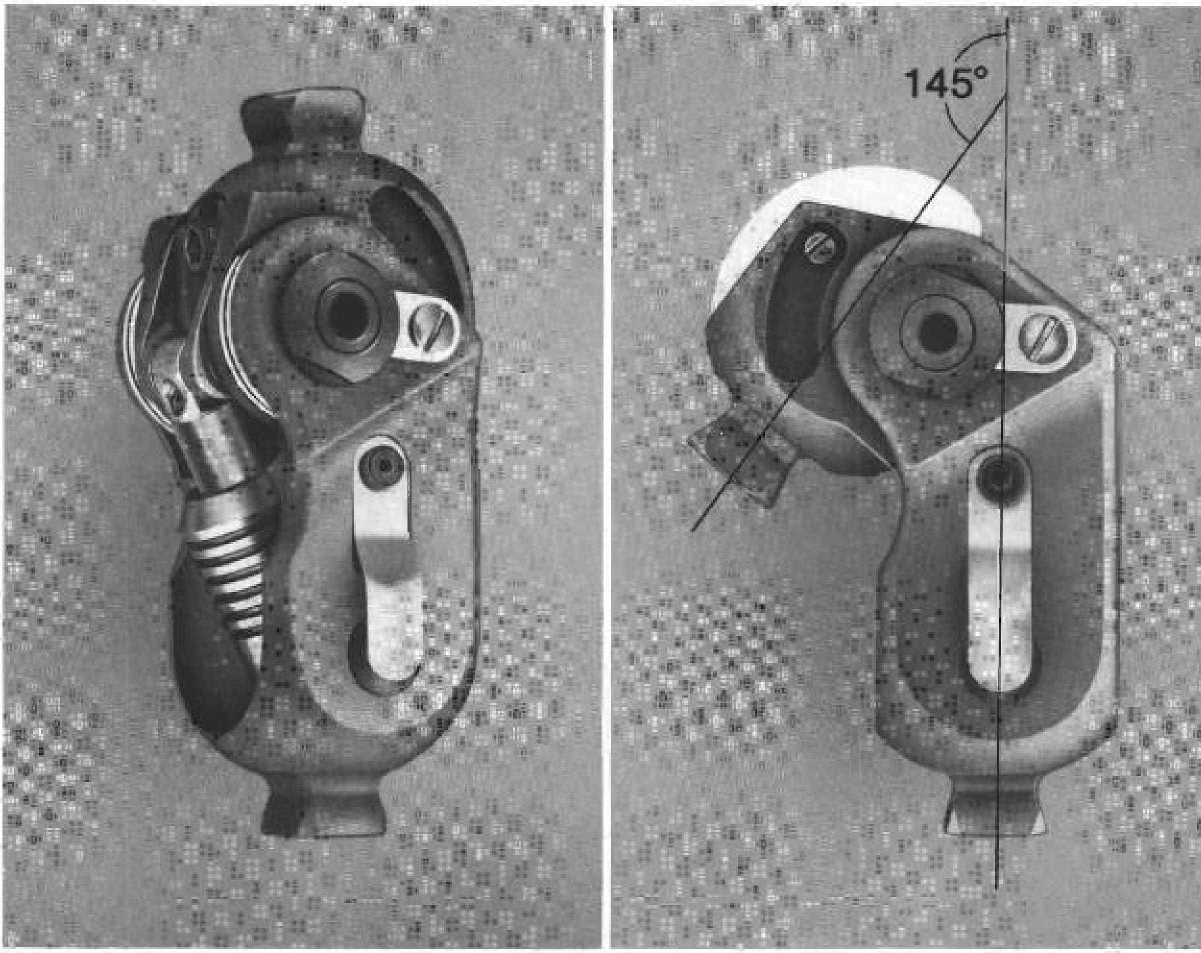
The Journal of the International Society
for Prosthetics and Orthotics

Prosthetics and Orthotics International

April 1983, Vol. 7, No. 1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Prosthetics and Orthotics International

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The Journal of the International Society for Prosthetics and Orthotics

April 1983, Vol. 7, No. 1

Contents

Executive Board of ISPO

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Editorial

The number of activities in any Society and the degree of success achieved depends on a number of factors of which economics and human resources are the most important.

In this issue of the Journal you will find a presentation of the complete accounts for the fiscal year 1982 as well as this analysis of the accounts for the years 1980, 1981 and 1982.

As indicated in Table 1, the membership fees constitute the main source of income and averaged approximately 75% over the last two years. Contributions over the last two years average 14% of the total income, however it should be known that an additional sum of D.Kr. 37.500 due at the end of 1982 has been received in 1983. Interest from bank accounts and bonds are now approaching 10% of the total income. As shown in Table 2 the cost of the Secretariat in Copenhagen amounts to an average of 63% over the last two years. Meetings and travel expenses amount to approximately 28% over the same period.

Table 1. ISPO Income 1980, 1981 and 1982

Year	Total Income	Membership Fees	Contributions	Interest	Other
1980	358·104 100%	240·203 67·1%	89·019 24·8%	28·882 8·1%	0
1981	472·911 100%	366·229 77·4%	62·393 13·2%	38·890 8·2%	5·399 1·2%
1982	590·136 100%	437·995 74·2%	91·526 15·5%	55·354 9·4%	5·261 0·9%

Table 2. ISPO Expenses 1980, 1981 and 1982

Year	Total Expenses	Secretariat[1] Copenhagen	Journal[2] P/O International	Meetings and[3] Travelling	Other
1980	275·971 100%	133·109 48·2%	54·324 19·7%	69·747 25·3%	18·791 6·8%
1981	316·436 100%	200·365 63·3%	27·142 8·6%	86·637 27·4%	2·292 0·7%
1982	385·345 100%	241·724 62·7%	30·230 7·8%	110·851 28·8%	2·540 0·7%

[1]Secretariat expenses include: salary, pension contribution, stationery, printed matter, postage and freight, telephone, data system, repairs and maintenance, auditing and sundry.

[2]Journal: indicates the deficit. (see Table 3).

[3]Travel and Board Meetings: indicates expenses related to board meetings, participation of board members as representatives of ISPO at meetings of other international organisations as well as travel expenses for the honorary secretary connected with his duties in Copenhagen.

Table 3. The Journal of the International Society for Prosthetics and Orthotics 'Prosthetics and Orthotics International' 1980, 1981 and 1982

Year	Total Expenses Incl. Air Mail	Income Advertising	Income Subscriptions	Deficit
1980	158·955 100%	57·930 36·4%	46·701 29·4%	54·324 34·2%
1981	195·182 100%	91·338 46·8%	76·702 39·3%	27·142 13·9%
1982	213·648 100%	89·721 42·0%	93·697 43·9%	30·230 14·1%

The expenses for the Journal indicate its deficit. Table 3 presents the total expenses for the Journal as well as income from advertising and subscriptions.

In the complete accounts for 1982 you will find that the "Advanced Course on Below-knee and Through-knee Amputations and Prosthetics" which took place in Køje, Denmark in May shows a surplus of D.Kr. 227.408.

Although our accounts are satisfactory, it must be remembered that this is only so because of many contributions which do not appear in the accounts. For example, we do not pay any rent for office space in Copenhagen, where the Secretariat is located, nor do we pay rent in Glasgow, where the Journal is produced. Meeting and travel expenses indicate only part of the total expenses, as Board Members, Committee Chairmen as well as others participating, normally cover their travel expenses from other sources than ISPO.

At the International Committee meeting and the General Assembly which will take place during the World Congress in London, in September of this year, we will discuss finances and activities in more detail. We hope that many members will be able to participate.

On behalf of the Executive Board I would like to express their gratitude to all our contributors including those who contribute to the activities of our National Societies. The Board also expresses its gratitude to the Editors of the Journal as well as their co-workers for excellent and dedicated work.

Erik Lyquist

Acting President

Amendments to the Constitution

The following amendments to the "International" Constitution have been formulated by the Executive Board and will be discussed by the International Committee in September, 1983.

These amendments to the Constitution are required to permit co-option to the Board in the event of resignation or retiral of any of the members. The inadequacy of the Constitution in this respect has been highlighted in this triennium, as we have had the resignation of both the President and a Vice-President.

The following additions to the Constitution are offered to meet this situation where it may arise in the future:—

4.3.5 In the event of a vacancy arising in the Executive Board during the Triennium through illness or other reason, the Executive Board may co-opt from the Fellowship at large to fill that vacancy. A Fellow co-opted in this way, where applicable, enjoys full voting rights and has the same status as those members of the Executive Board elected in the normal way.

4.3.6 Where the vacancy involves the President, or the Vice-Presidents, the Executive Board may elect from their membership, including co-opted membership, to fill that vacancy.

4.3.7 In the case of the President-Elect the Executive Board will offer a nomination to the International Committee seeking agreement or alternatives. If necessary a postal vote will then be conducted.

Existing clauses 4.3.5, 4.3.6 and 4.3.7 will become, respectively, 4.3.8, 4.3.9 and 4.3.10.

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I.S.P.O. Statement of Accounts, 1982

Balance as at December 31, 1982				
Income				
Membership fees			437.995	
Sponsorship fees			—	
Contributions:				
Society and Home for Disabled		57.000		
The War Amputations of Canada C.$5.000		34.526	91.526	
Sundry:				
Literature		353		
Film		97	450	529.971
Interest:				
Bank accounts			53.554	
Bonds			1.800	55.354
Expenditure				
Salary: Aase Larsson			150.517	
A.T.P. and pension			18.421	
Secretarial Service (Louise Rizzi)			2.540	
Printing expenses:				
Journal: Prosthetics and Orthotics International:				
Printing cost incl. air mail posting		199.597		
Production service		13.036		
Labels		1.015		
		213.648		
Less income:				
Advertising	82.688			
+Indebted less repaid				
December 31, 1982 $840	7.033			
	89.721			
Subscriptions	93.697	183.418	30.230	
Printing expenses:				
Journal: Deformed Foot		—		
Less income		4.811		4.811
Stationery and printed matters			25.269	
Postage and freight			12.754	
Meeting and travelling expenses:				
Miscellaneous		9.415		
Honorary Secretary		37.280		
Executive boards, incl. meetings				
Copenhagen, Nice		64.156	110.851	
R.I. fee 1981			—	
Telephone			8.159	
Repairs and maintenance			—	
Miscellaneous expenses:				
Data system		15.645		
Sundry		3.664	19.309	
Auditing			7.295	
			385.345	590.136
Surplus as at December 31, 1982			204.791	
			D.kr. 590.136	D.kr. 590.136

Advanced course on below-knee and through-knee amputations and prosthetics, 10–13 May, 1982:

Income:			
Course fees			453.515
Exhibition:			
Sponsorships		58.178	
Accommodation		7.403	65.581
Interest bank accounts			16.856
			535.952
Expenditure:			
Travel and meetings-instructors	29.771		
Secretarial Assistance	21.144		
Correspondence, printing, mailing	17.863		
Miscellaneous	5.879		
Accommodation, participants and instructors	233.887		308.544
Surplus			D.kr. 227.408

Balance as at December 31, 1982

Assets			
Cash on hand		601	
Bank accounts:			
Handelsbanken Chech no. 542.052	48.207		
Handelsbanken Book no. 705.154	472.825		
Handelsbanken Book no. 659.519	227.408	748.440	
Debtors: Advertising US$1.456		12.190	
Bonds:			
Nom. kr. 18.000 10% Østifternes Kreditforening 18/2003 (Course 31.12 1982 62¼ value D, kr. 11.205)		12.690	
Contributions to: World Congress 1980	91.109		
Less repayment	8.241	82.868	
World Congress, London 1983		100.738	
Liabilities			
Creditor:			
ATP, tax and pension			7.598
Auditing			3.660
Advertising: Repaid $616			5.157
Balance as at January 1, 1982 (Capital account)	508.913		
+Surplus for the period 1.1.–31.12 1982	204.791		
+Surplus, advanced course, Køge 10–31. maj 1982	227.408		941.112
		D.kr. 957.527	D.kr. 957.527

The above mentioned accounts, which have been examined, are in accordance with the book-keeping for the year 1982.

Bogsvoerd, February 11, 1983.

GUNNER PETERSEN,
Registered Accountant,
Denmark.

Prosthetics and Orthotics International, 1983, 7, 6–8

1983 World Congress 5–9 September, 1983, London

Final call for Papers, Posters, Films, Videotapes and Scientific Exhibits

PAPERS/POSTERS

Please note that the submission date for Papers/Posters has been extended to 1st May, 1983.

Contributions can be accepted only if an ABSTRACT FORM is completed and returned to the Congress Office by the following dates:

Papers/Posters	1st May 1983
Films/Videotapes/Scientific Exhibits	15th May 1983

Abstract forms may be obtained from Conference Services Ltd., 3–5 Bute Street, London SW7 3EY, U.K. Telephone 01 548 4226, Telex: 916054, Confer G.

Abstracts should be in ENGLISH ONLY and TYPEWRITTEN in the box provided. This will be used as camera ready copy for inclusion in the Book of Abstracts, so please ensure that all information is correct at the time of submission.

Display boards 800 × 1600 mm will be provided for Poster Displays and the allocation of boards will be advised nearer the Congress. Films can be accepted *only* in the following formats 8/Super 8mm and 16mm. Videotapes can be accepted in U-MATIC format *only* to PAL, SECAM and NTSC standards.

For Scientific Exhibits please include a covering note detailing the space and facilities required.

The Committee will consider the Abstracts and advise whether papers, posters and scientific exhibits have been accepted by the end of May 1983. It is hoped that all films and videotapes submitted will be included in the programme.

Full details of the Congress programme and Registration Forms were included in the December, 1982 issue of this journal.

TIME AND PLACE

The meeting will take place at the Imperial College of Science and Technology, Exhibition Road, London SW7, from 5th to 9th September 1983.

The Imperial College of Science and Technology is situated in a very pleasant area of London close to Hyde Park, with a wide selection of hostels and hotels nearby. The venue offers excellent conference facilities combined with a large exhibition area for both the trade and scientific exhibits. All areas are accessible to the disabled.

PROGRAMME

The programme has been divided into two main areas; Instructional Courses and the main Congress Programme.

Instructional Courses

Instructional Courses covering the following topics have been planned for Sunday, 4th September, all day, and from 08.00–10.00 hrs. Monday-Friday, 5th-9th September 1983:

Amputation Surgery, Neuromuscular Disorders, Prosthetics, Paediatric Orthopaedic Problems, Orthotics, Rehabilitation Engineering.

The Courses have been arranged on the basis of 2-hour or multiples of 2-hour sessions and full details of these are enclosed. Those wishing to register for the Courses should complete the appropriate section of the enclosed registration form.

Congress Programme

The Congress programme will offer morning plenary sessions and afternoon concurrent sessions covering prosthetics, orthotics and all other aspects of rehabilitation engineering. Amongst the main topics to be discussed are amputation surgery, neuromuscular disorders, relative to extremity orthotics, spinal disorders, spinal cord injury, multiple sclerosis, arthritis and the multiply-handicapped person.

There are seven afternoon periods for concurrent sessions—two each day on Monday, Tuesday and Thursday, and one on Friday. There will be two panel discussions and three sessions of submitted papers in each concurrent session. One panel will cover each day's plenary topic employing the same chairman and plenary speakers; the other will cover a topic of particular importance.

Those wishing to submit papers should read the instructions above. Papers will be vetted from abstracts and are expected to report innovation and to promote discussion.

Films and Videotapes

Presentations in the form of film and videotape will be invited for screening on weekdays nominally from 13.30–18.00 hrs. and in parallel with the submitted paper sessions. A schedule of the film sessions will be included in the Congress documentation. If you wish to submit a film or videotape please read the instructions above.

Poster Sessions

There will also be facilities for the display of papers by poster. Those wishing to submit a poster should read the instructions above.

Scientific Exhibits

Space will be available for scientific exhibits from non-commercial institutions and organizations. Those wishing to exhibit should read the instructions above.

EXHIBITION

There will be a trade exhibition from Monday-Friday, 5th-9th September 1983 and participants will have ample time to visit the exhibits during the Congress.

LANGUAGE

The official language of the Congress is English and there will be no simultaneous translation.

Instructional Course Programme

*Course Organiser

	Sunday 4th September 0900-1300 1400-1800	**Monday 5th September 0800-1000**	**Tuesday 6th September 0800-1000**	**Wednesday 7th September 0800-1000**	**Thursday 8th September 0800-1000**	**Friday 9th September 0800-1000**
A	Introductory Biomechanics and Normal Locomotion (2 hrs) D. Jones (UK)* Below-Knee and Syme Prosthetics (6 hrs) N. A. Govan (UK)*	Above-Knee and Knee Disarticulation Prosthetics (Cont.) (2 hrs) W. Krieger (FRG)*	Above-Knee and Knee Disarticulation Prosthetics (Cont.) (2 hrs) W. Krieger (FRG)*	Above-Knee and Knee Disarticulation Prosthetics (Cont.) (2 hrs) W. Krieger (FRG)*	Hip Disarticulation Prosthetics (2 hrs) J. J. Bray (USA)*	Management of the Bilateral Lower Limb Amputee (2 hrs) R. G. Redhead (UK)*
B	Spinal Orthotics (4 hrs) N. Berger (USA)* Lower Limb Orthotics (4 hrs) M. Stills (USA)*	Lower Limb Orthotics (Cont.) (2 hrs) M. Stills (USA)*	Lower Limb Orthotics (Cont.) (2 hrs) M. Stills (USA)*	Upper Limb Orthotics (2 hrs) Margaret Ellis (UK)*	Upper Limb Orthotics (Cont.) (2 hrs) Margaret Ellis (UK)*	Upper Limb Orthotics (Cont.) (2 hrs) Margaret Ellis (UK)*
C	Communication Aids (4 hrs) M. A. Le Blanc (USA)* Clinical Gait Analysis (4 hrs) J. P. Paul (UK)*	Wheelchairs (incl. Adaptations and Prescription (2 hrs) A. B. Wilson (USA)*	Wheelchairs (incl. Adaptations and Prescription) (Cont.) (2 hrs) A. B. Wilson (USA)*	Seating for the Severely Disabled (2 hrs) R. L. Nelham (UK)*	Seating for the Severely Disabled (Cont.) (2 hrs) R. L. Nelham (UK)*	Functional Electrical Stimulation (2 hrs) A. Kralj (Yugoslavia)*
D	Rehabilitation of Stroke Patients (4 hrs) W. H. Eisma (Netherlands)* Cerebral Palsy (4 hrs) D. N. Condie (UK)*	Amputee Gait Training (2 hrs) Gertrude Mensch (Canada)*	Scoliosis (2 hrs) A. Bahler (Switzerland)*	Scoliosis (Cont.) (2 hrs) A. Bahler (Switzerland)*	Spina Bifida (2 hrs) G. K. Rose (UK)*	Spina Bifida (Cont.) (2 hrs) G. K. Rose (UK)*
E	Fracture Bracing (4 hrs) D. Wardlaw (UK)* Amputation Surgery (4 hrs) G. Neff (FRG)*	Amputation Surgery (Cont.) (2 hrs) G. Neff (FRG)*	Amputation Surgery (Cont.) (2 hrs) G. Neff (FRG)*	Amputation Surgery (Cont.) (2 hrs) G. Neff (FRG)*	Paediatric Problems (Perthes: CDH: Clubfoot) (2 hrs) J. Kjølbye (Denmark)*	Extension Prostheses (2 hrs) H. J. B. Day (UK)*
F	Partial Foot Prosthetics (2 hrs) R. G. S. Platts (UK)* Upper Limb Prosthetics (6 hrs) B. Klasson (Sweden)*	Upper Limb Prosthetics (Cont.) (2 hrs) B. Klasson (Sweden)*	Footwear and Adaptations (2 hrs) G. Veres (Norway)*	Footwear and Adaptations (Cont.) (2 hrs) G. Veres (Norway)*	Footwear and Adaptations (Cont.) (2 hrs) G. Veres (Norway)*	Footwear and Adaptations (Cont.) (2 hrs) G. Veres (Norway)*

Plenary Sessions

Monday 5th September
Knud Jansen Lecture
G. Murdoch (UK), Chairman: E. Lyquist (Denmark), Co-Chairman: E. G. Marquardt (FRG).
Lower Limb Amputations
Chairman: R. Baumgartner (Switzerland), Co-Chairman: J. Zettl (USA).
Prostheses for Lower Limb Amputees, J. Fischer (Denmark). The Rehabilitation Training of Lower Limb Amputees, Joan Edelstein (USA).

Tuesday 6th September
Lower Limb Disabilities
Chairman: E. Lyquist (Denmark), Co-Chairman: A. K. Mukherjee (India).
Surgical and Orthotic Treatment of Patients with Neurological Deficit in Lower Limb, W. J. W. Sharrard (UK). Future Trends in Treatment, J. Foort (Canada). Current Practice in Europe for Treatment of Patients with Lower Limb Disabilities, W. H. Eisma (Netherlands). Assessment and Description of Lower Limb Disability, M. Stills (USA).

Wednesday 7th September
Upper Limb Prosthetics and Orthotics
Chairman: D. Lamb (UK), Co-Chairman: B. Klasson (Sweden).
Upper Limb Prosthetics, D. Childress (USA). Upper Limb Prosthetics, J. Ober (Poland). Orthoses of the Upper Limb.

Thursday 8th September
The Severely Disabled
Chairman: B. Sankaran (India), Co-Chairman: P. Dollfus (France).
Spinal Cord Injury, P. R. Meyer (USA). Mobility, D. A. Hobson (USA). Communication Aids, M. Milner (Canada). Environmental Aids, H. Funakubo (Japan).

Friday 9th September
Spinal Problems
Chairman: A. Bahler (Switzerland), Co-Chairman: R. G. S. Platts (UK).
Spinal Problems and their Treatment by Surgery and Orthosis, J. O'Brien (UK). Measurement Systems Related to Spinal Problems, J. D. Harris (UK). Orthotic Treatment of Spinal Problems, M. E. Miller (USA).

Concurrent Sessions

Day	Hall 1	Hall 2	Hall 3	Hall 4	Hall 5	Hall 6
Monday 5th September 1983	Lower Limb Amputation *R. Baumgartner (Switzerland)	The Special Problems of the Elderly *M. Devas (UK)	Submitted papers	Submitted papers	Submitted papers	Submitted films/ videotape
	Back Pain–Management and Social Problems *J. Angel (UK)	Establishing Services in Developing Countries *S. Heim (FRG)	Submitted papers	Submitted papers	Submitted papers	Submitted films videotape
Tuesday 6th September 1983	Lower Limb Disabilities *E. Lyquist (Denmark)	Prosthetics and Orthotics Education *S. Fishman (USA)	Submitted papers	Submitted papers	Submitted papers	Submitted films/ videotape
	Gait Analysis *K. Oberg (Sweden)	The Patient's Viewpoint combined with Psycho-social considerations *C. Dunham (UK)	Submitted papers	Submitted Papers	Submitted papers	Submitted films/ videotape
Wednesday 7th September 1983	FREE AFTERNOON FOR TOURS OR INFORMALLY ARRANGED VISITS					
Thursday 8th September 1983	The Severely Disabled *B. Sankaran (India)	Arthritis and the hand *A. B. Swanson (USA)	Submitted papers	Submitted papers	Submitted papers	Submitted films/ videotape
	Upper Limb Prosthetics and Orthotics *D. Lamb (UK)	The Foot and Footwear *G. Veres (Norway)	Submitted papers	Submitted papers	Submitted papers	Submitted films/ videotape
Friday 9th September 1983	Spinal Problems *A. Bahler (Switzerland)	Biofeedback *M. Milner (Canada)	Submitted papers	Submitted papers	Submitted papers	Submitted films/ videotape

* Chairmen

Prosthetics and Orthotics International, 1983, 7, 9–14

Amputations for vascular insufficiency

P. NETZ, A. STARK* and H. RINGERTZ**

Department of Orthopaedic Surgery, Danderyd Hospital, Danderyd.
**Department of Orthopaedic Surgery, Karolinska Hospital, Stockholm.*
***Department of Radiology, Sachska Hospital, Stockholm.*

Abstract

A study was carried out of 302 major amputations for vascular insufficiency in the lower limb with respect to levels of amputation, postoperative revisions, re-amputations on a higher level and postoperative mortality. This information was related to vascular disease (diabetes mellitus/arteriosclerosis) and to the experience of the surgeon.

There was a high incidence of above-knee amputations both of diabetics and arteriosclerotics and the rate of complications was high for "senior" as well as "junior" surgeons. The amputations were performed during 1978 and the study has shown that there is an urgent need to lower the level of amputation without increasing the rate of complications. The study indicates that there is a need for further information about the problems involved in rehabilitation of above-knee amputees.

Introduction

Amputation of a lower limb causes a handicap which in many cases makes the patient dependent on other people. The more proximal the amputation, the greater the risk that the patient will not regain his ability to walk at all (Wagner, 1978; Robinson, 1980). The majority of amputations performed in the Western world today are due to arterial insufficiency (Hansson, 1964; Burgess et al. 1971, Potts et al., 1979). The patients are elderly and their main disease—arteriosclerosis or diabetes mellitus—has caused changes in other organs besides the lower limbs, such as brain and heart disorders and in diabetics frequently eye and kidney disorders (Widmer et al. 1964).

All correspondence to be addressed to Dr. P. Netz, Department of Orthopaedic Surgery, Danderyd Hospital, S-182 88 Danderyd, Sweden.

Walking with an above-knee (AK) prosthesis is much more energy-consuming than with a below-knee (BK) prosthesis (Waters et al. 1976). This means that many patients will never be capable of using their prosthesis after AK amputations (Romano and Burgess, 1971; Wagner, 1978). Furthermore even wheelchair or bedridden patients are much better off when the knee joint is preserved or through-knee (TK) amputation performed, than after an AK amputation (Hirsch et al. 1975; Hölter et al. 1980). The sitting patient achieves better balance with a longer stump and for the patient confined to bed it will be easier to shift his position (Persson, 1974).

Preoperative determination of the optimum level of amputation is difficult and still depends to a great extent on a clinical evaluation. A number of authors, however, have presented methods aiming at objective measurement of circulation and blood flow in the intended level of amputation (Carter, 1973; Holstein, 1973, Gibbons et al. 1979, Wagner, 1979a, Pollock and Ernst, 1980). Even though the general interest in amputation surgery has increased in recent years, the number of published articles in this field are still relatively few (Persson, 1980). Burgess et al. (1971) and Murdoch (1977) have recommended that the selection of amputation level and the operation itself always be performed by surgeons with long experience and adequate surgical skill. However, it is our impression that this recommendation is not always followed. The aim of the present study, therefore, was to analyse a large number of amputees, with particular reference to the level of amputation, the incidence of complications, and the experience of the surgeon.

Material and methods

Through the kind co-operation of all surgical and orthopaedic clinics in Stockholm, all patients who had a lower limb amputation in 1978 could be traced in 1980 with the aid of the computer centre of the Stockholm health care system. The material comprises all patients amputated due to arteriosclerosis or diabetes. All patient files have been studied and the material computerized.

Patients with a diagnosis of diabetes mellitus were, regardless of concomitant arteriosclerosis, registered as diabetics (Goldner, 1960). The surgeon was classified as "senior" if he had more than 5 years surgical experience, those with less were classified as "junior". Only major amputations (BK, TK and AK) are included in the statistical analyses as the figure for toe amputations is uncertain and the number of foot amputations were limited.

The population of Stockholm on December 31, 1978 was 1,519,114, comprising 735,458 men and 783,656 women. The age group above 50 years of age was 475,401, of which 207,208 were men.

In 1978, 308 major amputations were performed on 289 patients in 9 surgical and 5 orthopaedic departments in Stockholm. In four cases complete patient files were not available. These patients, as well as two patients with the diagnosis of Buerger's Disease (43 and 39 years old), were included in the above figures. The statistical figures presented are thus based on 302 amputations in 283 patients.

In some cases it was impossible to obtain complete data from the records. For this reason, a footnote is added to the appropriate Table stating the number of dropouts with respect to the analysed parameter.

The sex and age distribution is shown in Figure 1. The average ages for men and women with arteriosclerosis and diabetes are presented in Table 1 along with the number of patients, sex distribution and the number of amputations.

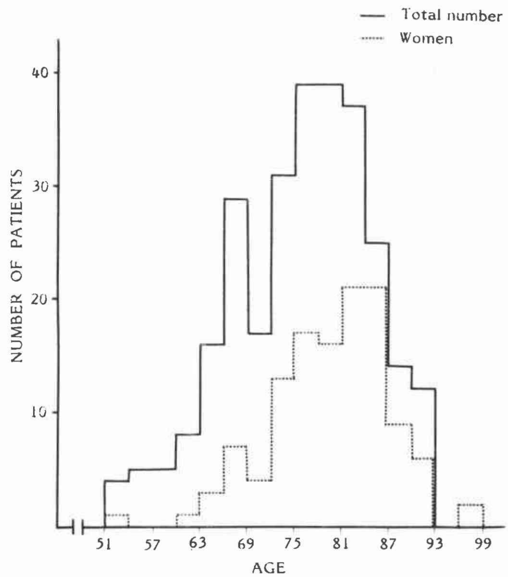

Fig. 1. Age and sex distribution of 283 patients with major amputations of the lower limb for arterial insufficiency during 1978 in Stockholm.

Results

For each patient the first major amputation performed during 1978, revisions and more proximal amputations are presented in Table 2. The same table shows the postoperative mortality, defined as death occurring within one month of the major amputation.

Some 64 per cent of all amputations performed by "junior" surgeons were below-knee, while the corresponding figure for "senior" surgeons was 63 per cent. The frequency of re-amputations was higher for operations performed by "junior" surgeons as shown in Table 3.

Three different techniques for below-knee amputations were used:

1. The "Fishmouth" technique with approximately equal anterior and posterior skin flaps (Rob and Smith, 1969). The available

Table 1. Distribution of 283 amputees with respect to sex and diagnosis. Mean age ± 1 SD (years) has been stated for each group of patients. The total number of amputations is also shown.

	MEN		WOMEN		TOTAL		Number of amputations
	No.	Mean age	No.	Mean age	No.	Mean age	
Diabetes mellitus	65	70·0±8·4	48	76·5±7·4	113	72·8±8·6	122
Arteriosclerosis	104	75·1±8·7	66	81·6±7·1	170	77·5±8·6	180
Totals	169		114		283		302

Table 2. Levels of amputations, postoperative revisions and re-amputations related to the number of lower limb amputations during 1978 (n=302). Postoperative mortality, i.e. mortality within one month from the operation, is expressed in relation to the number of patients (n=283).

	BK		TK		AK		Revisions		Re-amputations		Postop. mortality	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Diabetes mellitus	90	74	0	0	32	26	11	9	18	15	14	12
Arteriosclerosis	102	57	1	1	77	43	15	8	27	15	18	11
Totals	192	64	1	0	109	36	26	9	45	15	32	11

records seldom indicated whether or not the operation was combined with myoplasty.

2. The Ghormley-Burgess technique with a long posterior musculocutaneous flap (Ghormley, 1946; Romano and Burgess, 1971).

3. The Tracey-Persson sagittal technique with equally long lateral and medial flaps (Tracey, 1966; Persson, 1974).

In a few cases the operative report did not expressly specify the method used but considering the other amputations performed by the same surgeon or the "tradition" of the institution, a reasonable assumption could be made as to the method most likely to have been used.

The frequency of revisions, re-amputations at a higher level, and postoperative mortality associated with different surgical techniques is presented in Table 4. Plaster cast was used more frequently by "senior" surgeons (21%) compared with "junior" surgeons (16%). The frequency of re-amputations is higher in cases in which the "Fishmouth" technique was used at below-knee amputations.

The mean age for patients with the ultimate level above-knee was 75·3±8·9 years (n=152) and for patients with below-knee amputations 75·9±9·0 years (n=149).

The differences were not statistically significant.

Discussion

During 1978, 283 patients were amputated because of arteriosclerosis or diabetes mellitus. Patients with diabetes mellitus accounted for 40 per cent of major amputations. This figure is worth noting, as many of the series presented in the literature show a higher incidence of diabetes than of arteriosclerosis (Harris et al. 1961; Sarmiento and Warren, 1969, Fleurant and Alexander, 1980).

There is a tendency towards more proximal amputations in the arteriosclerotic patients, with 43 per cent above-knee amputations as compared to 26 per cent in the diabetic patients. The sum of postoperative complications—revisions, re-amputations at a higher level and postoperative mortality—is high and amounts to 34 per cent in the entire series. This high incidence of complications, together with the initially fairly high percentages of above-knee amputations, means that of the primary amputations in 1978 only about 60 per cent of diabetic and 40 per cent of arteriosclerotic patients were left with an intact knee joint (Table 5).

Table 3. Levels of amputation, revisions, re-amputations and postoperative mortality related to surgical experience. Percentage distribution is related to the total number of amputations for each group (senior and junior surgeons) and postoperative mortality, i.e. mortality within one month from the operation, is related to the number of patients in each group.

	BK		TK		AK		Revisions		Re-amputations		Postop. mortality	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Senior surgeon	85	63	0	0	50	37	12	9	14	10	14	11
Junior surgeon	103	64	1	1	56	35	13	8	28	18	18	12
Totals	188*	64	1	0	106*	36	25*	8	42*	14	32*	12

*In seven amputations on seven patients the experience of the surgeon is unknown. Of these seven cases four had below-knee, and three above-knee amputations, one had a revision and three were re-amputated.

Table 4. Diagnosis, surgical experience, revisions, re-amputations and postoperative mortality related to the three different methods used for below-knee amputations. The percentage distribution is related to the number of amputations (for postoperative mortality the number of patients) in each group, i.e. operation method.

	"Fishmouth"		Ghormley		Persson		Total
	No.	%	No.	%	No.	%	No.
Diabetes mellitus	38	46	43	48	4	27	85*
Senior surgeon	32	39	43	48	9	60	84*
Plaster cast	21	25	24	27	9	60	54
Revisions	8	10	10	11	1	7	19*
Re-amputations	22	27	16	18	2	13	40*
Postoperative mortality	10	12	5	6	2	13	17
Total number	83		89		15		187*

*The method of operations is unknown in five below-knee amputations on diabetic patients. One amputation of these was performed by a senior surgeon, one had to be revised and three below-knee amputations were re-amputated.

The comparison between "senior" and "junior" surgeons demonstrated no significant difference regarding primary level of amputations, frequency of complications or postoperative mortality. However, the amputations performed by "junior" surgeons were complicated by re-amputations at a higher level in 18 per cent, as compared with 10 per cent in operations performed by "senior" surgeons. It can furthermore be noted that "senior" surgeons more often used Ghormley's and Persson's methods in below-knee amputations.

Plaster was scarcely used but somewhat more frequently by "senior" surgeons. In only about 20 per cent of the cases was the operation combined with a plaster cast, which is remarkable in view of the meticulous follow-up study by Mooney et al. (1971), which showed fewer healing disturbances among patients who had a rigid dressing in comparison with those with soft dressings.

The average age of our patients is comparatively high (Condon and Jordan, 1970; Persson, 1974). The mean age for women is higher than that for men and the mean age for arteriosclerosis is higher than that for diabetes mellitus.

Table 5. Results after lower limb amputations (ultimate level) during 1978 in Stockholm. Deceased patients are included.

	BK		KD		AK	
	No.	%	No.	%	No.	%
Diabetes mellitus	73	60	0	0	49	40
Arteriosclerosis	76	42	1	1	103	57
Totals	149	50	1	0	152	50

The success of the amputation in terms of rehabilitation of the patient hinges on the ability to lower the level of amputation and at the same time to achieve primary healing (Fleurant and Alexander, 1980). In a recently published material from Roehampton the knee joint had been left in 67 per cent of the cases, 17 per cent had been operated with through-knee amputation and only the remaining 16 per cent had been amputated above-knee (Robinson, 1980). Compared with Burgess et al. (1971) and Fleurant and Alexander (1980), our sample has a high incidence both of above-knee amputations, re-amputations at a higher level, and postoperative mortality. We have not been able to explain the high frequency of complications by the fact that the amputations were performed by "junior" surgeons. It has earlier been pointed out that it is important that amputations are performed by experienced surgeons, and that the same surgeon takes care of the whole rehabilitation (Murdoch, 1977; Romano and Burgess, 1971). While there is every reason to believe that this is true, one wonders why it has not been reflected in our material. Our distinction between experienced and inexperienced surgeons may be too rough, but the high total number of above-knee amputations suggest that the operations were performed with an excessively wide margin with respect to circulation in the extremity, so wide in fact, that not even the more traumatic surgical technique of the less experienced surgeon could jeopardize healing of the stump. It is highly probable that if we are to obtain a higher frequency of primary healing than found in our material, improved surgical technique is needed in order to prevent necrosis and infection in stumps with a borderline skin blood flow (Persson, 1974). Romano and Burgess (1971) feel that nearly all amputations can be carried out at below-knee level and that the only indications for above-knee amputations are severe contracture of the knee and gangrene at the operation site. The same authors also point out that it is extremely unusual for a healed below-knee stump to be amputated later at a higher level. The development of orthopaedic engineering during the last decade has made through-knee amputation a better alternative than above-knee amputations when severe contracture of the knee is present (Wagner, 1979b).

Apart from the surgical technique the attitude of the surgeon towards the rehabilitation of the patient is also important (Burgess, 1964). An analysis of individual hospitals in our material reveals large differences, probably reflecting different policies. Some hospitals for instance, have performed only above-knee amputations, perhaps with a view to providing instant relief of pain, but probably without considering the difficulties involved in the rehabilitation of the patient, even if he can only sit or lie in bed (Persson, 1974).

In 1978 the hospitals in Stockholm only rarely used Doppler ultrasound for the preoperative evaluation of the patients. Wagner reports an exceptionally high primary healing rate even for very distal amputations and it is not unlikely that the adoption of this technique could lead to more frequent preservation of the knee joint (Wagner, 1978). The average age in our material is higher than in many other published studies, and the frequency of diabetes would seem to be lower, although some earlier investigations have not presented the incidence of diabetes (Robinson, 1980). Although high mean age and low incidence of diabetes theoretically might explain the higher percentage of above-knee amputation in our material, there was no difference in average age between above-knee and below-knee amputees which is why there is reason to suspect that the operative results could be improved in future and the incidence of above-knee amputations reduced.

The analysis of our material gives us cause to believe that there is a possibility to lower the level of amputations in patients operated upon for arterial insufficiency. On the basis of the literature and our own experiences we feel that the most urgent steps to achieve this are the following:

1. To perform above-knee amputations only if below-knee amputations is contraindicated because of infection in the knee region (Romano and Burgess, 1971).
2. To abandon the "Fishmouth" method for below-knee amputations in favour of the Ghormley-Burgess and Tracey-Persson methods.
3. To refine the surgical technique, for example by never detaching skin from underlaying fascia or periosteum, or by causing damage to the edges of the wound by pulling with hooks or tearing with forceps (Burgess et al. 1971; Persson, 1974, Murdoch, 1977, Hicks and McClelland, 1980).
4. To use plaster in all below-knee amputations (Mooney et al. 1971; Murdoch, 1977, Kane and Pollak, 1980).
5. To accept longer healing periods in order to retain the original level of amputation when complications occur. This can sometimes be achieved by wedge excision of the necrosis (Murdoch, 1975), or else the patient can temporarily use an ischial tuberosity bearing prosthesis so that he can be mobilized during the healing period (Marsh et al. 1969).

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Consumer concerns in prosthetics

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Abstract
Surveys and questionnaires were sent to 3,400 upper limb and lower limb amputees ranging in age from 18 to 72. Replies were received from 2,176 (64%). The major points brought out by the survey are presented and discussed.

Amputee concerns

Surveys and questionnaires were sent to 3,400 amputees ranging in age from 18 to 72. The causes of amputation were divided on a percentage basis as follows:

Trauma	55%
Congenital	20%
Disease	15%
Tumour	10%

There was no apparent difference in the replies in any group. The major concerns of the respondents (64% in all) together with some qualifying notes follow:

1. Lack of information. The only contacts which the amputee has are with the doctor or the prosthetist. The amputee appears to be asking for an independent source of information (such as bulletins by manufacturers and clinics) dealing with:

(a) New prostheses
(b) Modifications to existing prostheses
(c) New fitting techniques.

Note
Is there any reason why the amputee should not regard his prosthesis in the same way as he regards other consumer (durable) goods such as automobiles? In the latter case the product is advertised publicly.

2. The amputee often complains of lack of knowledge of new prostheses by the medical profession.

Note
Remedial action could well be the function of ISPO, assuming the premise is correct.

3. The amputee often lacks a source of information from other amputees concerning ways and means through which he/she could learn to live with his/her disability. This concerns such mundane matters as the washing of stump socks and the use of soft versus hard-soled shoes.

Note
ISPO might be able to produce source material which could be distributed by veterans organizations, and other groups representing the disabled.

4. Another major concern is the lack of adaptive equipment for recreation.

Note
The development of facilities for amputee skiers is a positive indication that, if the equipment is available, the amputee can be encouraged to engage in sports.

5. Relationships with the prosthetist.

Note
We have carried out in-depth studies of this matter in Canada. It may be that the situation does not exist elsewhere, although, for the past few years, we have been making arrangements to have our personnel fitted in the United States, and the same situation seems to exist there. The problem seems to be that the amputee is more-or-less intimidated by the prosthetist. He or she may feel that the socket does not fit or that the alignment is wrong but is afraid to speak up on the matter. The remedy seems to be two-fold. Firstly, prosthetists should be encouraged to elicit greater response from the amputee; secondly, amputees should be

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encouraged to make their views known during the fitting stages.

6. Weight of prosthesis. The amputee is bewildered in this area. Some like to feel a "little weight"; others have the opinion that a weighty prosthesis will tire them easily.

Note

Possibly some physiological studies have been made and information could be disseminated on this subject.

7. Feet. Our surveys indicate that, very often, an amputee wearing a SACH foot does not know whether the heel insert is soft, medium or hard. He is usually unaware that there are other types of feet available. Generally, he takes what is given.

Note

It would seem that there is room for an optional fitting technique in this area so that he or she could try various feet and decide which one is most compatible with gait, use, etc.

8. Soft sockets versus hard sockets for below-knee amputees. Canadian amputees from World War II indicate a decided preference for a soft socket. They seem to feel better about a soft socket and consider they can tolerate more weight with less discomfort. On the other hand, that they are very often given no option but have to abide by the preference of either the doctor or the prosthetist. Replies from other groups indicate almost total ignorance on the subject.

9. Upper extremity amputees. This is obviously a neglected group. (Recently the then Canadian Minister of Veterans Affairs, who was a double amputee (above-knee and above-elbow), was questioned as to why he was wearing a formidable leather harness, when suction sockets are being fitted quite regularly in Canada for above-elbow amputees. He stated that he had no information on the subject.) It may seem strange, but our surveys indicated that many World War II above-elbow amputees, who had never worn a prosthesis, still have *not* become used to the loss of cosmesis involved in the empty sleeve.

Note

An attempt should be made to see that upper limb amputees are encouraged to be fitted with cosmetic limbs, particularly now that there are light designs which do not require extensive harnessing.

10. Myo-electric hands. The replies were enthusiastic, but the amputees lacked knowledge. There is a tendency among the older below-elbow amputees to consider that they are "too old" to be fitted with myo-electric hands.

Note

Our experience has proved this to be false. Moreover, when fitted, there is a decided upward swing in morale.

11. Shoes. Great concern was shown for the fact that it is becoming increasingly difficult for a leg amputee to purchase stock shoes in view of the heel height and difficulty in modifying heels which are made on a "one piece construction" last.

Note

There seems to be a great need to develop a prosthetic foot with adjustable heel height.

12. Controls for above-knee amputees. Wearers sometimes found that a heavy leg, particularly one with swing and stance phase controls, gave better function. They question whether the additional energy required to lift a leg of this nature during the swing phase outweighs the advantages of better function.

Note

It would be helpful if the amputee had available reference material stating a definite opinion on the subject, one way or the other.

13. Sequelae. The surveys indicate that there are decided sequelae to amputation including advanced arthritic changes in the pair of an amputated limb; lumbar and cervical problems, gastric disturbance, etc.

Note

The question arises as to whether this should be treated as a problem arising from amputation and, more importantly, could a more comfortable fitting eliminate or correct the situation.

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A clinical standard of stump measurement and classification in lower limb amputees

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Abstract

The dimensions and healing of 93 consecutive below-knee stumps were studied and based on observations a standard formula of stump classification was constructed (and discussed at the ISPO Meeting in Bologna 1980).

Muscular atrophy and redistribution of oedema caused a mean reduction of calculated arbitrary stump volume of about 7% during the first 12 post-operative weeks accompanied by a change in distal circumferential measurement ranging between 7 centimetres reduction and 5 centimetres increase.

The classification formula was tested in 135 examinations in 86 patients with 96 stumps in Lund. A new proportional definition of stump length was used. Eighty per cent were ordinary in length and shape. Ten of 59 were conical before one year compared to 12 of 42 after more than one year following amputation. Pain was a problem in 20%. Scar problems are common early but other skin damage increases with time. Skin problems are separated according to cause, i.e. pressure, suction, infection and allergy. One third of below-knee stumps had unhealed wound or damaged skin. Surgical correction was indicated in 2% and prosthetic correction in 7%. Prosthetic correction seemed to be more often needed in below-knee stumps and surgical correction in above-knee stumps.

Introduction

The detailed condition of an amputation stump is seldom discussed in literature, although there is generally an unspoken concept of stumps being bad or good ones. The increased number of amputations among the elderly with occlusive arterial disease increases the need for objective evaluation of stumps because old patients are less often well informed themselves. To structurize the basic clinical parameters of stumps we considered the alternative dimensions which could be used and created a test for basic characteristics. At the third world meeting of the International Society for Prosthetics and Orthotics in Bologna, October 1980, a special Round Table was devoted to such discussions with Sydney Fishman, New York, William Wagner, Los Angeles, P. A. Isherwood, Roehampton, S. Goldbranson, San Diego, P. Renström, Gothenburg, M. Wall, Uppsala, Sweden and the authors. At this meeting a standard test form was discussed, modified and accepted for use in clinical trials focussing on the stump itself. Function, however, also depends on the general condition of the patient and the type and condition of the prosthesis and finally the fit and training level that has been achieved.

This paper presents the basic parameters studied in the preparatory work and the use of the standard form in a consecutive series of lower limb amputees. By this systematic examination important qualities of major amputation stumps should be identified, increasing the possibilities of analysing problems and correcting malfunction.

Material and methods

In part one measurements were made repeatedly during the first 12 weeks after amputation in a consecutive series of 93 below-knee stumps. All patients had amputations using the sagittal technique (Persson, 1974) at the Department of Orthopaedic Surgery in Lund. They were kept in plaster of Paris for 2 weeks and had stitches removed at 3 weeks. The measurements were made at 2, 3, 4, 6 and 12 weeks after amputation recording proximal stump circumference with the knee at 60° flexion, distal stump circumference, and length

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Clinical Standard of Measurement and Classification of Amputation Stumps

ISPO 1982

International Society for Prosthetics and Orthotics, Standing Committee on Research.

Name and address of patient:

General condition of patient:
☐ Highly active walker ☐ Average ☐ Little

Indication of amputation:
☐ Ischemia ☐ Trauma
☐ Tumour ☐ Other

Date of amputation
....

Basic Parameters of Stumps

1. Length
2. Shape
3. Scar
4. Skin

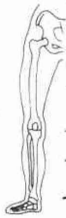
} Inspection

5. Solidity
6. End
7. Mobility
8. Pain

} Palpation

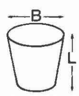
Side:
☐ Rt ☐ Lt

Mark level of amputation on figure:



Pelvic amputation	(Hemipelvectomy)
Hip amputation	(Disarticulation)
Femoral amputation	(AK)
Knee amputation	(TK)
Crural amputation	(BK)
Ankle amputation	(Syme etc)

1. *Length of stump*
☐ Ordinary: Length=(1–2)×Breadth
☐ Short: Length < Breadth
☐ Long: Length > 2×Breadth



2. *Shape of stump*
☐ Cylindrical (ordinary)
☐ Conical
☐ Club-shaped

3. *Scar of stump*
☐ Well healed
☐ Unhealed (...×...cm) ☐ Bone exposed
☐ Adherent

4. *Skin of stump*
☐ Undamaged ☐ Deep wrinkle
Pressure
☐ Abrasion ☐ Ulcer
☐ Blister ☐ Epidermoid cyst
Suction
☐ Suction discolouration
☐ Verrucous hyperplasia
Infection
☐ Folliculitis ☐ Infected ulcer
Allergy
☐ Eczema

5. *Solidity of stump*
☐ Firm (ordinary)
☐ Soft (fatty or loose muscle)
☐ Oedematous

6. *End of stump*
☐ Rounded—well protected bone
☐ Pointed—poorly protected bone

7. *Mobility of stump in proximal joint*
☐ Normal
☐ Limited extension..........degrees
☐ Limited flexion.............degrees

8. *Pain of stump*
☐ None or little
☐ Significant local
☐ Significant diffuse

9. *Phantom pain*
☐ None ☐ Some ☐ Severe

10. *Maximal end-weight-bearing* on a scale
☐ With naked stump...........kilogram
☐ With prosthesis on...........kilogram
☐ Body-weight ....kilogram

11. *Summary*
☐ No correction indicated
☐ Special problems noted above
☐ Prosthetic correction indicated
☐ Surgical correction indicated
☐ Prosthesis prescribed
☐ No prosthesis indicated

12. *Date and signature:*

....

Fig. 1. The clinical standard form used for the measurement and classification of amputation stumps.

of stump from distal end of the soft tissues to the medial joint space of the knee. Simultaneously the healing was recorded. The measurements were intended to describe size, shape and atrophy allowing classification of stumps into cylindrical, conical or club-shaped, which determines the type of suspension, as well as short, ordinary or long, which determines the lever arm of movements. It also allowed calculation of volume changes, which determines changes of socket fitting.

In part two the ISPO standard form was used in a consecutive series of 135 stump examinations at the prosthetic clinic January–September 1981 (Fig. 1). During this time 86 patients with 96 stumps were followed. Two stumps were measured four times, 5 three times and 23 twice. Fifty-eight per cent of the patients were males and 85 per cent had been amputated within the last five years. The median age was 72·5, range 10–94 years.

Classification was made of general condition, indication, level, size, shape, scar, skin, solidity, end of stump, mobility in proximal joint, pain of stump and phantom pain. The definitions of the different classes of the parameters are explained in Figure 1 regarding proportional length, shape, scar, skin and mobility. Regarding solidity, end of stump, stump pain and phantom pain the limits between different classes were not defined exactly. Age, sex, side, date of amputation and date of examination were recorded and it was summarized whether correction was indicated technically or surgically.

Results

In part one the 93 new below-knee stumps had a median length of 16 cm, range 10–25 (Fig. 2, top). The proximal circumference of the stump was recalculated to diameter and used as a measure of breadth describing the length to breadth proportion (Fig. 2, bottom). The mean quotient was 1·7 with the range from 0·9–2·5. In this material one stump was classified as short and 10 stumps as long (Fig. 2, bottom).

The proximal circumferential measurements (Fig. 3) showed changes between 2 and 3 weeks and 2 and 12 weeks, respectively. Less than 1 cm in mean value of reduction occurred from 2 to 3 weeks and less than 2 cm between 2 and 12 weeks. Similarly the distal circumferential measurements (Fig. 4) showed about 1·5 cm of reduction from 2 to 3 weeks, and about 2·0 cm between 2 and 12 weeks, but in the latter case with range from a maximum of 7 cm reduction to 5 cm increase. The mean quotient between proximal and distal circumference was at two weeks 1·01 (SD 0·07) and at 12 weeks 1·04 (SD 0·09) indicating a tendency towards a more pointed stump.

The length of the stump should be constant as bone does not shrink but shrinking soft tissues may cause reduction and acquired oedema may cause increased length. We found an average shortening of 0·5 cm (Fig. 5).

Using proximal and distal circumferential measurements and the length we arbitrarily calculated a volume at 2, 4, 6 and 12 weeks after

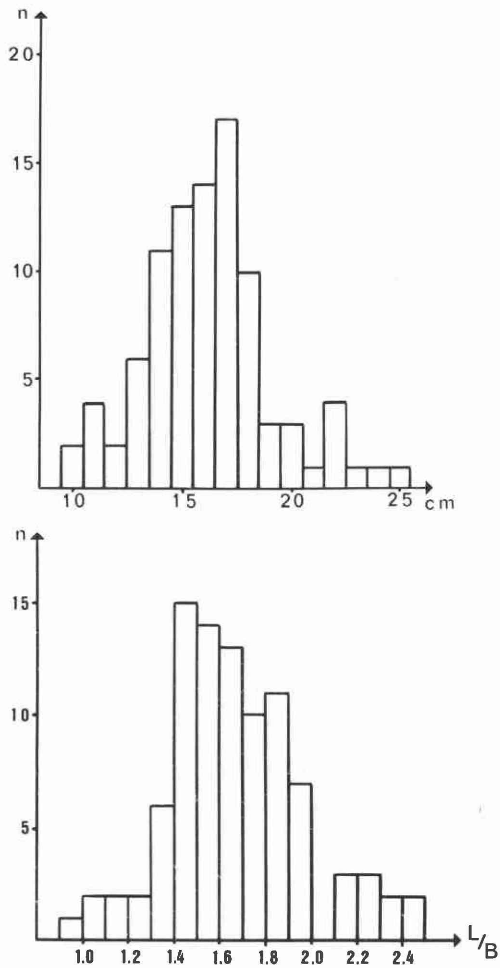


Fig. 2. Top, length of below-knee stumps. Bottom, proportional length of below-knee stumps.

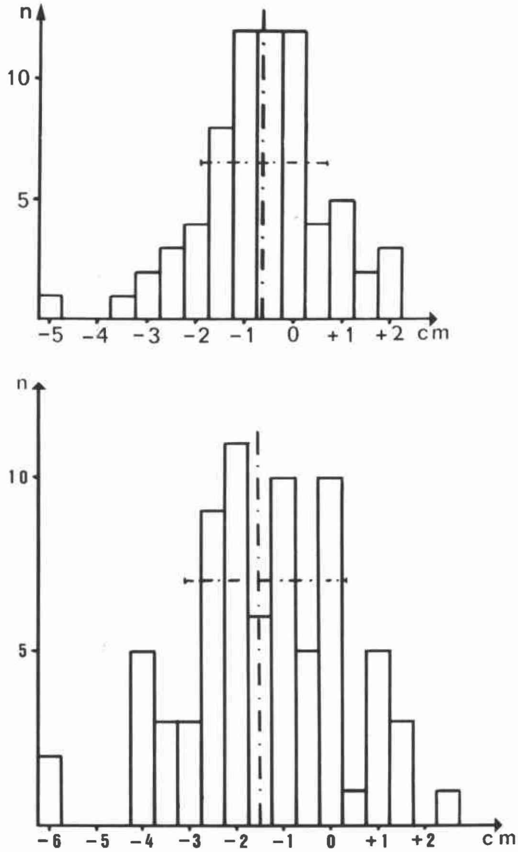


Fig. 3. Top, change of proximal circumference between 2 and 3 weeks in below-knee stumps. Bottom, change in proximal circumference between 2 and 12 weeks in below-knee stumps. Dotted cross indicates mean value and standard deviation.

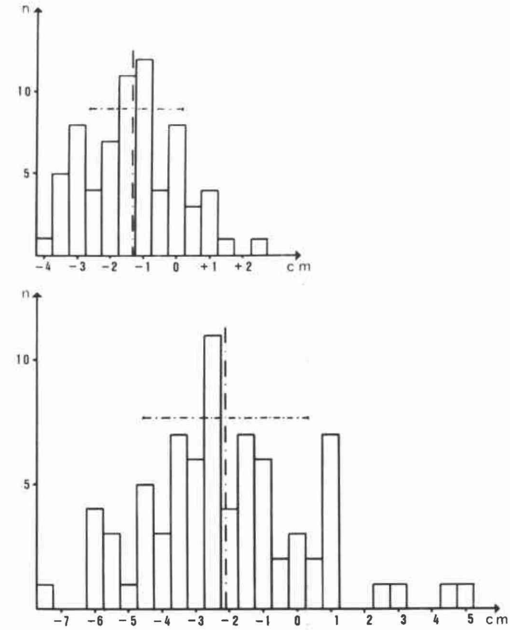


Fig. 4. Top, change in distal circumference between 2 and 3 weeks in below-knee stumps. Bottom, change in distal circumference between 2 and 12 weeks in below-knee stumps. Dotted cross indicates mean value and standard deviation.

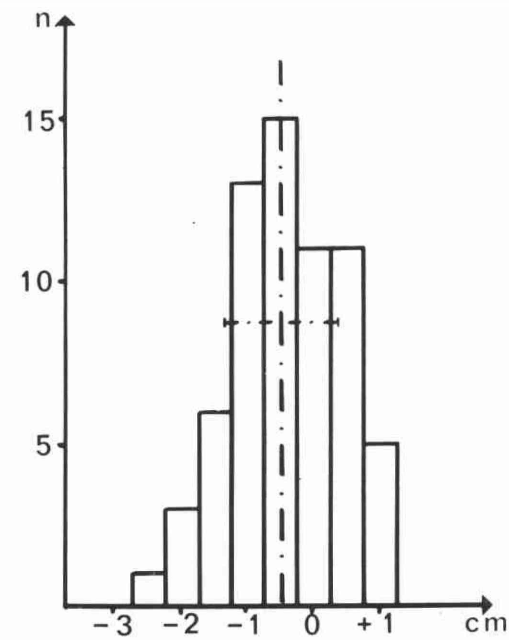


Fig. 5. Change in measured length of below-knee stumps between 2 and 12 weeks. Dotted cross indicates mean value and standard deviation.

amputation with the stump considered as a cut cone. Figure 6 describes this volume at 2 weeks after amputation with a mean value of 1·3 litres ranging from 0·5–2·1 litres (SD 0·3). At 2, 4, 6 and 12 weeks after amputation this calculated volume showed a gradual decrease with the most significant reduction from 2–4 weeks and with a total reduction during the first 3 months of about 7 per cent (Fig. 7).

Stumps that were between 1 and 1·5 times longer than the breadth had a non significant lower proportion of unhealed wounds than the longer stumps (Fig. 8).

In part two the result of using the ISPO classification form showed that some classifications are totally dependent upon level. Of the lower limb stumps created by joint disarticulation, for instance, all five were long and club-shaped with insignificant stump pain and phantom pain. Only the below-knee level, however, contained enough patients to make statistical analysis reasonable, 116 of all 135 measurements were below-knee, 12 in above-knee and the residual 7 in disarticulations at hip, knee and ankle levels. Eighty-two per cent of the patients had been amputated for arterial occlusive disease with or without diabetes.

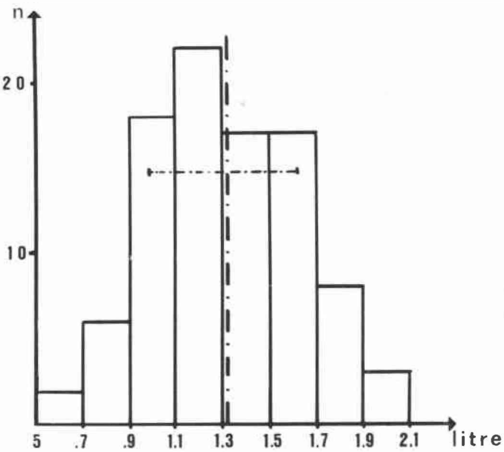


Fig. 6. Arbitrary volume of calculated cut cone representing below-knee stump volumes.

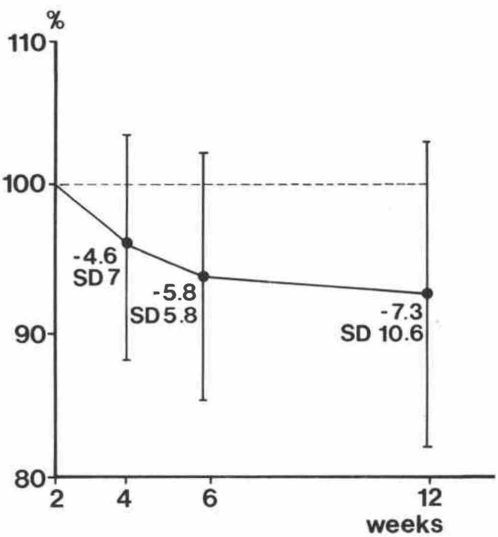


Fig. 7. Change in calculated below-knee stump volumes between 2 and 12 weeks. Mean values and standard deviations.

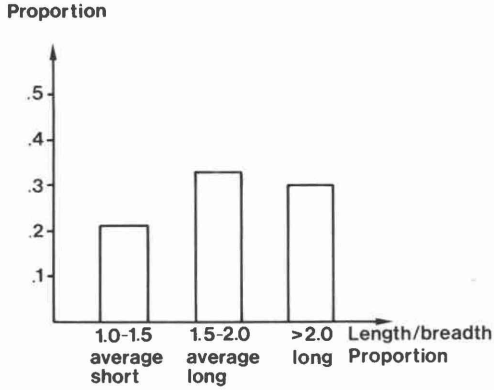


Fig. 8. Proportion of unhealed wounds of below-knee stumps in three groups of proportional length.

In the below-knee group the proportions of different characteristics were as follows. Highly active walkers 0·20, average 0·58 and less active 0·35. Ischemia was the indication in 0·89. The stump length was ordinary in 0·81, short in 0·13 and long in 0·06. The shape was cylindrical in 0·80, conical in 0·19 and club-shaped in 0·01. The scar was well healed in 0·77 compared to 11 of 12 in the above-knee group. It was adherent in 0·09 among below-knee and this proportion was the same in above-knee patients.

The skin was undamaged in 0·71 of all patients without any difference between above and below-knee levels (Table 1) but stumps older than 3 years had a significantly higher proportion of skin damage ($p < 0·005$).

Above-knee stumps were soft in 3 of 12 compared to 16 of 116 in below-knee and they were pointed in 2 of 12 compared to 25 of 110

Table 1. Skin condition among above and below-knee stumps.

Condition	AK only	BK only
Undamaged	9	81
Abrasion	1	8
Ulcer	—	5
Infected ulcer	—	5
Epidermoid cyst	1	2
Suction discolouration	—	4
Blister	—	1
Verrucous hyperplasia	—	1
Folliculitis	1	1
Eczema	—	1
Total	12	109

below-knee stumps. Mobility was registered as normal in 88 of 116 in the below-knee group and 23 of 116 had limited extension of at least 10 degrees.

There was no significant difference when the material was separated according to sex. Stump pain was equally a problem in 0·2 and when separated according to level, 0·18 of below-knee amputees had stump pain and 0·21 had phantom pain. There was no significant change in stump pain or phantom pain when the material was separated into four different time intervals at 6, 12 and 36 months.

The end of below-knee stumps had a tendency to be more pointed with time. Ten of 59 (0·17) were pointed at less than one year, compared to 12 of 42 (0·29) after more than one year.

In summary, correction was found to be indicated equally in 7–8% of above and below-knee stumps concerning prosthetic changes and in 3 compared to 1% concerning surgical changes.

Discussion

There are few publications on general conditions of amputation stumps. Stumps are left to the orthopaedic technicians to fit and few reports describe the encountered problems. Staros (1963), Hansson (1964), Eriksson (1965), Burgess et al. (1971), James and Öberg (1973), Murdoch (1975), Grevsten and Stalberg (1975), and Baumgartner and Langlotz (1980) describe different aspects of rehabilitation problems. Weiss, Fishman and Krausse (1971) made a thorough analysis of 100 lower limb amputees considering psychological and pain aspects but they did not study other parameters like shape, solidity, strength or range of motion. Persson and Brunk (1974) found that strength seldom set the limit on walking ability.

Renström (1981) examined 63 below-knee amputees and found 18% with phantom pain corresponding to the authors' figure. Among 58 stumps he found a mean length of 14 cm compared to our 16 cm. To the circumferential measurements he made on thigh and on middle of stump we have no corresponding observations. Thirty-six per cent of his stumps had wounds or erosions compared to our 14% unhealed below-knee stumps and 30% with other skin damage. The measurements of volume changes due to oedema and muscle atrophy reported by Renström using computer tomography and ours using a tape do not exactly correspond. Renström measured 5 patients 1–12 months after amputation and found a decrease of 25% during the first 4 months compared to our 8% during the first 12 weeks using tape measurements and calculation of volume. The circumference of the stump decreased by 5% during the first 4 months and another 3% by 12 months in Renström's material which possibly corresponds to our observations. Renström, however, also took into consideration the increase in circumference of the non-amputated leg simultaneously being 3% at 4 months and 6% at 12 months. Renström also made another interesting observation using dator tomography (CT-scanning). The attenuation in Houndsfield units was significantly lower in the stump after amputation compared to the non-amputated leg. Dator tomographic examination of amputation stumps showed decreased skeletal and soft tissue density also in studies published by Hübner et al. (1981). The volume observations made by Fishman et al. (1971), Goldbranson et al. (1980) and Renström (1981) describe volume fluctuations in mature stumps which we have not studied in this paper. It seems to be about 5% in many cases and can cause great problems in prosthetic fitting. This is illustrated by Goldie's et al. (1974) liquid pad and Isherwood's (1975) adjusting pad. Increased distal stump circumference was seen in active patients who had been forced to inactivity by their disease and could reinstate their muscle mass by walking postoperatively.

The definition of long and short stumps used in this text is new. Earlier classifications have utilized the length of stump as an *absolute measure* in centimetres. To consider the difference between tall and short stature a *relative measure* has also been used as a percentage of the unamputated side. Some patients, however, have relatively fat limbs and a certain relative length compared to the unamputated side does not explain the problems with fitting a socket. Therefore, a *proportional measure* considering the diameter of the stump has been used by us. For this the proximal breadth of the stump has been noted. This measure is much easier appreciated than a measurement of circumference and is very quickly estimated (Fig. 1). This pragmatic method of differentiation of stumps into short, long and ordinary is easy in practical clinical judgement. Stumps shorter than the breadth are felt to be short and those longer than twice the breadth are felt to be long. This impression of length is the same whether it is a below-knee or an above-knee amputee and probably about the same also on the upper extremity.

In the clinical standard of measurement and classification the condition of the scar has been separated from the condition of the skin. It was felt that the healing of the amputation wound could be simply classified as *healed, unhealed or adherent*, which is a result of secondary healing when skin adheres to bone. If unhealed the length and breadth of the defect should be noted to follow the healing. The skin of the stump otherwise is either undamaged or damaged by mechanical factors like pressure or shear imposed by the socket. This is listed separately from suction discoloration to chronic verrucous hyperplasia. Mechanical or hydraulic effects mentioned can be separated from skin damage where infection contributes as in folliculitis and infected ulcers. If pressure, suction or infection is not the causative agent of damage it might be hypersensitivity reactions to materials simply labelled eczema. These different categories of skin lesions of stumps have been especially dealt with by Levy (1980). We found that scar problems were common during the early period and the other skin problems increased with time (Table 1).

Most aspects found on inspection and palpation have been taken into consideration and simplified. One parameter has been omitted. That is strength. Muscular atrophy, shortness of lever arms, softness of stumps and pain altogether make it difficult to record strength of stumps, and it is our belief that strength is of little importance in walking.

This study has not included the patient with a prosthesis. Judged by the stump a prosthetic correction was considered to be indicated in 7 per cent and a surgical correction in 2 per cent. Surgical correction was more often indicated in above-knee stumps and prosthetic correction more often in below-knee stumps. In 39 per cent special aberrations had been noted signifying that all was not well. Important parameters influence selection of socket or type of suspension, components, alignment and training of a patient. These simple criteria of ordinary and special stumps and the systematic separation of skin problems is helpful in finding a cure.

Acknowledgements

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Structural matrices for use in rehabilitation

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Abstract

Progress is reported on the development and application of structural matrices in rehabilitation. The development of a stronger and more adjustable matrix than was previously reported is detailed, together with the principles necessary to achieve this. Application of this new matrix to adult seating is described. The emergence of programmable beams and the need for containment matrices are also documented and the advantages of these approaches to a variety of problems in rehabilitation are given.

Introduction

One of the fundamental problems in designing devices for the disabled is that of providing a strong and lightweight yet adjustable structure. This problem is common to the design of a variety of devices ranging from seats to spinal orthoses. A diversity of materials are currently employed to build these structures, such as thermoplastics for spinal body jackets, plaster of Paris for limb fracture management and thermosetting plastics for seating the cerebral palsied child. These materials perform satisfactorily in their various configurations but often the need for adjustability is frustrated. The need for strength is not adequately met by thermoplastics unless the structure can be formed into an integrally strong shape.

The design of a universal structure, or structural matrix, was therefore considered necessary. A matrix in this context is defined as an array of small components that can be linked, shaped and locked to form a strong enclosing or supporting structure. This matrix would have a wide range of rigidities and be adjustable both in stiffness and in shape. The adjustability of the structure was considered to be the most important feature, as this would allow the structure to be used in such diverse applications as seating of the cerebral palsied child, where changes in shape of the seat are needed as the child grows; or in fracture management, where the rigidity of the orthosis should be changed as the fracture heals. Early attempts at a solution to this design problem have been reported (Foort et al. 1978) and since that time considerable progress has been made. The purpose of this report, therefore, is to demonstrate this progress, to illustrate the current clinical applications and to outline the problems remaining.

Progress

The first structural matrix to find useful clinical application was reported as a shapeable matrix for use as a seat for disabled children (Cousins et al. 1979). The latest version of this seat, as shown in Figure 1 (left), is a major advance over

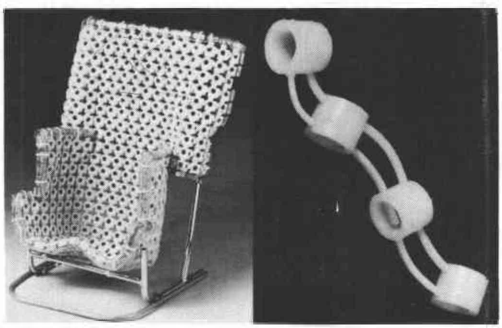

Fig. 1. Left, the shapeable matrix used by Cousins for child seating. Right, prototype of the node and beam structure.

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conventional seating systems as it permits fine adjustment to meet the critical shapes needed to effectively seat and control the cerebral palsied child. The limitations of this system are that, because it is constructed as a matrix of fixed increments, it can only be easily contoured to cylindrical-conical shapes. A second disadvantage is that the locking force of the matrix, that is the tension in the wires, is opposed by the loading forces. These opposing forces act along the neutral axis of the structure, that is along the wires themselves, and so very high friction is needed at the nodes to give a secure lock.

It was felt that the ability of a matrix to form around spherical and complex anatomical shapes was required; and secondly, any loading forces applied to the matrix should aid in locking the matrix. Design efforts continue.

An important improvement was the use of the I-beam principle, where the structural beams are separated as far as possible away from the neutral axis. This is shown in Figure 1 (right), where two rods are separated by nodes. The locking of the rods occurs at the top and bottom of the nodes, that is well away from the neutral axis. Loading of this system puts one beam in tension and the other beam in compression. A strong structure with positive locking was therefore possible. This concept was also very attractive as the nodes could be positioned and locked at any point along the beam, so giving continuous rather than incremental adjustment. The nodes could be inserted and removed to vary the strength of the beam and variability of link length at the nodes gave a structure that could encompass complex shapes.

This design process resulted in a structure that overcame the strength and adjustability problems of the first matrix; this new structure has been named Node-and-Beam. Examples are given in Figure 2 of different early versions of this approach and full-scale models of a lower limb support (Fig. 3, left) a seat (Fig. 3, right) and a spinal orthosis (Fig. 4) are shown to demonstrate the versatility of the structure.

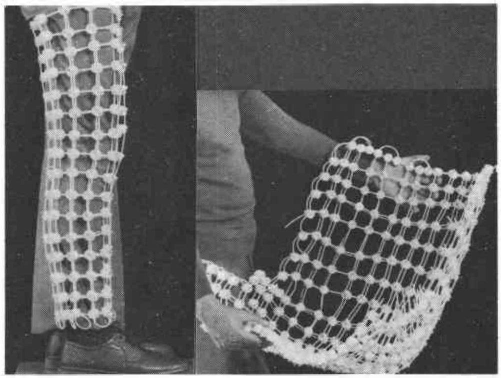
Fig. 3. The node and beam matrix, left, encasing the lower limb and, right, as a seat.

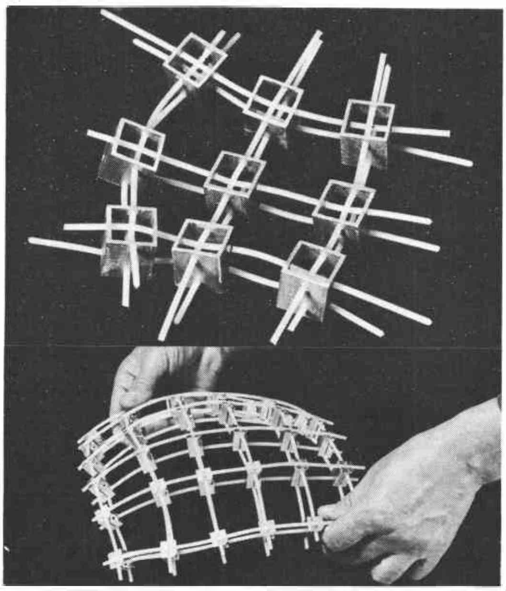
Fig. 2. Early node and beam matrices.

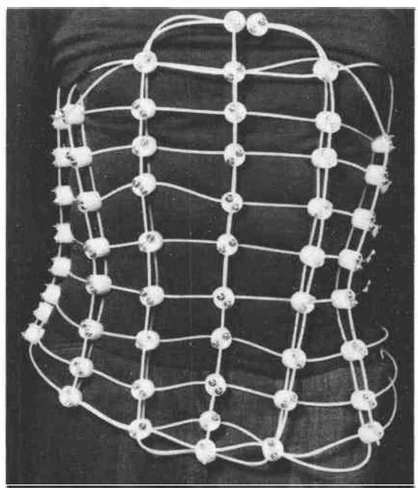
Fig. 4. The node and beam matrix as a spinal orthosis.

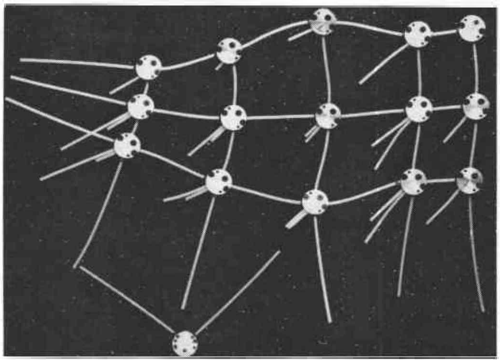

Fig. 5. A single layer of node and beam that "swallows" its neighbour.

However, speedy and secure locking of the beams at the nodes remained a major design problem. Simplification of the locking procedure was achieved through the use of a single screw that gripped all four beams as they crossed at a node. An example of this is shown in Figure 4. This system still necessitated the unlocking of many nodes to achieve a change in the shape of the structure as the beams were continuous. It was felt that the use of short beams, reaching from node to node, would give greater local adjustability of the matrix. This was first modelled as a system where the node "swallowed" the beams of the next node, as shown in Figure 5. This arrangement did give greater adjustability and was incorporated into the original I-beam design to increase its strength. Incremental lock points set along the beam aid in the locking. The resulting structure is illustrated in Figure 6. A clip-on surfacing element was added and the structure is currently being put to clinical use as a seat for the severely disabled adult.

Discussion

Parallel developments of matrices for use in seating have been taking place at a sister unit, the Bioengineering Centre of University College London. The latest seat design emerging from this centre has been reported by Cousins (1981), who was an original member of the MERU team engaged in formulating the shapeable matrix concept in 1975. It is expected that many new applications will emerge from the concept of structural matrices and certain directions for improvement are already apparent.

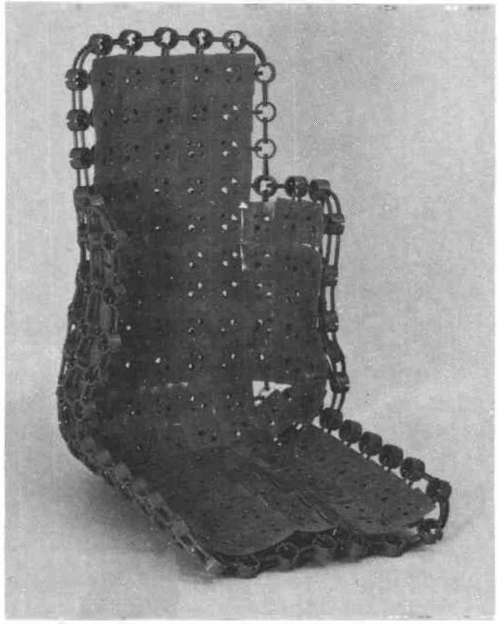

Fig. 6. The latest node and beam matrix assembled as a seat.

There is a need, for example, for node and beam systems of different sizes to accommodate differing problems. The structure illustrated in Figure 6, currently being applied to adult seating, represents one of the most demanding applications of a structural matrix in rehabilitation. Smaller and more adjustable versions are needed for children and for orthoses to be worn on the body. One of our early objectives was to develop a replacement for plaster of Paris for many orthotic applications. It is possible however, that the structural and containment functions will have to be separated to achieve a finely tuneable matrix. This will mean the development of a distinct containment matrix that is compatible with the supporting structural matrix. Containment matrices will find application in non-weightbearing situations such as upper extremity orthoses, or in conjunction with structural matrices for more demanding applications.

Further refinements will include the use of different surfacing elements under different loading conditions; and the use of insertable modules for various functions such as load measurement, surface mobility feedback and attachment of additional structures. Examples of the latter would be the interfacing of the halo apparatus with a body jacket and the addition of hinges to femoral fracture orthoses.

The development of structural matrices has led to the introduction of programmable beams (Dewar, 1979) that can be shaped, or programmed. An example of a common programmable beam is that of the laminated wood beam used in architecture. This structure can be shaped to position and then bonded to the fixed shape. Beams constructed in such a manner will find ready application as side irons for lower limb orthoses or as strengthening members for spinal orthoses. Adjustable programmable beams have been developed by the MERU team and these present exciting opportunities for a diversity of applications. A time lapse photograph of a programmable beam in motion is shown in Figure 7. These beams consist of nodes spaced along flexible plastic rods. Pushing or pulling the ends of the rods will shape the beam. Hinging through various degrees of freedom can be obtained by crossing over the rods, and selective mobility can be achieved by locking the beams at intermediate nodes. Application of mobile programmable beams will be found as feeder/manipulator arms and as joysticks for wheelchair control.

It is felt that the use of adjustable structural matrices and rigid, flexible or mobile beams in rehabilitation will have the effect of reducing costs and speeding provision time of orthoses and other devices. This will be possible because the matrix approach takes advantage of mass-production techniques for producing the standard components. These can then be assembled with no special tools or facilities. The frequency of patient visits may be reduced, as changes to the shape and strength of the orthosis can be made while the patient waits. The comfort of the patient will be increased by the provision of lightweight and cool structures that conform and respond to their needs.

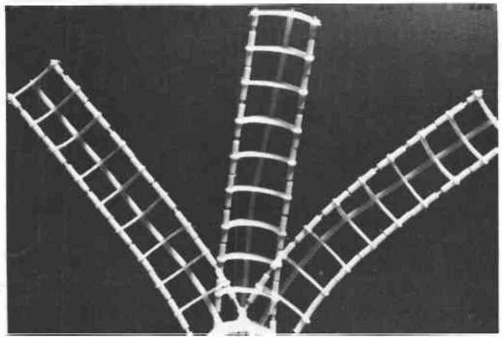

Fig. 7. Time lapse photograph of a programmable beam in motion.

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A clinical study of post polio infantile paralysis

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Abstract

This study reports on 3,000 cases of poliomyelitis seen at the Rehabilitation and Artificial Limb Centre at Lucknow between January 1976 and December 1980.

Factors such as age and sex incidence, extremity involvement, incidence of deformities at hip, knee and ankle, lower limb discrepancy, treatment and orthoses prescribed are discussed.

Introduction

Poliomyelitis is still endemic in India and on average poliomyelitis may be seen in 15–20% of the cases in the outpatient clinics of any paediatric or orthopaedic hospital. These patients, if not given proper care, develop various deformities and contractures which further delay their rehabilitation programme. Those deformities are directly proportional to the amount of disability and this depends upon the site and extent of the involvement, but there is no definite data to indicate the patterns of distribution of paralysis due to poliomyelitis. Thus this clinical study was undertaken in retrospect to determine the magnitude of the problem and with the aim of deciding the early rehabilitation programme for such cases.

Methodology

All the cases of poliomyelitis who reported for treatment in the outpatient clinic of the Rehabilitation and Artificial Limb Centre, Lucknow, from January 1976 until December 1980, have been studied. Each case was assessed by a team of medical and paramedical staff. The paramedical team consisted of a medical social worker, an occupational or physiotherapist, an orthotist and a vocational counsellor. The cases with severe contractures and deformities, in whom corrections could not be achieved in spite of conservative treatment, were subjected to surgery and were later fitted with suitable orthoses. Patients with involvement of all four extremities and spine posed a special challenge for the whole rehabilitation team.

Discussion

During the last 5 years, 20,200 new cases were seen in the outpatient clinic of the Rehabilitation and Artificial Limb Centre, Lucknow. Of these, 3,000 cases (14·8%) were of poliomyelitis. A steady increase in the attendance of polio cases was noted (Table 1) which may be due to the increased incidence of poliomyelitis (Arora et al. 1978; Basu, 1981; Pandey, et al. 1979; John, 1981) or to increased awareness of facilities available for management of the condition.

Table 1. Incidence of poliomyelitis

Year	Number of cases	Polio cases	Percentage
1976	2,697	293	10·8
1977	2,432	308	12·7
1978	3,881	513	13·2
1979	5,079	786	15·5
1980	6,131	1,100	17·9
Total	20,220	3,000	14·8

The involvement of males was found to be greater than females in the ratio of 1·3:1; most of the patients were children mainly in the age group 1–3 years (Ajao and Oyemade, 1981; Kumar and Arun,). Although the majority of cases, 50·5% (1,510 cases), were less than 3 years of age, many older patients also reported for treatment, 17·7% (531 cases) were over 9 years of age (Table 2).

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Table 2. Age and sex incidence

Age (years)	Male	Female	Total	Percentage
Less than 1	202	133	335	11·2
1–3	656	523	1,179	39·3
3–6	392	270	662	22·1
6–9	160	133	293	9·7
Above 9	300	231	531	17·7
Total	1,710	1,290	3,000	100

Most of the cases in the acute stage or in the early stage of poliomyelitis did not attend the specialized clinics due to ignorance and other socio-economic factors. Those who come some distance for treatment usually report at first to general practitioners or paediatric or orthopaedic clinics. Thus treatment in the specialized centres is usually given in the later stages, either in the convalescent or residual stage. In the present study, 48% (1,440) cases were in the convalescent phase and 41·3% (1,210) were in the residual stage. Thus it becomes more difficult to plan the future rehabilitation programme in such cases. As far as rural and urban population is concerned there was not much appreciable difference in the incidence in this series.

More than half of the total cases (50·7%) had not taken any treatment prior to their first attendance (Table 3) at the Rehabilitation and Artificial Limb Centre, Lucknow and the others had undertaken various types of conservative or surgical treatment. A large number of these cases have no access to proper facilities and a good referral system is not available. A long term rehabilitation programme for such patients should be mapped out for individual cases and emphasis should be placed on regular follow-up management. This will really help in preventing the recurrence of deformities and contractures.

It was observed that the lower limbs were more often affected (95.2%) than the upper limbs and, in addition, the paravertebral muscles were also involved at times along with the lower limb (Table 4). Many workers in the study of poliomyelitis have reported affection of lower limbs varying between 85 and 90%, (Ajao and Oyemade, 1981; Kumar and Arun; Punatar and Patel, 1977; Sachdeva and Gupta, 1972).

Table 3. Treatment received before attendance

Treatment taken	Number of cases	Percentage
No treatment	1,520	50·7
Conservative treatment	1,266	42·2
Surgical treatment	214	7·1
Total	3,000	100

Table 4. Extremity involvement

Extremity involved	Number of cases	Percentage
One upper limb	139	4·63
Both upper limbs	5	0·17
One lower limb	1,909	63·63
Both lower limbs	809	26·97
One upper limb and one lower limb	64	2·13
One upper limb, spine and one or both lower limbs	37	1·23
Both upper limbs, spine and one lower limb	3	0·10
All four limbs and spine	34	1·13
Total	3,000	100

In further evaluation of the upper limb, 55 cases (19·5%) had completely flail upper limbs and 38 cases (13·5%) had partial involvement (Table 5). In the rest of the cases either the shoulder or wrist and hand were flail. In unilateral upper limb involvement, satisfactory readjustment occurs due to the normal upper limb and the person is more or less independent in his activities of daily life and can perform sedentary types of work. With the limited resources and manpower available it is not feasible to undertake long term planning and follow-up of these cases. Even after surgical intervention results are not very encouraging in such cases.

A detailed evaluation of lower limb involvement revealed that more than half of these cases had mild to severe deformities on their first attendance (Tables 6, 7 and 8). This is a

Table 5. Upper limb—clinical presentation

Presentation	Number of cases	Percentage
Flail (complete)	55	19·5
Flail shoulder	115	40·8
Flail elbow	6	2·1
Flail wrist and hand	68	24·1
Limbs with partial involvement	38	13·5
Total	282	100

significant observation which reflects not only the health care delivery system, but shows lack of proper guidance, apathy and other socio-economic problems. The majority of these cases presented themselves crawling or in some other badly deformed posture due to the severe soft tissue and bony involvement and malposition (Ajao and Oyemade, 1981; Cross, 1977; Huckstep, 1975).

Table 6. Incidence of ankle deformities

Deformity	Number of cases	Percentage
Equinus	687	40·2
Valgus	296	17·3
Cavus	249	14·5
Varus	186	10·9
Calcaneus	121	7·1
Others	171	10·0
Total	1,710	100

Other studies have shown a greater variation in the deformities (Sachdeva and Gupta, 1972). The present study reveals various combinations of deformities. Deformities around the ankle (1,710 cases) outnumbered those of hip (614 cases) and knee (608 cases). Equinus deformity (681 cases) was the most common ankle problem followed by valgus and varus deformities (Table 6). Surprisingly, weakness of the plantarflexors was seen only in 121 cases leading to calcaneus deformity. Around the hip the commonest deformity was flexion, abduction and external rotation (546 cases); subluxation or dislocation was found in only 21 cases (Table 7). The pattern of deformities around the knee is shown in Table 8, the most common being hamstring contractures, found in 259 cases, followed by genu recurvatum (174 cases) and genu valgum (158 cases).

Table 7. Incidence of hip deformities

Deformities	Number of cases	Percentage
Flexion, abduction and external rotation	546	88·9
Abduction	3	0·5
Pelvic obliquity	44	7·2
Dislocation/subluxation	21	3·4
Total	614	100

Table 8. Incidence of knee deformities

Deformity	Number of cases	Percentage
Flexion	259	42·6
Genu recurvatum	174	28·6
Genu valgum	158	26·0
Genu varum	13	2·1
Subluxation	4	0·7
Total	608	100

Lower limb discrepancy in the form of shortening was observed in 460 cases out of which 262 cases had shortening of more than ½″ (12·5 mm) (Table 9). One case had shortening of 6″ (150 mm).

Table 9. Lower limb shortening

Age (years)	Less than ½″ (12·5 mm) Male	Female	Between ½″–1″ (12·5–25 mm) Male	Female	More than 1″ (25 mm) Male	Female
1–3	49	25	20	12	2	1
3–6	49	25	23	6	—	—
6–9	25	10	25	8	2	—
Above 9	9	6	53	37	51	22
Total	132	66	121	63	55	23

Initially all these cases were subjected to different regimes of occupational and physiotherapy for their comprehensive management. They were provided with proper treatment to support or prevent deformities during their conservative management (Table 10). Out of 3,000 cases, 2,210 were prescribed an orthosis or special footwear along with conservative management; 404 cases required some surgical procedure prior to fitting an orthosis. It should be mentioned here that due to socio-economic and cultural constraints every patient was unable to undertake the treatment as prescribed and there were many dropout cases. However, 2,210 appliances for proper

Table 10. Treatment prescribed

Treatment prescribed	Number of cases	Percentage
Conservative treatment alone	386	12·87
Orthosis and shoes along with conservative treatment	2,210	73·66
Surgery	404	13·47
Total	3,000	100

ambulation of these cases have been fitted, the most common being KA and AF orthoses followed by surgical footwear and bilateral HKA orthoses (Table 11).

Table 11. Supply of orthoses

Orthosis	Number of appliances	Percentage
Bilateral HKA orthosis with pelvic belt and hip joint	266	12·04
KA orthosis	999	45·20
AF orthosis	575	26·02
Special orthopaedic shoes	370	16·74
Total	2,210	100

Summary and conclusions

A retrospective clinical study of 3,000 cases of post polio infantile paralysis was carried out at the Rehabilitation and Artificial Limb Centre, Lucknow with an incidence of 14·8%.

The prevalence of poliomyelitis has shown a trend to increase. The greatest number of cases reported were found in the 1–3 years age range (39·3%)

Males were more common than females, however this difference was in proportion to the general sex ratio of the population at large. The study reveals a greater number of attendances during the later stages of poliomyelitis.

No appreciable difference was noticed between the incidence in rural and urban population.

Affection of the lower limb was the greater compared to the upper limb. Nearly half of the cases had not received any treatment prior to attending the outpatient department at the Rehabilitation and Artificial Limb Centre.

To conclude, it is strongly suggested that an adequate inoculation campaign against polio, early detection and proper treatment of the cases will decrease the incidence of poliomyelitis and reduce the morbidity. Further, the opening of specialised centres, as recommended by Agarwal and Goel, (1978), on a three tier system is a necessity in the present circumstances. In the light of the experience gained over the past 5 years in rural camps, unless and until medical and rehabilitative facilities are provided at the doorsteps of the patients, no great advance can be achieved.

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A comparison of the SACH and single axis foot in the gait of unilateral below-knee amputees

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Abstract

The gait patterns of unilateral below-knee amputees wearing prostheses with either a SACH foot or a single axis foot were compared. A temporary below-knee prosthesis was fabricated for each subject using plaster of Paris and Plastazote for the socket, a pylon and an artificial foot. Eight subjects were filmed at two separate sessions, one in which the SACH foot was worn on their prosthesis and one with the single axis foot on their prosthesis.

Measurements of the normal leg with a SACH foot on the prosthetic limb were compared to measurements of the normal leg with a single axis foot on the prosthesis. Measurements of the prosthetic leg with both devices were also compared. A one tailed t test ($p<.05$) was used to determine statistical significance of the results obtained in six measurements of lower limb joint angles and on the percentage of the time of gait cycle for stance and swing phase of the prosthetic leg.

Discussion centres on the interpretation of the results from both statistical and clinical points of view. Major differences (excepting the ankle at foot-flat) between the prosthetic devices were not found.

Introduction

The two artificial feet used in this study were the single axis foot and the SACH (solid ankle cushion heel) foot. These devices seem to be the most commonly used at present. Throughout the 1970's the SACH foot was the artificial foot of choice in North America when fitting the majority of below-knee amputees (Fishman, et al. 1975). However, the single axis foot, which was first used during World War 1, appeared to be capable of more closely simulating human gait, due to the dorsiflexion and plantarflexion movement of the device.

The choice of prosthetic foot is important to the amputee and to the amputee clinic team prescribing the prosthesis. According to Statistics Canada, there were 1,198 below-knee amputations performed in Canada in 1974. Patients in the 55 to 67 age group are usually amputated for peripheral vascular disease which accounts for 80 per cent of the total number of amputations (Hunter and Waddell, 1976).

Breakey (1976) observed the effect of lost ankle movement on the gait of below-knee amputees by comparing the gait of five normal subjects to the gait of five unilateral below-knee amputees. These amputees were wearing a patellar tendon bearing prosthesis with a SACH foot. Breakey (1976) suggested that the lost ankle movement affects the knee movement and foot timing. He stated that knee flexion was decreased to 7 degrees from a normal value of 17 degrees during the stance phase, decreased to 30 degrees from a normal value of 37 to 43 degrees during toe-off and decreased to 57 degrees from a normal value of 61 to 68 degrees during the swing phase of gait.

Stance phase occurred for 57% of the time of the gait cycle for the involved limb and 63% for the uninvolved limb in Breakey's amputee subjects.

Robinson et al. (1977) tested 19 unilateral below-knee amputees, mean age 43, wearing a SACH foot on their patellar tendon bearing prosthesis. They observed a mean stride length of 1·32 metres, a mean step length from uninvolved to involved limb of 0·68 metres, and a mean step length from involved to uninvolved

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of 0·63 metres. An increased amount of time spent on the uninvolved limb compared to the involved limb contributes to an increase in stance phase. The mean walking velocity of these subjects was 1·07 m/s.

Subjects

Eight males were selected according to the following criteria: unilateral below-knee amputees wearing a patellar tendon bearing prosthesis with cuff suspension. These subjects were between the ages of 55 and 67, in good general health and had no skin problems with their stump.

Methodology

Each amputee was fitted with a temporary prosthesis to accommodate the interchange of prosthetic feet. The temporary prosthesis consisted of a plaster socket lined with Plastazote, cuff suspension, a pylon and prosthetic foot. The socket was fabricated and aligned on the pylon and foot following the same principles as a permanent patellar tendon bearing prosthesis.

The selection of the first prosthetic foot to be measured was made according to the availability of the prosthetic feet. The subjects were tested two days after fitting of a prosthetic foot if the foot was the same design as the one on their permanent prosthesis. A time lapse of one week was allowed if the prosthetic foot was not the same design as the one worn on their permanent prosthesis. The first prosthetic foot was changed after the filming was completed. The second foot was aligned on the prosthesis and the subject given a date for the second filming.

Data collection

A distance of approximately six metres (on level ground) was used as a walking zone allowing the subjects to complete three gait cycles. The subjects were filmed simultaneously from lateral and frontal perspectives. The anterior view (Bolex camera, 64FPS) was used to check knee angle measurements (varus, valgus), lateral deviation of the trunk and shoulder elevation. The subjects were filmed twice with the normal (non-amputated leg) closest to the side camera (Locam camera, 86FPS) and twice with the prosthetic leg closest to the camera.

A one foot measurement board was filmed in the centre of the walkway and used to convert digitized co-ordinates. The processed film was projected on to a digitizing tablet by a stop action projector. The nineteen body parts necessary for the computer to calculate the centre of mass were digitized and recorded on paper tape for each subject at heel-strike and every fifth frame following until the gait cycle for the leg was completed. The nineteen body parts in sequence, were the head, sternum, crotch, right shoulder, elbow, wrist and hand, left shoulder, elbow, wrist and hand, right hip, knee, ankle and foot and left hip, knee, ankle and foot. The paper tape was fed into a computer terminal and data points stored on a magnetic disc. Key punch cards were used to obtain the program output from the computer which included the path of the centre of mass for each subject.

The measurements obtained in this study to compare the gait of the amputee subjects were as follows:

1. The vertical displacement and velocity of the centre of mass of each subject on each trial were obtained from the computer printout.
2. The lower limb joint angles were measured by projecting the lateral view films on to a wall using a stop action projector. The selected angles of the hip, knee and ankle were measured using a goniometer. The joint angles for heel-strike were measured as the heel came in contact with the floor following swing phase. Foot-flat was measured as soon as the entire foot came in contact with the floor. As the hip moved directly over the foot, angle measurements for mid-stance were taken. The angle measurements for heel-off, as the heel left the ground and toe-off, as the toe left the ground completed the stance phase measurements.

   During swing phase the angle measurements were taken as the knee passed directly under the hip for acceleration, as the foot passed directly under the hip for mid-swing and as the knee ceased to extend for deceleration.
3. The percentage of time of gait cycle of stance phase, swing phase and double support phase and the time of the gait cycle were calculated using the number of fames and the frame rate of the film.

Table 1. Statistically significant variables

Variables	p value	Mean SACH	Standard deviation	Mean SA	Standard deviation
Hip angle, toe-off normal leg	·041	−3·0°	7·1	−7·0°	5·3
Knee angle, acceleration normal leg	·020	55·6°	5·0	59·0°	5·1
Hip angle, foot-flat prosthetic leg	·035	13·1°	6·8	17·1°	9·6
Ankle angle, foot-flat prosthetic leg	·001	−5·4°	2·1	−11·9°	3·0
Ankle angle, heel-off prosthetic leg	·034	4·4°	4·1	0·9°	3·3
Hip angle, acceleration prosthetic leg	·009	11·0°	1·2	13·9°	2·3
Percentage of time of gait cycle stance phase prosthetic leg	·040	61·8%	1·7	60·5%	0·9
Percentage of time of gait cycle swing phase prosthetic leg	−·040	38·2%	1·7	39·5%	0·9

4. Step length and stride length were obtained using the digitizing tablet and the projected film.

Results

The measurements obtained when the subjects were wearing a single axis foot on their prosthesis were compared to those obtained when they were wearing a SACH foot on their prosthesis. A paired t-test was used to determine whether the two means were significantly different. A probability level of 0·5 was selected for a l-tailed *t* test. The degrees of freedom for all comparisons was seven. Statistical significance was obtained in six comparisons of lower limb joint angles and the percentage of the time of gait cycle for stance and swing phase of the prosthetic leg (Table 1). The mean velocity of the body's centre of mass for both the SACH foot and the single axis foot measurements was 1·22 m/s. The difference in velocity comparing the subjects SACH foot gait and single axis gait was no greater than 0·2 m/s. (Table 2).

Discussion

Although statistical significance was obtained in six comparisons, only one variable was felt to have any clinical significance. The determination of clinical significance was based on research by Murray (1967) on 30 subjects which identified one standard deviation of ankle angle measurements to be approximately 7°, knee angle to be 5° and hip angle to be 11° at an average walking speed of 1·39 m/s. In this study the ankle angle at foot-flat of the prosthetic leg measurements showed a difference of 6·5° between the single axis foot and the SACH foot measurements. The design of the single axis foot permits a greater range of plantarflexion and dorsiflexion around a transverse ankle axis with the range limited by posterior and anterior rubber bumpers. The SACH foot permits a limited range of plantarflexion through the compression of the posterior rubber heel insert. The remaining statistically significant lower limb joint angles were not considered clinically significant since a measurement difference of 4° or less was obtained.

The percentage of time of gait cycle for stance and swing phase of the prosthetic leg fell within the reported normal ranges of 60 and 40 per cent

Table 2. Velocity of centre of mass

Subject	Velocity m.s SACH foot	Single axis foot
1	1·17	1·16
2	1·31	1·33
3	1·41	1·26
4	1·06	1·25
5	1·15	1·34
6	1·39	1·18
7	1·23	1·27
8	1·04	0·99
$\bar{x}$	1·22	1·22
S.D.	0·13	0·11

(Drillis, 1958) and 62 and 38 per cent (Peizer et al. 1969) for stance and swing phases. Although the difference obtained was statistically significant, once again it was not felt to be of clinical significance.

Conclusion

In this study, interchanging the prosthetic foot on a prosthesis did not appear to have a significant effect on the gait patterns of unilateral below-knee amputees. The ankle of the prosthetic foot during the foot flat phase of gait showed a significant statistical and clinical difference.

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Research and development of functional aids

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Abstract

Four aids, developed by the Department for Research and Development from existing ideas and being used in Revalidatiecentrum "De Hoogstraat" by patients with a spinal cord injury, are described. These aids are: a dynamic elbow extension orthosis; a modified flexor hinge splint; a rolling writing aid, and a urinary device for females.

Introduction

Disabled people are confronted with many problems resulting from the loss of various functions. Solutions are sought for the problems they meet in everyday life and these may be found in surgery, physiotherapy or in the use of technical aids.

When developing aids, it is important to keep the user's abilities and needs in mind. To obtain a simple but functional aid, the basic requirements should first be outlined and then the aid designed to fulfill these requirements. This approach results in useful aids and with more experience may also be applied to the development of more complex aids.

Methods:

Criteria

The aim of development is to tackle the heart of the problem. In making an aid, one strives for the following goals:

lightweight
as small as possible
preferably without external power supply
silent
acceptable form
easy fitting
anti-allergy material
aesthetic value.

Some practicalities are:

use of standardized parts;
possibility of adjustment;
simplified assembly.

Fitting

User acceptance of an aid depends on a good fit, therefore attention should be paid to the following:

The distribution of pressure (force) on the body. The force must be perpendicular to the skin; the pressure on the skin must be lower than the systolic blood pressure in the capillaries ($< 0{\cdot}5\ N/cm^2$).

The positioning of the parts on the body: the axes of movement of the aid must correspond with those of the joints of the body.

Comfortable fit: i.e. snug fit, allowance for ventilation, easy to clean/hygienic, cosmetic.

The aim is to make a device/aid with adjustable and easily fitted parts.

Material

The material used for the devices described is thin-walled stainless steel tubing. This material has several advantages: sufficient strength, lightweight (and slender of structure), easily assembled and disassembled by brazing. Therefore, fitting adjustments and maintenance are easy to carry out.

Results

In general, the problems have been approached from a basic mechanical point of view as well as considering the importance of cosmetic aspects. Advanced techniques have not been used.

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Elbow extension orthosis

Patients with a C5 or C6 spinal cord injury have only active elbow flexion and no elbow extension. It is therefore rather difficult to prevent flexion contractures of the elbows, especially shortly after the spinal cord injury (Bedbrook 1981). Various methods are used to prevent these contractures e.g. maintaining full passive range of movement and (the use of) splinting. A year ago fitting of the elbow extension orthosis began. This is derived from an elbow flexion orthosis, designed for patients with a brachial plexus lesion, which was developed at the University of Technology in Delft (Cool, 1976). In the extension orthosis a spring provides the necessary extension force. The orthosis is easy to apply and may be fitted in the acute phase soon after the spinal cord injury to prevent flexion contractures.

The physiotherapist tries to teach the patient to consciously relax the flexors, thus reducing the flexion force. This allows the spring to pull the elbow into extension.

Therefore, by consciously contracting or relaxing his biceps, the patient is able to flex or extend his elbow which increases his abilities in activities of daily living.

Description

The orthosis (Fig. 1) is made so that with increasing flexion of the elbow, the pull in extension also increases. It is also possible, technically, to keep the extending force constant or to decrease it with increasing flexion.

With this method of achieving extension, there is some chance of causing an increase in spasm. However, by using the maximum force of the rubber band, possible in extension, the elbow can be kept in extension for better advantage. In this position spasm does not occur so readily.

It is not certain whether the orthosis causes an increase in muscle strength in biceps, thus not achieving the required result (Abrahams et al, 1979).

To achieve extension one can use a single hinge joint. If active pronation is also required, it may be necessary to use a hinge on both sides of the arm for additional strength. The fitted parts of the system were developed at the University of Technology in Delft. It consists of adjustable, hinged plastic fittings which provide an adequate distribution of pressure on the skin surface.

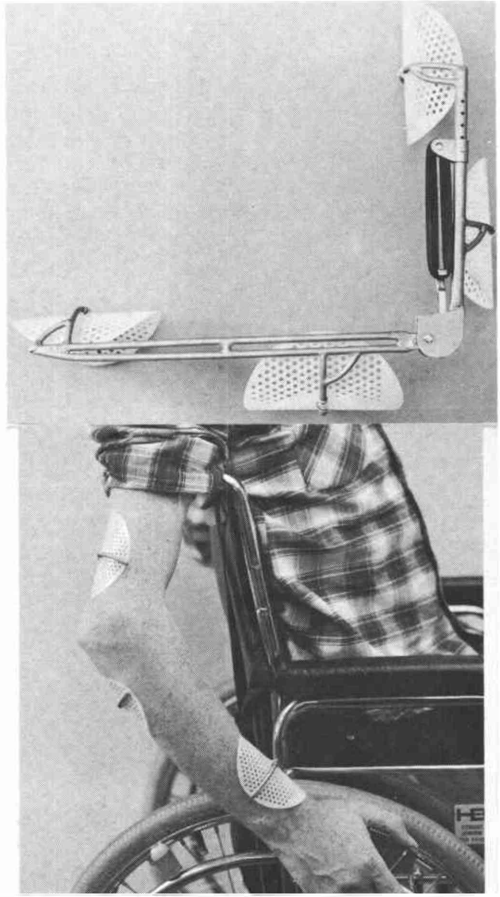

Fig. 1. Elbow extension orthosis. Weight 120 g; material, stainless steel and polyethylene; construction time 5–10 hours. Number issued 7, cervical lesions 5, others 2.

The plastic fittings are perforated to allow for ventilation. Normally they do not require padding and being plastic, they are hygienic.

As the orthosis is maintained in its correct position by spring tension, no straps are required. The tension of the rubber band is adjustable. The usual value of the torque of the spring is 1 Nm in 90° flexion. The maximum value is limited however by the acceptable pressure on the skin surface and the possibility of oedema.

This orthosis has only been used in seven cases. From this limited experience it has been learned that the orthosis should not be used for patients with a spastic paralysis as it causes increased spasticity in the elbow flexors.

On the other hand it seems a good solution for cases with flaccid paralysis, especially in the early phase.

Flexor hinge splint

Various types of flexor hinge splints are available. The many publications concerning this subject and the amount of research done in this field indicates the importance of prehension of the hand. The flexor hinge splint is used to obtain a pinch-grip between the thumb, in opposition, and the second and third finger. By extending the wrist, both fingers are passively flexed towards the thumb by means of a dynamic splint mechanism. In this way the patient is able to grip and release objects (Malick and Meyer 1978; Nichols et al. 1978).

A new splint of simple design and construction is described.

Description

If prehension occurs between thumb and fingers and the initiating movement takes place from the forearm, it must be sufficient to support the fingers, thumb and forearm only.

With the splint (Fig. 2) made as described, it is evident that with dorsiflexion of the wrist the fingers are passively flexed towards the thumb—immobilized by the splint. In this way a useful pinch grip is achieved by the use of minimum force. Yet, with strong dorsiflexion of the wrist, the fingers may slip out of the fittings. As the C6 lesions usually do not have a strong wrist dorsiflexion this will not happen. Thus this results in a flexor hinge mechanism which leaves the metacarpals free.

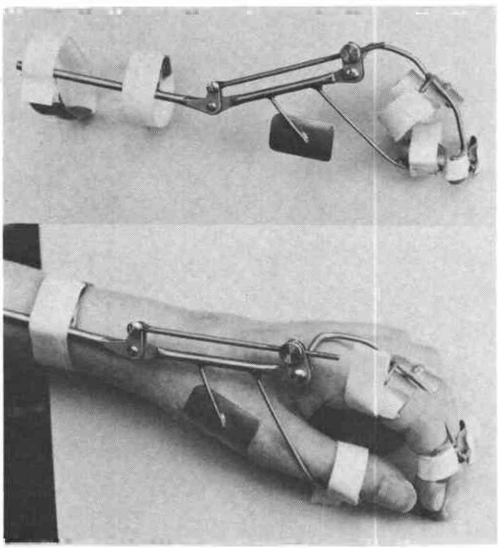

Fig. 2. Flexor hinge splint. Weight 90 g; material stainless steel; construction time 4–8 hours. Number issued 5.

An accurate fit is obtained because the small fittings on the fingers and thumb are separately adjustable. A future consideration may be the introduction of self-adjustable fittings. Velcro straps keep the fingers in the required position. As the straps are not very aesthetic, a better solution e.g. "clip on" fittings is being sought.

As the surface area of the fittings of the fingers and thumb are small, the corresponding areas of support on the forearm must also be small. As this splint fits snugly, there is no need to pad it, which improves its cosmetic appearance and is more hygienic.

During fitting the arm is placed on a special armrest which allows easy access to the required areas of the forearm and hand. Thus the construction time is about four hours. It is possible to use a spring assist consisting of one or more elastic bands, if the dorsiflexion of the wrist is too weak.

The new flexor hinge splint has been issued in 5 cases. The most important advantage of the orthosis is that it is easily fitted and therefore can be assembled soon after referral.

It is a well-known fact that the earlier splints are supplied, the better they are used. Another advantage is that this flexor hinge splint is more aesthetic than the old type and therefore more readily accepted.

Rolling writing aid

Writing is a tiring activity for patients who lack sufficient muscle power to lift the hand, due to the friction of the hand shifting over the paper. The rolling writing aid (Fig. 3) has been developed in order to decrease this resistance. Due to the wheeled support of the hand, the person is able to write legibly using shoulder and upper arm movements. The hand is placed on the support, which rolls by means of two ball-bearing fittings attached to the support. The ballpoint-pen provides the third support, thus forming a stable base. The ball-bearing fittings are placed in such a position that the hand can be tilted in order to lift the ballpoint-pen off the paper. The advantage of this aid is that the patient can rest his hand on the splint and therefore need not support his whole arm and hand with his own muscle power while writing. This aid has been supplied in 12 cases. No pressure sores have been observed.

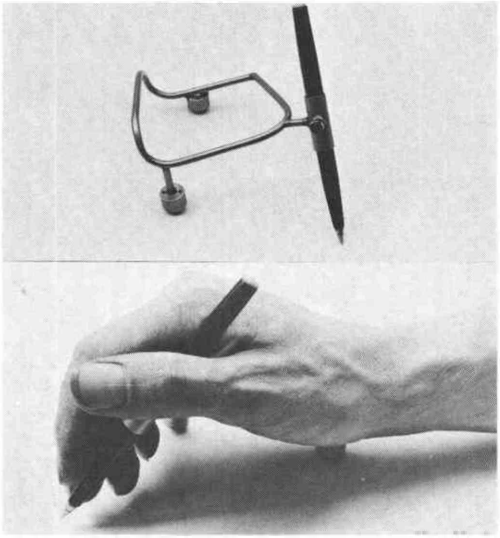

Fig. 3. Rolling writing aid. Weight (with pen) 45 g; material stainless steel. Number supplied 12.

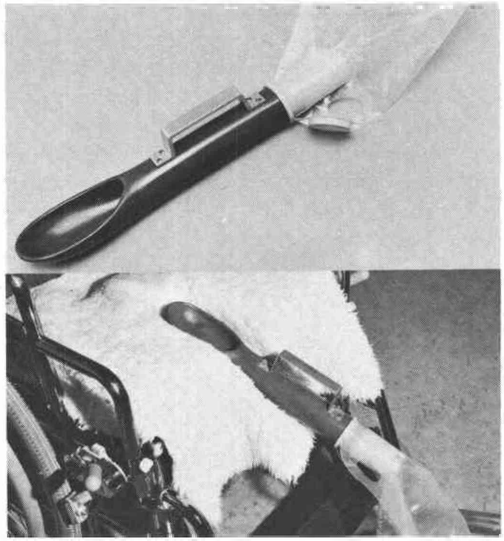

Fig. 4. Urinary device. Weight 400 g; material PVC tubing 50 × 450 mm. Number issued 30.

Urinary device for females

With this urinary device, females are able to void while seated in the wheelchair. Without this aid, the person would have to transfer to the toilet or use a catheter with its attendant increased risk of infection.

If the patient uses the lavatory, it should always be accessible for a wheelchair-bound person, which is not always the case. Due to the effort made when transferring to the lavatory, the person may void spontaneously.

If the urinary device is used, the patient avoids all the above mentioned problems.

Description

The urinary device (Fig. 4) has the advantage that it is relatively small and easy to handle. The one that is being used at present is being developed and is still undergoing modification.

The urinary device consists of a plastic tube with an oval opening at one end, and a plastic urinary bag attached to the other end. The urinary bag can be closed after use.

When using this urinary device, the person has to slip forward in the wheelchair so that she is half-lying. In order to keep the urinary device sloping downwards, a removable centre piece is made in the wheelchair cushion.

Instead of having to take off the trousers, the patient uses an extra long zip. Usually the underpants have enough stretch to allow use of the urinary device, but if not, the underpants may be adapted with zips or Velcro. The urinary device is then placed under the body and pressed downwards with one hand, while the other hand is used to stimulate the bladder (by tapping or constant pressure) to void.

This device has been used in about 30 cases. It is very useful because it means that female patients need not be dependent on a catheter with its risks, in addition they are also not dependent on a wheelchair-adapted toilet.

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Effects of alignment variables on thigh axial torque during swing phase in AK amputee gait

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Abstract
It is suggested that a major source of discomfort for above-knee amputees during the swing phase of walking, is the thigh axial torque (TAT) transferred at the stump–socket interface. The relation between TAT and variations in its six relevant alignment adjustments, has been investigated. A computerized routine has been established which indicates optimum choice of alignment setting, based on minimal TAT peaks. Feasibility for attenuating swing phase TAT has been demonstrated in three simulated patterns of amputee gait. As a conclusion, it is suggested that a useful clinical tool could be based on the presented alignment optimization procedure and may be expanded to include other factors associated with swing and stance phase comfort and performance.

Introduction

Dynamic effects which occur during the swing phase of walking, of above-knee (AK) amputees frequently cause a sensation of discomfort which is closely related to the thigh axial torque (TAT) transferred at the stump–socket interface, and to the associated shear stresses and angular displacement between the socket and the femur. Time characteristics of the TAT is a function of leg kinematics, mass properties of the prosthetic shank, and of knee-bolt and shank alignment with respect to the socket. The susceptibility of the amputee to TAT during swing phase is higher than during the stance phase due to inertia and gravity loosening the stump socket attachment while the prosthetic leg is swinging forward.

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The kinematics of the prosthetic leg during swing phase is governed by the amputee so as to fulfil functional requirements, such as cadence and ground clearance control. Because his ability to compensate for discomfort associated with TAT is limited, due to loss of voluntary knee control, it is the responsibility of the prosthetist to align the shank and knee-bolt in an optimum manner satisfying both comfort and functional considerations.

New York University (1979) and Radcliffe (1955, 1968), relate to the kinematic phenomenon associated with the TAT, namely, the internal or lateral "whips". Radcliffe states that an artificial leg must usually have the axis of its knee bolt rotated externally about the thigh axis by as much as 5 degrees to compensate for the tendency of the stump to rotate internally during the swing phase and to minimize whip. Two other adjustments which are referred to by Radcliffe (1968) as critical for proper alignment are the amount of abduction of the shank with respect to the socket, affecting both stance phase medio-lateral stability and swing phase TAT, and the inset and outset of the foot which is mainly concerned with whip at the beginning and end of the stance phase. Clinical experience indicates that these guidelines are inapplicable in some complicated cases where final settings are arrived at after many trials. These tire the patient, and moreover, the end result may not fully satisfy the patient and the prosthetist. The source of the problem is mainly due to variability in amputees' gait pattern and in stump musculature as well as the intricate spatial motion of the prosthetic leg, which make achievement of an alignment optimum too complicated without the assistance of quantitative measurements and assessments. Objective measurements via appropriate tools or models may be useful in the clinic only if they determine the magnitude of kinetic variables most closely related to discomfort level and performance in walking, as well as indicate the desired changes in the alignment adjustments.

A previous study (Ishai and Bar, 1981) established a mathematical model, representing the relation between alignment setting and TAT, known to be one of the major causes of discomfort during swing phase. In the present work, TAT characteristics were investigated as a function of gait pattern, and an optimization routine was developed to indicate an alignment setting.

Determination of TAT

Mathematical model

A mathematical model of the swinging prosthetic leg (Ishai and Bar, 1981) determined TAT-time variations. The principle of operation of the model is shown in Figure 1. The values of the alignment variables together with the instantaneous knee flexion angle, determine shank–thigh position at each instant of time. These relative positions together with the measured absolute kinematics of the thigh, are used to determine shank spatial kinematics. The force and moment exerted on the shank by the thigh, at the uppermost point of the shank axis, is calculated using the shank equations of motion. The resultant solution is the torque transferred from the shank to the thigh about the thigh axis (−TAT).

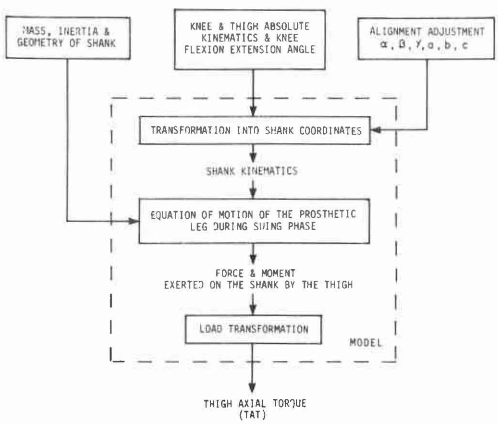

Fig. 1. The mathematical model used to determine thigh axial torque (TAT) characteristics during swing phase.

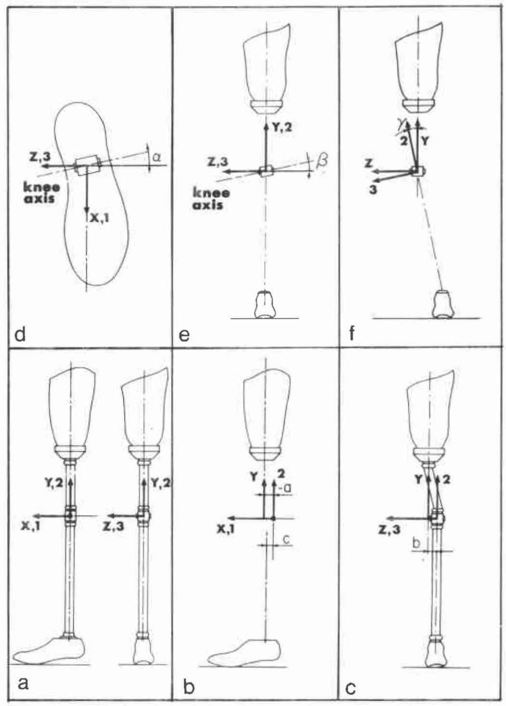

Fig. 2. Definition of alignment variables which affect the swing phase thigh axial torque (TAT).

Alignment variables

A set of six alignment variables has been defined, representing the relevant adjustments which affect the swing-phase TAT (Fig. 2). An $\{X, Y, Z\}$ system of coordinates is attached to the socket of the prosthesis. The Y-axis is the socket's central axis and the Z-axis is parallel to the instantaneous flexion-extension axis of the thigh, referenced to the pelvis. A $\{1, 2, 3\}$ system is attached to the prosthetic shank with the 2-axis coinciding with the shank axis. In the "zero-alignment" state (Fig. 2a), where all alignment variables are set to zero, the two systems of coordinates are coincident.

The alignment variables are:

a and *b* which define knee centre location in the X–Z plane: *a* represents the location along the X and *b*, along the −Z direction (Figs. 2b and 2c)

α and β which define the orientation of the knee bolt relative to the thigh system (Figs. 2d and 2e): α represents the external rotation angle of the knee-bolt about the Y-axis, and β the angular inclination of the knee-bolt with relation to the X–Z plane.

c and γ define the position of the shank with respect to the thigh system (Figs. 2b and 2f): the c adjustment is achieved by shifting the shank forward with respect to the knee bolt. The angle γ is formed by the shank axis relative to the X–Y plane while standing ($\theta_K = 0$).

It should be noted that some alignment systems do not allow the adjustment of all the 6 parameters mentioned, and that each alignment parameter does not necessarily correspond to a single degree of freedom in the alignment device.

Leg kinematics and mass properties of the prosthesis

Due to the unavailability of spatial kinematic data of AK amputees' gait, the kinematic inputs introduced to the model were based on normal gait data published by Lamoreux (1971). In cases where amputees' typical gait patterns were investigated, the normal data were modified: to simulate a case where the amputee has an abducted stump, a constant abduction was added to the normal abduction–adduction angle between thigh and pelvis, at each instant of time. The simulation of circumducted gait was carried out by multiplying the normal thigh abduction–adduction data by a constant factor.

Geometrical dimensions and mass properties of the prosthetic shank are similar to a USMC AK prosthesis type U.S. Universal Multiplex Mark V.

TAT optimization

The TAT simulation based on the mathematical model in Figure 1, may be used in the clinic in the search for an optimum alignment setting which causes minimal peak values in TAT characteristic during swing phase. Using measured leg kinematics and mass properties of the prosthetic shank, the mathematical model may be used to estimate the time change of the TAT for all possible combinations of alignment setting. The setting which results in minimal peak values of TAT is chosen as optimum. The foregoing procedure was found to be time consuming and impractical for clinical use, because it demanded excessive computer time to determine TAT at each alignment setting. In the search for a shorter optimization procedure the relation between TAT and the alignment variables was investigated.

The TAT at zero alignment in the normal, abducted and circumducted gait patterns, are shown in Figure 3. TAT sensitivity to unit variations in the alignment variables about the zero alignment state (1 degree in α, β, γ and 1 cm in a, b, c), is depicted in Figure 4, for each of the walking patterns. There is a fundamental difference between the effects on the swing phase TAT of changes in the γ and b adjustments and of changes in α and β. γ and b cause the shank axis to lie outside the X–Y plane during walking. Both the orientation of the shank axis and the distance of the shank centre of mass from this plane remain constant during the whole walking cycle. On the other hand, α and β cause the orientation of the shank axis with relation to the X–Z plane to change as a function of the magnitude of knee flexion. The greater the knee flexion, the larger the angular deviation of the shank axis relative to the X–Z plane. This difference is expressed in TAT characteristics at the beginning and end of swing phase where TAT values are noticeably higher for a change in γ and b as compared to those obtained by changes in α and β. It should be noted that a numerical filter with a 7 Hz cutoff frequency was used to smooth the kinematic information during data processing and may have filtered out the expected high frequency contents at knee full extension impact near the end of the swing phase. It is expected that contributions to TAT of the γ and b deviations from zero adjustment, would be even larger than those obtained by the simulation.

It is evident that while the sensitivities to α, β, γ and b variations are practically invariant with the investigated walking patterns, the sensitivity of TAT to variations in the a and c adjustments is largely influenced by the investigated gait

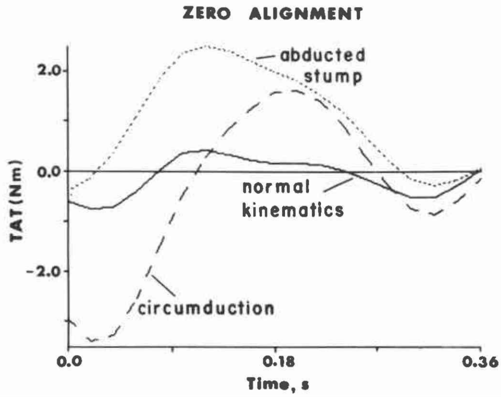

Fig. 3. Thigh axial torque (TAT) during the swing phase in normal gait and in simulated abducted and circumducted amputee gait, at zero-alignment setting.

patterns. This is explained by the a and c adjustments affecting the antero-posterior (X-direction) placement of mass elements of the shank relative to the thigh, thus influencing the magnitude of the moment-arm about the thigh axis, and of medio-lateral (Z-direction) "inertia-forces" acting on the shank. Since the walking patterns mentioned above differ in medio-lateral character of motion, and subsequently in the characteristics of medio-lateral inertia force acting on the shank, the TAT sensitivity to variations in the a and c adjustments is largely affected by the walking patterns. Conversely, since α, β, γ and b adjustments influence the positioning of mass elements of the shank in the Z-direction, the TAT sensitivity to these alignment variables is practically unaffected by the changes in the walking patterns.

TAT sensitivity to alignment variations was investigated in a wide range of simulated alignment adjustments: α, β and γ, -8 to $+8$ degrees,

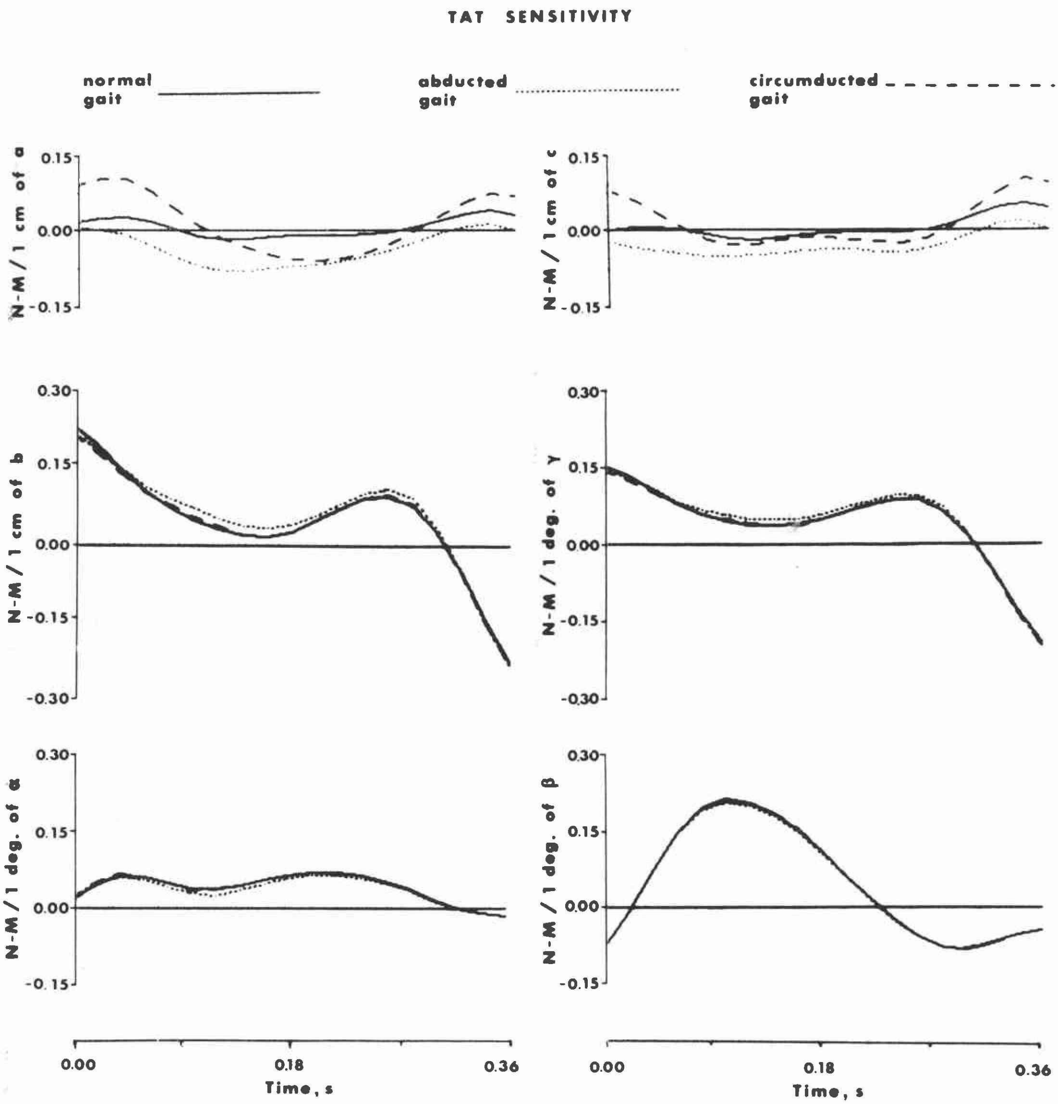

Fig. 4. Thigh axial torque (TAT) sensitivity to unit variations in the alignment variables (1 degree in α, β, γ and 1 cm in a, b, c) about the zero-alignment state.

a and c -5 to $+5$ cm, and b from -8 to $+8$ cm. By introducing unit variations to the alignment variables within these ranges, it was found that deviations of the α, β, γ and b sensitivities from the respective zero-alignment sensitivities, were less than 5%. Conversely, the sensitivity to unit variations in a and c was found to vary significantly within the alignment range. Since the values of the a and c adjustments are usually predetermined from stance phase considerations (as they play an important role in achieving knee stability), their values may not be changed in the optimization of swing-phase TAT.

TAT (denoted by T) is a function of time t and of the six alignment variables:

$$T = T(\alpha, \beta, \gamma, a, b, c, t) \qquad (1)$$

The total differential of T for constant t is given by:

$$dT = \frac{\partial T}{\partial \alpha} d\alpha + \frac{\partial T}{\partial \beta} d\beta + \frac{\partial T}{\partial \gamma} d\gamma + \frac{\partial T}{\partial a} da + \frac{\partial T}{\partial b} db + \frac{\partial T}{\partial c} dc \qquad (2)$$

Since the sensitivity of TAT to variations in α, β, γ and b is practically constant throughout the alignment range and as a and c are constrained by stance–phase considerations and are kept constant in the optimization process:

$$dT(t) = S_\alpha(t)\,d\alpha + S_\beta(t)\,d\beta + S_\gamma(t)\,d\gamma + S_b(t)\,db \qquad (3)$$

where $S_\alpha(t)$, etc., denote the sensitivity characteristics of TAT to unit variations in α, β, γ and b, which are independent of the values of the alignment variables. The TAT, therefore, may be determined by:

$$T(\alpha', \beta', \gamma', a, b', c, t) = T(\alpha, \beta, \gamma, a, b, c, t) + S_\alpha(t).\Delta\alpha + S_\beta(t).\Delta\beta + S_\gamma(t).\Delta\gamma + S_b(t).\Delta b \qquad (4)$$

The meaning of equation 4 is that the TAT for any combination of the alignment variables $(\alpha', \beta', \gamma', a, b', c)$ may be estimated from a given TAT and its sensitivities at another setting $(\alpha, \beta, \gamma, a, b, c)$, providing that a and c are kept the same at the two settings. This equation replaces the mathematical model of Figure 1 in the iterative process of TAT optimization. As a result, the optimization procedure is significantly shortened (only a few minutes), because the lengthy calculations involved in the mathematical model are carried out for just the determination of TAT sensitivities and characteristic at the initial setting.

Results

The TAT-simulation of Figure 1 and the optimization routine of equation 4, were used to test their feasibility in optimizing prosthetic alignment in three cases, each representing a different simulated gait pattern.

Case 1. Normal hip and knee kinematics; 7 cm effective shank valgus

In the conventional alignment procedure, adjustment of γ and b both serve to control the medio-lateral position of ground reaction relative to the hip joint during the stance phase of walking. These control medio-lateral stability and regulate load transfer characteristics to the stump. The result of the b and γ deviations from the zero-adjustment is, therefore, an "effective valgus (or varus)", defined as the resulting medio-lateral shift of the foot from the X–Y plane. An effective valgus may be achieved by an alignment device located immediately above the knee bolt ("lower-thigh device"), or alternatively, by a device located just below the knee ("upper-shank device"). For the former, in addition to shin abduction (γ), the knee bolt is angularly tilted by $\beta = \gamma$; in the latter, the knee bolt remains perpendicular to the thigh axis ($\beta = 0$). For example, an effective valgus of 7 cm may be achieved by a lower-thigh device, having $\beta = \gamma = 7{\cdot}2$ degrees, at a shank length of 55 cm. Stance requirement for knee stability usually dictates a negative setting of a, while the shank axis coincides with the thigh axis at standing, i.e.: $c = -a$. In the present example a and c were $-1{\cdot}5$ and $+1{\cdot}5$ cm, respectively. The resulting TAT, which is depicted in Figure 5, shows peak values of $+2{\cdot}31$ and $-1{\cdot}61$ N-m. The same effective valgus may be obtained by setting $\beta = 0$ and $\gamma = 7{\cdot}2$ degrees, using an upper-shank device. It is clear from Figure 5 that the upper-shank device is preferred, as it gives a markedly lower positive peak value of 0·82 N-m (in the direction of outward rotation about the thigh axis). Using the optimization routine based on equation 4, the setting of $\alpha = -2$ degrees, $\beta = -7$ degrees, $\gamma = 7{\cdot}2$ degrees and $b = 0{\cdot}0$ cm, gave even lower peaks. In the optimization procedure α, β and γ were varied in 1 degree increments over a range of ± 8 degrees. b was determined by the constraint equation:

$$b = EV - l.tg\gamma$$

where EV is the effective valgus of 7 cm, and l the

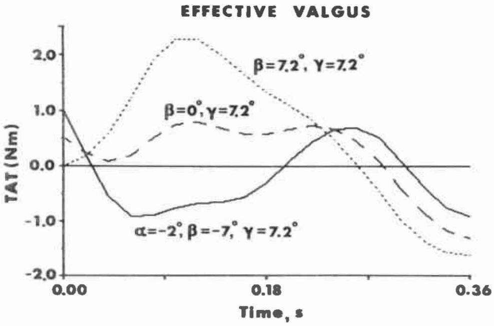

Fig. 5. Thigh axial torque (TAT) during the swing phase, for normal thigh and knee kinematics and with a 7 cm effective valgus of the prosthetic shank. In all settings a and c have the same values as in the reference state, i.e. $a = -1{\cdot}5$ cm and $c = +1{\cdot}5$ cm.

shank length of 55 cm. b was limited to the range of ± 5 cm.

Case 2. Abducted stump

A typical case often met in the clinic requiring special attention, vis-à-vis TAT attenuation, is that of the abducted stump amputee. For example, a 12 degrees of abduction was simulated as previously described where a and c were set to $-1{\cdot}5$ and $+1{\cdot}5$ cm, respectively, to fulfil stance requirements. Figure 6 is the resulting TAT, for the case where all other alignment variables are set to zero. Unfortunately, this setting is usually unacceptable for both stance and swing phase considerations, and it being necessary to medially shift the foot with respect to the thigh. A 7 cm shift results by making $\gamma = -7$ degrees utilizing the upper-shank alignment device. The resulting TAT (Fig. 6), has peak values of $+2{\cdot}2$ and $-1{\cdot}45$ N-m. Using the lower-thigh device, instead of the upper-shank device, to obtain the same medial shift of the foot, i.e., $\beta = \gamma = -7$ degrees, results in a TAT peak reduction to $+1{\cdot}8$ and $-1{\cdot}0$ N-m (18% and 28% attenuation in the positive and negative peaks respectively). Further attenuation of the positive TAT peak to 1·5 N-m, which occurs at the end of the swing phase, is obtained by using optimization routine, as in case 1. Nevertheless, it should be noticed that the further reduction of 14% in TAT peaks (having the $\gamma = -7$ degrees as reference) causes a significant increase of TAT magnitude near mid-swing.

Case 3. Circumducted gait

Another pattern of amputees' gait associated with high TAT magnitudes, is circumducted gait, e.g., the exaggerated medio-lateral movements of the leg in this gait pattern were simulated by multiplying thigh abduction by a factor of 2·0. The resulting TAT (Fig. 7), demonstrates high peak values of $+1{\cdot}8$ and $-3{\cdot}5$ N-m, at the reference setting of $\alpha = \beta = \gamma = b = 0{\cdot}0$, $a = -1{\cdot}5$ cm and $c = +1{\cdot}5$ cm. In this case the high TAT magnitude cannot be significantly reduced by the limited available adjustment range of α, β, γ and b, because of low TAT sensitivity to these parameters. The peak values can be attenuated by shifting the knee centre forward, together with the shank, i.e., by making a more positive and setting c to zero; as depicted in Figure 7, by setting α, β, $\gamma = 0$, $a = 5$ cm, $b = 3$ cm and $c = 0$ cm, a 22% and 34% attenuation is obtained in the positive and negative peaks, respectively. This alignment is unacceptable in commonly used prostheses, because it contradicts the stance phase

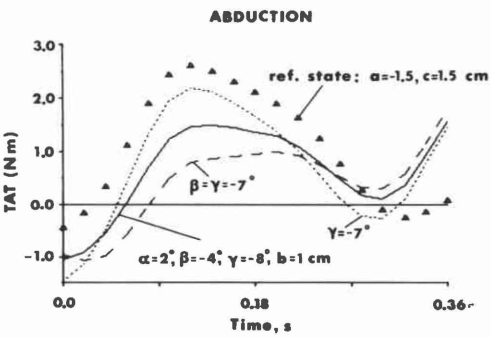

Fig. 6. Thigh axial torque (TAT) during the swing phase, in a simulated gait of an amputee with a 12 degrees abducted stump. In all settings a and c have the same values as in the reference state, i.e. $a = -1{\cdot}5$ cm and $c = +1{\cdot}5$ cm.

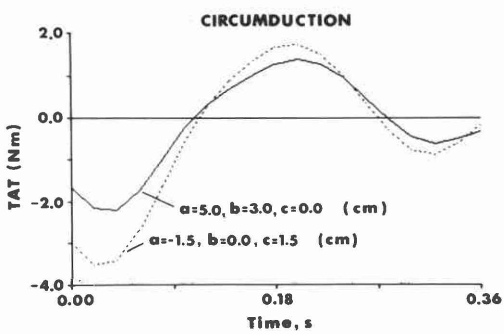

Fig. 7. Thigh axial torque (TAT) during swing phase, in circumducted amputee gait. Circumduction was simulated by multiplying normal thigh abduction angle by a factor of 2. In the two settings $\alpha = \beta = \gamma = 0°$.

stability requirement. However, it may be beneficial for amputees with circumducted gait to have a knee mechanism which allows a positive a-setting. One possibility is a control system which ensures knee locking during the weight-bearing phase, even for a positive a-setting. An alternative is a polycentric knee design having a negative a-setting at full extension which becomes positive with knee flexion.

Discussion and conclusion

1. A mathematical model estimates the thigh axial torque (TAT) during the swing phase of walking, for measured leg kinematics and alignment setting. The model, together with the optimization routine, potentially form a clinically efficient "tool", quickly predicting a final optimum alignment setting.
2. Where determination of TAT may be accomplished by a "pylon transducer" (Berme, 1976) installed in the prosthetic shank and knee goniometer, alignment optimization is made simpler. The reference TAT and the four sensitivity curves (S_α, S_β, S_γ and S_b) are obtained from five successive gait trials. The required changes in alignment are subsequently predicted by the optimization routine, using equation 4. It should be noted that, in this case, the initial alignment setting is not involved in the optimization process and, therefore, need not be measured.
3. The results obtained in cases 1 and 2 indicate that both lower-thigh and upper-shank alignment devices should be used to achieve optimum setting.
4. Because of an absence of rigorous definition of the interaction between TAT and patient comfort, the present paper bases optimum alignment in terms of TAT peak reduction. When defined, an expanded form of optimization criteria, presumably involving parameters such as TAT derivatives and integral, may be incorporated in the optimization procedure.
5. Modified simulated kinematics for normals were introduced to the model of the swinging leg. The optimization procedure will be verified in clinical alignment routines, using measured amputee data in the model. The procedure will be expanded to include other swing and stance phase considerations.

Acknowledgements

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Technical note—modified above-knee socket to relieve anterior pressure caused by abdominal hernia

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Abstract

The plastic quadrilateral socket has a high anterior brim which can cause considerable discomfort in some patients, especially when seated. A simple modification to the anterior brim is described allowing a female patient with a huge abdominal hernia a considerable degree of comfort when both sitting and standing. The creation of a large radius producing a wide area for adequate pressure relief proved valuable. This might be considered for patients with less pendulous abdomens who find conventional methods inadequate.

Problem

A 58 year old lady with peripheral vascular disease had an above-knee amputation. The healing of a cholecystectomy operation was modified by concurrent steroid therapy and a huge ventral abdominal hernia resulted. Conventional prosthetic management did not accommodate the problems generated by the hernia.

Prosthetic management

This patient had a particular problem with the above-knee prosthesis, caused by her pendulous abdomen. When seated, she experienced great discomfort from the anterior brim of the quadrilateral socket. The standard solution to this would be to increase the anterior flare of the brim. This solution proved unsatisfactory as a wide enough flare was not easily attained at cast rectification due to subsequent laminating difficulties, so an alternative solution was sought to redistribute the pressure. Several layers of Plastazote were built up externally on the anterior aspect of the socket, extending over the socket brim, then shaped to increase the radius of the anterior flare. This, as shown in Figure 1, greatly increased the pressure bearing area and thus spread the load from the pendulous abdomen and reduced the discomfort.

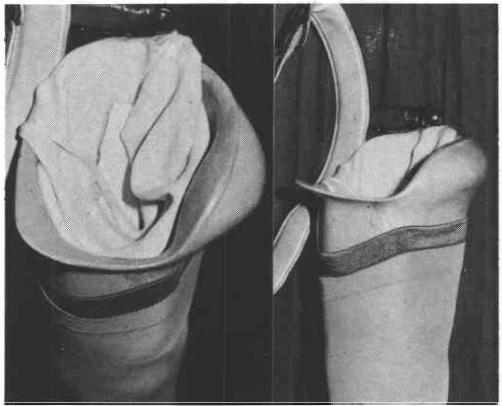

Fig. 1. Quadrilateral socket with anterior Plastazote build up.

Discussion

The amputee population is an aged one. In Dundee 76·1% are over 65 years old and of these, 27·8% are at an above-knee level. The patients are less active than their younger counterparts and spend increasing periods of time seated. Many patients wearing above-knee prostheses with a quadrilateral socket have discomfort over the high anterior brim, in particular during the stance phase and on sitting. During the stance phase considerable force is passed through this area of the socket and in patients with pendulous abdomens considerable problems arise at the interface between the brim of the socket and the anterior abdominal wall. While seated these forces are greatly increased when the abdomen and anterior brim are in close proximity. In some cases, this discomfort is relieved by flaring the brim to allow a greater area for pressure redistribution. The anterior

All correspondence to be addressed to Dr. C. P. U. Stewart, Tayside Rehabilitation Engineering Services, Dundee Limb Fitting Centre, 133 Queen Street, Broughty Ferry, Dundee DD5 1AG, Scotland.

brims are generally suitable for standing patients and are biomechanically sound, however, when seated considerable discomfort can arise. Patients who sit for long periods frequently complain of pain which is often not completely relieved by simply flaring the brim. In the case described discomfort occurred both when standing and when seated and it was found that a large area was necessary to redistribute the pressure and this could not be achieved by conventional means. The construction of a built up Plastazote flare provided a large enough area to achieve satisfactory relief of discomfort allowing the patient to walk independently and sit in comfort. The patient described had a fairly severe problem caused by the incisional hernia. However, many patients with less pendulous abdomens do not get satisfactory relief from the simple conventional method of flaring the anterior brim of the socket. The design of the quadrilateral socket does not adequately take into consideration the problems of the seated patients and the solution described above might well be applicable to many other patients, in particular the elderly, for whom comfort has not been achieved.

Acknowledgements

We are grateful to Dr. I. M. Troup and Mr. D. N. Condie for their constructive criticism, Mrs M. Gruber for producing the illustration and Mrs M. Copland for typing the script.

Prosthetics and Orthotics International, 1983, 7, 50–51

Technical note—a wheelchair ergometer for assessing patients in their own wheelchairs

W. M. MOTLOCH and M. N. BREARLEY*

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**RAAF Academy, University of Melbourne, Victoria, Australia*

Abstract
There is a need in Physical Therapy Departments of hospitals for an inexpensive ergometer which can be used to gauge the improvement in the physical performance of a wheelchair occupant in his or her own chair. This technical note describes such a device.

Introduction

In response to a request from the staff of the Physical Therapy Department of the Ralph K. Davies Rehabilitation Center in the Franklin Hospital, San Francisco, for an inexpensive ergometer for use by patients in their own wheelchairs, the authors of this article devised and made the device here described.

The requirement was for an ergometer which could be used to make a quantitative judgement of the improvement with time of the power output of each patient while operating his or her wheelchair. To prepare patients for the hilly terrain of San Francisco, the fore and aft inclination of the chair while on the ergometer was to be variable so as to simulate operation on slopes ranging from 6° upwards to 6° downwards.

Other required features were continuous read-outs during the test of the equivalent distance travelled by the wheelchair, and of the pulse rate of the patient.

The mechanical system

At the front of the ergometer is a short steep ramp (Fig. 1) up which the wheelchair must travel backwards, the aid of an attendant usually being required. The main wheels of the chair come to rest between two pairs of rollers 15 cm (6 in) in diameter, which are mounted on two parallel horizontal shafts supported on self-aligning ball bearings. The attendant locks the chair in this position by clamping the castor wheels between two restraining bars and then tightening wing nuts which hold the ends of these bars down on the ramp (Fig. 2).

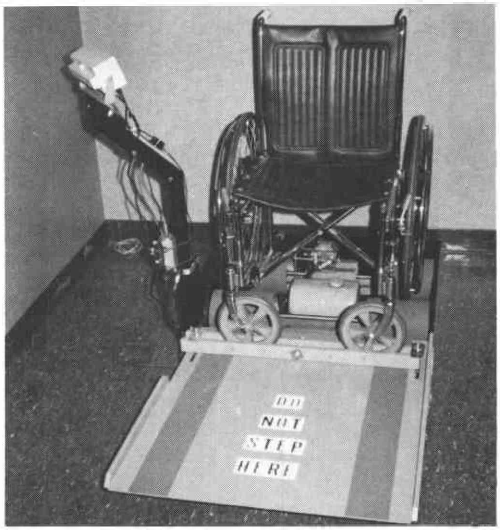

Fig. 1. Front view of the ergometer.

When the occupant of the chair pushes forward on the main wheels or their hand rims, the rollers and their supporting shafts rotate. The front shaft revolves freely in its bearings, and the rotation of the rear shaft is resisted by a closed hydraulic system consisting of a reservoir, a pump and a regulator valve. By rotating the valve, the resistance to the rotation of the rollers can be varied over a large range.

To save expense, the hydraulic system from a commercial exercise cycle was used in its entirety. The drive from the rear roller shaft to the pump is by way of a polyurethane timing belt

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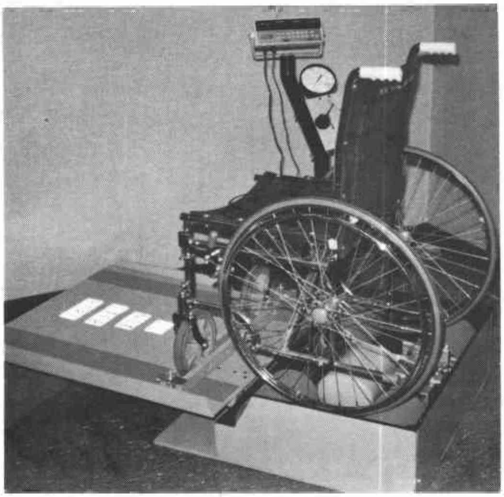


Fig. 2. Side view of the ergometer, ramp raised to horizontal position.

and aluminium sprockets. The gear ratio was chosen so that one complete revolution of the wheelchair main wheels produces the same number of revolutions of the pump axle as did one complete revolution of the bicycle pedals. This quite arbitrary choice was unimportant, as indeed was any calibration of the system, since the wheelchair ergometer is to be used only to compare the performance of each patient with his or her own performance on successive days. Likewise it was considered unnecessary to take any account of the inertia and resistance of the rollers and their axles, and of the additional tyre resistance due to indentation by the rollers.

The fore and aft inclination of the wheelchair may be varied between the limits $\pm 6°$ by altering the angle of the ramp on which the castor wheels rest. The ramp is hinged at its top edge, and a mechanical jack beneath the ramp enables the ramp to be rotated up about this edge. When the ramp is horizontal, so is the wheelchair under test. The castor wheel locking device should be released from the ramp while a change is made in the angle of the ramp. To make the ergometer more compact for storage purposes, the ramp can be raised past the vertical, where it rests against a stop, and the arm carrying the instrument display can be rotated inwards.

The equivalent distance travelled by the wheelchair during the test is determined by the rotation of a small wheel which rests on one of the supporting rollers. This device was also part of the exercise cycle equipment.

The display console

The hydraulic system includes a gauge which registers the power output of the chair occupant in the units of kilopon metres per minute. Since a kilopon is the weight of a mass of one kilogram, this power unit is a gravity-dependent one; it is approximately equal to 1/6 watt. Because of the intermittent nature of the effort applied to the wheels of a chair by the occupant, the power gauge reading also pulsates; it is easy, however, to observe the peak value of the power at each stroke, and this is a suitable measure for daily comparisons. The gauge of the regulator valve carries marks listed as '30,60,90,120,150 pedal revolutions per minute'; the pointer of the valve is turned to the number appropriate to the capacity of the patient; the smaller the number, the greater the resistance.

The instrument console gives a digital display of the equivalent distance travelled by the wheelchair, and of the pulse rate of the patient. The latter information comes via a colour-sensing light cell which is clipped to the ear lobe of the patient, and is also part of the exercise cycle equipment.

Conclusion

The wheelchair ergometer here described is very simple in concept, and because it is based on the hydraulic and electrical components of a commercial exercise cycle it is inexpensive. A final verdict on its value must wait on the results of a programme of patient testing by the hospital staff who are using it, but it appears promising enough to be reported at this stage.

Prosthetics and Orthotics International, 1983, 7, 52

Book Review

Symposium on total joint replacement of the upper extremity. A. E. Inglis (Ed.) American Academy of Orthopaedic Surgeons. Published by C. V. Mosby Co., 1982.

This clearly set out book is divided into four parts; part one summarizes the therapy of rheumatoid disease, describes basic anatomy and surgical approaches to the shoulder and elbow; indications, technique, limitations and danger points are emphasized.

Part two is devoted to the shoulder. The biomechanics behind prosthetic replacement of the gleno-humeral joint preceeds description of the Trispherical and the Neer non-constrained prostheses detailing their structures, indications, surgical techniques and results.

Part three deals with the elbow. Evolution of the modern American total elbows, e.g. the semi-constrained metal to polyethylene Mayo, Pritchard-Walker, Tri-axial, Coonrad, Voltz and Schlein; total unconstrained metal to polyethylene resurfacing implants such as the Ewald and the London is described. The Mayo and Voltz prostheses include a radial head in their design. The Stevens-Street hemi-arthroplasty resurfacing the lower humerus is mentioned.

A series of papers illustrates the development, biomechanics, surgical use, complications and results of each. In addition to the usual implant complications, triceps muscle rupture and ulnar palsy pose additional problems in some series.

Some interesting suggestions on revision surgery after failed elbow arthroplasty are made. Hopefully the new era implants will not require these measures. Elbow arthroplasty has been regarded as a salvage procedure. Perhaps the disease is being treated too late; future prostheses capable of use at an earlier stage of the disease may be more therapeutic.

In an interesting chapter on biomechanics, compression loading of the radio-humeral joint, its enhancement by the hand musculature and its relevance to implant design is perhaps under emphasized.

Part four reviews the hand and wrist. There is an excellent section on the production of the ulnar drift. The Steffee, Shultz and Swanson metacarpo-phalangeal joint replacements are presented. Detailed post-operative rehabilitation programmes for the metacarpo-phalangeal and the proximal interphalangeal flexible implants are given; stress is laid on dynamic bracing with illustrations of orthoses.

The developments of the Meuli, the Spherical-tri-axial, the Voltz total wrist prostheses and the Mayo metacarpo-trapezio arthroplasty are given. The value of even a limited range of wrist movement over the rigidity of an arthrodesis is stressed, e.g. perineal toilet. The lower rate of dislocation encourages one to persist in the future development of such prostheses.

Finally the hypothesis underlying the Swanson flexible radio-carpal arthroplasty and the technique of insertion is discussed; being cementless makes revision easier. Such revision may be needed, e.g. recurrent synovitis; no mention is made of hypersensitivity to silicone implants.

Summary

An excellent book for those trainee and established orthopaedic surgeons with a special interest in the upper limb. It is presented by a distinguished group of surgeons of recognized expertise in their respective fields. The problems discussed suggest that perhaps only those with special experience or undergoing training in such surgery should involve themselves in it. For such surgeons the detail, wealth of knowledge and experience presented in this book will enhance their ability to utilize the various ingenious devices to the full benefit of the patient.

J. H. Miller, FRCS,
Glasgow, Scotland.

Prosthetics and Orthotics International, 1983, 7, 53–56

Calendar of events

New York University Medical Center
Prosthetics and Orthotics Short Term Courses 1983

Courses for Physicians and Surgeons

751 C Lower-Limb and Spinal Orthotics, 9–13 May, 1983.
744B Upper-Limb Prosthetics and Orthotics, 6–10 June, 1983.

Courses for Therapists

752 C Lower-Limb and Spinal Orthotics; 9–13 May, 1983.
742 C Lower-Limb Prosthetics; 16–27 May, 1983.
757 Upper-Limb Orthotics; 20–24 June, 1983.
745 Upper-Limb Prosthetics; 27 June–1 July, 1983.

Courses for Orthotists

758 Upper-Limb Orthotics; 31 May–10 June, 1983.
753 Lower-Limb Orthotics; 5–22 July, 1983.

Courses for Prosthetists

743 Above-Knee Prosthetics; 13 June–1 July, 1983.

Further information may be obtained from Ms. Sandy Kern, Registrar, Prosthetics and Orthotics, New York University Post-Graduate Medical School, 317 East 34th Street, New York, NY 10016. Tel: (212) 340–6686.

8–13 May, 1983
10th World Congress on the Prevention of Occupational Accidents and Disease, co-sponsored by International Labor Office and International Social Security Association, Ottawa, Canada.
Information: Canadian Organizing Committee, 500–300 Slater Ottawa, Canada K1P 6A6.

28 May–5 June, 1983
11th Paediatric Orthopaedic International Seminar, Chicago, Illinois.
Information: Mihran O. Tachdjian, M.D., Marriott Hotel, 540 North Michigan Avenue, Chicago, Illinois. 60611.

30 May–7 June, 1983
VI Advanced Course on Arthritis Surgery, Edinburgh.
Information: Mr. W. A. Souter, Princess Margaret Rose Orthopaedic Hospital, Fairmilehead, Edinburgh EH10 7ED.

20 June–1 July, 1983
NATO Advanced Study Institute on the Biomechanics of Normal and Pathological Human Articulating Joints. Sintra-Estoril Hotel, Estoril, Portugal.
Information: Prof. Necip Berme, The Ohio State University, 206 West 18th Avenue, Columbus, Ohio 43210, USA or Dr. Kelo M. Correia da Silva, Laboratorio de Fisiologia, Instituto Gulbenkian de Ciencia, Apardato 14, 2781 Oeras, Portugal.

26 June–1 July
X European Congress of Rheumatology, Moscow.
Information: Secretary General, Institute of Rheumatism, 25 Petrovka Street, Moscow, USSR.

2–5 July, 1983
15th Congress of the World Federation of Hemophilia, Stockholm.
Information: SCB, Jacobs Torg 3, S–11152 Stockholm, Sweden.

24–29 July, 1983
4th International Conference of European Association for Special Education (EASE) Theme "Special Education and Social Handicap" Tel Aviv, Israel.
Information: Dr. E. Chigier, Kenes, P.O.B. 29784, Tel Aviv 61297, Israel.

August, 1983
International Sports Festival for Paraplegics, Vienna-Strebersdorf.
Information: Verband der Querschittgelahmten (Association for Paraplegics), Liechtensteinstrasse 6, A-1090 Vienna, Austria.

7–12 August, 1983
9th Congress of the International Society of Biomechanics, Waterloo, Canada.
Information: Mrs. J. Karger, Department of Kinesiology, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1.

5–9 September, 1983
I.S.P.O. Fourth World Congress, London.
Information: Conference Services Ltd., 3 Bute Street, London.

5–9 September, 1983
3rd. Mediterranean Conference on Medical and Biological Engineering, Portorz, Yugoslavia.
Information: Mrs. Darje Ude, J. Stefan Institute, Jamova 39,6100 Ljubljana, Yugoslavia.

9–11 September, 1983
5th Annual Conference of the IEEE Engineering in Medicine and Biology Society; Frontiers of Engineering and Computing in Health Care. Columbus, USA.
Information: Dr. G. Gerhard, Dept. of Electrical Engineering, University of Arizona, Arizona 85721, USA.

12–13 September, 1983
International symposium—Biomaterials in Artificial Organs.
Information: Professor J. P. Paul, University of Strathclyde, Bioengineering Unit, Wolfson Centre, 106 Rottenrow, Glasgow G4 0NW.

21–23 September, 1983
British Orthopaedic Association, Autumn Meeting, Nottingham.
Information: British Orthopaedic Association, Royal College of Surgeons, 35–43 Lincoln's Inn Fields, London WC2A 3PN.

22–24 September, 1983
International Congress on Sports and Health, Maastricht, The Netherlands.
Information: Dept. of General Surgery, University of Limburg, At. Annadal Hospital, P.O. Box 1918, 6201 BX Maastricht, The Netherlands.

5–7 October, 1983
11 Simposium de Inginieria Biomadica, Madrid, Spain.
Information: 11 Simposium de Ingenieria Biomadica, E.T.S.I. Telecomunicacion, Ciudad Universitaria, Madrid 3, Spain.

5–9 October, 1983
1st European Congress on Scoliosis and Kyphosis, Dubrovnik, Yugoslavia.
Information: "ATLAS" Congress Department, Zrinjevac 17, YU-41000, Zagreb, Yugoslavia.

25–30 October, 1983
American Academy of Orthotists and Prosthetists (AOPA) National Assembly, Hyatt Regency, Phoenix, Arizona.
Information: Mr. Norman E. McKonly, AOPA, 717 Pendleton Street, Alexandria, VA 22314, USA.

7–10 November, 1983
VIII Congress Brasileiro de Engenharia Biomedica, Brazil.
Information: EEL-UFSC, P.O. Box 476, Florianopolis-SC88000, Brazil.

13–18 November, 1983
2nd International Symposium on Design for Disabled Persons, Tel Aviv, Israel.
Information: Dr. E. Chigier, KENES, P.O.B. 29784, Tel Aviv 61297, Israel.

1984
15th World Congress of Rehabilitation International, Lisbon.
Information: Rehabilitation International, 432 Park Avenue South, New York, NY 10016, USA.

3–5 April, 1984
Canadian Association of Prosthetists and Orthotists Biennial Convention, Vancouver.
Information: John Girling, Chairman Foreign Liaison Convention Committee, 813 Darwin Avenue, Victoria, B.C. V8X 2X7, Canada.

11–13 April, 1984
British Orthopaedic Association, Spring Meeting, Aviemore, Scotland.
Information: British Orthopaedic Association, Royal College of Surgeons, 35–43 Lincoln's Inn Fields, London, WC2A 3PN.

27 April–1 May, 1984
Second World Congress on Biomaterials, 10th Annual Meeting of the Society for Biomaterials and the 16th Annual Biomaterials Symposium, Washington D.C.
Information: Samuel F. Hulbert, Chairperson, Society for Biomaterials, 6220 Culebra Road, San Antonio, Texas.

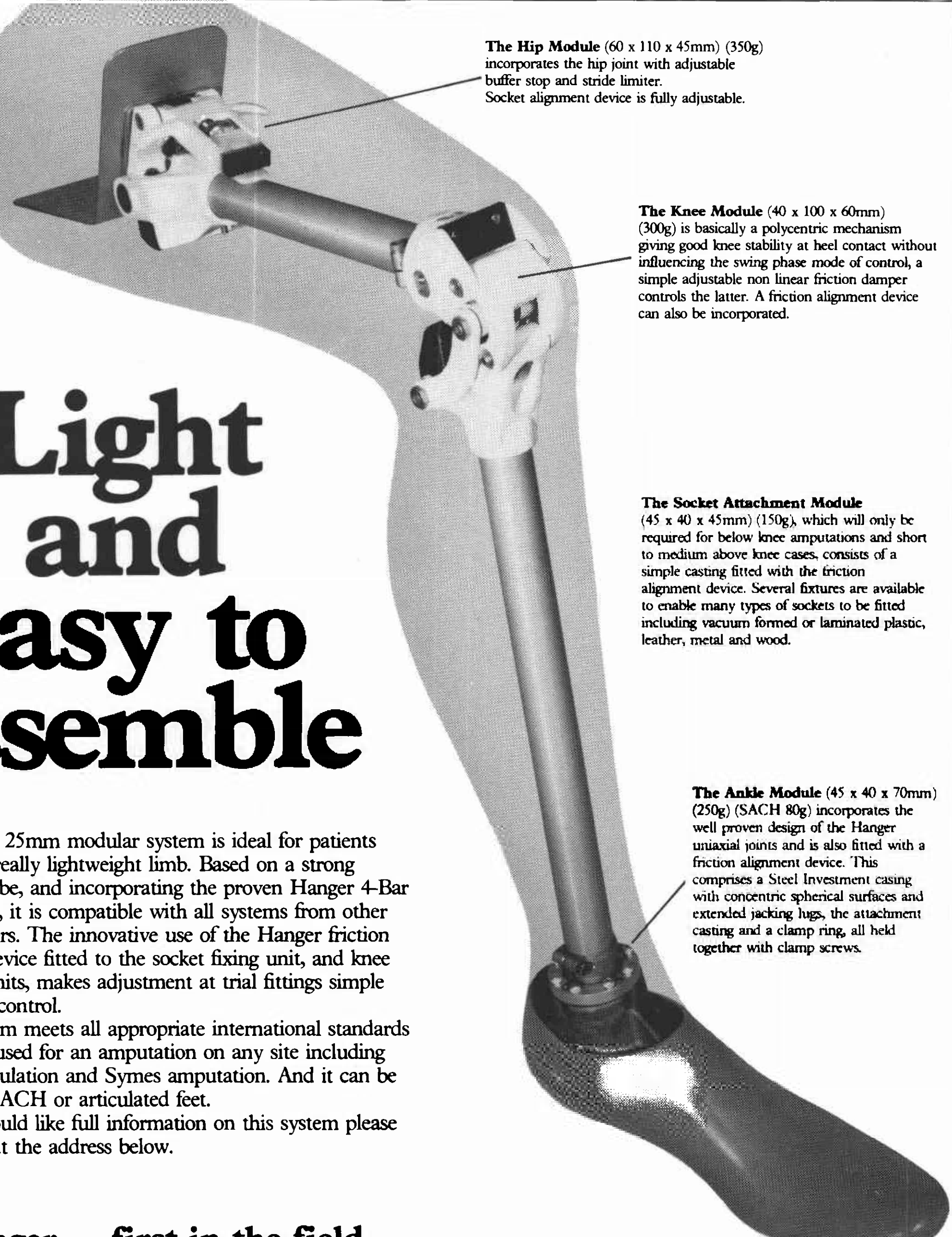
7–11 May, 1984
15th World Congress of Rehabilitation International, Lisbon, Portugal.
Information: Rehabilitation International, 432 Park Avenue South, New York, New York 10016, U.S.A.

13–19 May, 1984
9th Congress of the International Federation of Physical Medicine and Rehabilitation, Jerusalem, Israel.
Information: Prof. Joshua Chaco, Chairman, Israel Society of Rehabilitation Medicine and Rheumatology, P.O.B. 29784, Tel Aviv, Israel.

26–28 September, 1984
British Orthopaedic Association, Autumn Meeting, Barbican Centre, London.
Information: British Orthopaedic Association, 35–43 Lincoln's Inn Fields, London WC2A 3PN.

17–22 October, 1984
AOPA–INTERBOR International Congress and General Assembly, Fontainebleau Hotel, Miami Beach, Florida.
Information: Mr. Norman E. McKonly, AOPA, 717 Pendleton Street, Alexandria, VA 22314, U.S.A.

1985
7–13 July, 1985
14th International Conference on Medical and Biological Engineering, Helsinki, Finland.
Information: Dr. Hiilo Saranummi, Finnish Society for Medical Physics and Medical Engineering, P.O. Box 27, 33 231, Tampere 23, Finland.



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References

References in the text should follow the author/date system, for example Peizer (1971). If there are more than two authors *et al.* should be used as in Solomonidis *et al* (1974). References cited in the text should be listed on a separate sheet alphabetically by first author. All authors should be listed and journal titles given in full.

Reference to an article in a journal

Should include Author(s); Year of publication; Article title; Journal title; Volume number; First and last page numbers.

Newcombe, J. F., Marcuson, R. W. (1972). Through-knee amputation. British Journal of Surgery, 59, 260–266.

Reference to a contribution in a book

Should include Author(s) of contribution; Year of publication; Title of contribution (followed by 'In:'); Author(s), Editor(s) of book; Book title; Edition; Place of publication; Publisher; Volume number; First and last page numbers.

Cruickshank, C. N. D. (1976). The microanatomy of the epidermis in relation to trauma. In: Kenedi, R. M. and Cowden, J. M. (eds). Bedsore biomechanics, London, Macmillan Press Ltd, p. 39–46.

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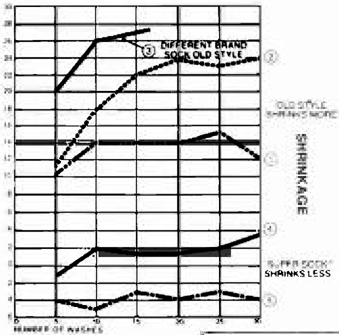

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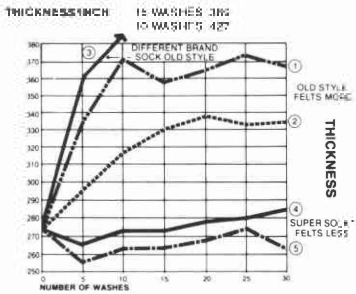

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If the average amputee purchased twelve socks and wore a clean sock after each wearing, he would need approximately 30 wash-wears, from each sock, to service him for one year.

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