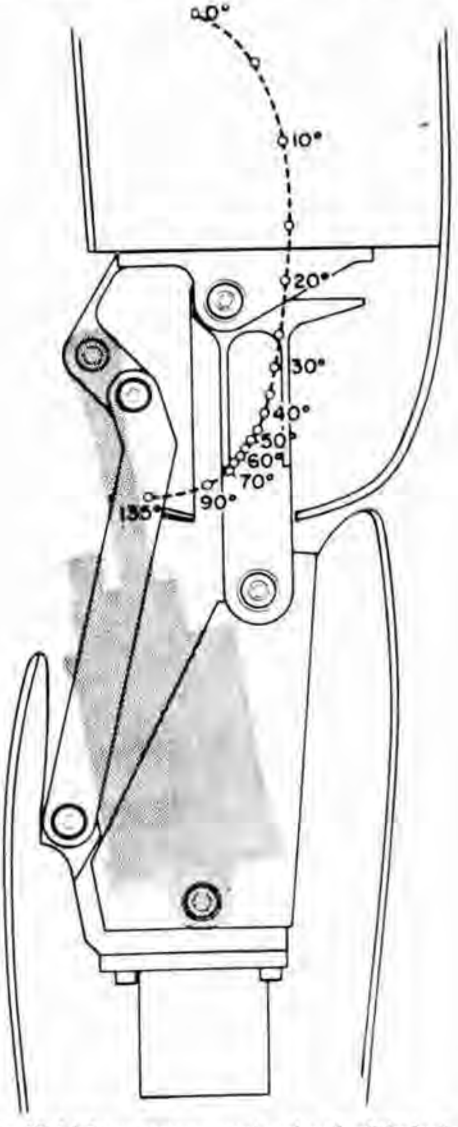


Fig. 10. Linkage arrangement and path of the instant centre for the UC–BL four-bar linkage polycentric knee.

Figure 11 indicates the manner in which the rotation centre (plotted on the moving socket) changes position during a full walking cycle. Note that it is possible to have a relatively large dimension d in full extension, which is beneficial to the amputee near the end of the stance phase. The elevated position of the centre of knee rotation compensates for the large value of d by allowing the amputee to make better use of available muscle moments at the hip, and therefore provides improved *voluntary control* of knee stability. It is interesting to note that voluntary control is equally important in both flexion and extension, particularly to the younger, more active amputee.

Swing phase control

A swing control is a device which can be incorporated into the design of a prosthetic knee mechanism such that it simulates the action of the quadriceps and hamstring musculature which act about the normal knee joint during the swing phase of walking. Such a device has three functions: (1) to limit the maximum knee flexion angle and cause the shank-foot to swing forward smoothly in a manner similar to quadriceps action about a normal knee, (2) allow the knee to extend smoothly into full extension without impact, (3) provide automatic changes in the level of the resistance patterns to allow walking over an extended range of walking speeds.

One means of establishing design criteria for swing control mechanisms is to calculate the knee moment pattern which must be generated by the device in order to cause the shank-foot to swing through space with a motion pattern which approximates that of an average normal person. Figure 12 illustrates qualitatively the

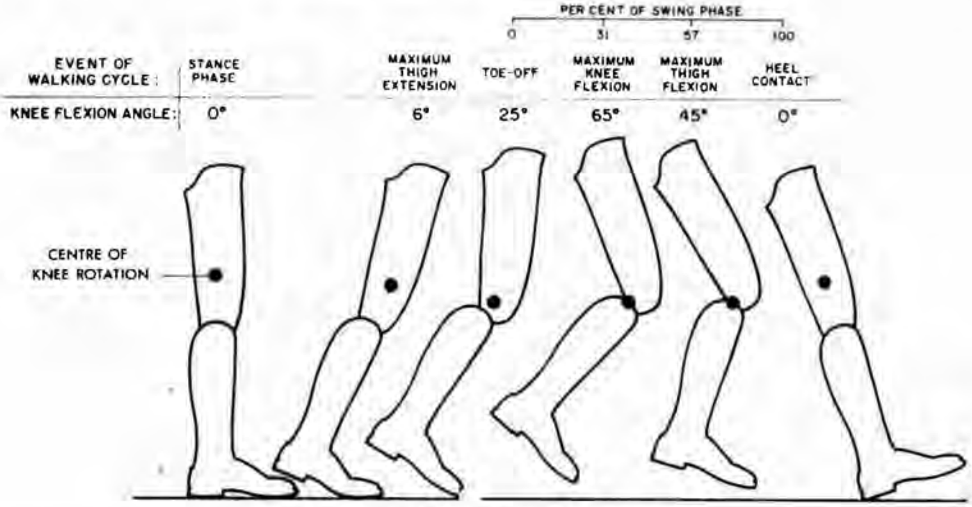


Fig. 11. Change in knee centre during walking.

results of such calculations. It is seen that the device should provide a resistance pattern with four phases.

In normal walking the knee begins to flex before the foot loses contact with the floor. The rate of flexion is controlled by the quadriceps group acting over the anterior aspect of the knee joint. Such action at present is difficult to duplicate in prosthetic knee mechanisms although the gliding action of certain polycentric knee designs is an approximation.

After the foot leaves the ground the quadriceps continue to act to limit the knee flexion to a maximum of approximately 65 degrees. As extension of the knee begins, there is a second burst of quadriceps activity associated with forward acceleration of the shank-foot. During the forward swing the quadriceps action decreases abruptly and the shank-foot swings as a pendulum. Almost immediately the hamstring muscles begin to act behind the knee to decelerate the rate of extension and allow the foot to move smoothly into contact with the floor.

This sequence is difficult to simulate accurately with the typical mechanical friction swing control mechanism. Figure 13 illustrates the resistance characteristic of a constant friction device with elastic extension bias. When properly adjusted, the amputee is able to walk reasonably well at the speed for which adjusted but the device lacks automatic adjustment for changes in walking speed.

Hydraulic devices of the type shown in Figure 14 offer much better possibilities for meeting the design objectives shown in Figure 12. A typical design incorporates multiple holes in the cylinder wall which are progressively covered by the piston to reduce the available flow area and create a highly non-linear resistance characteristic. Hydraulic devices can match the desired curves very closely. The peak moments of the characteristic curve are increased automatically with increasing walking speeds with a resistance level approximately proportional to the square of the walking speed.

Another method of achieving a variable moment pattern is with a pneumatic device of the type shown in Figure 15. The pneumatic devices rely upon a combination of air compression and controlled leak rate to achieve an approximation to the desired moment characteristic. As the walking speed is increased, the time available for air to leak from one side of the piston to another is decreased hence higher peak pressures are maintained at fast walking speeds.

Biomechanics of socket fitting

The following discussion assumes a socket in which the major support of the body weight is through the ischial tuberosity with additional contributions from the pressures acting upward against the gluteal musculature and provided by the flare of the anterior socket brim. Any pressure against the distal stump tissues is assumed to be of low magnitude and of primary benefit in preventing the development of oedema in the distal stump.

As an example, consider the pressure patterns shown in Figure 16 acting between stump and socket as viewed from the side. The pressure

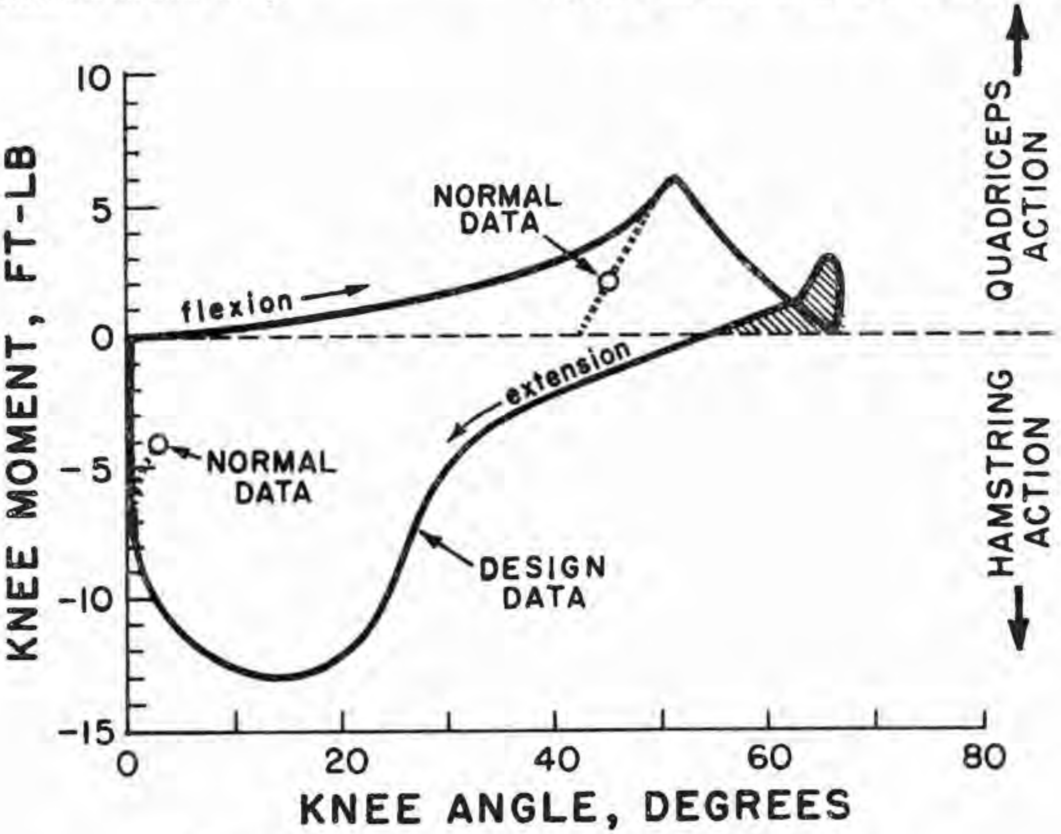


Fig. 12. Prosthetic knee moment vs. knee angle during swing phase.

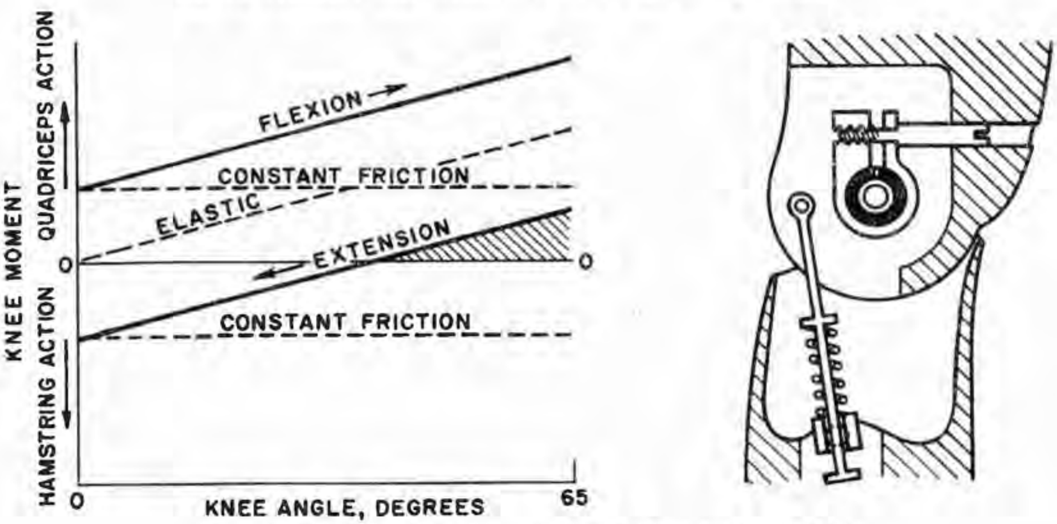


Fig. 13. Mechanical swing control with linear extension bias.

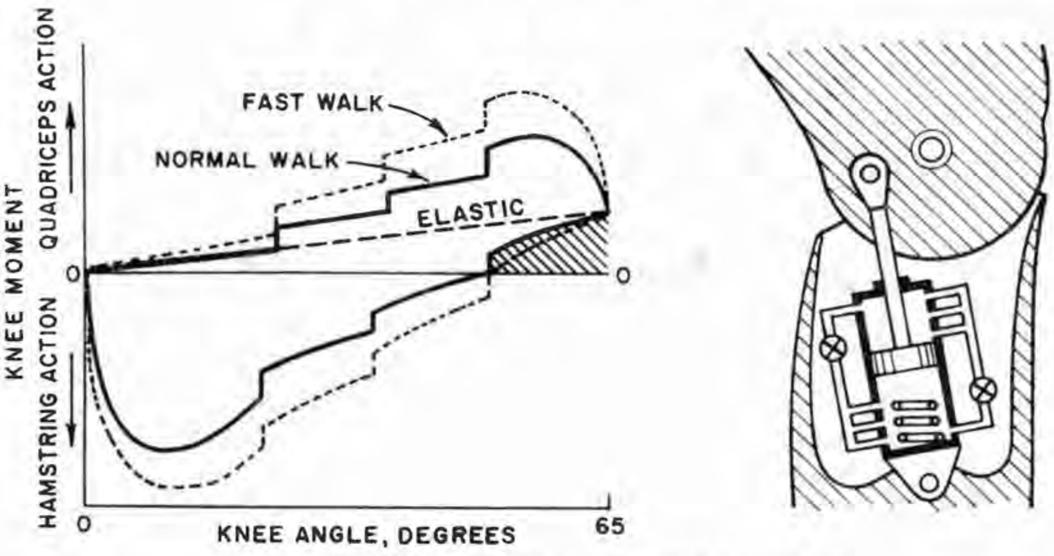


Fig. 14. Hydraulic swing control with linear extension bias.

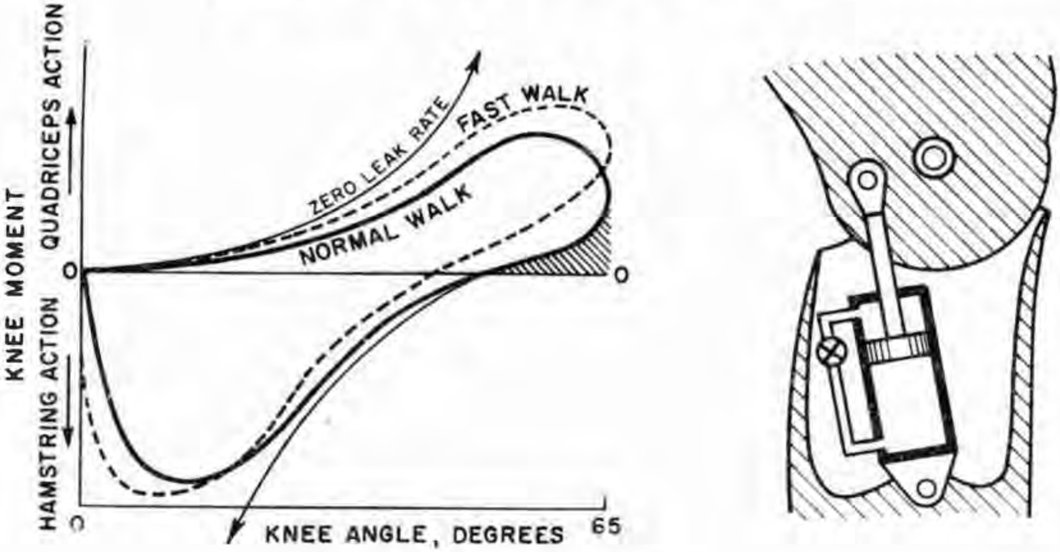


Fig. 15. Pneumatic swing control.

patterns shown are the result of the active use of the hip musculature to control stability at heel contact and initiate flexion at the end of the stance phase. Examination of such patterns reveals the need to pay particular attention to the proximal anterior brim area. The socket must provide sufficient anterior support to prevent the ischium from sliding forward and downward into the socket with inevitable painful contact of the pubic ramus on the medial wall of the socket. At the same time, the fitting must anticipate the movement of the femur stump within the soft tissue as the femur first presses posteriorly to maintain knee stability then moves anteriorly to initiate knee flexion in the swing phase. The ischial seat should be sloped slightly inward and rounded to avoid skin irritation, but must provide a definite contribution to support of the body weight. The gluteal area of the posterior brim should fit snugly

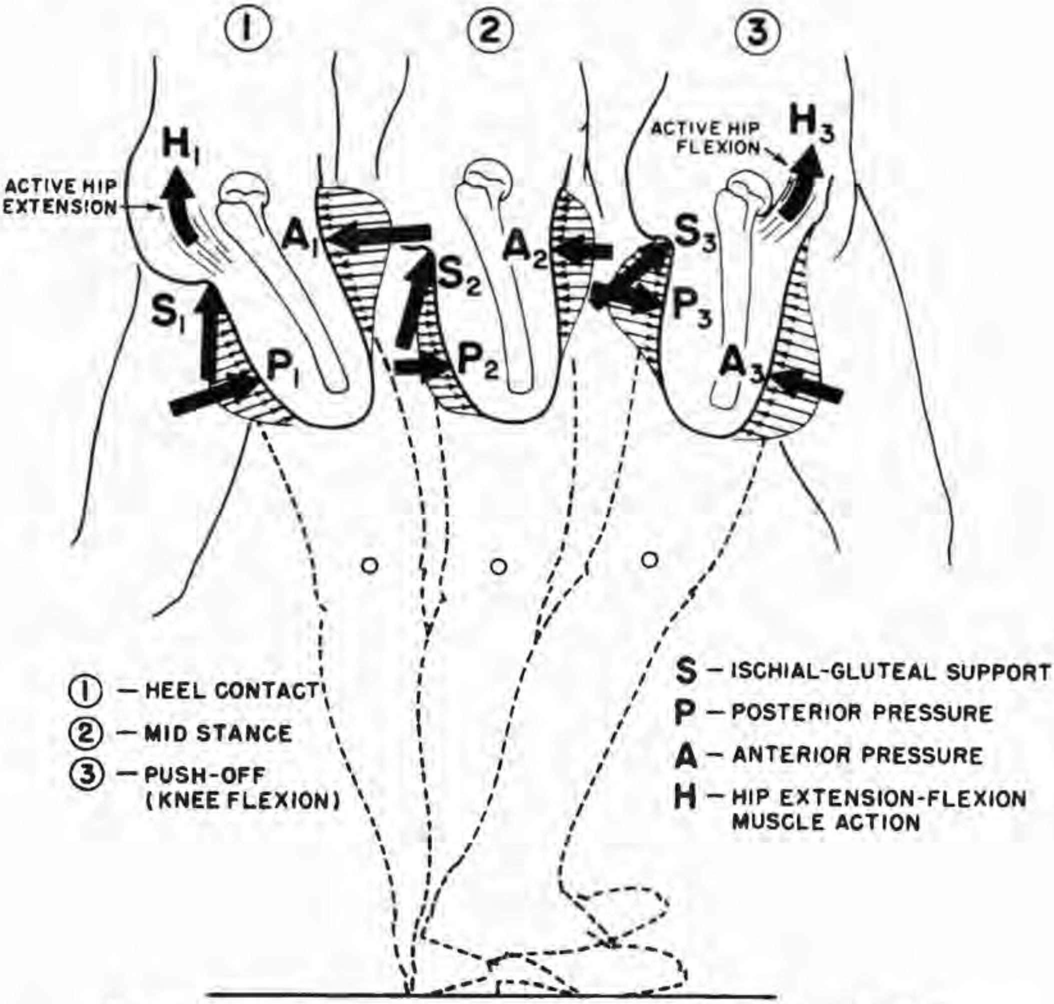


Fig. 16. Anterior-posterior stump-socket pressures during the stance phase of walking.

against the musculature to distribute the pressure on the socket brim and relieve the ischial pressure particularly in those cases where the ischium may be sensitive to excessive pressure.

Figure 17 illustrates the pressure patterns on the stump as viewed from the rear. In this case the need for lateral contact between socket and stump is clearly indicated. The lateral pressure pattern is associated with the balancing of the body weight above the level of the socket brim. The support point in the region of the ischium serves as a fulcrum for the body weight acting downward on the pelvis. The gluteus medius muscle acts to stabilize the hip joint which results in abduction of the stump against the lateral socket wall. This type of pressure pattern always accompanies a narrow base gait with erect torso. The need for lateral pressure on the stump is diminished if the amputee walks with a wide walking base or leans the torso over the support point during the stance phase.

The quadrilateral socket shape

The socket shapes shown in Figure 18 are based upon the requirements as discussed in the previous section. The shape is not a duplicate of the free stump since soft tissue must unavoidably be compressed in areas where higher pressures must be tolerated on soft tissue, particularly in the Scarpa's triangle area along the anterior aspect of the stump and in the

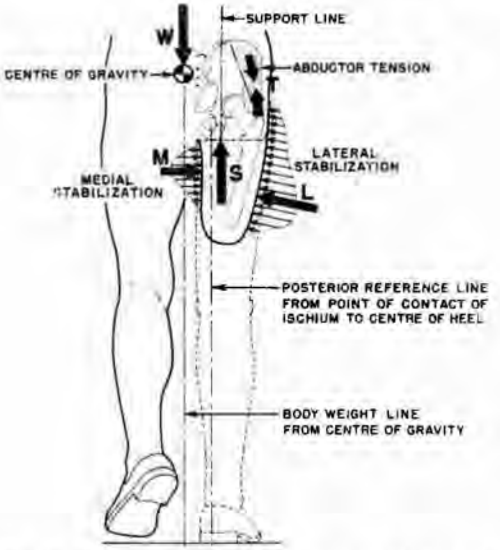


Fig. 17. Use of hip abductor musculature for lateral stabilization of the pelvis.

gluteal region of the posterior brim. Regions of firm musculature such as along the rectus femoris muscle are channelled to avoid excessive pressure as required. Tendon insertions on the pelvis such as the hamstring tendons or adductor longus must be accommodated in appropriate channels in the posterior-medial and anterior-medial corners of the socket. The width of the medial wall of the socket is defined by the anatomical dimension measured between ischium and adductor longus. If this dimension is incorporated into the socket accurately, the pubic ramus will always be supported well above the medial brim of the socket. If the medial dimension is too wide, the ischium will slide forward during weight bearing with inevitable painful pressure against the pubis.

The contours of the socket must always be considered in three dimensions. One of the most difficult problems in the fitting process is to achieve the proper degree of tightness of fit along the length of the stump. With open-end sockets carved from wood the socket circumference dimensions were often less than the free stump circumference with the result that the soft tissues of the stump were pulled deeply into the socket as the socket was donned. With the modern total-contact suction socket, this reduction in socket circumference is often less and the socket dimensions more nearly approximate the free stump measurements.

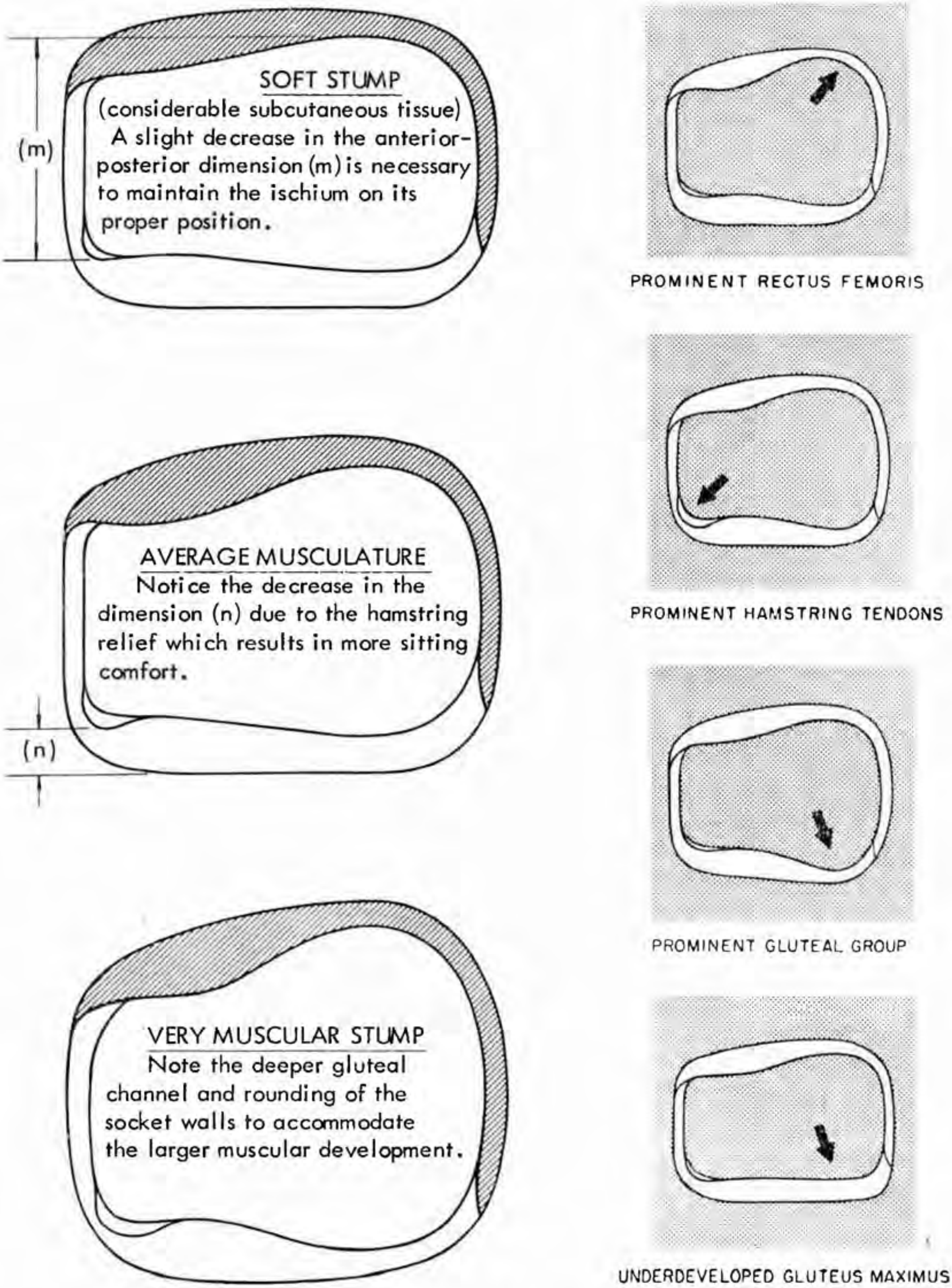
The pressure pattern created between the socket and the tissues of the stump and pelvis is a function of the forces and moments being transmitted at any instant during the walking cycle. The pressure pattern varies dramatically over the walking cycle and it is remarkable that a socket of fixed shape can transmit these pressures comfortably for long periods of use.

Conclusion

Much progress has been made over the past 30 years in the refinement of principles, devices, fitting and alignment procedures and materials used for above-knee prostheses. Prosthetists all over the world have been trained in the application of modern methods and components and in many cases have successfully adapted local materials in the construction of prostheses.

There is considerable current interest in the design of modular components with international standards for dimensions which will allow all nations to benefit from advances in component design and manufacture.

The major problems to be solved are generally associated with the increasing age of the amputee population. Lighter weight prostheses which can be produced quickly and at minimum cost are required. Problems associated with cosmesis remain to be solved. Improved patient management procedures to reduce the time between amputation and fitting with a permanent prosthesis must be developed if the elderly amputee is to be rehabilitated. Amputee training procedures which have proved successful with young vigorous amputees must be re-examined to account for lower levels of physical capability. Finally, we must encourage the dissemination of knowledge on an international basis so that all persons concerned with the welfare of above-knee amputees can benefit from the success of our more progressive institutions.



SOFT STUMP

(considerable subcutaneous tissue) A slight decrease in the anterior-posterior dimension (m) is necessary to maintain the ischium on its proper position.

AVERAGE MUSCULATURE

Notice the decrease in the dimension (n) due to the hamstring relief which results in more sitting comfort.

VERY MUSCULAR STUMP

Note the deeper gluteal channel and rounding of the socket walls to accommodate the larger muscular development.

PROMINENT RECTUS FEMORIS

PROMINENT HAMSTRING TENDONS

PROMINENT GLUTEAL GROUP

UNDERDEVELOPED GLUTEUS MAXIMUS

Fig. 18. The quadrilateral suction socket shape.

Prosthetics and Orthotics International, 1977, 1, 161–172

Graphic analysis of forces acting upon a simplified model of the foot

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Abstract

Application of a graphical technique to analyse internal forces on a simplified model of the foot in various external loading patterns. The method is applied when the external load is acting purely upon the forefoot, the hindfoot and on both locations. The pes planus situation and the effect of the "rocker" and inlay sole are studied.

Introduction

It is often of interest for people taking care of patients with foot diseases to know how the load is distributed on the internal structure of a normal and a pathological foot; how variation of the external load changes the internal load distribution pattern and how a pathological structural change can be followed by a deviation from the normal loading pattern.

The answer to this problem can aid the orthopaedic surgeon in deciding what can be achieved by changing the structure of a foot through surgery. The foot orthotist can make use of the answer by constructing the orthopaedic footwear in such a way that the external load will be satisfactorily accommodated by the internal load distribution. (By external loads is meant the reaction forces from the floor acting upon the foot, while internal loads mean any force acting inside the body.)

The foot with its active and passive structures (muscles, bones, aponeuroses and ligaments) represents a complex three dimensional system. In addition it is not only purely a mechanical system, as an engineer would prefer, but a biological one controlled by the central nervous system. Even emotional conditions make a difference in how the foot acts in certain situations.

A method that is easy to use in daily practice is presented which analyses the relationship between the internal and external loads. This is extended to forecast how variations of the external load and structure of the foot, whether deliberate or not, influence its internal loading.

For the purpose of the analyses the foot is considered to be a segmented solid coplanar body, placed in the sagittal plane of the foot and articulating with the crus in the talocrural joint. We will further simplify the structure of the foot by substituting the whole plantar passive apparatus with an idealized plantar ligament, taking into consideration just a few of the main muscles. All analyses are limited to static equilibrium situations in the above mentioned sagittal plane. All forces are given in Newtons.

The externally loaded forefoot

Figure 1 shows the forefoot bearing the total bodyweight assumed to be about 800N. This corresponds to the situation which is found when standing on one foot, for example on a stair.

For simplicity, let us start with a foot consisting only of one segment which articulates with the crus through the talocrural joint. The foot as a free body is acted upon by three forces; the ground reaction force R, the load TC on the trochlea tali through the axis of the talocrural (tc) joint and the force TS in the muscle triceps surae.

The reaction force R can be measured and its magnitude and direction are known. However only the direction of TS is known and the only information we have about TC is that it must pass through the axis of the talocrural joint (tc).

We start by drawing the force R on the force diagram and continue downwards with the action line of TS as is shown in Figure 1a. The point 0 is chosen quite freely and is connected to the head of R by means of line 1 and

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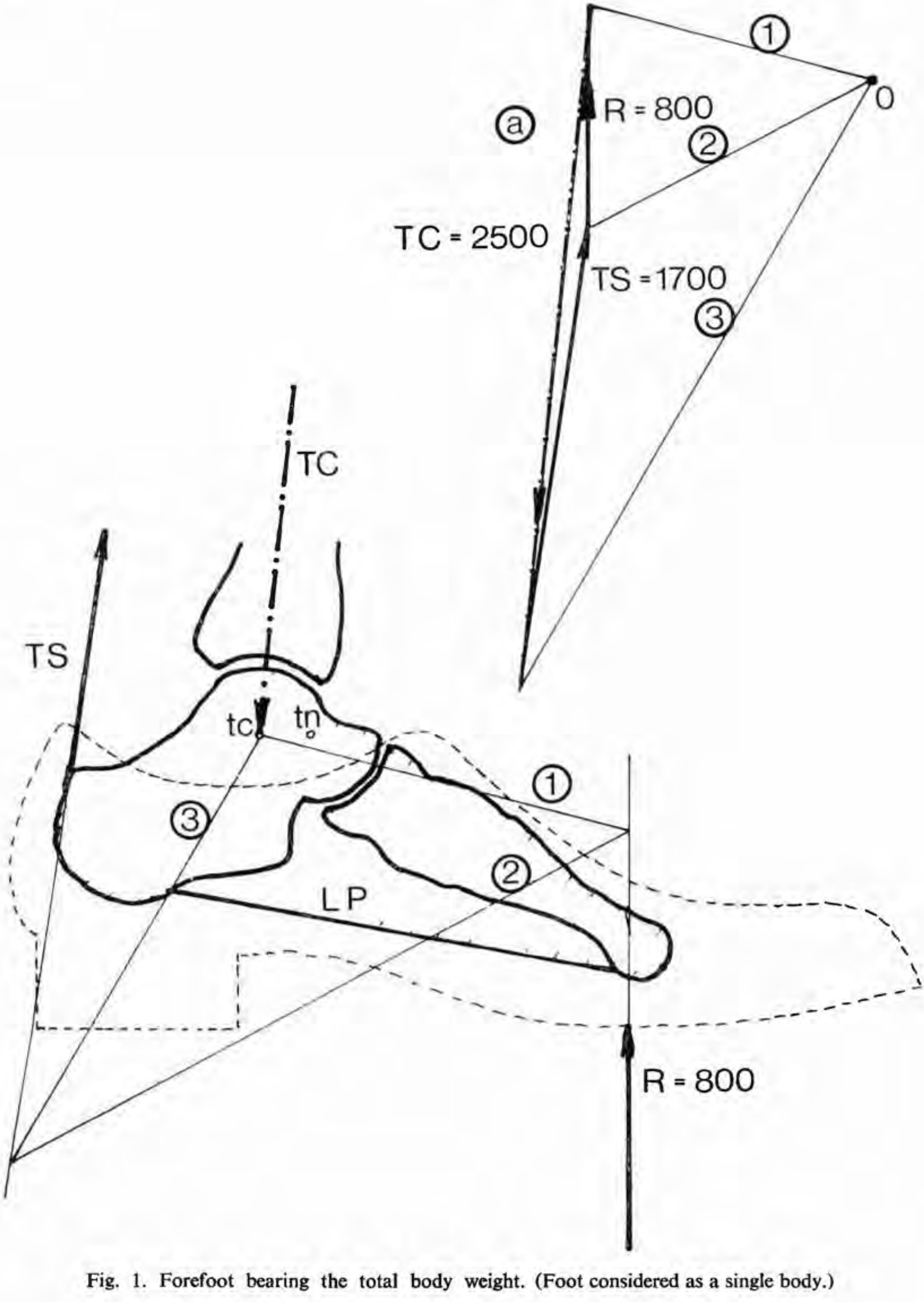

Fig. 1. Forefoot bearing the total body weight. (Foot considered as a single body.)

to the tail of R by means of line 2. On the schematic architectural diagram of the foot we start from the axis of the talocrural joint (tc) and construct line 1 parallel to the above mentioned line until it crosses the action line of R. From this point there must be drawn a construction line parallel to the line 2 on the force diagram. The intersection point on the action line of TS must be connected to the starting point tc which results in construction line 3. A parallel to this

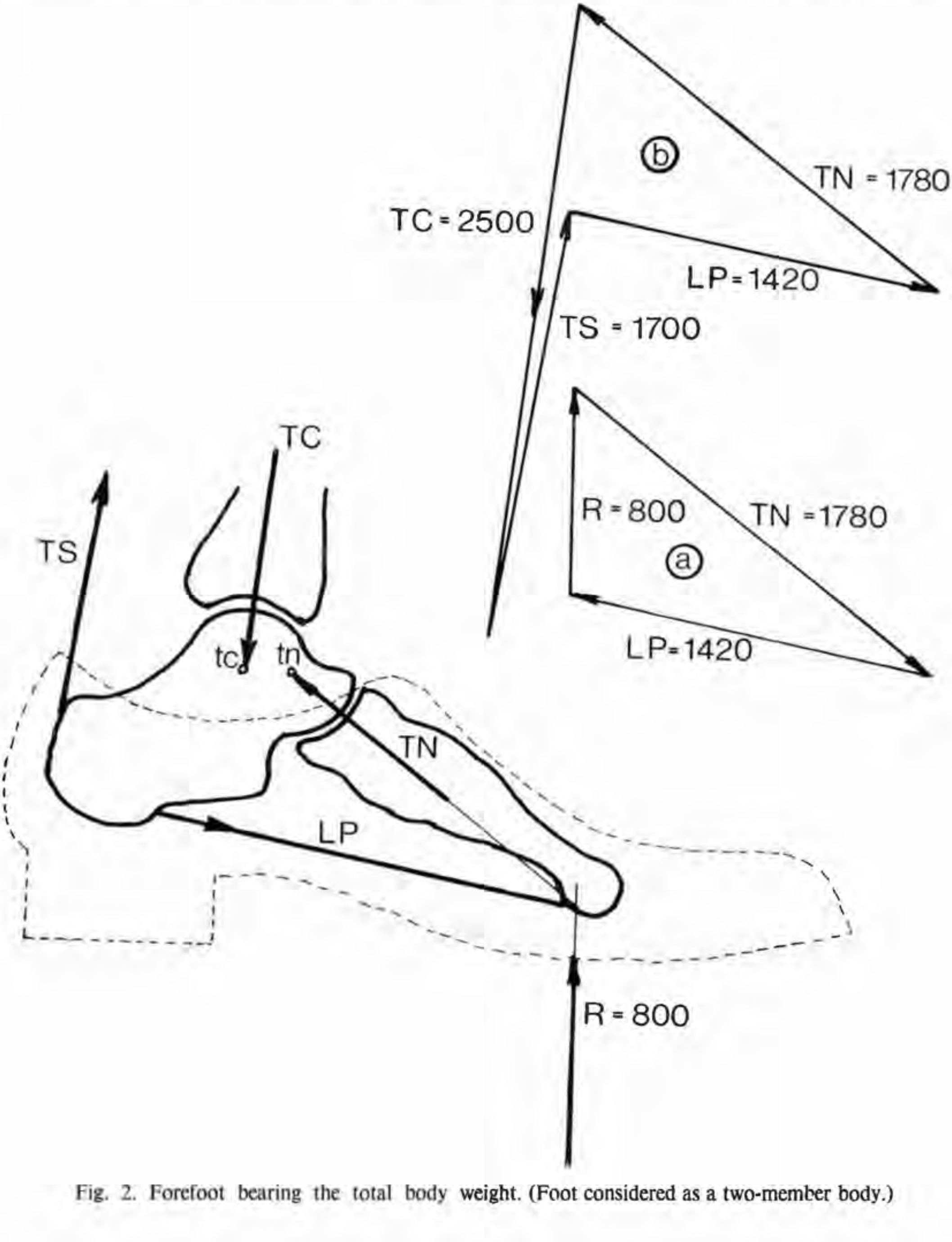

Fig. 2. Forefoot bearing the total body weight. (Foot considered as a two-member body.)

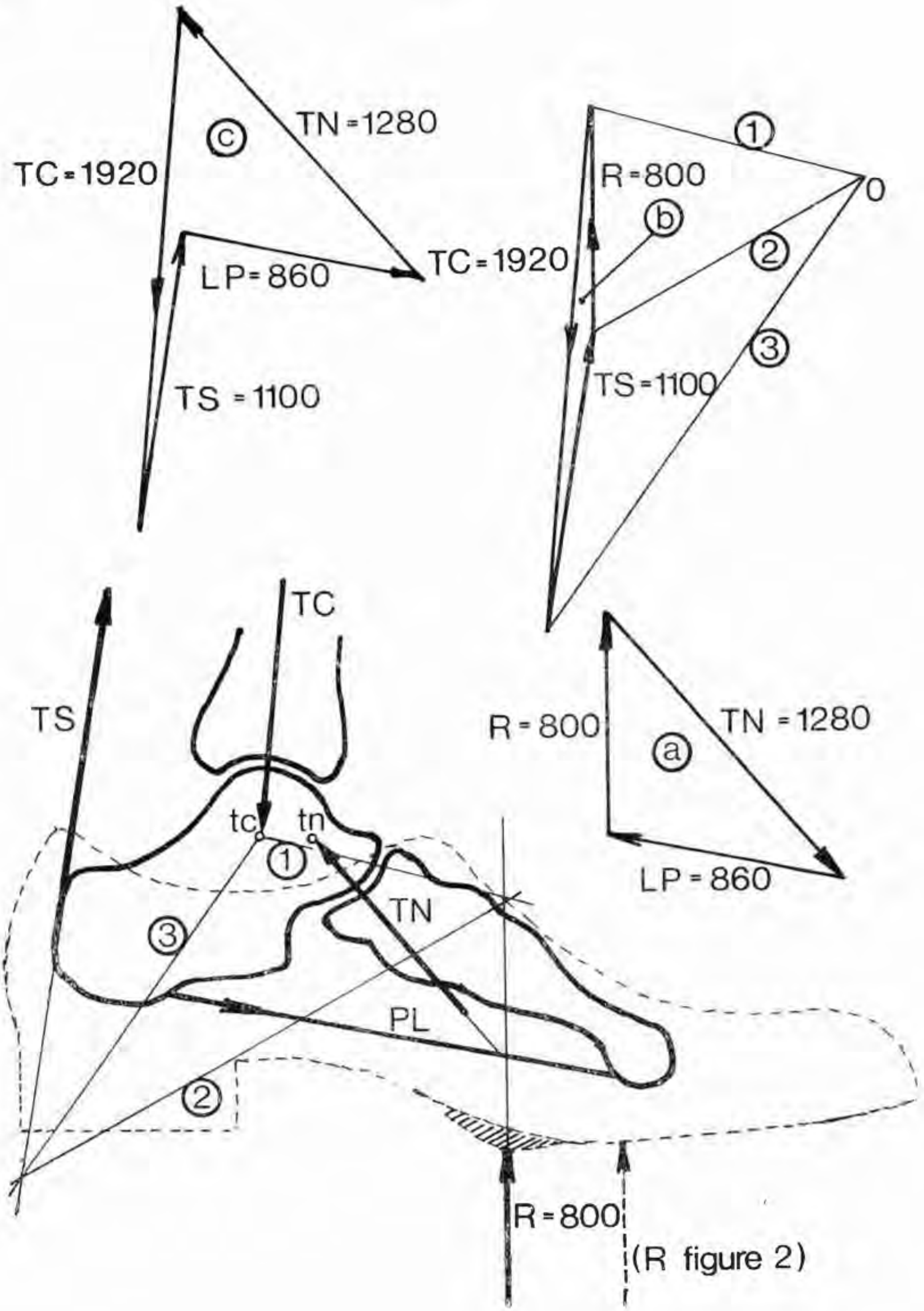

Fig. 3. Forefoot bearing the total body weight by using a shoe with rocker.

from point 0 on the force diagram will cut out the correct length of the force TS. By closing the force diagram we can obtain the magnitude and direction of the unknown force TC and the unknown magnitude of the force TS.

Figure 2 shows the same situation as before, but we now take into consideration the existence of the talonavicular joint. In this way the "foot" consists of a solid hindpart and forepart which are linked together on the plantar side by means of the idealized plantar passive structure, ligament LP. The forefoot is acted upon by three coplanar forces. The equilibrium in this case demands that these must have a common intersection point. This immediately gives the direction of the load on the talonavicular joint which must pass through the axis of the joint (tn).

The force diagram of the forefoot as a free body in equilibrium can be constructed as shown in figure 2a.

Similarly the force diagram of the hindfoot is shown in figure 2b. The directions of forces TN and LP are changed in relation to figure 2a, because these are now taken into consideration as forces acting on the hindfoot.

The directions of the forces acting on the hindfoot are shown in the figure of the schematic foot architecture.

It is interesting to observe that the load on the talocrural joint is about three times greater than the total reaction force.

The foot orthotist can reduce the large internal loads on the foot by using a rocker on the sole of the footwear. Figure 3 shows a rocker which moves the reaction force R posteriorly by a distance of about 15 per cent of the length of the footwear compared with the R shown in figure 2. At first we handle the foot as one solid single free body acted upon by the forces R, TC and TS. By analogy with the graphical method applied in figure 1 we can get the load TC and TS (fig. 3b). Figure 3a shows the force diagram of the forefoot and figure 3c the same for the hindfoot. The rocker reduces the load on the talocrural joint by about 20 per cent and on the idealized plantar ligament by about 40 per cent.

It is informative to take a look at the foot when it is loaded externally, but with a moderate

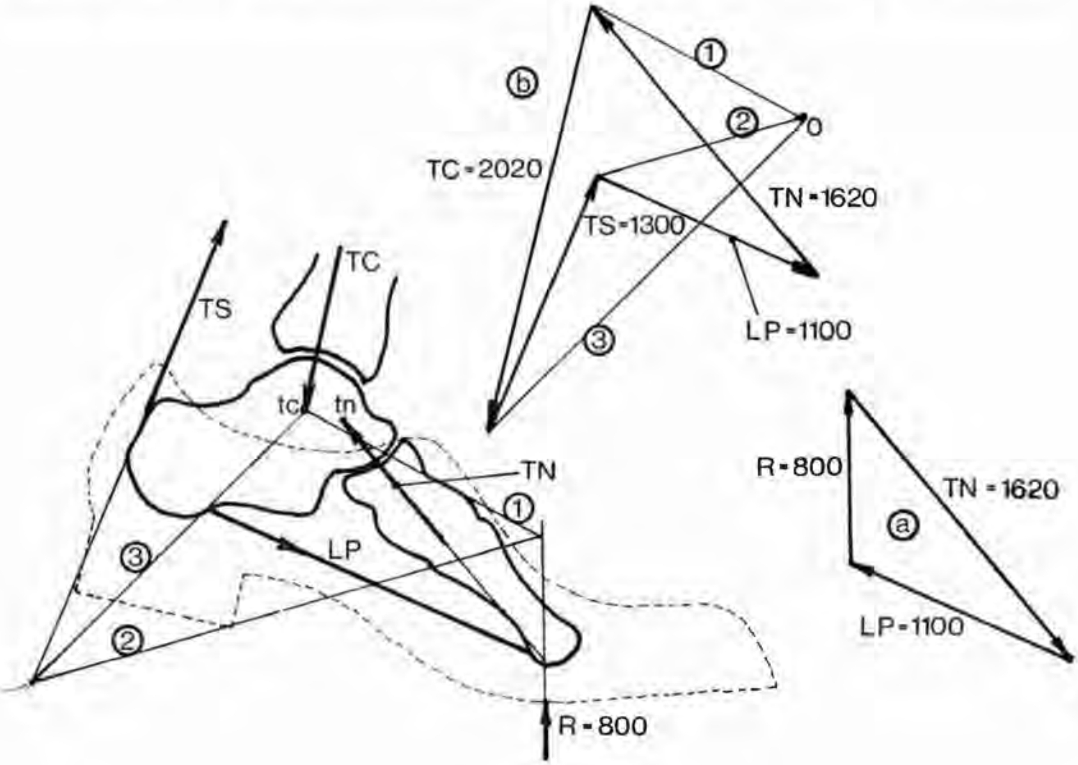

Fig. 4. Flexed forefoot bearing the total body weight.

flexion as shown in figure 4. The graphical analysis gives the force diagram for the forefoot (fig. 4a) and for the hindfoot (fig. 4b). Note that the flexion in this configuration decreases the internal forces, for example the load on the talocrural joint falls by about 20 per cent.

Figure 5 indicates how the internal load distribution will change in the case of pes planus. The pes planus situation is approximated by moving the axis of talocrural and talonavicular joints distally (tc^1 and tn^1) compared with the normal foot (tc and tn). Figure 5a shows the force diagram of the forefoot. In this approximation we maintain the form of the foot and therefore the loads TC and TS are the same as in the case of the normal foot. (On the schematic architecture of the foot the forces are shown as they act upon the forefoot).

The results of the four cases we have discussed can be most conveniently compared by looking at table I.

	R	TC	LP	TS	TN
Normal sole, nonflexed	800	2500	1420	1700	1780
Normal sole, flexed	800	2020	1100	1300	1620
With rocker, nonflexed	800	1920	860	1100	1280
Pes planus	800	2500	1700	1700	2040

Table I. Comparison of internal loading in different circumstances as a result of externally loading the forefoot (all values are given in Newtons).

The externally loaded hindfoot

It is also important to know how the load on the hindfoot affects the internal load distribution. Let us examine the case when standing on a stair with the heel as shown in figure 6. We assume that the foot as a solid free body is acted

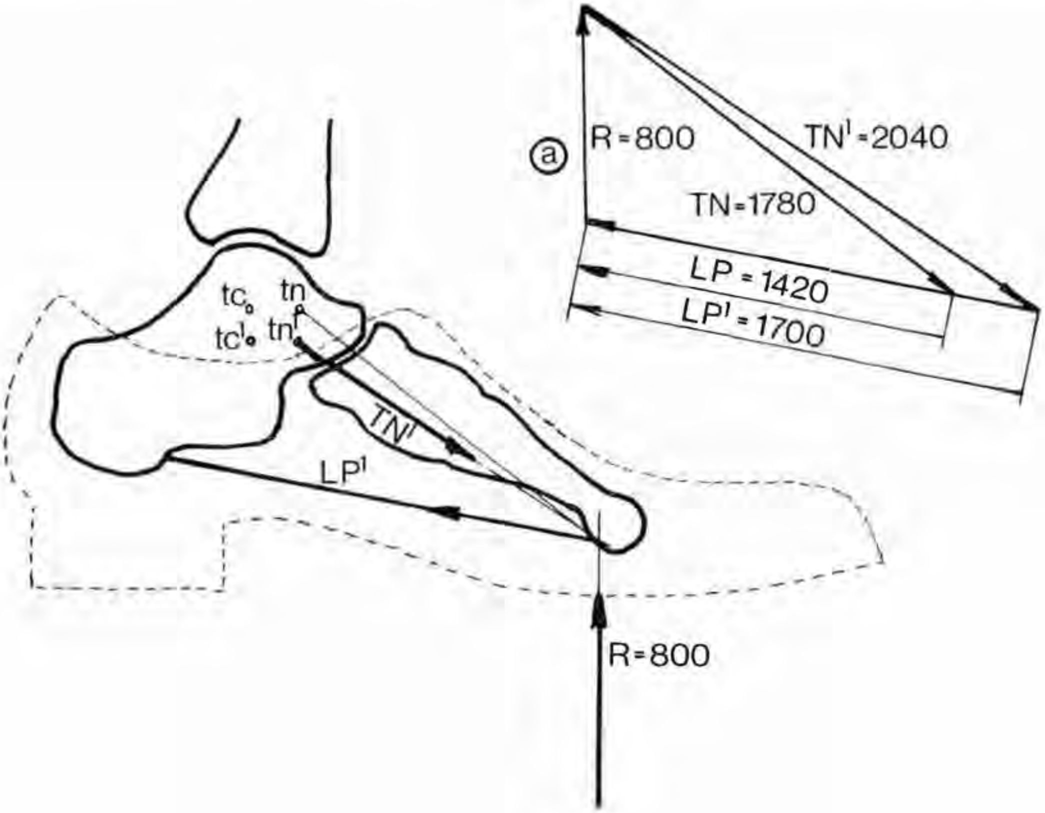

Fig. 5. Forefoot bearing the total body weight in the case of pes planus.

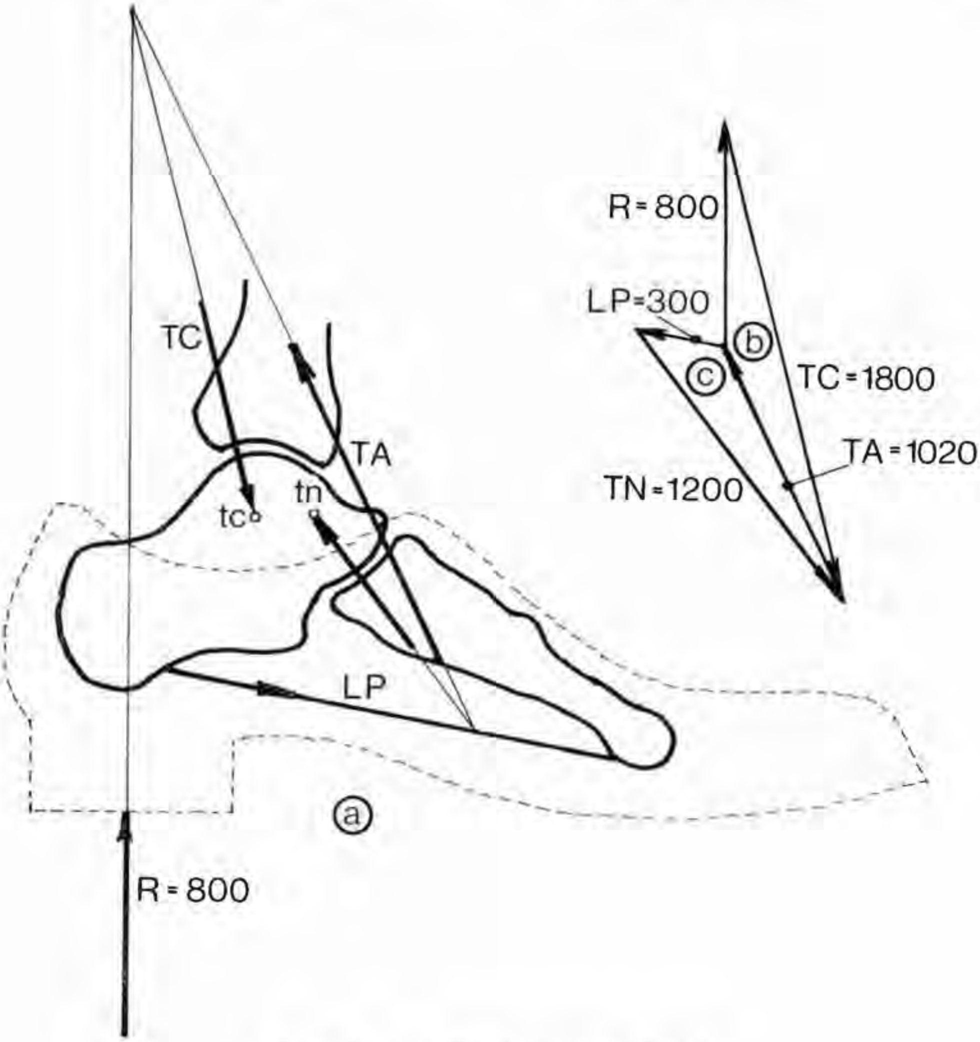

Fig. 6. Hindfoot bearing the total body weight.

upon by three coplanar forces and that the muscle tibialis anterior (TA) is the only dorsiflexor. The equilibrium demands a common intersection point for the three forces. This gives the force diagram in figure 6b. In the same way we can find the intersection point for the three coplanar forces of the forefoot which leads to the force diagram in figure 6c. In figure 6a all the forces are directed as if they are acting on the hindfoot with the exception of TA which is acting on the forefoot.

The foot orthotist is able to moderate the internal loads also in this case. He adjusts the heel giving it a profile (fig. 7d) which moves the reaction force anteriorly, as the R^1 indicates on figure 7, for example by about 5 per cent of the total length of the shoe. The corresponding internal loads are indexed in the same way, for example LP^1 or TN^1. Figure 7b is the force diagram for the foot as one solid free body. (The force diagram in figure 7c shows the loads acting upon the forefront as a free body).

The modern fashion with a heel profile (fig. 7e) can move the reaction force posteriorly counteracting the work of the foot orthotist. Such a reaction force is represented by R^{11} which is displaced posteriorly by about 5 per cent of the total length of the shoe compared with the normal situation (R). The corresponding internal forces are indexed in the same way, for example LP^{11} or TN^{11}.

The internal load distributions for externally loaded hindfoot situations are shown in table II.

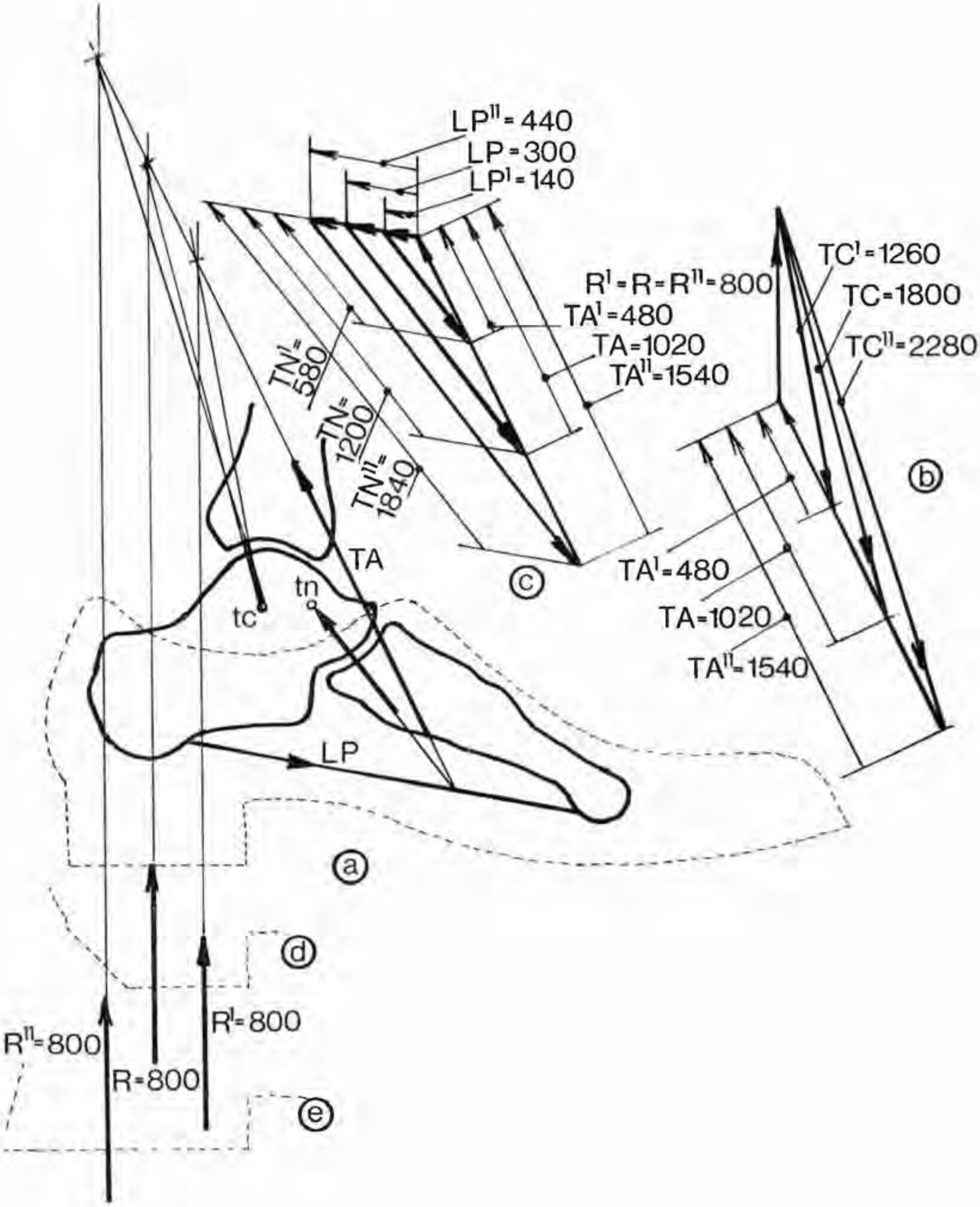

Fig. 7. Influence of the heel profile variation on the internal force distribution when the hindfoot is bearing the total body weight.

	R	TC	LP	TA	TN
Normal heel profile	800	1800	300	1020	1200
Shortened heel profile	800	1260	140	480	580
Extended heel profile	800	2280	440	1540	1840

Table II. Comparison of internal loadings using different heel profiles when externally loading the hindfoot (all values given in Newtons).

The simultaneously externally loaded hindfoot and forefoot

The graphical construction methods applied previously can be useful in analysing the internal load distribution in a situation when the reaction force is acting simultaneously on the forefoot and the hindfoot. Such a case is shown in figure 8 with symmetrically divided equal partial loads (each 400N).

In the first step we determine the loads acting on the foot as a one-piece solid body and we consider the total reaction force $R=R_1+R_2$ and construct the force diagram in figure 8a. In this

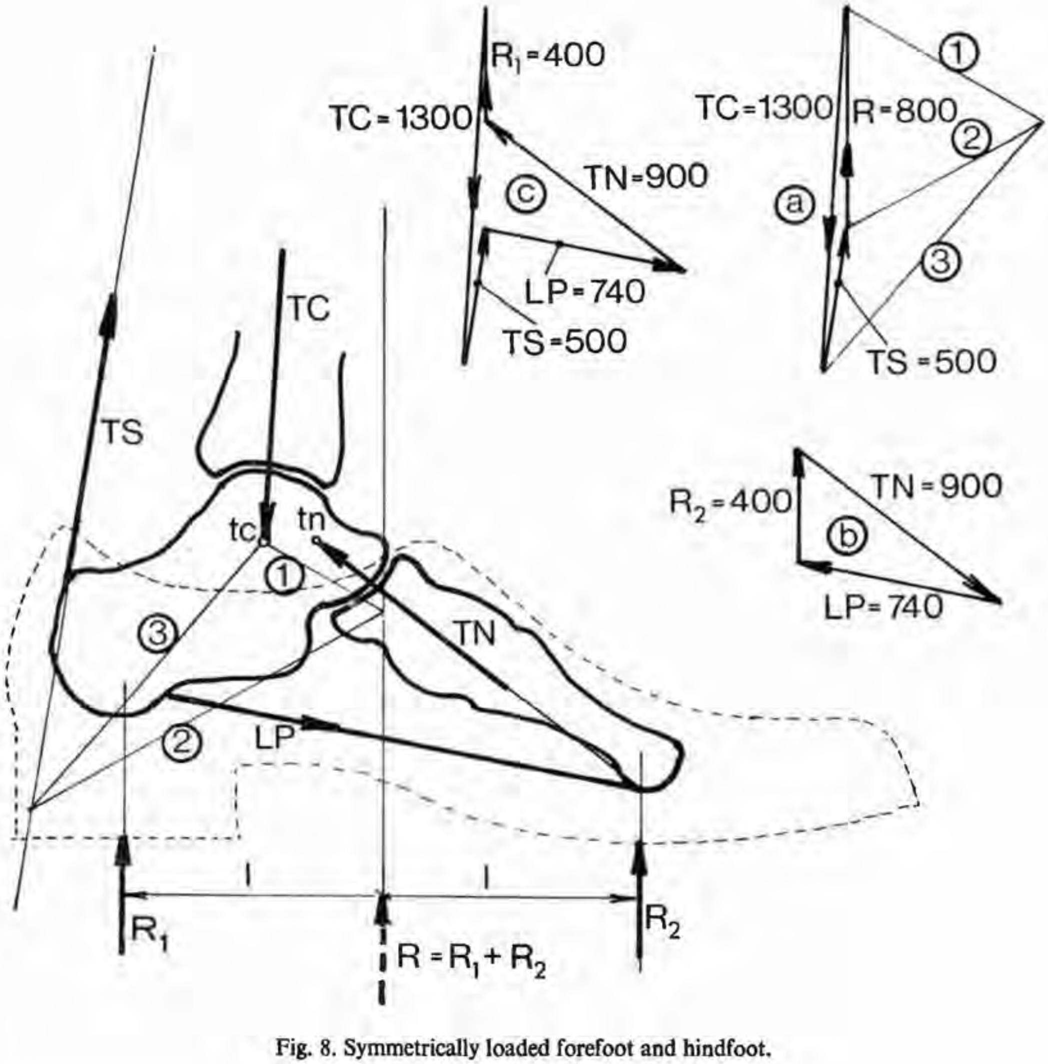

Fig. 8. Symmetrically loaded forefoot and hindfoot.

way we can determine the forces TC and TS. In the next step we can find the loads acting on the forefoot as is done in figure 8b. Figure 8c shows the force diagram of the hindfoot. (The forces on the schematic architecture of the foot are directed as they are acting on the hindfoot).

How a pes planus will behave in this combined externally loaded case is shown in figure 9. The pes planus situation is indicated in the same way as in figure 4. The graphical construction method is similar to the one that is used before. It is worth noticing that the load in the idealized ligament increases in this case by one fourth compared with the normal situation.

The foot orthotist helps the patient by applying an inlay sole and moving the hind partial reaction anteriorly as shown in figure 10, the unchanged total reaction force R will be divided into partial reaction forces in inverse ratio to their distance from R. The construction of force diagrams are similar to the ones we have used before. A significant reduction in the magnitude of the internal load is obtained.

The results of the investigations on the foot

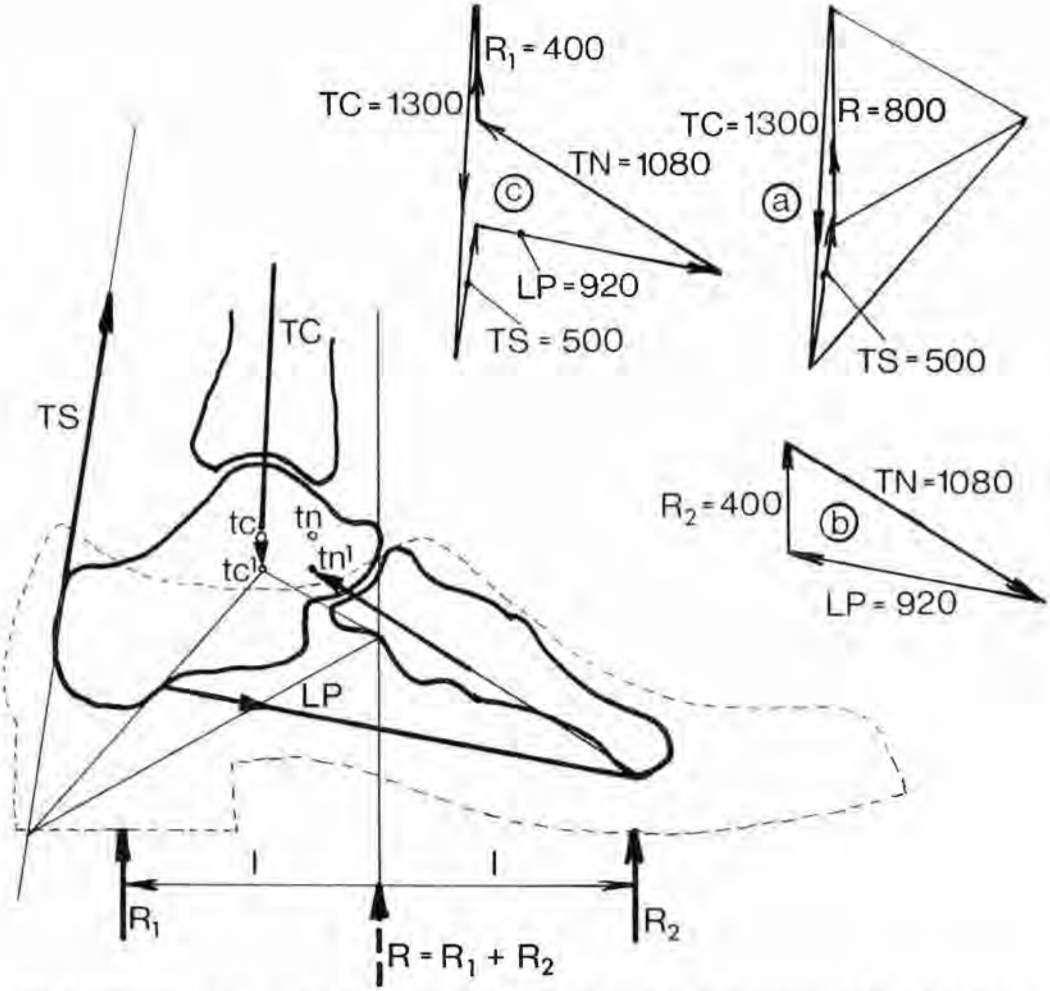

Fig. 9. Influence of pes planus configuration on the internal forces of the symmetrically loaded forefoot and hindfoot.

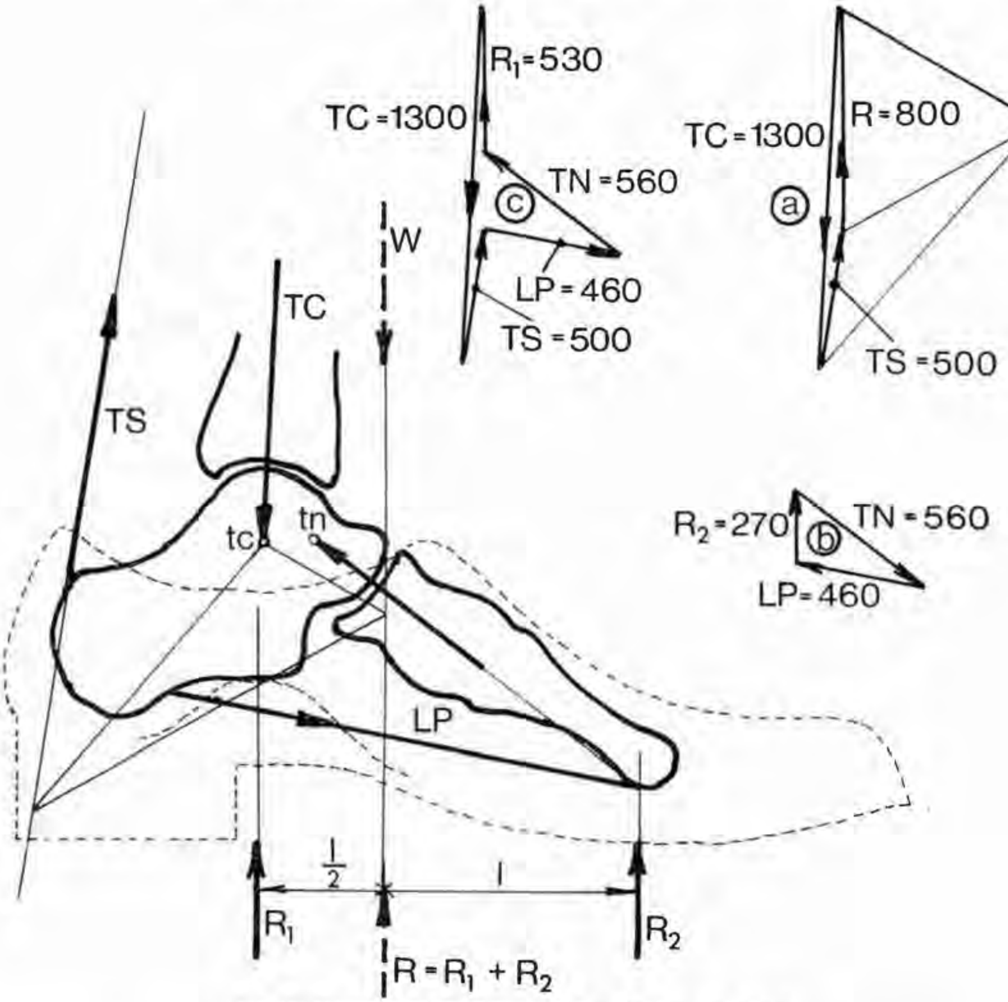

Fig. 10. Influence of pes planus inlay on the internal force.

acted upon by the reaction forces acting simultaneously on the forefoot and hindfoot are shown in table III.

	R	TC	LP	TS	TN
Normal foot without inlay	800	1300	740	500	900
Pes planus without inlay	800	1300	920	500	1080
Pes planus with medial support	800	1300	460	500	560

Table III. Comparison of internal loading in different circumstances as a result of simultaneously loading the forefoot and the hindfoot (all values given in Newtons).

The destabilizing trend of the pes planus

The figure 11 shows the foot structure in an even more simplified form than before. The reason for this is to show as clearly as possible the important feature of the pathomechanics of the pes planus. The forefoot and hindfoot are substituted by solid bars articulating at one idealized ankle joint and held together by the idealized plantar ligament. We assume that only the passive structures are engaged to maintain equilibrium with the external load.

Figure 11e shows the model of the normal foot. The force diagram in figure 11a belongs to the hindfoot and in figure 11b to the forefoot of such a model.

If the plantar passive structure in any way is

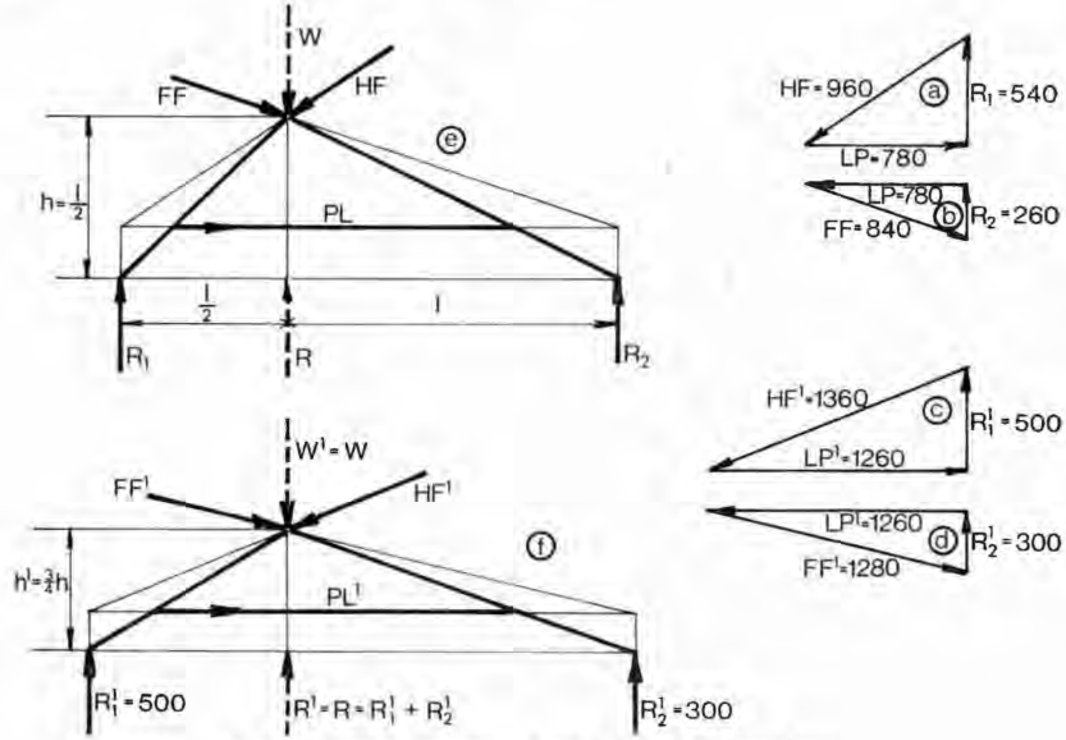

Fig. 11. Diagram showing the destabilizing effect of pes planus.

too weak to resist the load acting on it, the structure will give way and be lengthened. This lengthened passive plantar structure causes a pes planus architecture where the lengths of the solid forefoot and hindfoot are constant, but the height of the ankle joint will fall as shown in figure 11f. The forces acting on the forefoot in this case are shown in figure 11d and on the hindfoot in figure 11c. The load on the plantar passive structure in this case increases by about 60 per cent compared with the normal foot. This means that if the plantar passive structure is unable to resist a normal load it will cause an architectural change which results in an even greater load on the same structure. This is a runaway trend which should be stopped.

In closing it must be remembered that all these analyses are carried out by reducing to the utmost the complex situation to get an easy method which gives the relative magnitude and directions of these loads depending on various situations.

Prosthetics and Orthotics International, 1977, 1, 173–182

The foot and footwear*

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Coming from a country where the majority of people walk in unshod feet and where shoes are an expensive luxury, I would like to offer some unconventional thoughts which might provide a global overview of the problems involved in the design of footwear and foot and ankle orthoses.

I was brought up with the traditional concept of the foot being merely a static tripod or a semi-rigid support for superincumbent body weight. The arches of the foot were held to be very important and the height of the longitudinal arch was correlated with a superior kind of foot.

We owe it to Hicks (1961) of Birmingham who taught us to clearly differentiate between a beam, an arch and a truss, and the role of muscles and the plantar aponeurosis in the weight bearing and balancing mechanism of the foot.

But the foot can no longer be viewed as a mere weight-bearing device meant only for standing. It has evolved, as the bioengineering team at the University of California (1947) has been telling us over the last two decades, as a dynamic mechanism functioning as an integral part of the locomotor system. The human foot is primarily meant for walking and it is important to understand its behaviour in the walking cycle.

The foot is a remarkably mobile mechanism, adapting itself to the contours of the ground as well as responding to the forces transmitted via the suprapedal segments from above. By supinating and pronating, it causes the weight line to follow a curved pathway leading to an even load distribution on the metatarsal heads. It becomes supple as it is grounded from heel strike to foot flat, and rigid as it prepares itself for heel rise and the final take-off. There is a locking mechanism in the foot, operated through the medium of the subtalar and transverse tarsal articulations, using the musculature as well as the windlass effect of the plantar aponeurosis (Figure 1). Inversion of the heel against a fixed forefoot locks the foot; eversion of the heel unlocks it. Curiously, the traditional designs of orthoses have been preoccupied essentially with the ankle joint and have more or less neglected the subtalar joint. Lehneis (1965), in an attempt to refine the congruence of the orthotic ankle joint to the anatomic ankle axis, which is directed laterally and backwards, designed his torsion measuring device. But the problem is not nearly so simple. The ankle axis is not truly horizontal but also inclines downwards and laterally, having a range of variation from 68 degrees to 88 degrees, with a mean of 79 degrees (Figure 2). The implication of this obliquity is that when the leg is

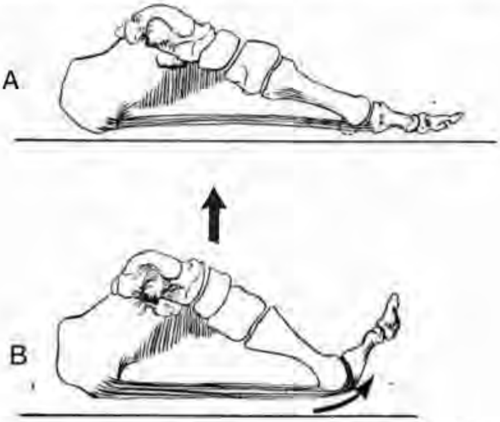

Fig. 1. Diagrammatic representation of "windlass action". A. Foot flat. B. Increased tension of plantar aponeurosis caused by dorsiflexion of toes, with resultant elevation of longitudinal arch.

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*Based on Lead Paper in the Colloquium on Foot and Footwear. First World Congress on Prosthetics and Orthotics, ISPO 1974 Montreux, Switzerland.

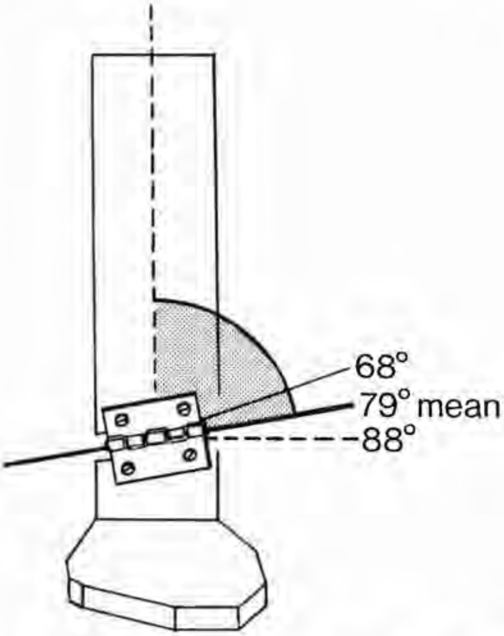

Fig. 2. Variations in inclination of axis of ankle joint, derived from anthropometric studies of 107 cadaver ankles at the University of California, San Francisco. (After Inman.)

fixed, the free foot deviates medially in plantarflexion and laterally in dorsiflexion (Figure 3). When the foot is fixed, as during the stance phase of walking, the tibia has to rotate medially or laterally (Figure 4).

The subtalar joint, to my mind, is the key joint in the mechanism of the foot. It has several roles to play.

(1) It allows adaptation of the foot to uneven ground or slopes. This not only results in an even distribution of load on the sole of the foot but also protects the more proximal segments of the limb. This is brought out very clearly when we see the ground reactions transmitted up to the stump-socket interface and bruising of the stump when our villagers use prostheses with conventional uniaxial ankles or SACH feet. In a way, therefore, the subtalar joint acts as a shock absorber.

(2) It acts like a mitred hinge with its axis inclined about 45 degrees to the horizontal plane. It, therefore, functions as a torque converter, with a one-to-one ratio (Figure 5). When the leg is rotated inwards, the foot pronates; when the leg is rotated outwards, the foot supinates (Figure 6).

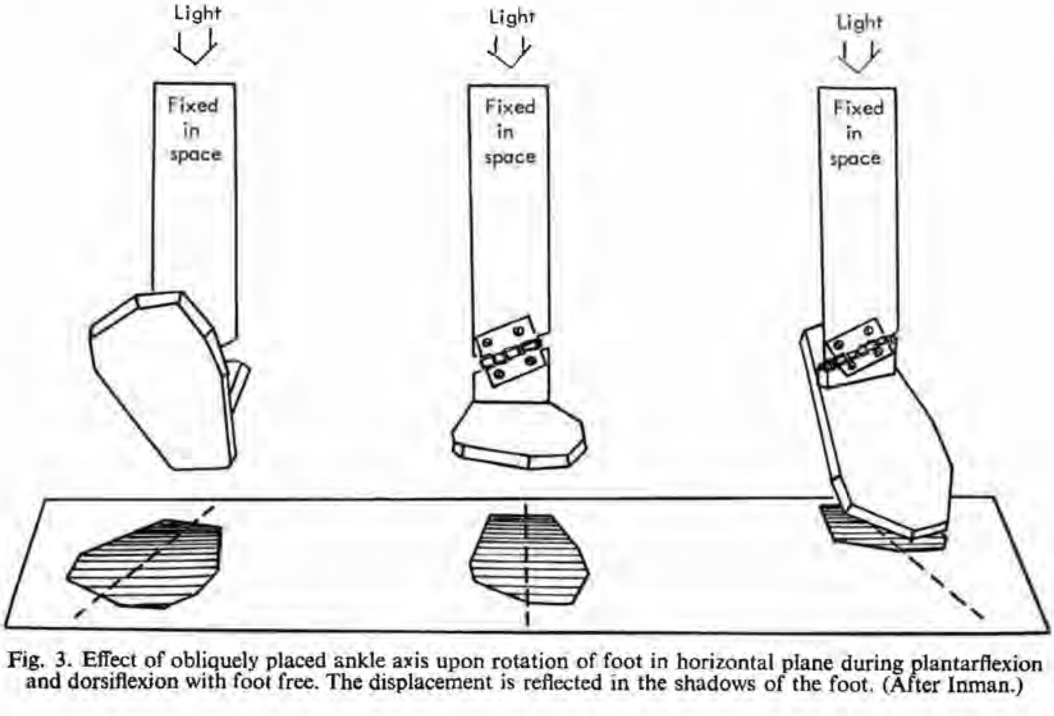

Fig. 3. Effect of obliquely placed ankle axis upon rotation of foot in horizontal plane during plantarflexion and dorsiflexion with foot free. The displacement is reflected in the shadows of the foot. (After Inman.)

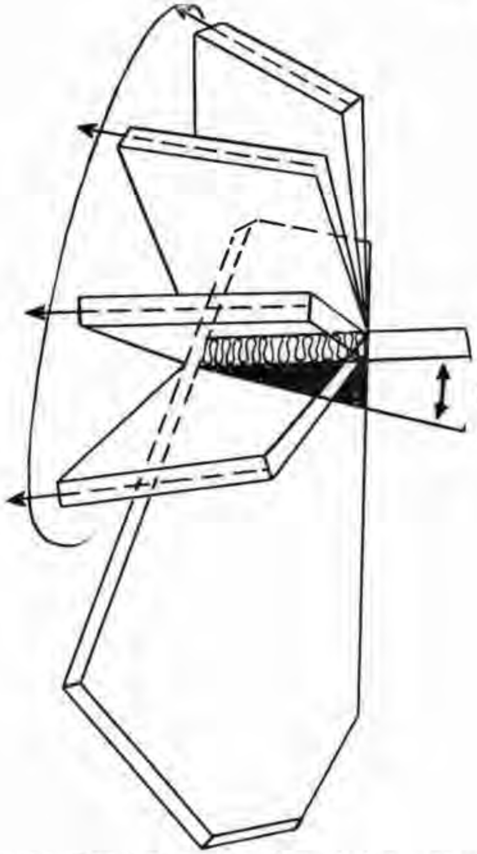

Fig. 4. Foot fixed to floor. Plantarflexion and dorsiflexion of the ankle produce horizontal rotation of the leg because of the obliquity of the ankle axis. (After Inman.)

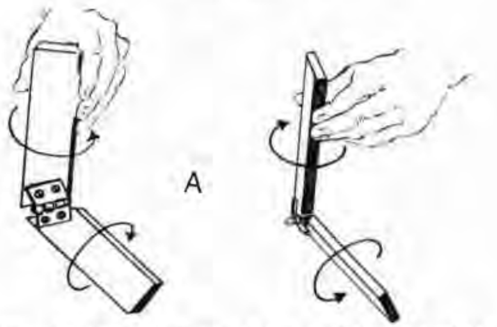

Fig. 5A. Action of mitred hinge. If the axis of the hinge is at 45 degrees, a simple torque converter is created. Rotation of the vertical member causes equal rotation of the horizontal member, with a one-to-one relationship.

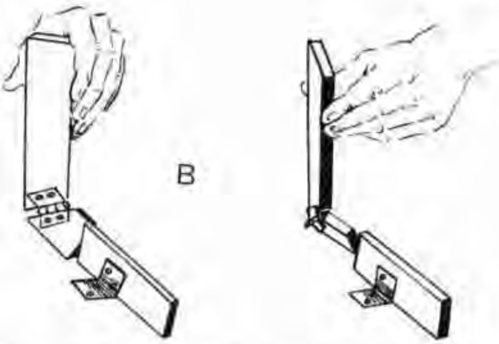

Fig. 5B. To prevent the entire horizontal segment from rotating, the horizontal member has been divided into a short proximal and a long distal segment with a pivot in between. (After Inman.)

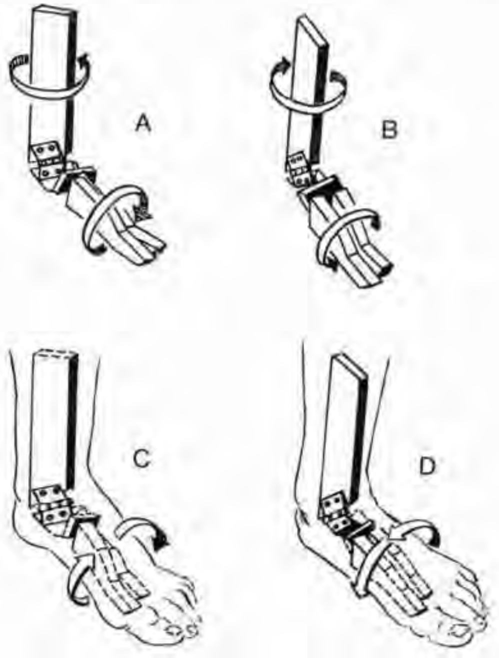

Fig. 6. Distal portion of horizontal member replaced by two structures A and B. Mechanical analogue of principal components of foot C and D. Mechanical components inserted into foot and leg. External rotation of the leg causes inversion of the heel, elevation of the medial side of the foot and depression of the lateral side. Internal rotation of the leg produces the opposite effect on the foot. (After Inman.)

(3) If there were no subtalar joint, the obliquity of the metatarsophalangeal break would cause the leg to tilt out during heel rise and toe-off. Here, the subtalar joint acts as a correcting device, allowing the leg to remain vertical (Figure 7).

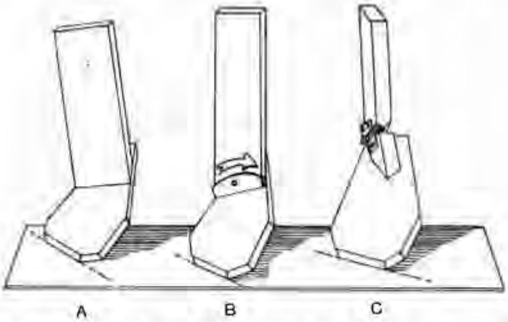

Fig. 7. In spite of the obliquity of the metatarsophalangeal break, raising of the heel allows the leg to remain vertical. This is another function of the subtalar joint. (After Inman.)

The close relationship between subtalar movement and horizontal rotation of the tibia during gait cycle has been demonstrated in several studies (Figure 8). From heel strike to foot flat, the foot pronates and the tibia rotates medially. During mid-stance, the foot supinates and the tibia reverses its rotation. At heel rise and toe-off, the heel is in inversion, the tibia is rotated out. This tibial rotation has not received the attention it deserves in the design of foot orthoses and prostheses. I would like to emphasize that most quantitative data on subtalar movement and tibial rotation has been collected on level walkway studies. It is inevitable that the dimensions of these movements would be considerably greater when walking on irregular ground.

Any footwear, shoe modification, or a prosthetic foot should respect this system of linkage between the various articulations of the human foot.

In unshod communities the foot muscles get freedom for exercise and the joints remain supple. This is why functional disorders of the foot are so rarely seen in such people.

However, footwear becomes necessary to protect the skin of the sole against rough ground or hard pavements and to keep the foot warm in cold climates. Over the ages, various communities have used locally available raw materials to design footwear which suit their own needs, and it is unnecessary and unwise to dictate to them that only a particular design of footwear is correct. In fact I sometimes like to look upon closed shoes as braces, a necessary evil, which take up the work of muscles, causing them to atrophy from disuse and make the joints stiff. I feel it is wise, at least for some time during the day, to take the shoes off and allow the foot to function unhampered. Use of an open sandal without a heel strap, where the toes have to grip to prevent their slipping off, is an excellent exercise for the intrinsic muscles. For those who may argue that this cannot be applicable for the cold climates, I suggest the example of a Japanese Geta and Tobi, a very sensible combination to provide warmth as well as freedom of foot action (Figure 9).

In short, for normal feet, the use of a shoe is optional. But when a foot is abnormal a shoe becomes compulsory, to realign the foot, to redistribute pressure especially in an anaesthetic sole, to accommodate deformities, to equalize leg lengths, or to act as a foundation over which an orthosis has to be erected.

I feel a little puzzled about the long and repetitive list of shoe modifications which are illustrated in most texts on foot ailments. Whenever many alternatives are available for a particular situation it usually means that none is really effective. Also, I have never been sure that when I prescribe a wedged heel or an arch support, I am really being rational. I am particularly sceptical about arch supports which are based on a static concept of the foot. The advertising media exploit such devices, and I do feel that some long term controlled clinical trials should be held to evaluate these devices. All useless and occasionally harmful modifications should be pruned. I must confess, however, that there is a great temptation to use them as placebos.

There is a need for controlling an abnormal inclination of the heel such as in valgus feet. Plastic heel seats were described by Helfet (1956) and later modified by Rose. For some reason, I have not seen them being used. I wonder why? The UCBL foot support (Henderson and Campbell, 1969) developed at the Biomechanics Laboratory, University of California appeals to me. Its fabrication, however, is not such as to be used except by skilled orthotists and it requires raw materials not available to us in the underdeveloped countries. I do feel that there has been no clear understanding of this problem and its solution so far.

From my basic theme of emphasizing the mobility of the foot, I now move in the opposite direction, that is, the need in some situations, for rigid footwear. Further work on the design of

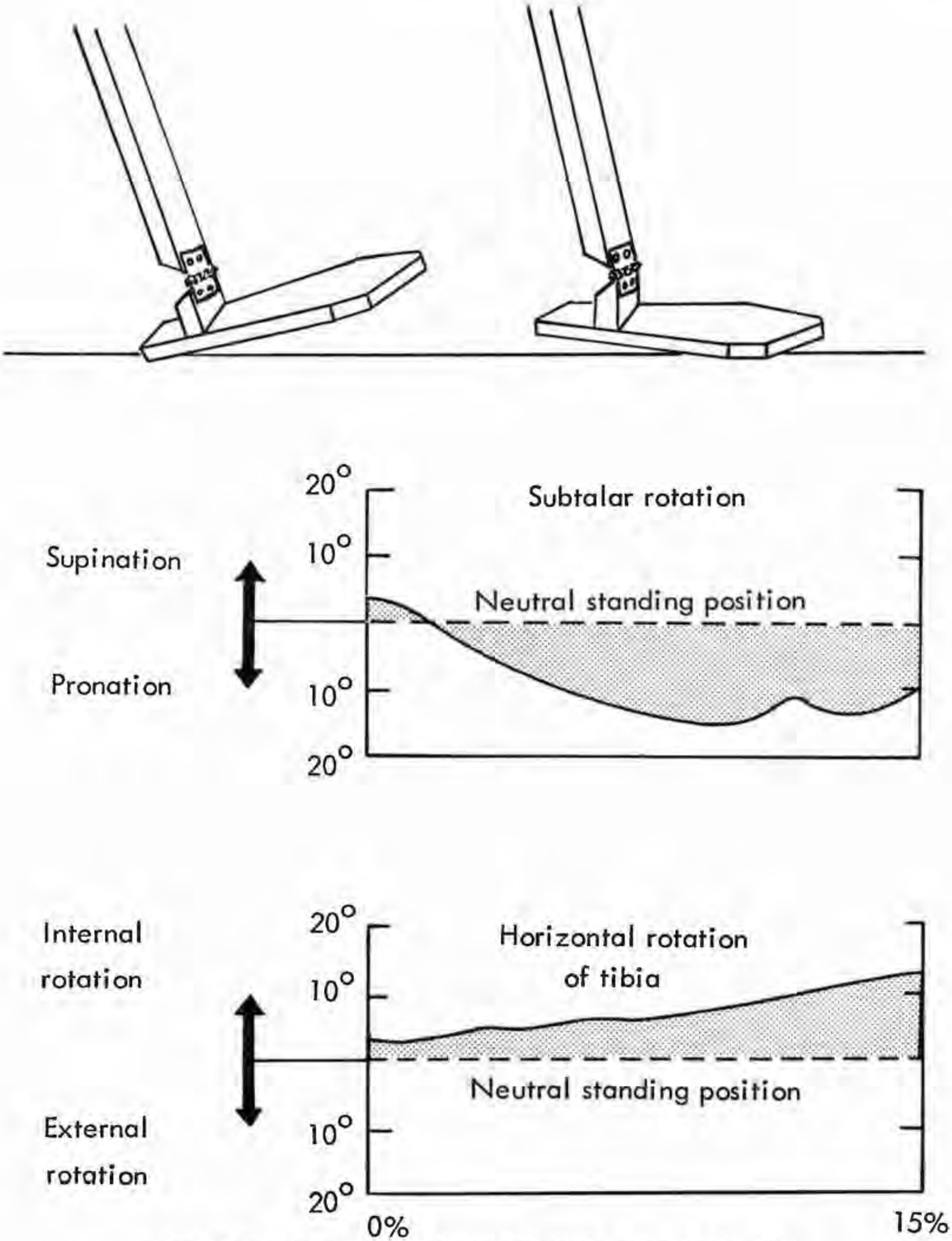

Fig. 8a. Subtalar rotation and horizontal rotation of tibia in gait cycle.
Heel-strike to foot-flat—the heel is elevated and the tibia rotates medially.

rigid footwear has become necessary. This is so for several reasons. An absolute indication for such rigid footwear is the anaesthetic foot with healed ulcers or with toe deformities. Once the toes have lost their bite during push off, the metatarsal heads are exposed to tremendous

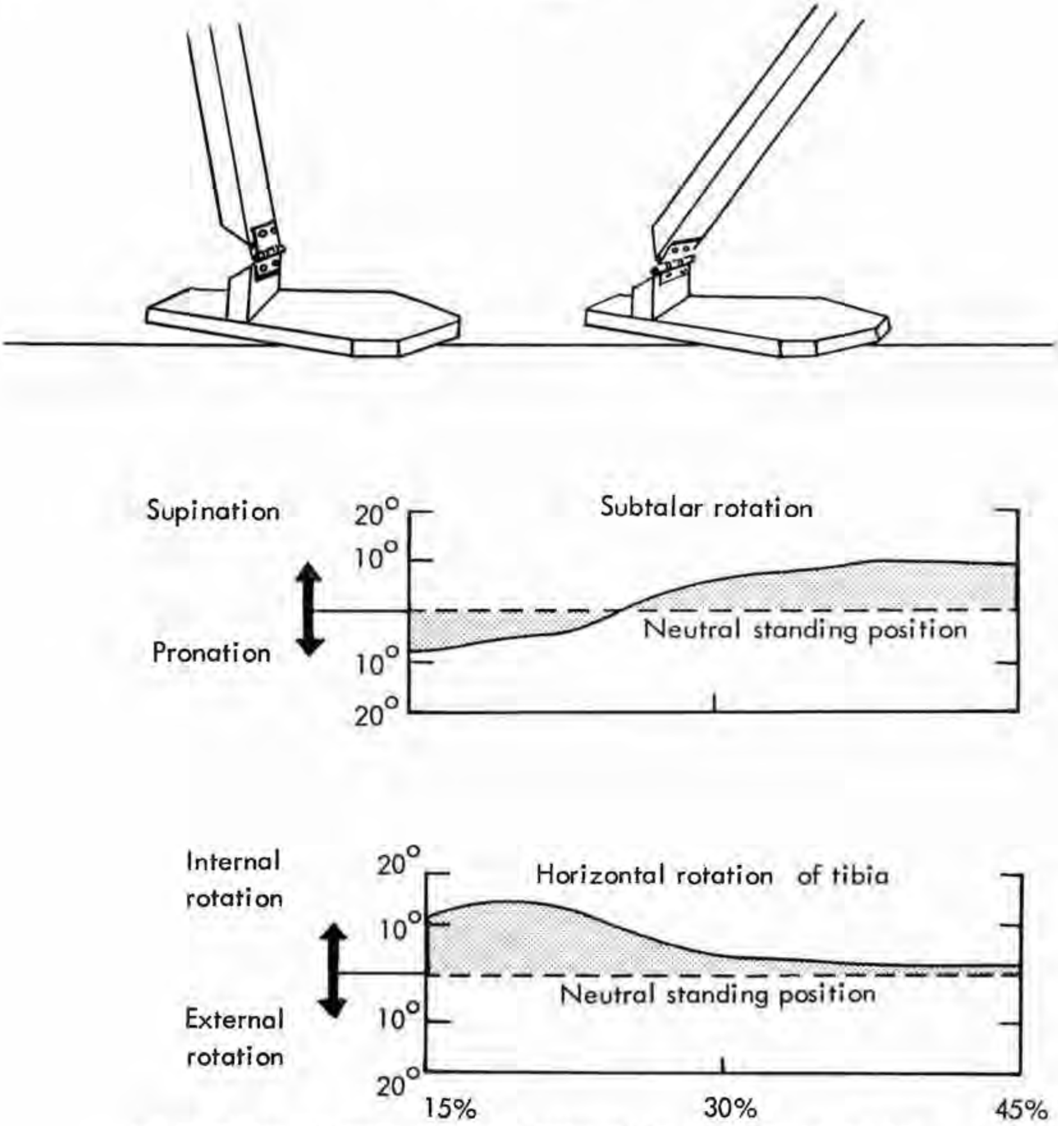

Fig. 8b. During mid-stance—the foot supinates and the tibia reverses its rotation.

pressure. There is also the shearing effect due to the roll of the metatarsal heads on the soft tissues underneath them. A microcellular rubber insole of 15 shore hardness, as described by Paul Brand (Ward 1964) can only prevent ulcers in an unscarred balanced foot. This resilient insole, over a wooden clog with a rockered sole, abolishes peak pressures on the sole during the walking cycle. I think there is still considerable scope for research in the problem of redistribution of load on the anaesthetic skin. A resilient insole is only one approach. There can be other approaches.

Such rigid wooden clogs have also been used in a completely different context by Huckstep (1974) in Uganda for polio patients. Huckstep was concerned about the cost of leather shoes, the long waiting lists piling up in his workshop, and the lack of trained orthotists. Therefore, he tried to simplify the fabrication of calipers by using wooden soles and a rocker bar as a substitute for orthodox shoes. This is a realistic

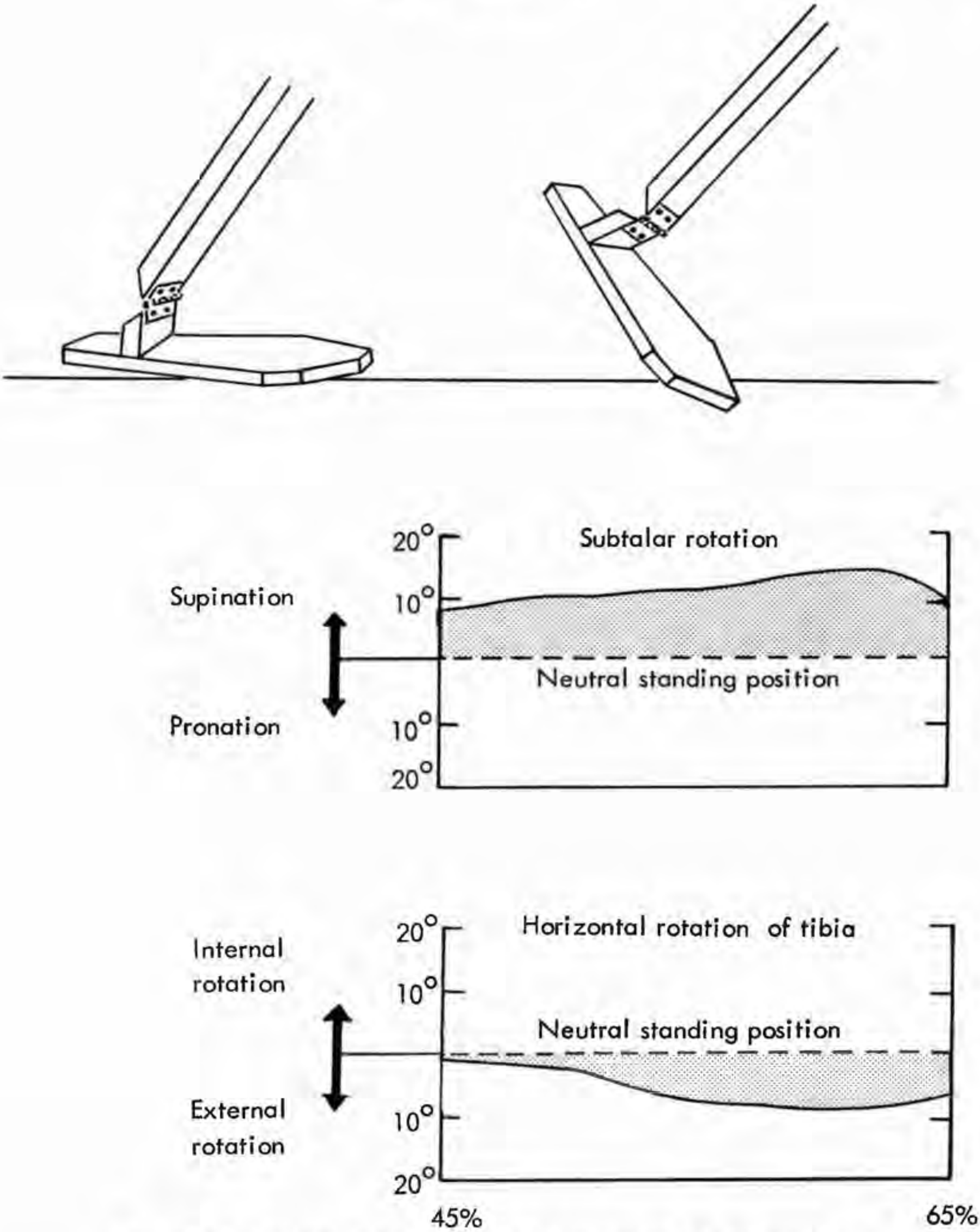

Fig. 8c. At heel rise and toe-off, the heel is in inversion and the tibia rotates out.

approach in underdeveloped countries.

Rigid footwear with a rocker sole has been advocated in a more sophisticated setting by John Glancy (1971) where he has used it to programme the heel rise by the body tripping over a rocker bar. A preset toe-off metal shoe plate can convert the entire length of the shoe into an efficient "resistance arm" which not only prolongs the life of a shoe, but allows a "booster" spring to act efficiently.

Fig. 9. A Japanese Geta and Tobi provides a very sensible combination of warmth and freedom of foot action.

The crux of the matter lies in the design of the rocker bar. If a narrow rocker bar is used, the tip-off is very abrupt (Figure 10). Its height is critical; the further back it is placed, the higher it has to be to prevent the front edge of the clog from striking the ground. A Lancashire clog gives a more smooth roll. However, when side bars are fixed to rigid footwear, as in Huckstep's design for paralytic feet, the line of progression of the limb is difficult to match with the pathway of the rolling clog. The arc of curvature of the rocker would have to vary with the length of the step, the length of the leg and whether or not the knee was affected. It appears well nigh impossible to devise a standard formula. John Girling has devised an ankle-foot orthosis for leprosy patients which has many thoughtful features (Wollstein and Girling, 1972). It takes into consideration the angle of inclination at heel strike, a broad area of support in mid-stance, and a suitable take-off angle. Is it possible to utilize the SACH wedge principle to simplify the solution? If an easy biomechanical solution can be worked out, it would be a great boon to the poorer countries (Figures 11, 12). We have some very skilled craftsmen who can handle wood with amazing dexterity and we can then make full use of them to produce a cheap and sturdy appliance.

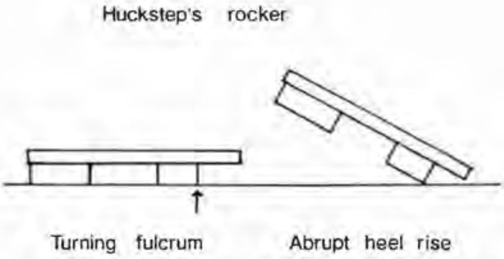

Fig. 10. Huckstep's wooden rocker provides an abrupt heel rise.

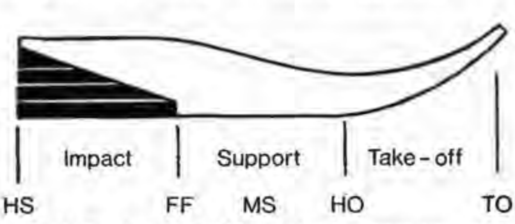

Fig. 11. Design of a rigid wooden footwear currently being used at Jaipur, utilizing a SACH wedge for the impact surface, a broad surface for mid-stance and a gentle rockered surface for take-off.

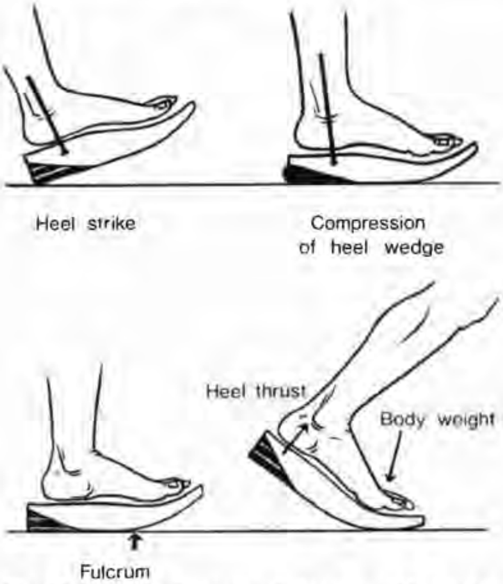

Fig. 12. With the foregoing design, an ankle joint is not needed. The orthosis can be quickly and very economically fabricated.

Top, compression of SACH wedge leads to grounding of foot. Bottom, body weight can be harnessed for simulating action of plantarflexors. Excellent performance characteristics are seen in paralytic calcaneus feet.

Finally a word about foot and ankle orthoses. There has been an unfortunate "orthotic lag". In spite of rapid progress in the field of prosthetics, the design of orthoses has witnessed, till lately, no basic change over the last half century. Only recently, a break-through has appeared. There is a greater realization that any mechanical analogue should match the biomechanical system. I have already referred to the value of subtalar movement in the walking cycle and I would like to have a device which preserves it, especially when most of my patients have to walk on a rugged terrain. The UCBL dual-axis ankle was, in my opinion, a step in the right direction. But the recent work by Lehneis (1972) at New York University, such as the use of a plastic spiral ankle-foot orthosis, is much more appealing because these orthoses rely on the natural anatomic axes rather than some arbitrarily imposed external joints of the traditional brace systems. While plastics seem to have a great future, they are still very expensive and being rigid, require a great deal of expertise in the fabrication of such orthoses to avoid the creation of pressure points. Also, I am not quite sure whether these can withstand the merciless beating in our rugged terrain. It is in this context that I want you to consider the use of a cord-cum-rubber bracing, which is more akin to the properties of skeletal muscle

Fig. 13. Jaipur Foot—The external covering is vulcanized rubber with rayon cord reinforcement.

Fig. 14. Jaipur version of Syme's prosthesis. The cord-cum-rubber provides a combination of resilience and stability.

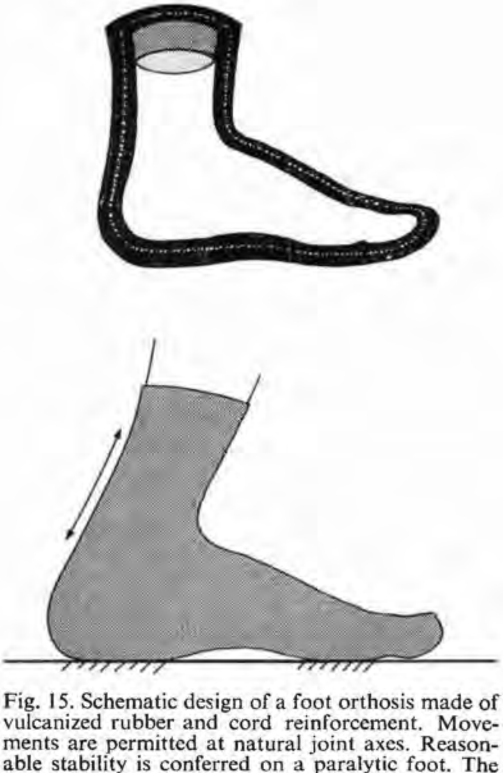

Fig. 15. Schematic design of a foot orthosis made of vulcanized rubber and cord reinforcement. Movements are permitted at natural joint axes. Reasonable stability is conferred on a paralytic foot. The orthosis is worn like a gym shoe.

and is not subject to the failure encountered in all mechanical spring systems. As a "spin-off" effect of our work on the Jaipur Foot (Figure 13) and its modification for Syme's amputation (Figure 14), it has recently occurred to us that we could extend the same principle for orthotic purposes. If a Syme's amputee can feel secure in this resilient container, I see no reason why a flail ankle and foot cannot be stabilized by this device. I am sure it can be used to programme motion in any direction. We intend to pursue this idea and have a feeling that, at least for problems of the foot and ankle, it may answer many of our needs (Figure 15).

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Prosthetics and Orthotics International, 1977, 1, 183–192

Amputation surgery in the lower extremity—part II

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Introduction

Part I of this contribution was published in the last issue of "Prosthetics and Orthotics International" (Vol. 1, No. 2). This part presents the application of the techniques and considerations previously discussed in a variety of special circumstances.

Vascular disease

Vascular disease has played an increasingly important role in the field of amputation. Atherosclerosis is widespread in Northern Europe, North America and elsewhere in the world and several publications (Hansson, 1965 and Robinson, 1976) demonstrate that over 80 per cent of primary amputations are now performed on patients with vascular disease and this despite a number of significant advances in vascular surgery. Our experience in the Tayside area of Scotland with a very stable population, indicates a figure of 86 per cent (Murdoch *et al*, 1977).

Typically, these patients are elderly and subject to other handicaps which are often multiple (Troup, *et al*, 1973). Mazet *et al* (1959) and Olejniczak (1967) indicate that as recently as twenty years ago some 90 per cent of these patients had above-knee amputations performed.

One event focused attention on the lot of the amputee—the advent of immediate post-surgical fitting of prostheses. Following the first report of Berlemont (1961) experience in a variety of places, notably that of Burgess and Romano (1968)[1] and Sarmiento *et al* (1970), has underlined that a high proportion of these patients can be rehabilitated following successful fitting with a prosthesis. While the emphasis on immediate post-surgical fitting itself has now diminished a number of centres around the world have achieved similar success. Our own studies have demonstrated that close to 90 per cent can be returned, independent in some degree, to a home environment. We also know that this rehabilitation need take no more than forty or fifty days. However, to achieve this kind of result an integrated programme of rehabilitation with a properly co-ordinated management of concurrent handicaps is required. Moreover, the knee joint should be saved when possible and to achieve this, the accuracy of level selection and the success of surgery are critical. Should level assessment be in error or the surgery fail for any reason the rehabilitation time is doubled.

Once presented for possible amputation the dysvascular patient must be aggressively investigated as every day lost causes deterioration with increasing depression, muscle wasting, the development of flexion contractures and a variety of systemic changes due to inadequate fluid intake. The assessment must be of the patient as a whole and of the vascular tree in particular to decide whether vascular surgery can offer a solution. This usually involves arteriography which, however, is not in itself of particular value in determining any proposed level of amputation (Murdoch, 1967; Burgess *et al*, 1971; Burgess and Romano, 1971). The clinical appearances of the limb remain important providing information about peripheral pulses, frank gangrene or partial ischaemia and particularly the state of the skin. The surgeon need not be put off the lower levels of amputation by hairless, thin, inelastic skin but he will certainly have doubts where there are frank ischaemic ulcers or a severe temperature drop is noted.

For a number of years a variety of ancillary methods of investigation have been available and all provide information of value although, even at this date, one cannot make categorical decisions on the basis of any single technique.

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These methods include plethysmography, skin blood flow and skin blood pressure estimations (Browse, 1973; Lassen and Holstein, 1974), the use of the Doppler ultrasound in providing information about the total blood flow (Barnes *et al*, 1976) and thermography (Murdoch, 1975). Significantly useful results have been claimed for each of these methods. However it is necessary that work continues so that not only the crude level of amputation, for example, above-knee or below-knee, is selected but also in the case of possible below-knee amputation, the precise state of each of the tissues involved can be determined permitting the surgeon to fashion skin flaps appropriate to the individual case, according to the state of the pathology and, if need be, to excise muscle groups which are likely not to survive the assault of the operation. Many of the successes reported in this field have been dependent on the ability to achieve amputation at below-knee level and there is the suggestion that the employment of the posterior flap operation has also contributed (Burgess and Romano, 1968[2]; Burgess *et al*, 1969; Murdoch, 1970). When it is considered that below-knee amputation is not feasible, and perhaps the final decision should be made only at operation, through-knee amputation, supracondylar amputation such as the Gritti-Stokes and above-knee amputations are all available. Several publications testify to good results from the through-knee amputation (Howard *et al*, 1969; Newcombe and Marcuson, 1972) and similarly good results with supracondylar amputation (Weale, 1969; Martin *et al*, 1967; Middleton and Webster, 1962). However, these publications do not include the composite view of the patient's life after amputation nor, in some instances, indicate on what basis these other levels of amputation have been selected. Whatever technique is employed one must pay respect to the importance of attachment of the muscles to the bone end, sculpturing of the bone end where the bone is divided, high division of the nerve, adequate haemostasis and proper abutment of the skin edges without tension.

In summary, the level of amputation selected should be based on as much information as possible, bearing in mind the value of the knee joint in the rehabilitation of the patient and in the quality of his life thereafter. The surgeon should have some knowledge of the prostheses available and confidence in his prosthetists to fit the patient competently. The surgery and prosthetic fitting should take place in an environment which ensures the proper treatment of concurrent handicaps, stimulates motivation and assures the patient an adequate follow-up in the fullest terms.

Diabetes

Depending on the population at risk, some 25–50 per cent presenting for amputation for vascular disease suffer from diabetes. The latter are often described as suffering from diabetic gangrene. There is no such single clinical entity. Meggitt (1973) emphasizes this in pointing out that the pathology can be the result of small vessel disease, major vessel occlusion as in atherosclerosis and in the absence of diabetes, neuropathy or infection to which diabetic tissue is more prone. Some or all of these factors may have an influence in a single case and thus each case must be assessed individually. Where there is no major vessel occlusion Meggitt has shown that some diabetic feet can be saved by careful surgery, excising all dead tissue, opening all infected areas and by careful pressure dressings (Figure 1). In some cases local toe amputations,

Fig. 1. Ischaemic and infected foot in diabetes. Wide exploration of tissues in sole of foot with excision of all dead and infected tissues. Sound healing achieved without amputation.

skin grafting and partial foot amputation such as the transmetatarsal procedure are appropriate. It has been shown by Meggitt and later by Wagner (1977) dealing with the same group of patients that Syme's amputation in the diabetic dysvascular patient is a useful procedure which can be performed with confidence provided level assessment has been carefully judged. Experience of the Syme's amputation in atherosclerosis without diabetes has been very variable and is not advocated. Where even a Syme's amputation is not deemed feasible the preponderance of major vessel occlusion in vessels below the knee rather than above the knee will normally permit a below-knee amputation.

Trauma

Amputation in the severe trauma resulting from road traffic accidents, war injuries and the like, can provide many serious but interesting problems. The long established principles will hold and the principal one to conserve all viable tissue should, in the initial operation, be mandatory. In a few cases in those regions where replantation teams have been organized and micro-surgical competence is established the completely severed limb with little local tissue damage should be presented with the patient as soon as possible in case replantation is feasible. (Chung-Wei, Che'en, 1962; Malt and McKhann, 1964). A considerable experience has been gained since these classic contributions although no conclusions can be reached (Editorial B.M.J., 1975; China Med. J., 1975).

The judgement as to whether a tissue is viable or not may be difficult but one should err on the side of conservation. Wounds should be closed when feasible. If there is much doubtful tissue destruction then open flaps should be employed. The contributions of Welch *et al* (1969), Mayfield *et al* (1972) and Brown (1970) suggest that skin traction has still an important part to play in this instance. By this approach and with the aid of plastic surgery joints can be saved and stump length maintained.

The problems that remain are clouded by a philosophical one, namely that given a well motivated patient and a skilled prosthetist even the most badly scarred stumps can be fitted well enough. However, the patients normally concerned have a life expectancy of 30, 40 or 50 years and accordingly the question of reconstruction of the stump when indicated must be formally presented to the patient at an early date. Stump reconstruction is often necessary to ensure that the stump will give the best service to the patient over the years and not interfere with his employment and social aspirations. The further possible procedures that may be discussed include excision of the fibula to increase load bearing area in very short stumps (Spira and Steinbach 1973), osteomyoplasty, scar excisions and mobilizations. Even if stump reconstruction is inconvenient at the time of consultation the patient must be informed of the long term implications of deficiencies in the stump so that he is in a position to make decisions regarding his future. The plastic surgeon in some instances should be consulted at this time to determine what role he may adopt.

Tumours

Osteosarcoma appears generally in the ages between 10 and 20 and continues to present horrifying decisions for the patients, parents and surgeons and, until recently, a five year survival rate of about 20 per cent was the common experience. Dahlin and Coventry (1967) confirmed the typical occurrence around the knee and the place of amputation in treatment. Radiotherapy has not significantly improved the patient's chances of survival although its application as recommended by Cade (1955), has spared many patients needless amputations by reserving the procedure for those most likely to survive. A series of publications since Jaffe's (1972) report on the use of high-dose methotrexate with citrovorum factor have awakened interest in chemotherapy because of the apparent improvement in survival rates. Marcove *et al* (1970) had shown the close relationship between the recognition of pulmonary metastases and death of the patient and so chemotherapy is now employed for treatment of the condition prior to the known existence of any pulmonary metastases and instituted at the time of amputation. Since then publications abound relating experience with a variety of drugs individually and in combination in differing doses (Sutow *et al*, 1974). They highlight in particular methotrexate in massive doses or adriamycin or combinations of both (Cortes *et al*, 1974). Jaffe and Watts (1976) in an editorial comment review the situation and point up some of the pathological and philosophical problems. Much of the emphasis on chemotherapy is based on the view that the time interval between diagnosis of osteosarcoma and the appearance of lung metastases on radiological examination does not represent spread of the disease but rather the unveiling of disease which is already present. Jaffe points out further that while reports confirm that chemotherapy has substantially improved the prognosis in patients with osteosarcoma he wonders whether the results will stand up to the passage of time. Prior to chemotherapy if a patient survived two years he could be considered "cured". It is not possible to say this about the new treatments yet. These drug regimes also carry a high degree of toxicity. There is, therefore, a clear need for collaboration between centres as in the United Kingdom Medical Research Council trial to determine the efficacy of these drugs, their optimum dosage and the best ways of reducing toxic effects.

For the surgeon while chemotherapy slows down the healing of amputation wounds, it also permits amputation through the affected bone provided it is at least 70–100 mm above the most proximal area of bone reaction seen on bone scan. Amputation remains the main weapon of treatment but the way may now be open for resection of tumour rather than amputation in some cases. I wholly agree with Jaffe and Watts' plea for referral of patients to centres staffed by experts who can provide the best overall results.

Soft tissue sarcomas in the extremities

A report by Simon and Enneking (1976) regarding the management of soft tissue sarcomas of the extremities outline their approach and decision leading to radical local resection or amputation. They place particular emphasis on the value of angiography and bone-scanning. Any surgeon contemplating radical local resection should read this paper with care.

Chondrosarcoma

Chondrosarcoma is not normally amenable to radiation and is difficult to categorically exclude in any individual case of chondroma, especially when the tumour is large and in the pelvis. Where X-ray examination, bone scans and the like have been performed, it is often possible to make a categorical diagnosis of chondrosarcoma and proceed to amputation as survival rates are higher than in osteosarcoma. The pelvic tumours usually require a hind-quarter amputation. Any argument for amputation in other cases will depend on a full histological examination of the tumour removed.

Other tumours for a variety of reasons may bring about the need for amputation but then usually because of failed local excision or progression of the tumour to the point where there is gross bone destruction not amenable to other forms of treatment.

Infection

Occasionally emergency amputation is required in the case of gas gangrene. Otherwise the question of amputation in infection is usually confined to cases of longstanding infection associated often with ununited fractures and partial ischaemia of the tissues. In these cases the infection is walled off and amputation can be carried out through the affected bone.

Congenital limb deficiency

Congenital limb deficiency is comparatively rare in the experience of any one surgeon and, in my view, the management of these cases is perhaps best undertaken by special Centres which by reason of their competence have accumulated a large experience. Even in these circumstances concern about a basic understanding of the nature of the defects and the difficulties in comparing methods of management has been expressed by a number of authors attempting to name and classify the defects. The International Society for Prosthetics and Orthotics took a lead in this regard, following the interest displayed by the Committee on Prosthetic Research and Development at the National Academy of Sciences in the United States, and created a Sub-committee to look at this problem. This group, through a series of workshops, has reached a measure of agreement and the results of their work has been published and tested under field conditions (Kay, 1974). It is intended that further work and trials will be conducted to revise the system as referred to in Part I. There is fairly general agreement that congenital absence of the fibula is best treated by ablation of the foot. On the other hand, in for example, proximal focal femoral deficiency, controversy continues and the debate on surgical management must include procedures such as arthrodesis of the knee, Syme's amputation, osteotomies and the more exotic procedures such as the Van Ness operation. Other deformities provoke similar controversy. In my view the clinic team, before proceeding to any operation, should have a clear picture of the likely natural history of the deficiency itself and of the patient in different situations. Parents should be fully informed and any decisions taken should be on the basis of a full understanding of the situation.

Limb discrepancy, deformity and paralysis

There remains a broad group of disease and disability categories which result in various combinations of deformity, paralysis and limb discrepancy. This group can provide the most difficult problems as amputation, if employed, is not a life saving procedure, nor indeed is it necessary to promote locomotion. A careful analysis of each of the elements of the problem must be undertaken and the team must have an intimate knowledge of the patient, her family and her aspirations if a correct decision is to be made.

Typical pathologies involved include septic arthritis of infancy, poliomyelitis, tuberculosis with premature closure of the epiphysis, the late effects of trauma and spina bifida. The result may include gross shortening, joint instability, arthritis, degrees of paralysis, deformity, neuropathy and ischaemia.

Westin (1967) in outlining the criteria for leg lengthening points out that the integrity of both hip and knee joints must be carefully evaluated and that in cases of extreme shortening amputation may be the treatment of choice. In his series of twenty-six patients, lengthening from 15 to 60 mm was achieved with residual discrepancies ranging from 15 to 110 mm. Over half the patients had major complications for example dislocation of the hip, fractures, osteomyelitis. This experience suggests that in discrepancies over 130 or 140 mm amputation should be considered.

Each case must be considered on its merits but knee disarticulation and Syme's amputation can be deployed with benefit as the usual cosmetic disadvantages do not apply as, by virtue of the shortening, the bulbous end can be contained within the prosthetic thigh or shank.

Joint instability may result from a variety of causes, for example paresis, architectural deficiencies or the development of arthritis. Each joint must be assessed prior to amputation as to how it will be affected by amputation and prosthetic fitting. It may be improved by some other surgical procedure, be eliminated by the amputation itself, or be so gross that after amputation it will still require external support with perhaps only marginal benefits. This applies especially to proposed amputations below an unstable knee.

If a joint is arthritic it is amenable to standard treatments such as joint replacement, it may be removed by the amputation or the operation can be carried out through the affected joint.

Deformity of the short limb may be compounded of many factors such as reduction or enlargement of the part, gross wasting and angulation of the major bones or at major joints. The deformity may be eliminated by the amputation or by a separate procedure, for example osteotomy above the level of amputation.

The decision cannot rest solely on functional considerations even in the male. The trap for the operating surgeon is to replace observed ugliness in static terms with an equally unpleasant and irremediable dynamic ugliness. Amputation in these cases may be a valid procedure but often it is only one of a programme of operations designed to ensure an improvement in both appearance and locomotor capacity. Surgeons not faced with prosthetic problems in their normal working lives are strongly recommended to consult surgeons in this field before undertaking the irrevocable step of amputation.

Special situations

Growth period

The surgeon must be especially cautious in undertaking amputation during the growth period. This caution has already been underlined with regard to congenital limb deficiencies but for the most part we are considering the question of trauma in children. Every effort should be made to retain joints and if a joint cannot be retained, the epiphysis may be saved. This should be attempted even when there is major skin loss. Quite extensive areas can be covered by split skin grafts and later, if need be, by full thickness skin. Split skin grafts are able to survive direct and shear forces during the growth period better than they do in the fully mature adult (Figure 2). Even when the epiphysis cannot be retained stumps should be as long

Fig. 2. Below-knee amputation in a boy of 12. Extensive skin loss. Survival of split skin grafts with prosthetic sore some years later. Refitting of PTB socket permitted sound healing.

as possible. If overgrowth of the bone occurs in relation to the soft tissues then trimming of the bone can be performed at later procedures. More proximal amputations should not be performed to avoid these further trimming procedures nor should operations such as epiphyseal arrest be considered. The procedures, therefore, which give the best long term results are clearly through-knee amputations and the Syme's procedure if they are justified on other grounds. In amputations through the shaft of a bone the general principles of tissue management should be maintained. At below-knee level it is my view that an osteomyoplasty should be performed if possible. Later developments such as a valgus deformity can be corrected by an additional surgical procedure as required.

Stump revisions

Revisions of initial amputation surgery are indicated from time to time. They should only be performed with clear objectives in mind and any procedure should be discussed with the prosthetist as he may be able to offer solutions which avoid surgery. The revision proposed may be required to eliminate adherent scars, bony spikes, neuromata etc. The surgeon in performing these procedures should be sensitive to the requirements of the "ideal" stump. For example, in my view it is rarely sufficient to excise a neuroma which is seen to be the cause of disabling symptoms. It is usually also necessary to reconstruct the end of the stump ensuring secure muscle fixation, a well sculptured bone end, and a newly cut end of the nerve so placed in healthy muscle that it will not be involved again in the development of terminal scar tissue. In longstanding stumps the surgeon should look carefully for evidence of local terminal ischaemia. This can be demonstrated by a significant drop in temperature and sensory changes. Before proceeding to stump surgery it is often worthwhile to consult the vascular surgeon with a view to possible lumbar sympathectomy. Close co-operation with the prosthetist is essential if the resultant scars are to be properly placed in relation to the load bearing areas.

In vascular cases it is all too common an experience for surgery to fail at below-knee level as the precise level of tissue viability is often difficult to determine. Before proceeding to a knee disarticulation or above-knee amputation the surgeon should carefully consider whether local excision of ischaemic and infected tissues can be done with a reasonable hope of primary wound healing and the retention of a useful below-knee stump. The author recommends a wedge resection certainly in those cases who have had a posterior flap amputation performed (Figure 3). In this procedure an undissected wedge of tissue is excised. After outlining the incisions to encompass the tissue, sharp dissection proceeds through the retained gastrocnemius muscle posteriorly to above the level of the affected tissue and the wedge is then removed en bloc by taking a Gigli saw upwards through soft tissue and bone alike. After minor bone sculpture at the anterior distal end of the tibia wound closure can be affected in a neat and precise way.

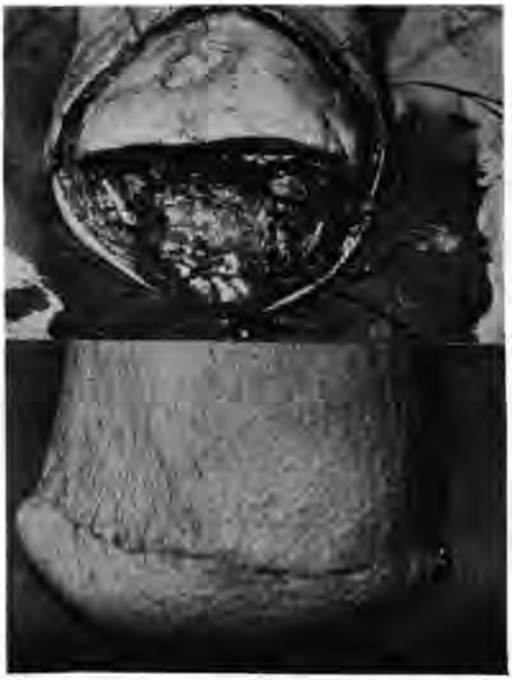

Fig. 3. Failed posterior flap amputation. Wedge resection with en bloc removal of infected and ischaemic tissues. Primary wound healing.

Amputation in the anaesthetic limb

Amputation in this situation is usually considered in cases of high sciatic nerve damage, leprosy, spina bifida etc., and becomes necessary because of intractable infected trophic ulcers which have usually invaded bone or joint. The trap for the amputating surgeon here is that he may proceed to amputation at too high a level in an effort to remove anaesthetic skin. He should remember that the skilled prosthetist is able to transfer force actions via the socket in a much better way than is normally effected by footwear for example. The surgeon should consult the prosthetist in selecting the level of amputation in the confidence that the prosthetist will be able to design a socket to transfer the forces of weight bearing without irremediable skin damage. Even in anaesthetic end bearing stumps successful prosthetic fittings have been achieved (Scrinivasan, 1973).

Flexion deformities

Flexion deformities are the bane of the surgeon and prosthetist's life. The best treatment is prevention and the clinic team's efforts in this direction must be initiated where possible from before amputation and throughout the period of rehabilitation. It is tempting to give angles of flexion deformity which can be accommodated by the prosthetic design but individual cases are best discussed with the prosthetist. These deformities usually occur as a result of contracting scar tissue or because of sustained flexion prior to amputation. In the latter instance it is usually an elderly patient with vascular disease who has had a long period of enforced bed rest accompanied by severe pain. The trap for the surgeon here is that he may be tempted to operate at a higher level because of an apparent gross flexion deformity. He should leave his final decision until the patient is completely anaesthetized. In the post-operative period splintage of the proximal joint may avoid the development of a chronic flexion deformity. Needless to say the role of the physical therapist is of paramount importance. Harmful stump postures in the rehabilitation period are well known and instruction in their avoidance should be part of the clinic team's programme of management.

Where physiotherapy and prosthetic alignment measures have failed to correct the flexion deformity surgery may be considered. At the hip this would certainly include elevation of the origins of the strap muscles and tensor fascia lata from the anterior superior iliac spine and adjacent iliac crest and division of the ilio-psoas tendon. It may also require elevation or division of the origins of rectus femoris. At the knee it may require division or elongation of the hamstrings and perhaps even division of the posterior capsule of the knee joint.

Recent advances

Skeletal attachment

Work on skeletal attachment of the prosthesis continues. Acceptable clinical solutions have been achieved in individual cases and the main problem relates to the percutaneous interface with the search for biocompatible materials and shapes. Other considerations will assume greater importance when the philosophy is applied to the lower extremity.

Biofeedback training for amputees

This approach appears to have benefits in training the amputee to walk in an optimum manner with his prosthesis and are clearly of great value in the primary, elderly amputee. These techniques are usually based on making the patient aware of the prosthetic knee position, trunk attitude, step length and weight transference by audible or tactile signals.

Stump environment

Since the pioneering work of the Seattle group many Centres employ a rigid cast as the initial dressing following amputation with benefits in terms of tissue stabilization, noninrteference with the wound, freedom to move and the ability to exercise the muscle (Burgess and Romano, 1968[1]; Mooney *et al*, 1971). Reference has already been made to controlled environment treatment and its benefits. One important aspect of this innovation is that it provides a "laboratory" for the study of wound healing in a controlled environment.

Fig. 4. Gross chronic indurated lymphatic oedema of leg and foot. Result following cyclic pressure in controlled environment treatment device and plastic surgery. No amputation.

Conclusion

The experience of the last twenty years demonstrates that the amputating surgeons need no longer be regarded as they were by Guy Patin in the 17th century

> "Mere booted lackeys—a race of extravagant coxcombs who wear moustaches and flourish razors."

The surgery is now more considerate, more conservative and more in tune with the patient's needs. Indeed the surgeon involved in amputation surgery is perhaps more sensitive to solutions other than amputation because of his awareness of the life of the amputee. Figure 4 shows a grossly ugle leg due to chronic indurated lymphatic oedema of doubtful origin. The patient was presented for amputation. Employing Controlled Environment treatment the oedema was gradually dissipated permitting plastic surgery and a very satisfactory result without amputation.

It has been demonstrated that this field of scientific endeavour covers the whole range of disciplines in medicine and the physical sciences. It is now clear that the rehabilitation of the amputee does not depend solely on the operating theatre and the prosthetist's shop but that a team approach is necessary if the amputee is to be returned to his home and work, integrated with his prosthesis and the community. There are clear implications for funding authorities in terms of the organization of systems to ensure that all the professional skills are brought together in a collaborative way for the benefit of the patient and underlying all the problems is the need for proper education of all professionals both at undergraduate and postgraduate level.

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Prosthetics and Orthotics International, 1977, 1, 193–199

Calendar of Events

PRELIMINARY NOTICE

A COURSE ON ABOVE-KNEE PROSTHETICS

DENMARK

5th to 11th NOVEMBER, 1978

A course covering all aspects of Above-Knee Prosthetics will be held in Rungsted, Denmark, from 5th to 11th November, 1978. Consideration will be given to medical and surgical factors; locomotion; biomechanics; socket shape; function; fabrication; components and their function; alignment; gait training. New practices in the fitting and design of the AK prosthesis will be highlighted and the different systems currently available will be discussed.

The Registration Fee will be U.S. $190. Accommodation will be available at the Course Centre at a cost for full board of $240 (including the Course Dinner).

Attendance will be strictly limited to 90 *participants.*

An indication of your interest in attending should be sent to the Secretariat in Copenhagen. The next issue of Prosthetics and Orthotics International will contain an application form.

January 1978

Second International Conference on Legislation Concerning the Disabled, Manila, Philippines.
Information: Rehabilitation International, 122 East 23rd St., New York, N.Y. 10010.

2–13 January, 1978

746 Course in Upper Limb Prosthetics for Prosthetists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

7–8 January, 1978

Instructional Course, British Orthopaedic Association, City University, London.
Information: Miss M. Bennett, Honorary Secretary, B.O.A., Royal College of Surgeons, Lincolns Inn Fields, London WC2A 3PN.

9–20 January, 1978

NC 203 Course in Knee-Ankle-Foot and Hip-Knee-Ankle-Foot Orthotics for Orthotists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

16–27 January, 1978

756 Course in Spinal Orthotics for Orthotists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

23–27 January, 1978

622–C, 623–C Courses in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic, Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

23 January–3 February, 1978

NC 205 Course in Above-Knee Prosthetics for Prosthetists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

26–27 January, 1978

681–C Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

30 January–3 February, 1978

744A Course in Upper Limb Prosthetics and Orthotics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

6–17 February, 1978

742C Course in Lower Limb Prosthetics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

13–17 February, 1978

NC 206 Course in Upper Limb Orthotics for Orthotists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

13–17 February, 1978

622–D, 623–D Courses in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

14–15 February, 1978

International Society for Prosthetics and Orthotics.
International Symposium 'PROTECH.' Martinihal Centrum, Groningen, The Netherlands.
Information: Martinihal Centrum, Afdeling Congreszaken, Postbus 8010 Groningen (V.K. 9700), The Netherlands.

16–17 February, 1978

681–D Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

20–24 February, 1978

NC 101B Course in Lower Limb Prosthetics for Physicians and Surgeons.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

27 February–3 March, 1978

745A Course in Upper Limb Prosthetics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

6–10 March, 1978

NC 102B Course in Lower Limb Orthotics for Physicians and Surgeons.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

6–10 March, 1978

652–B, 653–B Courses in Upper Limb Prosthetics and Orthotics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

6–11 March, 1978

741C Course in Lower Limb Prosthetics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

13–17 March, 1978

7th Congress of the World Federation of Occupation Therapists, Tel Aviv, Israel.
Information: (President of the Organizing Committee) Mrs. M. Clyman, 65 Aloof David Street, Ramat-Gan, Israel.

13–17 March, 1978

751B Course in Lower Limb Orthotics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

13–17 March, 1978

752B Course in Lower Limb Orthotics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

13–17 March, 1978

722–A, 723–A Courses in Lower Limb and Spinal Orthotics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

13–23 March, 1978

NC 207 Course in Spinal Orthotics for Orthotists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

20–24 March, 1978

757A Course in Upper Limb Orthotics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

20–24 March, 1978

622–E, 623–E Courses in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

23–24 March, 1978

681–E Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

27–31 March, 1978

7561 Course in Advanced Spinal Orthotics for Orthotists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

3–7 April, 1978

622–F, 623–F Course in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

5 April, 1978

International Society for Prosthetics and Orthotics, United Kingdom, 6th Scientific Meeting. To be held in conjunction with British Orthopaedic Association Spring Meeting, University of Surrey, Guildford.
Information: John Williams, Secretary, U.K. National Member Society, ISPO, Trustees Office, Queen Mary's Hospital, Roehampton, London SW15 5PN.

6–8 April, 1978

Spring Meeting, British Orthopaedic Association, University of Surrey, Guildford.
Information: Miss M. Bennett, Honorary Secretary, B.O.A., Royal College of Surgeons, Lincolns Inn Fields, London WC2A 3PN.

6–7 April, 1978

681–F Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

10–14 April, 1978

744B Course in Upper Limb Prosthetics and Orthotics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y.

10–14 April, 1978

652–C, 653–C Courses in Upper Limb Prosthetics and Orthotics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

17–28 April, 1978

742D Course in Lower Limb Prosthetics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

1–5 May, 1978

751C Course in Lower Limb Orthotics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.
752C Course in Lower Limb Orthotics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

1–5 May, 1978

772–B, 723–B Courses in Lower Limb and Spinal Orthotics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

8–12 May, 1978

622–G, 623–G Courses in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

8–13 May, 1978

741D Course in Lower Limb Prosthetics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics 317 East 34th Street, New York, N.Y. 10016.

11–12 May, 1978

681–G Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

15–18 May, 1978

631–B, 632–B, 633–B Courses in Management of the Juvenile Amputee for Physicians, Surgeons, Therapists and Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

15–26 May, 1978

758 Course in Upper Limb Orthotics for Orthotists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

22–26 May, 1978

622–H, 623–H Courses in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

25–26 May, 1978

681–H Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

June, 1978

8th International Congress of the World Federation for Physical Therapy, Tel Aviv, Israel.
Information: Secretary General, Miss M. M. McKay, W.C.P.T., Brigray House, 20/22 Mortimer Street, London W1P 1AA.

5–9 June, 1978

750B Course in Prosthetics and Orthotics for Rehabilitation Counselors.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

5–9 June, 1978

622–I, 623–I Courses in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

5–23 June, 1978

753 Course in Lower Limb Orthotics for Orthotists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

8–9 June, 1978

681–I Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

12–16 June, 1978

745B Course in Upper Limb Prosthetics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

19–21 June, 1978

755 Course in Spinal Orthotics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

26–30 June, 1978

757B Course in Upper Limb Orthotics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

26–30 June, 1978

751–A Course in Fitting and Fabrication of the C.T.L.S.O. (Milwaukee-type Orthosis) for Orthotists
Information: Charles M. Fryer, Director, Prosthetics-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

26–30 June, 1978

801–A Course in Pedorthic Management of the Foot.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

2–7 July, 1978

3rd World Congress of the International Rehabilitation Medicine Association, Basle, Switzerland.
Information: Dr. W. M. Zinn, Thermes, CH 7310 Bad Ragaz, Switzerland.

2–8 July, 1978

7th Pan-American Congress on Rheumatic Diseases, Bogota, Columbia.
Information: Secretariat, Associacion Colombiana de Reumatologia, Apartado Aeteo 90331, Bogota, D. E., Columbie.

5–21 July, 1978

743 Course in Above-Knee Prosthetics for Prosthetists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

8–11 August, 1978

Seminar on Functional Rehabilitation—Devices, Costs and Effectiveness, University of Strathclyde, Glasgow, Scotland.
Information: Professor R. M. Kenedi, University of Strathclyde, Bioengineering Unit, Wolfson Centre, 106 Rottenrow, Glasgow G4 0NW, Scotland.

13–25 August, 1978

British Council Course 836 on Biomechanics of the Human Body with Reference to Orthopaedic Implants, Prostheses and Orthoses, University of Strathclyde, Glasgow, Scotland.
Information: The Courses Department, The British Council, 65 Davies Street, London W1Y 2AA, or your local British Council Office.

23–28 August, 1978

9th Congress of the International Association of Educators for Handicapped Youth, Montreal, Canada.
Information: (President of the Organizing Committee) M. Marcel Saint-Jacques, C.E.C.M., 3737 Est, Sherbrooke, Montreal, P.Q., Canada.

28 August–1 September, 1978

The Sixth International Symposium on External Control of Human Extremities, Dubrovnik, Yugoslavia. Announcement and call for papers. Authors willing to submit papers are requested to send abstracts not later than February 1, 1978.
Information: Gordana Aleksic, Yugoslav Committee for ETAN, P.O. Box 356, 11001 Belgrade, Yugoslavia.

20–22 September, 1978

Autumn Meeting, British Orthopaedic Association, London (combined with Spanish Orthopaedic Association).
Information: Miss M. Bennett, Honorary Secretary, B.O.A., Royal College of Surgeons, Lincolns Inn Fields, London WC2A 3PN.

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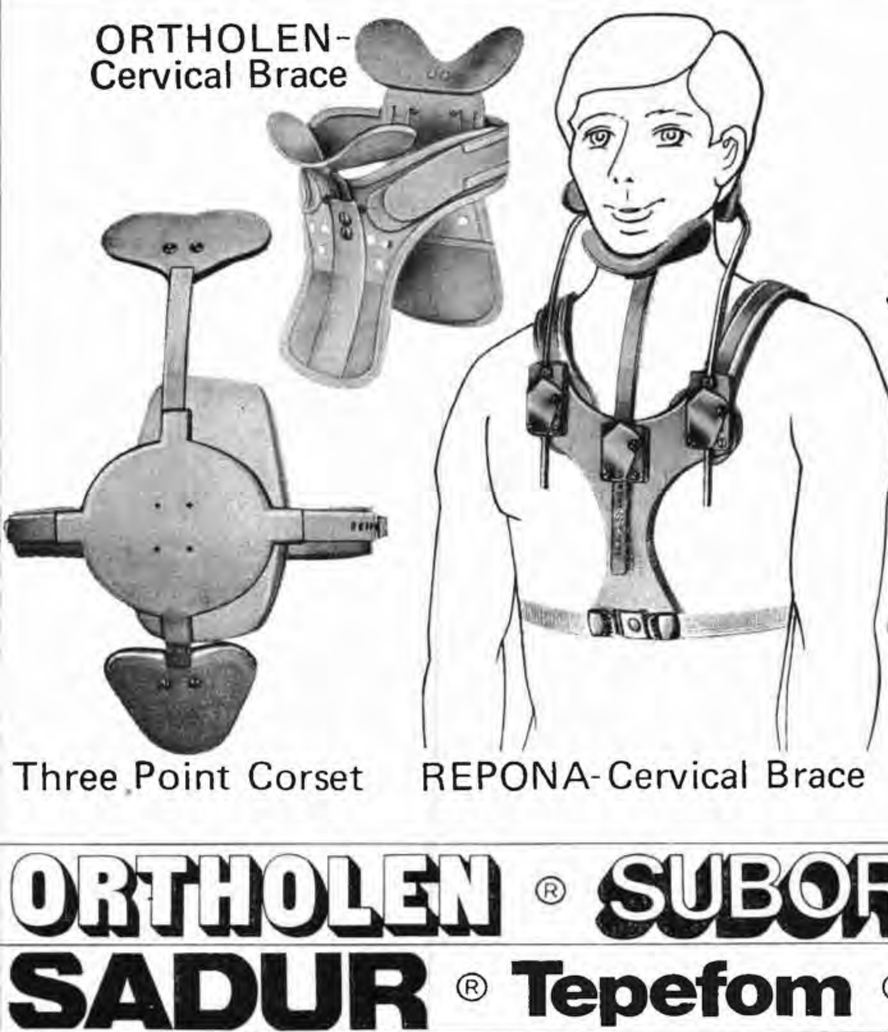

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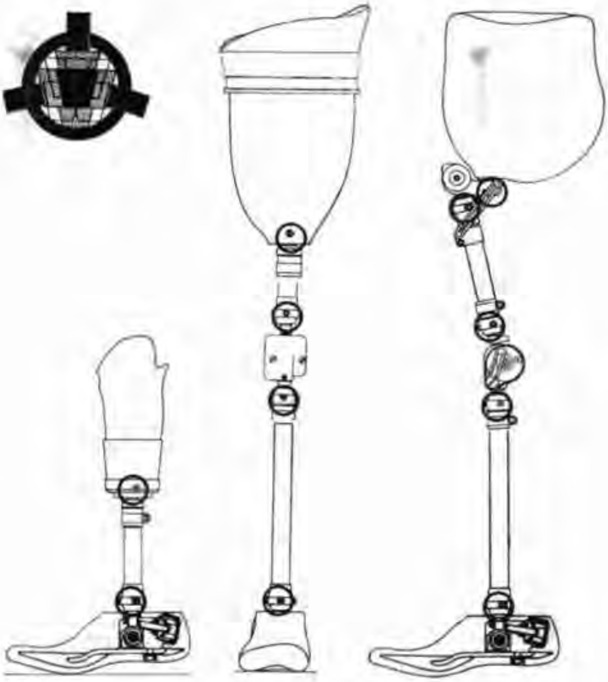

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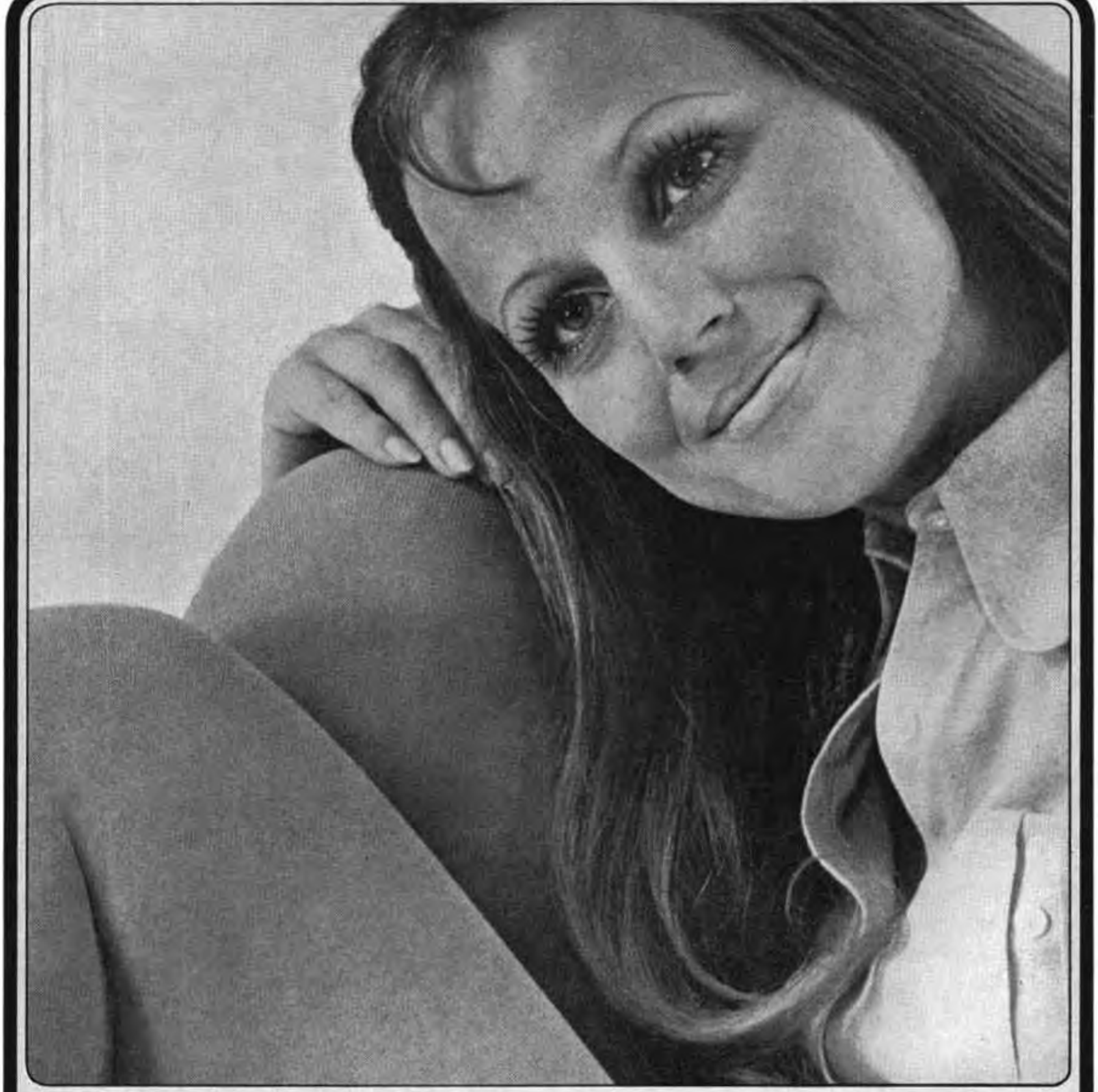

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References to articles in books should include author, year of publication, article title, book title, edition, editor (if different from author), first and last pages, publisher and place of publication. For example, Hughes, J. (1975). Recent developments in prosthetics and orthotics. Recent Advances in Orthopaedics (2) Ed. McKibbin, B., 196–216, Churchill Livingstone, Edinburgh.

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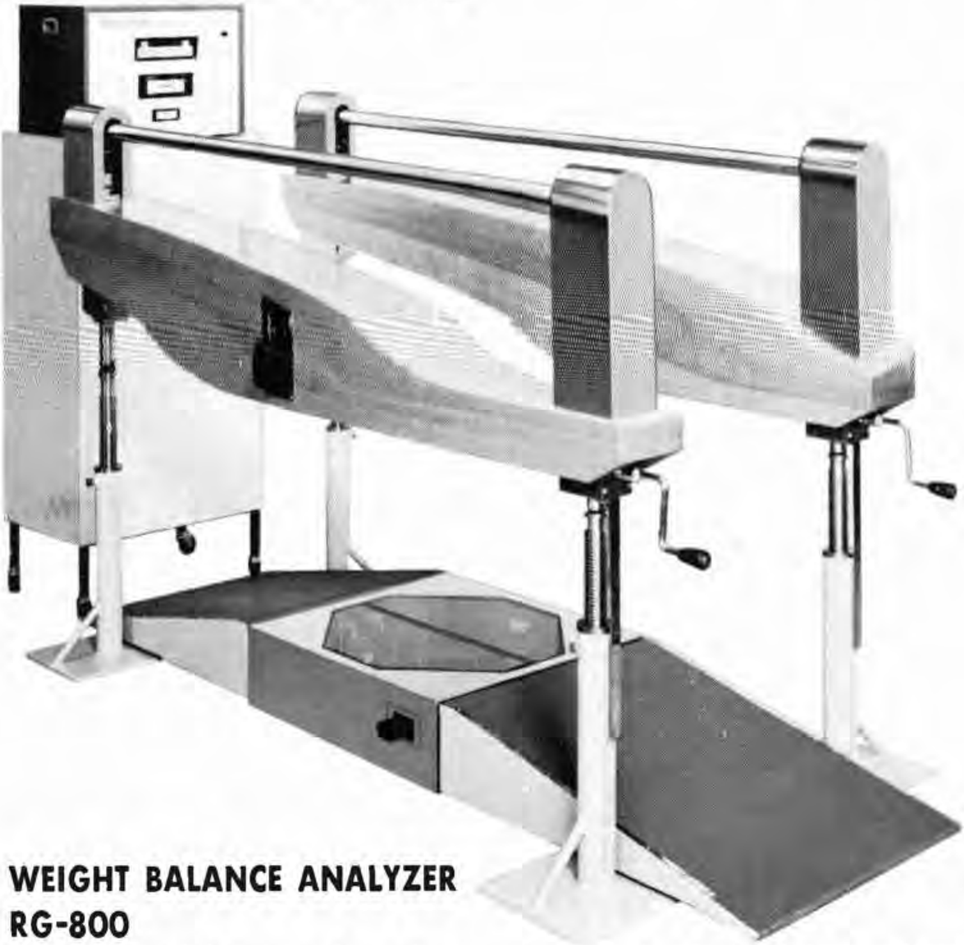

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