The Journal of the International Society
for Prosthetics and Orthotics

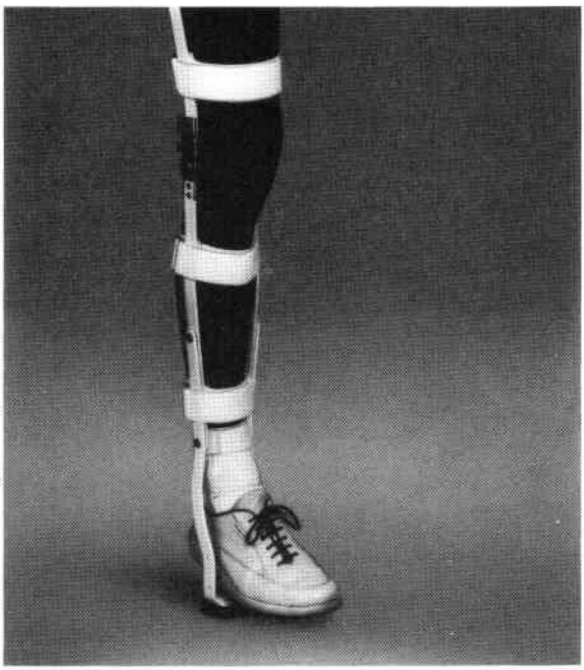
# Prosthetics and Orthotics International

April 1986, Vol. 10, No. 1

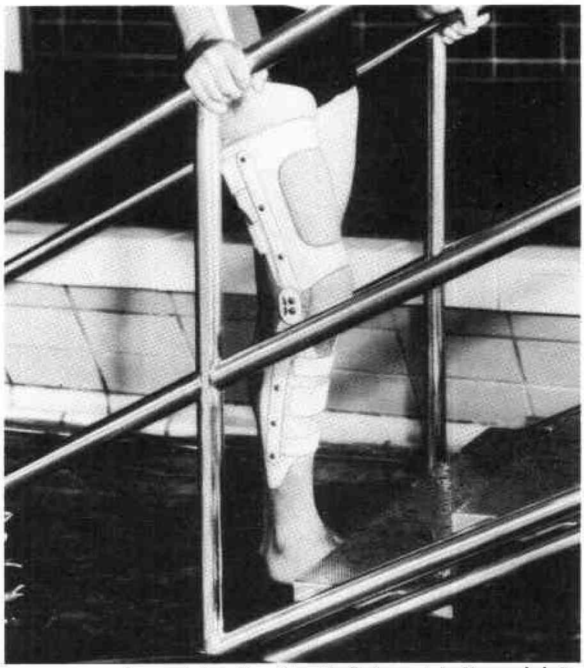
# Orthotic Kits and Joints from OTTO BOCK to provide up-to-date fitting

**Arm Abduction Orthosis in Modular Design combining comfort and relief in the shoulder joint area while allowing therapeutic motion to other parts of the body**

**Hyperextension Orthosis in Modular Design by A. Bähler, providing spinal relief for the lumbar and lower thoracic regions by means of the proven three-point system**



**Lower Extremity Orthosis – System Joint Design providing relief to the hip joint area**



**Knee Orthosis applying the Plastic Polycentric Knee Joints with adjustable stops – for temporary fitting after trauma and surgery**

# Prosthetics and Orthotics International



Prosthetics and Orthotics International is published three times yearly by the International Society for Prosthetics and Orthotics (ISPO), Borgervaenget 5,2100 Copenhagen Ø, Denmark, (Tel. (01) 20 72 60). Subscription rate is $50 (U.S.) per annum. The journal is provided free to Members of ISPO. The subscription rate for Associate Members is $25 (U.S.) per annum. Remittances should be made payable to ISPO.

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The Journal of the International Society for Prosthetics and Orthotics

April 1986, Vol. 10, No.1

## Contents

# ISPO

*Prosthetics and Orthotics International, 1986, 10, 1–2*

# Editorial

In this issue of the Journal, you will find the complete accounts for the fiscal year 1985. In addition, Tables 1 and 2 summarize and relate different sources of income and expenses.

As will be seen from Table 1, membership fees comprise half of the total income. Although the individual fee for 1985 was the same as in 1984, the total has increased by 64,000 DK, indicating a growing membership. Contributions amounted to 132,500 DK; however, 57,500 DK is a contribution for 1984, received early in January 1985.

The apparent income from advertising in Prosthetics and Orthotics International is reduced by 36,000 DK. This, however, is related to changes in international currency exchange rates and dates of payment. In fact, there was a slight increase in advertising volume. Income from subscriptions is steadily growing. Due to the dedicated, voluntary work of a number of people, Prosthetics and Orthotics International provides a surplus of 50,500 DK for 1985 — indeed an excellent result.

Included in other income is an additional surplus of 32,500 DK from the 1983 World Congress in London and a surplus from the Dundee Course in June of 8,054 DK.

As will be seen from Table 2, the expenses for the Secretariat in Copenhagen have been constant over the last two years. Expenditure on Prosthetics and Orthotics International has increased by 6%, which is approximately in line with inflation.

Table 1. ISPO Income 1983, 1984 and 1985

| Year | Total Income | Membership Fees | Contri-butions | Advertising P/O Int. | Subscription P/O Int. | Interest and Dividend | Other |
|---|---|---|---|---|---|---|---|
| 1983 | 1.053.003 | 517.261 | 152.410 | 159.719 | 125.143 | 89.398 | 9.072 |
| | 100% | 49.1% | 14.5% | 15.2% | 11.9% | 8.5% | 0.8% |
| 1984 | 1.401.230 | 609.567 | 59.767 | 159.403 | 164.486 | 37.301 | 370.706 |
| | 100% | 43.5% | 4.3% | 11.4% | 11.7% | 2.7% | 26.4% |
| 1985 | 1.369.405 | 673.261 | 132.500 | 123.334 | 180.205 | 204.424 | 55.681 |
| | 100% | 49.2% | 9.7% | 9.0% | 13.1% | 14.9% | 4.1% |

Table 2. ISPO Expenses 1983, 1984 and 1985

| Year | Total Expenses | Secretariat[1] Copenhagen | Journal P/O Int. | Meetings and[2] Travelling | Other |
|---|---|---|---|---|---|
| 1983 | 631.784 | 252.964 | 244.387 | 128.396 | 6.037 |
| | 100% | 40.0% | 38.7% | 20.3% | 1.0% |
| 1984 | 771.506 | 292.354 | 238.728 | 192.937 | 47.487 |
| | 100% | 37.9% | 30.9% | 25.0% | 6.2% |
| 1985 | 880.099 | 293.174 | 253.039 | 307.191 | 26.695 |
| | 100% | 33.3% | 28.8% | 34.9% | 3.0% |

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

[2]Meeting and Travel: indicates expenses related to board meetings, participation of board members as representatives of ISPO at meetings of other international organizations as well as travel expenses for the Honorary Secretary connected with his duties in Copenhagen. The expenses for 1985 include a meeting of representatives of the International Committee held in Dundee in June.

Meeting and Travelling expenses have increased by 59%. This increase is, for the most part, related to a meeting of representatives of the International Committee held in Dundee in June 1985. For the first time in the history of our Society it was possible to finance such a meeting — indeed an important step forward.

The economy of our Society is sound and will allow us to increase activities.

The Executive Board expresses its gratitude to our contributors for direct financial support, as well as for facilities provided free of charge. Thanks are also due to our members for their dedicated work.

Erik Lyquist
*Vice-President and Honorary Treasurer.*

## ISPO World Congress 29 June–4 July, 1986 Copenhagen

**Full details of the Congress programme and Registration Forms were included in the December 1985 issue of this journal.**

**For late Registration contact:**

**ISPO**
**c/o DIS CONGRESS SERVICE**
**Linde Allé 48**
**DK–2720 Vanløse**
**Denmark**

# I.S.P.O. Statement of Accounts, 1985

| | | | | |
|---|---|---|---|---|
| **Balance as at December 31, 1985** | | | | |
| **Income** | | | | |
| Membership fees | | | 673.261 | |
| Contribution: | | | | |
| Society and Home for Disabled | | | 132.500 | |
| Miscellaneous: | | | | |
| Bonds — (Profit) | | 21.770 | | |
| World Congress 1983 | | 32.550 | 54.320 | 860.081 |
| Interest: | | | | |
| Bonds | | | | 182.970 |
| Bank accounts | | | | 20.704 |
| Dividend-Stocks | | | | 750 |
| **Expenditure:** | | | | |
| Salary: Aase Larsson | | | 185.102 | |
| A.T.P., F.O.K. and pension | | | 24.732 | |
| Courses and Workshops: | | | | |
| Sweden | | 21.206 | | |
| Dundee | | ./. 8.054 | 13.152 | |
| Printing Expenses: | | | | |
| Journal: Prosthetics and Orthotics International: | | | | |
| Printing cost incl. air mail posting | | 228.818 | | |
| Production service | | 20.480 | | |
| Editor, travelling | | 0 | | |
| Labels | | 3.741 | | |
| | | 253.039 | | |
| Less income: | | | | |
| Advertising | 123.334 | | | |
| Subscription | 180.205 | 303.539 | | 50.500 |
| Deformed foot | | | | 1.361 |
| Postage and freight | | | 14.814 | |
| Stationery and printed matter | | | 16.662 | |
| Meeting and travelling expenses: | | | | |
| Miscellaneous | | 27.517 | | |
| Executive boards, incl. meetings | | | | |
| Copenhagen | | 95.334 | | |
| International Committee Meetings | | 184.340 | 307.191 | |
| R. I. fee | | | 13.543 | |
| Telephone | | | 4.739 | |
| Repairs and maintenance | | | 2.292 | |
| Miscellaneous expenses: | | | | |
| Data system | | 31.689 | | |
| Sundry | | 2.222 | | |
| Auditing | | 10.962 | 44.873 | |
| | | | 627.060 | 1.116.366 |
| Surplus as at December 31, 1985 | | | 489.306 | |
| | | | D.kr. 1.116.366 | D.kr. 1.116.366 |

**Balance as at December 31, 1985**

| | | | | |
|---|---|---|---|---|
| **Assets** | | | | |
| Cash on hand | | | 906 | |
| Bank accounts: | | | | |
| Handelsbanken Chech no. 524.052 | | 17.619 | | |
| Handelsbanken Book no. 856.742 | | 106.467 | | |
| Handelsbanken Book no. 863.110 | | 202.747 | 326.833 | |
| Handelsbanken: Book no. 650.591 | | | | |
| (Knud Jansen Foundation) | | | 2.105 | |
| Debtors: | | | | |
| Tax-Dividend | | | 450 | |
| Seed-money, Dundee, July 1985 | | 8.453 | | |
| Less repayment | 8.787 | | | |
| Less Currency exchange | 334 | 8.453 | 0 | |
| Bonds: | | | | |
| Nom. kr. 17.500 10% Østifternes Kreditforening 18/2003 (Course 86.01.08: 100 ¼ value D.kr. 17.543) | | 12.338 | | |
| Nom. kr. 403.000 10% Dansk Statslån S. 1988 (Course 86.01.08: 101 value D.kr. 407.030) | | 375.797 | | |
| Nom. kr. 347.500 10% Dansk Statslån 1979/89 (Course 86.01.08: 101 value D.kr. 350.470) | | 319.719 | | |
| Nom. kr. 1.157.000 12% Dansk Statslån 2001 (Course 86.01.08: 111 value D.kr. 1.284.270) | | 1.150.717 | 1.858.571 | |
| Stocks: D.kr. 7.700 Kjøbenhavns Handelsbank (Course 86.01.08: 338 value D.kr. 26.026) | | | 21.208 | |
| Contributions to: World Congress 1980 | | | 119.690 | |
| World Congress, Copenhagen 1986 | | | 182.070 | |
| Creditor: | | | | |
| A.T.P., F.O.K., tax and pension | | | | 10.156 |
| Auditing | | | | 3.977 |
| Knud Jansen Foundation | | | | 2.105 |
| Balance as at January 1, 1985: | | | | |
| (Capital-account) | | 2.006.289 | | |
| + surplus for the period 85.01.01–85.12.31 | | 489.306 | | 2.495.595 |
| | | | D.kr. 2.511.833 | D.kr. 2.511.833 |

The above mentioned accounts, which have been examined, are in accordance with the book-keeping for the year 1985.

GUNNER PETERSEN, H.D.
*Registered Accountant,*
Bagsvaerd, January 10, 1986.

*Prosthetics and Orthotics International, 1986, 10, 5–7*

# Executive Board Meeting

**18th and 19th January, 1986**

The following paragraphs attempt to summarize the major discussions and conclusions of the last Executive Board Meeting held in Copenhagen. They are based on the draft Minute of that meeting which has not yet been approved by the Executive Board.

*World Congresses*

Arrangements for the 1986 Congress, Copenhagen have reached an advanced stage. The initial responses to the Congress are good. Half the exhibition space has already been booked and the organizers were authorized to provide extra space which would not only house the overflow from the Commercial Exhibit but also allow a Scientific Exhibit. The venue for the 1989 Congress, Japan, is being investigated, with Tokyo, Købe and Yokohama as the possibilities. A final decision on the site will be made by the end of March.

*Meeting with Representatives of the International Committee*

The Executive Board discussed the suggestions made at the Meeting with Representatives of the International Committee and the following points were made:

a) the International Committee Meeting held in conjunction with the Copenhagen Congress would last one full day.
b) the possibility in the future of holding a separate meeting of the International Committee as well as a joint meeting with the Executive Board should be discussed at the next meeting of the International Committee.
c) the possibility of holding an interim meeting with the International Committee midway between the Congresses should be considered by the new Executive Board.
d) brief reports of ISPO meetings and Symposia and outstanding activities of National Member Societies should be published in "Prosthetics and Orthotics International".
e) the suggestion that the Society should publish an International Newsletter in addition to the Journal should be examined by the Editorial Committee.
f) a working group chaired by the President-Elect should prepare proposals to overcome the problems related to the level of membership fee and the developing countries.
g) proposals for a Professional Register of ISPO members should be reactivated in order that the individual ISPO members are better utilized in International activities.

*Flexible Socket Programme*

The Society's position related to providing information with regard to the flexible socket and other new lower limb socket concepts should be reviewed following the Copenhagen Congress.

*International Organizations*

The President and Honorary Secretary represented the Society at the 18th General Assembly of the World Veterans Association. The President-Elect represented the Society at a World Health Organization Working Group on Systems for the Provision of Aids for Disabled Persons which recommended that, "Non-governmental organizations, such as the International Society for Prosthetics and Orthotics . . . . should be used by WHO and, as appropriate, by National bodies in a consultative and supportive role in this area." Margaret Ellis, UK, represented the Society at a meeting of the International Commission of Technical Aids in August, 1985 in Finland which recommended that their contacts with groups such as ISPO should be strengthened. ISPO has been invited to organize a session on prosthetics and orthotics and present a poster session on the same theme at the Rehabilitation International Meeting in Tokyo, 1988. The possibility of ISPO's representative addressing a plenary session at that meeting is being explored. George Veres, Norway, had represented the Society at a meeting of the International Verband der Orthopadie-Schutechnik in September, 1985 in Switzerland at which IVO had indicated a wish to strengthen its contact with ISPO as a consultative partner. The Society had organized a workshop on the use of prostheses, orthoses and technical aids at the Second European Conference on Research in Rehabilitation held in November, 1985 in Dusseldorf. The Society also continues its contact with INTERBOR, the International Committee of the Red Cross, the Council of World Organizations Interested in the Handicapped, World Orthopaedic Concern, World Rehabilitation Fund, the International Labour Organization and the United Nations.

*Standing Committee and Task Officer Reports*

The accounts for 1985, shown elsewhere in this issue of the Journal, were presented to the Board. The budget for 1986 was presented, discussed, and accepted by the Board. It was agreed that should elected members of the Board be unable to find funds to attend Executive Board meetings from other sources their expenses should be paid for by the Society. A state authorized accountant from the firm Schøbel Marholt has been appointed to the Society. Sponsoring members fees should continue to be divided equally between the International Society and the National Member Society involved. It was agreed that Sponsoring Membership fees should continue to be at least six times that of the individual membership and that Institutional Membership fees should be three times that of the individual membership.

Seishi Sawamura reported on a meeting in November, 1985 in Bangkok, Thailand to promote ISPO in South East Asia. It was attended by 25 representatives from Burma, China, Hong Kong, India, Indonesia, Japan, Malaysia, Phillipines, Singapore and Thailand. Gertrude Mensch presented a draft for the publicity leaflet that she and Dick Lehneis had been working on. It was anticipated that it would be printed before the Copenhagen Congress. The Board discussed the position of the lapsed member and agreed that, in future, if a member had previously resigned and subsequently wished to rejoin the Society he should be allowed to do so without paying fees for the preceeding year.

Work on the reports of the Canadian and Jönköping meetings on education continues and it is intended that they should be published before the Copenhagen Congress. As an outcome of the Jönköping meeting, the Board agreed in principle to support a small meeting to examine the situation of the technicians working in the developing countries who had been trained by short courses such as those provided by the World Rehabilitation Fund. The purpose of the meeting would be to suggest ways in which they might be upgraded to the level of, for example, orthopaedic technologists. A more detailed proposal would be presented to the new Executive Board for its approval. The prosthetics and orthotics school in Togo had applied to ISPO for its approval to train Orthopaedic Technologists. It would be inspected in April, 1986 by the Honorary Secretary and Erik Lyquist, Vice President, on behalf of the Society.

Editing of the Design and Layout Manual for workshops in the developing countries, was proceeding and it was anticipated that it would be published in time for the Copenhagen Congress.

The returns from the National Member Societies with regard to current evaluation projects in their countries and possible collaboration in an international evaluation programme were sparse and required some follow-up.

The Editorial Committee is in the process of preparing a list of selected articles from "Prosthetics and Orthotics International" with a view to publishing a separate volume. The Committee were also discussing suggestions for an audiovisual publicity package and the establishment of an International Newsletter and proposals would be brought to the next Board Meeting.

The Society continues to be involved in the development of standards, through its participation in the International Standards Organization, and also in monitoring progress in the use of CAD/CAM in prosthetics and orthotics.

*Future Activities*

a) An ISPO Seminar on "Traumatic Amputations" will be held in Herzliya, Israel from 6–10th September, 1987.
b) A joint two-day meeting of the ISPO National Member Societies of the Netherlands, Belgium and the Federal Republic of Germany will be held in the University of Gröningen, Netherlands towards the end of October, 1987.

c) A Seminar on "Rehabilitation of the Physically Handicapped Child" will be held in Heidelberg, Federal Republic of Germany, in October 1988.
d) The possibility of holding a second workshop in Sweden on the Deformed Foot is being investigated.

*Fellowships*
Professor G. G. Kuhn, Federal Republic of Germany and Wilfred Kragstrup, Denmark, have been elected as Honorary Fellows of the Society.
Frank Golbranson (USA) and Melvin Stills (USA) have been elected as Fellows of the Society.

*Nominations to the Executive Board*
Valma Angliss (Australia) has been nominated by the Australian National Member Society as a member of the Executive Board and will be added to the slate of nominations announced in the last copy of the Journal. The results of the election of the new Executive Board will be announced at the Assembly held in conjunction with the World Congress, Copenhagen.

Norman A. Jacobs
*Honorary Secretary.*

# Honours for ISPO Members

We wish to congratulate two members of ISPO whose names appeared in the New Year Honours List in the United Kingdom.

Dr. Miroslav Vitali, formerly Principal Medical Officer, Department of Health and Social Security, Limb Fitting Centre, Roehampton, London received the O.B.E. (Officer of the Order of the British Empire).

Mr. David Begg, Principal Orthotist, Stracathro Hospital, Brechin, Angus, Scotland was awarded the M.B.E. (Member of the Order of the British Empire).

# Obituaries

## Brian G. Blatchford

Brian Geoffrey Blatchford, Fellow of our Society, died on Christmas Eve 1985.

He was a well known international figure, respected both as a gentleman and as a very competent engineer in the field of prosthetics. He joined the family business of Charles A. Blatchford and Sons Limited, at the age of 17, and in time succeeded his father, W. A. Blatchford, as head of the firm. He was largely instrumental in moving the firm from London to Basingstoke in 1963, and fostered the steady growth of the Company, particularly by his great personal talent for design, and for the inspiration and direction he provided to others.

He was awarded the M.B.E. (Member of the Order of the British Empire) in January 1974. In 1976 Blatchford's received the Queen's Award for Technical Achievement and the Design Council award and he, as Chief Designer, was awarded the Duke of Edinburgh Designer's Prize. He was subsequently accorded Fellowship of the Royal Society of Arts.

Brian took great pleasure in attending the many national and international meetings of I.S.P.O. and was always an attentive listener and a positive contributor, being concerned with the maintenance of high standards within our Society.

It had been hoped that he would have been able to celebrate the Centenary of the Company of Blatchford's in 1990. Sadly this will not be possible. However, through his forward-planning his work will be continued by his son and colleagues carrying on with the projects begun by him.

His family and colleagues and I, miss him very much.

Tommy Thompson

## J. Morgan Greene

J. Morgan Greene, President of the United States Manufacturing Company died on 21st November, 1985. Throughout the years since he first established his Company after the Second World War, he had an abiding influence on the prosthetic and orthotic professions. The Company he created was noted for its efficiency and for its high quality products. Beyond that however, he was supportive of all efforts to advance the welfare of the disabled. In particular, he supported I.S.P.O. through its formative years and made significant financial contributions without strings at times when the Society was in dire straits. He will be most sadly missed by his family and also by his large circle of friends and colleagues around the world.

George Murdoch

*Prosthetics and Orthotics International, 1986, 10, 9–14*

# Holte revisited — a review of the quality of prosthetic treatment

V. E. ANGLISS

*Veterans' Affairs, Central Development Unit, Melbourne*

**Abstract**

The standards recommended at the United Nations Inter regional Seminar on Standards for the Training of Prosthetists in Holte, Denmark, in 1968 were universally accepted as being ideal, practical and economical. As these standards and the services to patients are not always observed, world wide, a study was made to investigate the situation in Australia. Australia is a federation with responsibility for health and education vested in six States. The Federal Government is the principal taxing authority with the States dependent on it for financing services. The isolation of Australia led the Government during 1960 to send a rehabilitation medical officer to survey the system in Europe and North America. The best features of overseas practice became the basis for updating an Australian Service and establishing the Central Development Unit. The Artificial Limb Service is based on clinical care, formal in-service training of limb makers and fitters, patient training by therapists and the purchase of components from mass producers. The Service is answerable to lay and medical staff in the State Branches and to the Central Office of the Department, located in Canberra. The division of responsibility between the State and Federal Governments seems to lead to competition for control of services rather than to an integrated plan for Prosthetic-Orthotic training with services. Industrial conflict due to a perceived threat of the supplanting of apprentices by formally trained prosthetists-orthotists has also adversely affected development.

In this paper the views of Government authorities, medical prosthetic prescribers and of personnel who conducted a pilot study in delivery of a prosthetic service are discussed.

Principles outlined at Holte remain a yardstick with which to measure the quality of service. In practice, however, it has not always been possible to meet those standards as one would wish.

## Introduction

At a seminar in Holte, Denmark, in 1968, agreements were reached on standards for training and service delivery in prosthetics and orthotics (U.N., 1969). These standards were considered to be ideal, practical and economical. An Australian government representative participated in the conference. Following the conference, efforts have been made to develop training and services in prosthetics and orthotics which meet these standards.

Australia is a federation comprising six states and two Territories, the Australian Capital Territory and the Northern Territory, the latter a vast tract of arid land largely populated by aborigines (Fig. 1). The States are dependent on the Federal Government for finance but are responsible for the implementation of health and education services.

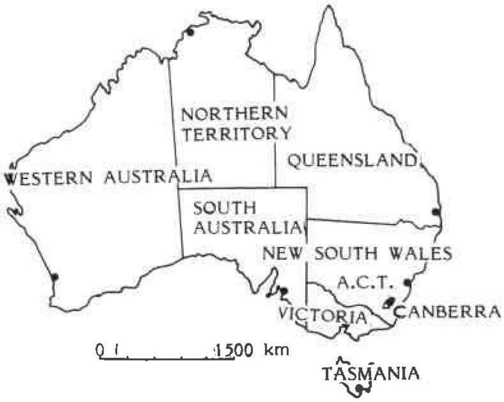


Fig. 1. Australia

All correspondence to be addressed to Mrs. V. E. Angliss, Consultant Therapist, Veterans' Affairs, Central Development Unit, 131 Sturt Street, South Melbourne, Victoria 3205, Australia.

Over the years, there has been competition between the States and the Commonwealth in relation to the areas of responsibility for delivery of health services. The Commonwealth controls the purse strings, but the States implement the programmes. The Commonwealth finances a free limb scheme whereby artificial limbs are available without cost to all persons in need, but the State doctors prescribe and approve the prosthesis for payment.

Due largely to its isolation and small population, Australia has relied heavily on overseas advice and standards, hence the Holte recommendations were particularly appropriate.

Prior to the Holte Seminar, the outstanding achievement was the establisment in 1961 of the Australian Institute of Limb and Appliance Research, that is the Central Unit in Australia for evaluation, education, research and development of prosthetics and orthotics based on the Artificial Limbs Research Project which existed in the U.S.A. in the past.

Although this Unit was established prior to the Holte Seminar, it has an establishment of two formally trained diplomates in prosthetics and orthotics, a bio-medical engineer and a therapist under medical direction.

The most outstanding achievement related to the Holte recommendation was the establishment in 1975 of a School of Prosthetics and Orthotics at the Lincoln Institute of Health Sciences, Melbourne, Victoria. This is a tertiary college which provides a three year course in prosthetics and orthotics, leading to a diploma. This institute is largely federally funded. There is an annual intake of 15 students. At the time this school was established, the Federal Government considered that one school should be able to meet the needs of the Australian population which is approximately 13,400,000.

**Method and results**

In order to ascertain the current situation regarding prosthetics and orthotics, information has been sought from all the States and Territories as to their current standards and services. Largely as a result of interviews and questionnaires (see sample), it has been ascertained that:

1. A low priority is given by States to prosthetic/orthotic services. The staff employed, whether medical, nursing, physio or occupational therapy, are generally junior or recent graduates, often employed on a rotating basis which means that inexperienced staff are providing the services.
2. Some disputes have arisen from the perceived fears of the apprentice trained limb makers that the employment of prosthetic/orthotic graduates would supplant them. There have been union bans on the employment of the prosthetic/orthotic graduates at the Limb Centre of the Department of Veterans' Affairs. This has been accompanied by a proposal that the designation "Prosthetist" be abolished. Industrial disputes might have been avoided by better communication in planning.
3. In Victoria, the Health Commission is responsible for all health and prosthetic/orthotic services. In 1978 it commissioned a report on prosthetics and orthotics which recommended *inter alia,* that two pilot prosthetic/orthotic units be established, one in the capital city of Melbourne and one in Ballarat, some 100 kilometres away. These units were established in 1981. It was intended that these pilot programmes be evaluated in 18 months and that the evaluation be used as the basis for developing further regional centres.

Largely due to employment of inexperienced staff and lack of adequate monitoring this evaluation has not been completed and no policy has been determined in relation to future development of a prosthetic/orthotic service on a State-wide basis.

Recently two "Workshops" were organized by I.S.P.O. (Australian National Member Society) held six months apart, for the voicing of opinions of medical and allied health personnel working in prosthetic and orthotic clinics. Although poorly attended, there was much valuable discussion, many questions, but few answers.

In Victoria with a population of 3,900,000 there are 20 prosthetic/orthotic diplomates employed — this is much less than the number required if we are to meet the Holte standards of one prosthetist/orthotist for 130,000 of population.

Technicians are not employed in Victoria nor are special courses provided or planned for this group — this is in contrast to the two tier structure recommended at Holte.

4. New South Wales has a population of 5,250,000 in an area the size of France. Most of the population live in the capital, Sydney. Of the remainder, most live along the fertile coastal strip; the hinterland is very sparsely populated. Unfortunately prosthetic/orthotic services are not considered to be of sufficient importance to be included in the Health Department's data collection scheme. This Health Department does not have a formal policy regarding the provision of prosthetic/orthotic services, but it does endorse the philosophies implicit in the standards established at the Holte Seminar, i.e. "that services should be located within large general hospitals and be an integral part of an othopaedic or medical rehabilitation centre". Five hospitals are listed in this State which have established these services. However, formally trained prosthetist/orthotists are not necessarily employed. There are four formally trained prosthetists/orthotists and approximately 105 informally trained prosthetist/orthotists working in the state.
5. Queensland, where the population is 2,250,000 for an area the size of Arabia, the stated policy is "to develop a hospital based prosthetic and orthotic service at three city hospitals and a rural community hospital; to continue using private contractors to construct prostheses; to upgrade staff establishments and to provide scholarships to the Prosthetic and Orthotic School at Lincoln Institute".

   The service in Queensland indicates longer than desirable waiting time for prostheses. There are five prosthetic/orthotic diplomates employed but the private limb makers undertake the bulk of prosthetic work in the State.
6. In South Australia (population 1,250,000 for an area the size of Germany), data is not readily available and there appears to be no State policy or even an officer for overseeing prosthetic/orthotic services.
7. Western Australia has a population of 1,250,000 and is the size of India. No response.
8. Tasmania, with a population of 500,000 is the size of Ireland. It seemed that there was little real appreciation of the difference between apprentice-type limb makers or apprentice-type orthotists, prosthetic/orthotics technicians, i.e. non-clinical assistants, and prosthetic/orthotics diplomates. The answers provided are difficult ot correlate.
9. Australian Capital Territory has a population of 230,000 and an area of 2½ thousand square kilometres. No information could be obtained.
10. Northern Territory has a population of 120,000 in an area larger than Germany. Advice was recieved that "the prosthetic/orthotic services in this territory are provided by the Federal Government's Department of Veterans' Affairs".

A literature search, attendance at conferences and seminars relating to prosthetics and orthotics and discussions with personnel in the field, indicate that prosthetic/orthotic services in Australia reflect the generally unsatisfactory situation world wide, that the service to the amputee patient remains haphazard or falls short of the ideal.

Rose (1978) states — "Many, and often bitter, complaints are made by patients and doctors about orthoses and no one disputes the need for very considerable improvement in quality, delivery and research".

James (1981) states — "It would seem that the disabled of today are coasting along on the inventiveness of the Victorian (era)", and his further comment is frequently expressed — "it was found difficult to integrate the Limb Fitting Service with the hospital and community".

In a commentary by Whipple (1982) — "The profession of prosthetics is beset by two major problems.
1) inadequate education and training and 2) too few prosthetists. The interaction of these problems has created a crisis in the profession".

English and Dean (1982) state the oft heard — "For many years a cause of dissatisfaction with the service has been delay in the provision of a finished prosthesis. The time between amputation and the fitting of a prosthesis is very important in the total management of amputees".

It would seem that Australian amputees are not alone in their plea for a priority in health care.

**Summary**

The quality of prosthetic service received by amputees in Victoria and in Australia, even world wide, could be optimum if the recommendations of the Inter-regional Seminar on Standards for the Training of Prosthetists are followed. The International Society for Prosthetics and Orthotics (I.S.P.O.) should be highly commended for instigating this Seminar. Obviously the recommendations did not go far enough.

The delegating of junior or inexperienced staff, both medical and paramedical, to the amputee/prosthetic patients, the attitude of key personnel at interviews, the poor response or lack of response to information requests from senior staff in the Health Departments, are all a reflection of the lack of concern for these patients and this field of medicine and rehabilitation.

Consideration should be given to "Revisiting Holte" and adopting "Holte type" recommendations which should be possible to implement as part of governmental policy, together with major committments by governments to rehabilitation programmes. This should include

a) case study presentations
b) amputee associations collectively voicing their views
c) greater emphasis in medical school curricula on amputee and prosthetic treatment.

The reasons why the Holte recomendations were not implemented in Australia would seem to be:—

1. The division of responsibility between State and Federal Governments and the lack of total government committments with policy in relation to prosthetic/orthotic training and services.
2. The absence of communication which would result in a greater government committment and reduce industrial unrest.

Accordingly, the following recommendations are made:

1. That all policy makers should consider prosthetic/orthotic training and services and prepare guidelines for the medical and allied health professionals.
2. That such policies and guidelines be widely publicised.
3. That there should be a community education programme in regard to prosthetist/orthotists and the role of trained workers in the field.
4. That training courses be established for technicians to work with prosthetists.
5. That the International Society for Prosthetics and Orthotics lobby international governments to give greater recognition to the needs of this relatively small sector of the disabled and those helping them.

Such recommendations would, if implemented, enable the patient to return in the shortest possible time to the best quality of life.

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## QUESTIONNAIRE

Assessment of the quality of prosthetic/orthotic service to patients in Australia

IN YOUR STATE

1. Does the Health Commission/Department have an official policy on Prosthetic/Orthotic service to patients? YES ........ NO ........
2. If yes, please outline policy ........................................................................................................
........................................................................................................................................
3. Does this relate only to employed, formally trained Prosthetist/Orthotist diplomates? YES ........ NO ........
4. Does this relate only to estblishing Prosthetic/Orthotic Departments? YES ........ NO ........
5. Does the policy follow the Holte recommendations, as outlined in your letter? YES ........ NO ........
6. If no, would you please explain your policy ........................................................................................
........................................................................................................................................
7. How many Prosthetic/Orthotic Departments or Centres are/were in your State in 1983 ........, 1973 ........, 1963 ........?
8. How many Prosthetic/Orthotic Departments are located
   a) In large General Hospitals? ........
   b) In Centres other than large General Hospitals? ........
9. How many Prosthetic/Orthotic diplomates are currently in the workforce in your State? ........
10. How many Prosthetic/Orthotic diplomates are currently in the workforce
    a) In large General Hospitals? ........
    b) In Centres other than large General Hospitals? ........
11. How many apprentice type Limb Makers are currently in the workforce
    a) In large General Hospitals? ........
    b) In Centres other than large General Hospitals? ........
12. How many apprentice type Orthotists (splint makers) are currently in the workforce
    a) In large General Hospitals? ........
    b) In Centres other than large General Hospitals? ........

13. How many Prosthetic/Orthotic "technicians" (non clinical assistants) are currently in the workforce? ........

14. What is the role of the technician in Prosthetic/Orthotic departments in your State?...................
........................................................................................................................

15. How many amputees in hospitals in your State during the 12 month period 1982-1983? ........

16. It has been estimated that one Prosthetist/Orthotist is required per 300 of amputee population, giving an indication of the number a hospital (or group of hospitals) should employ;
    a) Is this in accordance with your policy? YES ........ NO ........
    b) If no what policy do you adopt? ........................................................................
    ........................................................................................................................

17. Do returns indicate acceptable waiting time for prostheses and length of hospital stay?...............
    a) Average period from amputation to interim prosthesis ...............................................
    b) Average period from amputation to definitive ........................................................
    c) Average period from amputation to return home/job ..................................................

18. What is the effect of competition/private limb makers on the service to patients?.......................
........................................................................................................................
    i) on overall service of Prosthetic/Orthotic Clinics?....................................................
    ........................................................................................................................
    ii) on fit function, alignment of Prostheses and/or Orthoses?..........................................
    ........................................................................................................................
    iii) on period of waiting time? ...........................................................................
    ........................................................................................................................
    iv) on measuring up to recommendations of Holte? ......................................................
    ........................................................................................................................
    v) on follow-up?..............................................................................................
    ........................................................................................................................
    vi) does private enterprise decentralize? ..............................................................
    ........................................................................................................................

19. Is the amputee patient's treatment co-ordinated and completed by the hospital that commenced it?........................................................................................................................
........................................................................................................................

20. Is follow-up a point of total treatment or not?.............................................................
........................................................................................................................

Does this occur with the service to patients with other conditions? YES ........ NO ........

Please enlarge ..........................................................................................................

........................................................................................................................

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# Below-knee amputation: a comparison of the effect of the SACH foot and single axis foot on electromyographic patterns during locomotion

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**Abstract**

The purpose of this investigation was to measure the effect of two terminal prosthetic components, the SACH foot and the single axis foot, on the locomotion patterns of unilateral below-knee amputees. The ten subjects who participated in the study were evaluated on two occasions, once following prescription of a PTB prosthesis and one terminal device and once following its replacement with the second device. The two devices were allocated alternately at the time of prosthetic prescription to ensure that five of the subjects used the SACH foot initially and five used the single axis foot. The electromyographic activity of the vastus lateralis and medial hamstrings was recorded bilaterally during gait using Beckman surface electrodes. The EMG signals were full wave rectified and low pass filtered to obtain the linear envelope. Pressure sensitive footswitches were used to correlate the EMG signals with components of the gait cycle. The pattern of quadriceps and hamstring muscle activity of the contralateral limb was similar to that reported for normal individuals and was unaffected by changing the terminal device on the prosthetic limb. The pattern of quadriceps and hamstring activity of the prosthetic limb differed from that of the contralateral limb and was influenced by the change in terminal device. With both devices the muscles were active for a greater percentage of the stance phase when compared to the contralateral limb. With the SACH foot attachment there appeared to be more co-contraction of the quadriceps and hamstrings during the mid stance phase of gait.

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## Introduction

Surveys conducted in the United States have revealed that 60-90% of the lower extremity amputations performed are due to complications of peripheral vascular disease (Davies et al, 1970; Kay and Newman, 1974; Kerstein et al, 1974). Kay and Newman (1974) reported that 62% of all lower extremity amputations and 88% of amputations due to disease were performed on persons over 50 years of age. The increasing emphasis on saving the knee joint since the mid 1940's has resulted in a greater potential for this patient population to achieve independent ambulation. Successful rehabilitation depends in part upon the appropriate prescription of a prosthesis to replace "the missing limb segment. The prosthesis must be able to provide stability as well as to compensate in part for the lost joint movement and muscle action thereby minimizing the increased demands placed on more proximal joints and muscles.

The patellar-tendon-bearing (PTB) socket, designed in 1959 by the Biomechanics Laboratory, University of California, is most commonly prescribed for subjects with below-knee amputation (Fishman et al, 1975). The terminal devices most often used with the PTB socket are the SACH (solid ankle cushion heel) foot and the single axis ankle joint and foot (Davies et al, 1970; Fishman et al, 1975).

The SACH foot, as its name implies, has no ankle joint mechanism. A wedge of soft rubber inserted into the heel of this device compresses with weight bearing allowing the forepart of the foot to come in contact with the floor during initial stance, thus simulating plantar-flexion. A wooden or metal keel running forward from the ankle position to the mid-forefoot region is shaped to permit the leg to roll forward over the forefoot during the stance phase. A flexible forefoot allows roll-over at the end of stance.

The single axis ankle joint and foot, sometimes referred to as the conventional foot, is attached to the prosthesis by a hinge which allows 15-20° of plantar-flexion and 5-8° of dorsi-flexion. Both movements are limited by the action of rubber bumpers placed respectively anterior and posterior to the ankle axis. A pliable forefoot allows the toe section of the foot to bend during terminal stance.

Since the mechanism by which each of these devices attempts to substitute for ankle movement differs, it is conceivable that the adaptation required in the more proximal joints and muscles may also differ. Previous research, comparing these two devices, has indicated that there are minimal differences in the temporal parameters and in the knee joint angle during the gait cycle (Doane and Holt, 1983; Culham et al, 1984). The patterns of activity in the proximal musculature however have not been investigated. The purpose of this study therefore was to evaluate the effect of the terminal prosthetic component on the electromyographic activity of the quadriceps and hamstring muscle groups during gait.

## Subjects

Subjects who met the following criteria were recruited for the study: unilateral below-knee amputation, suitability for fitting of a temporary PTB prosthesis, relatively pain-free stump with no skin abrasions, and residency within the London, Ontario area. Eight male and two female subjects participated in the study. They were between the ages of 32 and 79 years with a mean age of 61 years. Mean height and weight were 174 cm and 75.5 kg respectively. Peripheral vascular disease was the cause of amputation in nine of the subjects and trauma in the tenth.

## Methodology

All subjects were fitted with a temporary PTB prosthesis with various methods of suspension. The terminal devices, the SACH foot and the single axis-ankle joint and foot, were alternately allocated at the time of prosthetic fitting so that five of the subjects were using the SACH foot initially and five were using the single axis foot. Subjects then received routine gait training by a physiotherapist. When able to ambulate independently for a distance of at least 10m subjects were evaluated in the Locomotion Laboratory, Department of Physical Therapy, University of Western Ontario, London, Canada. The mean time from surgery to initial evaluation in the laboratory was 5.5 months.

Following evaluation of gait using the first terminal device, the second was applied and the appropriate alignment changes were made by a prosthetist. Subjects were then allowed a minimum of one week to adjust to the change in terminal device. They then returned to the laboratory for evaluation of their gait when using the second terminal device. The mean time between the first and second evaluation was 24 days.

## Data collection

Electromyographic activity of the vastus lateralis and medial hamstrings was recorded bilaterally using Beckman, silver-silver chloride surface electrodes, 16mm in diameter, with an active electrode size of 9mm. The skin of the area to which the electrodes were attached was shaved when necessary, and cleansed thoroughly with gauze soaked in alcohol to remove the superficial layer of dead skin and protective oils. The electrodes were filled with gel and attached to the skin, in a bipolar fashion along the long axis of the muscle, using adhesive electrode collars. Interelectrode distance was kept constant by placing electrodes such that the adhesive collars met but did not overlap. A ground reference electrode was attached to the skin over the lateral femoral condyle.

A system of contact closing footswitches* was used to relate the electromyographic activity of these muscles to components of the gait cycle. Three pressure sensitive switches were taped to the sole of the subjects' shoes; at the heel, head of the 5th metatarsal and the great toe. Closure of a switch or series of switches resulted in an electrical signal indicating contact of any part of the foot with the floor.

The footswitch and electromyographic data were collected as subjects walked along the walkway at their preferred cadence. The signals were transmitted from the subject to a processing and recording unit by an FM telemetry system.** The EMG signals were

* Model T4-025, Mountain West Alarm Company, Pheonix, Arizona.

** Conestoga Medical Electronics, Waterloo, Ontario.

subsequently amplified, full wave rectified and filtered to provide the linear envelope representative of the EMG signal. Both the footswitch signals and the linear envelopes were recorded on a Gould Brush 8 channel ink recorder.

## Analysis

The EMG and footswitch data were visually inspected. Three consecutive strides, which appeared most representative of the subject's gait, were chosen for analysis. Each stride was divided into 10% intervals with initial contact representing 0% of the gait cycle. The lowest level of EMG activity recorded over the three strides was used as a reference point. The amplitude of the EMG linear envelope in microvolts above this baseline was then determined at each 10% marker. The data from the three consecutive strides were averaged to obtain a representative EMG pattern over one stride for each muscle.

In order to permit between subject comparison of EMG activity levels, the microvolt measurements were transformed into relative amplitudes. The method of normalization used was similar to that reported by Knutsson and Richards (1979) and Yang (1984). The average peak amplitude of the three strides for each subject was given a value of 100% and the mean values at the remaining points in the gait cycle were expressed as a percentage of this mean peak amplitude. Mean values for all subjects were then calculated at each 10% point of the gait cycle and this data was subjected to statistical analysis.

A Dunns Multiple Comparison procedure was used to test whether there were significant differences in EMG activity at any point in the gait cycle when the two terminal devices were compared.

## Results

To facilitate interpretation of the electromyographic data, a summary of the temporal parameters of gait, with the subjects using each of the terminal devices is presented in Tables 1 and 2. This data, as well as knee joint angle measurements throughout the gait cycle has been previously reported (Culham et al, 1984).

† Model 2800, Gould Inc., Instrument Systems Division, Alan Crawford Associates, Mississauga, Ontario.

**Table 1. Comparison of mean values and standard deviations — velocity, cadence and stride length**

| Parameter | SACH foot | Single axis foot | p value |
|---|---|---|---|
| Velocity (metres/minute) | 34.37±10.43 | 32.87±8.46 | .501 |
| Cadence (steps/minute) | 70.60±9.98 | 67.10±7.19 | .107 |
| Stride length (metres) | 1.173±.26 | 1.81±.19 | .230 |

**Table 2. Mean values of the temporal parameters of gait expressed as a percentage of the gait cycle**

| | Prosthetic limb | | | Contralateral limb | | |
|---|---|---|---|---|---|---|
| | SACH foot | Single axis foot | p value | SACH foot | Single axis foot | p value |
| Stance | 65.68 | 63.63 | .041 | 70.73 | 70.79 | .941 |
| Swing | 34.32 | 36.37 | .041 | 29.14 | 29.21 | .934 |
| Single limb support time | 29.14 | 29.21 | .934 | 34.32 | 36.37 | .041 |
| Initial double limb support time | 23.30 | 21.95 | .267 | 13.14 | 12.42 | .393 |
| Terminal double limb support time | 13.14 | 12.42 | .393 | 23.30 | 21.14 | .267 |
| Total double limb support time | 36.44 | 34.37 | .036 | 36.44 | 34.37 | .036 |

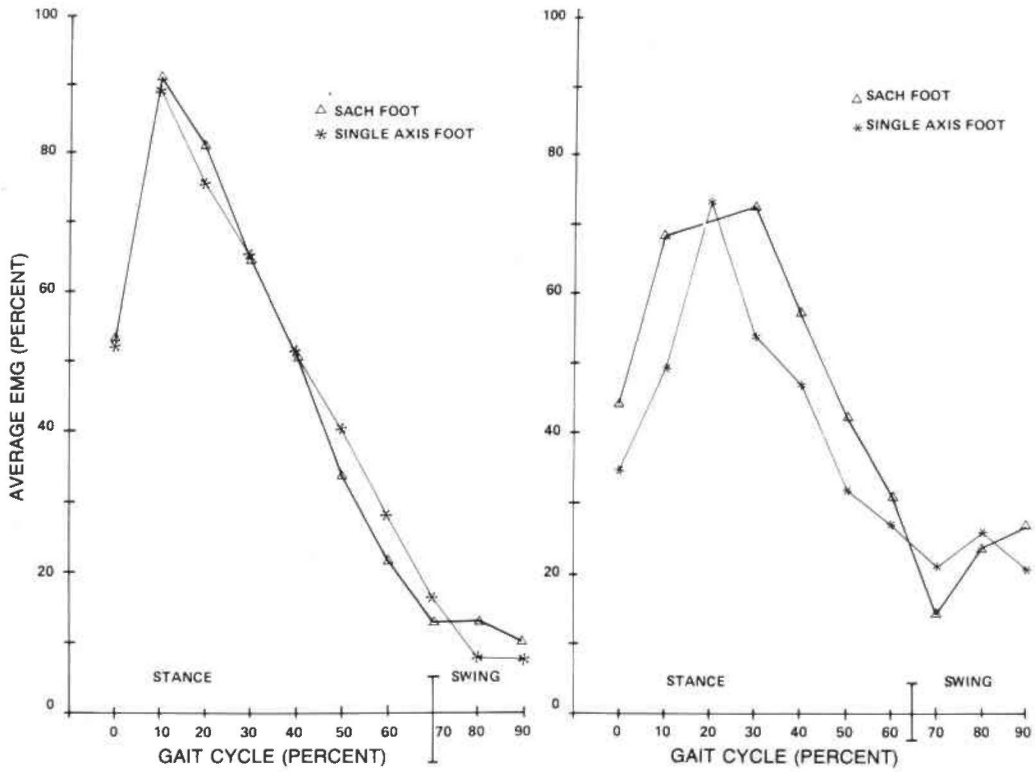


**Fig. 1. Mean EMG pattern of vastus lateralis expressed as a percentage of the mean peak amplitude (N=10). Left, non amputated limb SACH foot: 100% = 149.7 microvolts. Single axis foot: 100% = 154.6 microvolts. Right, prosthetic limb SACH foot: 100% = 105.2 microvolts. Single axis foot: 100% = 122.5 microvolts.**

The patterns of quadriceps (vastus lateralis) muscle activity of the contralateral (non-amputated) limb were very similar for the two terminal devices and did not differ statistically at any point in the gait cycle (Fig. 1, left). The highest levels of activity were recorded during early stance and peak activity occurred at 10% of the gait cycle with both devices. From this point activity levels decreased sharply throughout the rest of stance and remained at relatively low levels throughout most of the swing phase.

In the prosthetic limb, peak quadriceps activity occurred later in the stance phase at 20% and 30% of the gait cycle with the SACH foot and single axis foot respectively (Fig. 1, right). Following this peak the level of activity decreased throughout the remainder of stance and early swing with both devices.

The level of EMG activity did not differ significantly at any point in the gait cycle when the two terminal devices were compared.

The highest levels of hamstrings activity for the contralateral limb were recorded during early stance with both terminal devices (Fig. 2, left). Peak activity occurred at initial contact with the SACH foot and at 10% of the gait cycle with the single axis foot. From this point, activity levels fell sharply and relatively low levels of electromyographic activity were observed during late stance and initial and mid swing. The patterns were very similar and there were no statistically significant differences in the level of activity at any point in the gait cycle.

In the prosthetic limb, differences in the pattern of hamstring muscle activity were observed during the stance phase when the terminal devices were compared (Fig 2, right). When the SACH foot was used, the hamstrings

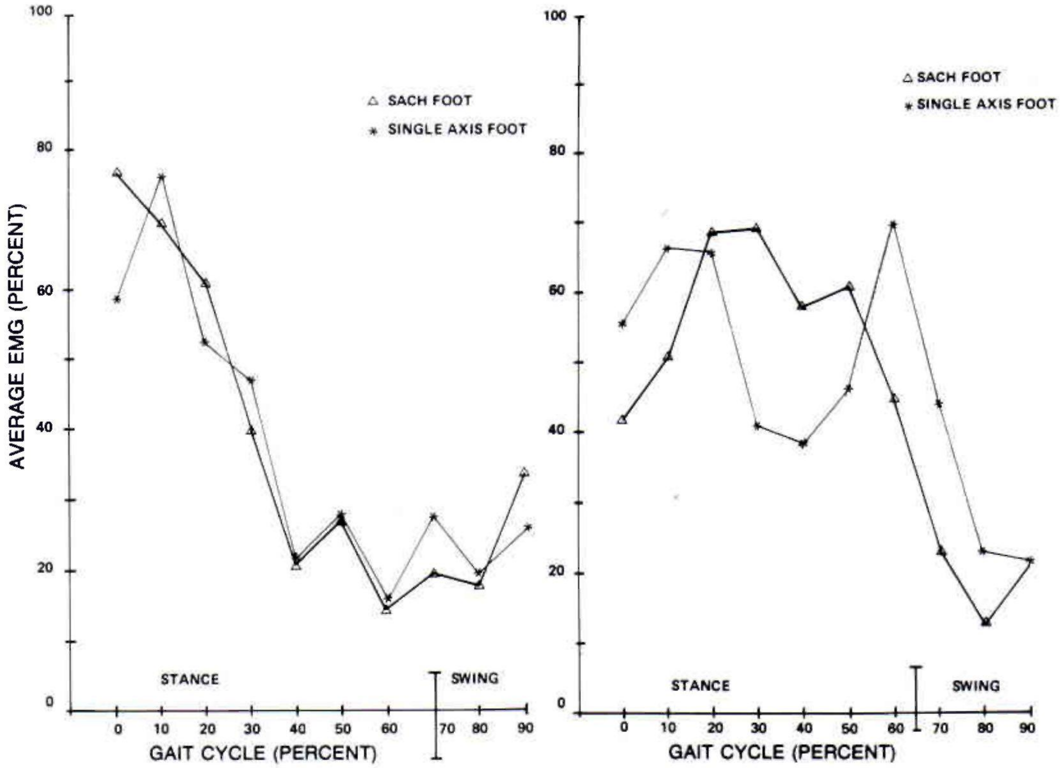


**Fig. 2. Mean EMG pattern of medial hamstrings expressed as a percentage of the mean peak amplitude. Left, non-amputated limb SACH foot: 100% = 179.6 microvolts. Single axis foot: 100% = 167.6 microvolts. Right, prosthetic limb SACH foot: 100% = 115.2 microvolts. Single axis foot: 100% = 83.3 microvolts.**

were active throughout the early and mid stance phase and peak activity occurred at 30 per cent of the gait cycle. The level of activity decreased from 50-80% of the gait cycle, corresponding to terminal stance and initial and mid swing. When the single axis foot was attached to the prosthesis two peaks of hamstring activity were observed, the first during early stance, at 10% of the gait cycle, and the second during the stance/swing transition, at 60% of the gait cycle. The level of activity decreased sharply during initial and mid swing. Statistically significant differences in the level of activity occurred at 30 and 60% of the gait cycle when the two terminal devices were compared ($p<.05$).

## Discussion

The electromyographic patterns of the quadriceps and hamstring muscles in the contralateral limb of the amputee subjects were unaffected by the change in terminal device and the patterns, with both devices, were similar to those reported for normal healthy individuals (Battye and Joseph, 1966; Dubo et al, 1976).

Peak quadriceps activity of the contralateral limb occurred during early stance, at 10% of the gait cycle, regardless of which terminal device was attached to the prosthesis. At this point in the gait cycle the knee is flexing and the centre of gravity falls posterior to the knee joint (Perry, 1974). Quadriceps action is necessary to restrain the flexion force at the knee and thereby preserve stability (Perry, 1974).

The sharp decrease in the level of quadriceps activity following weight acceptance, observed in the contralateral limb of subjects in this study is also typical of normal gait (Sutherland, 1966; Perry, 1974). Soleus is active during early stance and functions to restrain the forward movement of the tibia over the fixed foot (Murray et al, 1978; Simon et al, 1978). As momentum carries the body forward over the stabilized tibia, the centre of gravity moves anterior to the knee joint resulting in passive knee extension. The quadriceps are no longer needed to stabilize the knee and they become relatively silent by mid stance (Perry, 1974).

A second small peak of quadriceps activity has been reported to occur at the stance/swing transition in some normal individuals (Battye and Joseph, 1966; Milner et al, 1971). It has been postulated that quadriceps are active at this time to stabilize the knee and counteract the flexion tendency created by the gastrocnemius during 'push off' (Battye and Joseph, 1966). This second peak was not observed in the contralateral limb of the amputee subjects. Absence of this second peak may be related to the relatively slow walking speed of the subjects, decreasing the requirement for reactive stabilizing forces at the knee.

The highest levels of hamstring muscle activity in the contralateral limb of the amputee subjects were recorded during early stance, 0 and 10% of the gait cycle with the SACH and single axis foot respectively. This is similar to the pattern seen in normal locomotion in which predominant hamstring activity occurs during the deceleration period of swing activity continuing into the early part of stance (Milner et al, 1971) ; Dubo et al, 1976). During initial stance the centre of mass falls posterior to the knee joint. This combined with the downward and forward moving trunk results in a flexion force at the hip and knee. Hamstrings and quadriceps act to resist this flexion tendency by stabilizing the hip and knee during this part of the gait cycle.

In some normal individuals a second peak of hamstring activity occurs at the end of stance phase (Battye and Joseph, 1966; Milner et al, 1971). This second phase of activity may be related to knee flexion in preparation for swing. Two smaller peaks were observed in the contralateral limb of subjects in this study, the first during stance, at 50% of the gait cycle, and the second at the end of stance, at 70% of the gait cycle. The second peak may be related to swing phase flexion but the function of the peak at 50% of the gait cycle is unclear.

With both terminal devices the pattern of quadriceps muscle activity in the prosthetic limb of the amputee subjects differed from that of the contralateral limb. Peak activity occurred later in the stance phase and the period of activity appeared to be prolonged regardless of the terminal device used. The delay in the occurrence of peak activity is probably related to the lengthened period of initial double limb support. Body weight was not fully accepted by the prosthetic limb until 20-25% of the gait cycle had been completed. Quadriceps were active throughout this prolonged period of weight acceptance and the highest levels of activity occurred at the beginning of the single limb support phase when the prosthetic limb was most vulnerable.

The prolongation of quadriceps activity during stance may also be related to the absence of the restraining action of the soleus muscle from initial to mid stance necessitating a greater contribution from the quadriceps in order to stabilize the flexed knee. Prolonged quadriceps femoris activity in the absence of triceps surae has been reported by other investigators (Breakey, 1976; Murray, 1978). Breakey (1976) found that quadriceps were active from initial contact to 27% of the gait cycle in subjects with below-knee amputation using a PTB prosthesis and the SACH foot attachment, compared to 0-18% reported for normal individuals. The increased duration of quadriceps activity during stance phase was felt to be related to the loss of the stabilizing effect of soleus on the knee joint.

The pattern of quadriceps activity of the prosthetic limb was also influenced by the change in terminal device. With the SACH foot attachment, the period of stance phase quadriceps activity appeared to be more prolonged than with the single axis foot although this difference was not statistically significant. In normal gait the ankle dorsiflexes to approximately 10 degrees during the mid stance phase of gait as the body is propelled forward over the stationary foot (Murray, 1967; Lamoreux, 1971). As the ankle dorsiflexes the centre of mass of the body passes anterior to the hip and knee resulting in passive extension of these joints (Perry, 1974). The SACH foot, with no ankle mechanism, does not permit dorsiflexion and possibly provides some resistance to forward progression during the mid stance phase of the gait cycle. Prolonged quadriceps action may be needed to actively extend the knee and contribute to forward movement of the body. In addition, heel rise must occur earlier with the SACH foot than it would in normal gait. Breakey (1976) found that heel rise of subjects with below-knee amputation occurred at 31% of the gait cycle compared to 43% reported for normal subjects. Early heel rise would tend to decrease stability and might contribute to the somewhat prolonged and higher levels of quadriceps activity observed during stance when the SACH foot was used.

The pattern of hamstring muscle activity in the prosthetic limb of the amputee subjects differed from that of the contralateral limb and was affected by the change in terminal device. With both terminal devices, the period of peak activity of the hamstrings was prolonged compared to the contralateral limb. This finding may be related to the longer period of initial double limb support and the increased demands placed on the hamstrings by loss of the stabilizing function of the triceps surae.

The hamstrings were active throughout the stance phase when the SACH foot was attached to the prosthesis. The level of activity at mid stance (30% of the gait cycle) was significantly higher with the SACH foot than with the single axis foot. A similar finding of abnormal hamstring activity during mid stance has been reported to occur in subjects who had undergone surgical ankle fusion (Mazur et al, 1979). The rigidity of the SACH foot may be responsible for this difference, and for the apparent co-contraction of the quadriceps and hamstrings at the mid stance point of the gait cycle. Additional hamstring muscle action may be necessary to actively extend the hip and overcome the resistance to forward progression offered by the SACH foot. Early heel rise of the SACH foot may also necessitate additional stabilization of the hip at mid stance.

A more phasic pattern of hamstring activity was observed when the single axis foot was attached to the prosthesis. Two phases of activity were observed, the first during stance and the second at the stance/swing transition. Hamstring activity during early stance would be necessary to control the postural demands created by the flexed hip and knee as the limb accepts a weight bearing function.

The second peak of hamstring activity, with the single axis foot, occurred at 60% of the gait cycle and at this point the level of activity was significantly greater than with the SACH foot attachment. This phase of hamstring activity may function to actively flex the knee in preparation for swing. The average mass of the single axis foot was 1.298kg greater than the SACH foot. This difference may have contributed to the higher levels of activity observed with the single axis foot at the end of the stance phase. Previous research has demonstrated that foot mass had no effect on temporal parameters of knee joint angle (Godfrey et al, 1977). Patterns of electromyographic activity were not investigated.

## Conclusions

The patterns of quadriceps and hamstring muscle activity of the contralateral (non-amputated) limb of the amputee subjects were similar to normal and were not influenced by changing the terminal device.

Muscle activity patterns in the prosthetic limb differed from those observed in the contralateral limb and the patterns were influenced by the terminal device used. There appeared to be more co-contraction of the quadriceps and hamstrings during the mid stance phase of the gait cycle when the SACH foot component was attached to the prosthesis. The additional muscle activity may be necessary compensation for lack of ankle movement in this device.

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# The Pringle and Kirk four-bar crossed linkage and the "safety-knee"

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## Introduction

Historical literature on prosthetics is not large compared to other specialities, and there is relatively little written about the men at its origins. It is worth recording some of these men and their times.

Alexander Pringle (Fig. 1) was born at Bessbrook in Northern Ireland in 1880, where his father was the manager of a large spinning mill. His two brothers became doctors, but Alexander escaped to become an engineer, serving his apprenticeship in Belfast and Manchester. He was also lucky to have two sisters who married into the Mackie family, which owned a large textile machinery manufacturing firm in Belfast, that still exists today. As was fashionable in those days, he sailed for the United States in 1911, to be employed by GEC, and subsequently the Revere Rubber Company. This was a time when America was forging ahead with mass production methods, and young Alexander learned engineering from the floor up. His expertise came to the attention of James Mackie when he returned home in 1913. There was a whiff of war in the air, and he was engaged to reorganise the tool-room of the family firm in Belfast on American lines. He did this with remarkable success and in the 1914-1918 war Mackies played its part in making munitions.

**Fig. 1. Alexander Pringle.**

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It was at this stage that fate directed Alexander Pringle into an involuntary interest in prosthetics. There was at that time an eminent and successful, if eccentric, surgeon known as 'Surgeon Kirk' in Belfast (Fig. 2). Surgeon Kirk was invited to London in 1917 to discuss the problems of the amputees from the dreadfully mutilating war in Europe. He was not impressed by the artificial limbs provided at that time, and decided to change the situation. On returning to Belfast, he berated his friend James Mackie on the poor contribution engineers were making to the suffering imposed on limbless soldiers by the munitions they were manufacturing. There is little doubt that James Mackie's conscience was pricked, and he donated the part-time services of his best man, Alexander Pringle.

## *The P & K arm*

Surgeon Kirk and Alexander Pringle started by designing an artificial arm. In just over a year, they researched, designed, tested prototypes and were in mass production with their P & K

Fig. 2. Surgeon T. Kirk.

artificial arm. Undoubtedly, most of the expertise lay with Alexander Pringle (James and Orr, 1983).

Patent No. 114,220 (1918) related to their hand with a 'four finger' grip (Fig. 3), produced by a cable pulling through a 'D' shaped spring by

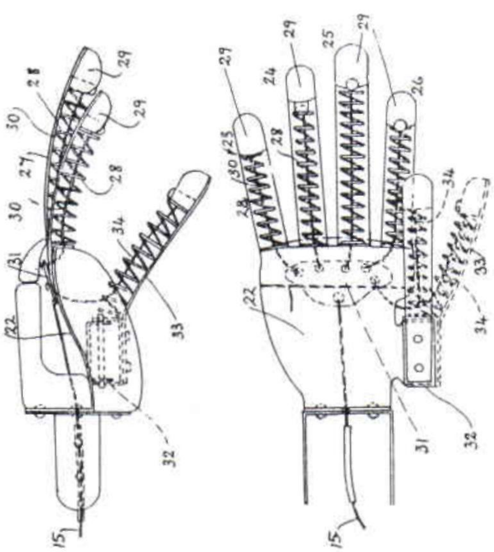

Fig. 3 The P & K hand. Patent no. 114220.

Fig. 4. Sergeant Major Cox,

means of a rachet lever at the wrist. There were three other patents relating to upper limb prostheses.

They were lucky to have as one of their first patients a Sergeant Major Cox (Fig. 4) who lost his arm in France in 1918. **A** fine looking military man, with a waxed moustache, who became adept with his P & K arm, he could use a hammer, doff his hat, grip a glass of water, and even lift a boy seated on a chair. He was a natural choice to head their sales team. Pringle and Kirk were in business. Their first contract was to supply 500 artificial arms to the Ministry of Pensions for limbless ex-servicemen. The P & K Artificial Limb Company was born with headquarters in Belfast, and branches in Glasgow, Southampton, New York and Melbourne.

### *The 'safety-knee'*

Pringle did not rest on his laurels, and carried on with his prosthetics research, turning his attention to the lower limb, no doubt because there were 41,000 ex-servicemen with lower limb amputations.

Until the 1920's the common form of knee joint was a simple hinge. In 1921 an advertisement appeared in the newspapers which read:

'Something new in Artificial Limbs.'

'The knee joint automatically locks every time the weight is taken on the artificial leg."

In other words, the 'safety-knee' had arrived, by courtesy of Pringle and Kirk.

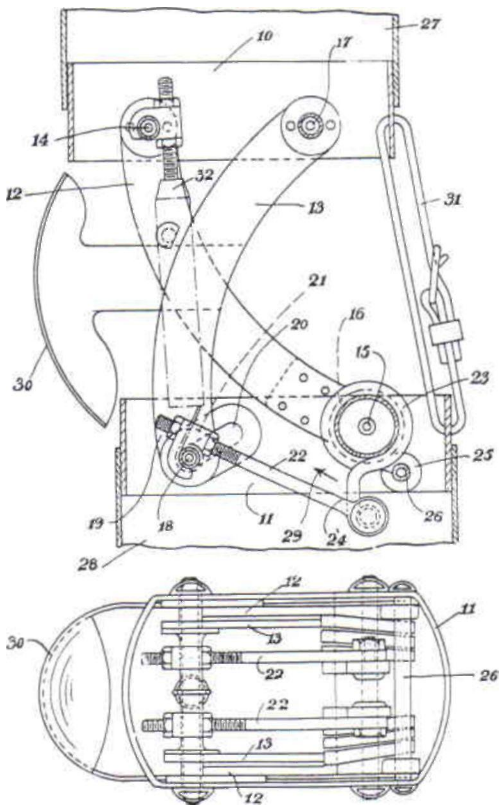


**Fig. 5. The safety-knee. Patent no. 184511**

Patent No. 184,571 (1922) was taken out for this device. The engineering drawings show the locking device acting on a crossed four-bar linkage, with a cosmetic knee-cap (Fig. 5). The Patent states:

'It has already been proposed to construct a knee joint comprising cross links. It has also been proposed in relation to other types of knee joints, to construct the joint with spring frictional means for automatically locking the joint under pressure of the wearer, the spring means re-enacting to release the frictional locking action when the pressure on the limb is relieved. It is however novel to combine a knee joint of cross-linked construction with spring action frictional means for automatically locking the knee joint under pressure of the person wearing the limb, the spring means re-acting to release the frictional locking action when pressure is relieved.'

Patent 150,901 (1920) shows a limb construction using a lattice-work. It said:

'At elbow, wrist, shoulder, or knee or other joints the crossed links connecting the cross frames or rings may be pivotally connected with the cross frames or rings, and be free to move relatively to each other so as to allow the structure to be moved in such manner as to simulate the movements of a human joint.'

It would seem that he was moving towards a 'four-bar' linkage of the 'crossed' type, although 'open' linkage is now more common (Radcliffe, 1970).

The present Pringle family well remember that one of the prototypes of the 'safety knee' failed, the wearer had an unfortunate gait pattern, and was subsequently arrested by the police for being 'drunk and disorderly'.

Pringle became Managing Director of the P & K Arm Ltd. in Belfast, and Surgeon Kirk continued with his wide interests. Kirk firmly believed, in a time when antibodies were the vogue, that dried serum from elderly cows and horses was the answer to infections and other ills. Were you honoured to have tea with him at the Royal Victoria Hospital in Belfast in the 1920's, your sandwiches might well taste gritty from the powdered serum put there for your benefit. Pringle assisted in the project by inventing a motorised 'pill making' machine which was installed in a bedroom of Kirk's elegant home. Private patients visiting the house were disturbed by the vibrations of the machine, and it was christened 'the flying bedstead'.

Competition in the prosthetics field was fierce in the 1920's and Pringle and Kirk were better inventors than business men. P & K Arm Ltd. slowly failed, Pringle returned to James Mackie and Sons Ltd. in 1937, no doubt to prepare for the next war, and P & K Arm Ltd. closed.

Pringle was a brilliant engineer. A quiet and thoughtful man who retired in 1949 to take up gardening, archaeology, geology and bee-keeping, and died in 1959. Kirk was an enthusiastic surgeon and a colourful character, who retired in 1938, and died in 1940, probably of boredom, for he was an energetic man. Three P & K arms remain in the Rehabilitation Engineering Centre at Musgrave Park Hospital in Belfast as a reminder of Pringle and Kirk.

Belfast is well known in this day for an unruly element in its population. It should not be forgotten that it is a University City and a seat of learning. Not least, it is the home of the Ferguson tractor, John Boyd Dunlop's pneumatic tyre, the 'hover-jet', the four-bar crossed linkage, and the 'safety-knee'.

**Acknowledgement**

We gratefully acknowledge the assistance of Mr. J. McCoy of the South Eastern Education and Library Board for his research into the Patents of Pringle and Kirk.

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# Prosthetic use in adult upper limb amputees: a comparison of the body powered and electrically powered prostheses

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**Abstract**
Three hundred and fourteen adult upper limb amputees were reviewed retrospectively at the Ontario Workers' Compensation Board. A questionnaire was used to evaluate the use of body and electrically powered prostheses. Follow-up ranged from 1 to 49 years with a mean of 15 years. Results indicated that complete or useful acceptance of an electrically powered prosthesis was reported by 69 of 83 amputees (83%); 199 of 291 amputees (68%) used the cable operated hook, 57 of 291 (20%) used the cable operated hand and 40 of 83 (48%) used the cosmetic prosthesis. The majority of amputees used more than one prosthesis for their functional needs and should be fitted with more than one type of prosthesis. Acceptance of an upper limb prosthesis by 89% (196/220) of below-elbow, 76% (56/74) of above-elbow and 60% (12/20) of high level amputees indicates that for most upper limb amputees, their prostheses are well used and essential to their personal and employment activities.

## Introduction

The Amputee Clinic at the Workers' Compensation Board, Downsview Rehabilitation Centre provides Ontario workers who have sustained an amputation in a work related accident with medical, prosthetic, psychosocial and vocational services. The multidisciplinary treatment team consists of a physician co-ordinator, nurse, prosthetist, physiotherapist, occupational therapist, remedial gymnast, social worker, research associate, vocational rehabilitation counsellor, secretary and medical director of the Clinic, who is an orthopaedic surgeon.

The impact on a person due to the sudden loss of a hand or arm cannot be overstated. Prosthetic fitting and training is crucial to successful rehabilitation and reintegration of the amputee into society.

The loss of fine, co-ordinated movements of the hand, tactile sensation, proprioceptive feedback, and aesthetic appearance can only be compensated for to a limited extent by the three types of prostheses that are at present available. These are a body powered and cable operated prosthesis with a split hook or hand as a terminal device; an electrically powered prosthesis controlled by muscle sensors (myoelectric) or by microswitches; and a cosmetic replacement with a passive hand.

The standard practice at this Amputee Clinic is initially to fit and train each below and above-elbow amputee with a cable operated prosthesis supplied with one or more hooks and a hand. Following the evaluation of a request for a myoelectric or cosmetic prosthesis, these prostheses may also be provided. Shoulder disarticulation and forequarter amputees are fitted from the onset of prosthetic training with electrically powered prostheses. The supply of more than one prosthesis has evolved from the recognition that different kinds of prostheses are frequently used in combination by the amputee to meet a variety of functional needs.

Although several research projects, including those at the Downsview Rehabilitation Centre have been undertaken to assess the value of the electrically powered prosthesis, (Herberts et al, 1980; Northmore-Ball et al, 1980; Millstein et al, 1982; Heger et al, 1985), there are very few detailed reports on the acceptance and use of the body powered prosthesis. (Fletcher, 1970; Vitali et al, 1978; Stein and Walley, 1983; van Lunteren et al, 1983; Chan et al, 1984).

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The purpose of this present review was to assess the use of the various types of body powered and electrically powered prostheses for different levels of upper extremity amputations in adults in order to determine their function and acceptance. Advantages and disadvantages of each prosthesis were examined to determine the factors that influence the amputee's choice of an upper extremity prosthesis over a long period of time.

**Patients and methods**

The population surveyed included 314 patients, who had sustained a single upper limb amputation in a work related accident and had been treated by the Workers' Compensation Board Amputee Clinic. There were 45 wrist disarticulations, 175 below-elbow amputations, 3 elbow disarticulations, 71 above-elbow amputations, 15 shoulder disarticulations and 5 forequarter amputations.

The amputee's age at amputation ranged from 14 to 68 years with a mean of 34 years. The average age of the patients at review was 49 years, the oldest being 82 and the youngest 15. There were 302 men and 12 women. The period between accident and follow-up ranged from 1 to 49 years with a mean of 15 years. The dominant side was amputated in 54 per cent of the population. Nine per cent had a revision of their amputation, of these 48% were revised to a higher level and 52% at the same level.

Evaluation included the completion of a standard questionnaire and a review of patients' records. The questionnaire examined the use of the various types of prostheses in activities of daily living, work and recreation. The questions were concerned with the amount of time a prosthesis was actually worn, its use and reliability and the problems the amputee encountered. For those amputees who possessed more than one type of prosthesis, a comparison was made in regard to the time the prostheses were worn and the activities for which they were used. The results of the questionnaire were coded and analyzed using the Statistical Analysis System.

Results

Ninety-six per cent of the amputees reported having a prosthesis at the time of review. Eighty-five per cent had a cable operated prosthesis with hook(s), 55% a cable operated hand, 10% a cosmetic prosthesis and 25% an electrically powered prosthesis.

At the below-elbow level, 95% (209/220) of the amputees had originally been fitted with a cable operated hook and 69% (145/209) of those amputees fitted were using this prosthesis. At the above-elbow level, 89% (66/74) had been fitted and 73% (48/66) were using it, and at the higher levels, 80% (16/20) had been fitted and 38% (6/16) were using it.

Although the same number of amputees at each level had been fitted with a cable operated hand, there were considerably fewer amputees making use of this prosthesis. Only 21% (44/209) at the below-elbow level, 18% (12/66) at the above-elbow level and 6% (1/16) at the higher levels reported using the cable operated hand.

Considerably fewer amputees had been fitted with a cosmetic prosthesis, but some had converted their cable operated hand into a cosmetic prosthesis with a nonactive hand by disconnecting the cable.

With respect to the cosmetic prosthesis, at the below-elbow level 26% (58/220) had been fitted and 59% (34/58) were using it, at the above-elbow level 27% (20/74) had been fitted and 20% (4/20) were using it and at the higher levels 25% (5/20) had been fitted and 40% (2/5) were using it.

One third (72/220) of below-elbow amputees had been fitted with an electrically powered prosthesis and 82% (59/72) of those fitted reported using it, 9% (7/74) of above-elbow amputees had been fitted and 86% (6/7) were using it and 20% (4/20) of high level amputees were fitted and all (4/4) were using it.

The number of hours of use on an average work day and weekend day indicated that these prostheses were well used. The cable operated hook was used for an average of 8 hours each work day and 7 hours on a weekend day. The electrically powered prosthesis was worn for an average of 8 hours each day throughout the week. The cable operated hand was used for an average of 5 hours each day and the passive cosmetic hand was worn an average of 4 hours each day.

The number of amputees using the various types of prostheses for an average of less than 4 hours per day, 4-8 hours per day and more than 8 hours per day is shown in Figure 1. There is very little difference in usage by time between the cable operated hook and electrically

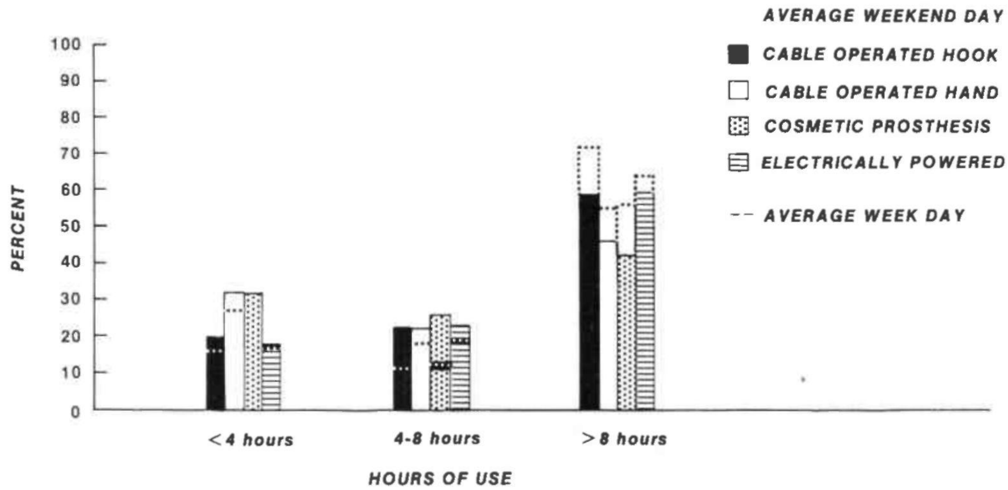


Fig. 1. Prosthetic use on average week day and weekend day.

powered prosthesis or between the cable operated hand and cosmetic prosthesis. During the week, (as indicated by the broken black line), the cable operated hook and electrically powered prosthesis were used the most often for over 8 hours and the cable operated hand and cosmetic prosthesis were used for the least number of hours.

For the cable operated hook as many as 73% of amputees reported they used it more than 8 hours on an average work day (Fig 1.). For the electrically powered prosthesis, 64% used it more than 8 hours during the week, 55% for the cable operated hand and 56% for the cosmetic hand. On the weekend, there was a change in the pattern of use of all types of prosthesis. More amputees were using their prostheses for shorter periods of time (less than 8 hours) rather than for longer periods of time (more than 8 hours) as was the case during the week. On the weekend 58% of amputees reported using the cable operated hook more than 8 hours, 59% of amputees used their electrically powered prosthesis, 46% used the cable operated hand and 42% used the cosmetic prosthesis.

Those upper limb amputees who reported rarely or never using their prosthesis, identified pain with limited function as the principal reasons. Other reasons included harness and stump problems. The percentage of nonusers was 11% (25/220) at the below-elbow level, 24% (18/74) at the above-elbow level and 40% (8/20) at higher levels (Table 1).

**Prosthetic activities of use**

Amputees were asked to indicate for what activities they used a prosthesis and which type of prosthesis they used for that particular

Table 1. Prosthetic use of body powered and electrically powered prostheses.

| | Below-elbow | | Above-elbow | | High level | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % |
| Cable-operated hook exclusively | 70 | 32 | 28 | 38 | 4 | 20 | 102 | 32 |
| Cable-operated hand exclusively | 14 | 6 | 2 | 3 | 1 | 5 | 16 | 5 |
| Cosmetic prosthesis exclusively | 13 | 6 | 4 | 5 | 1 | 5 | 18 | 6 |
| Electrically-powered exclusively | 22 | 10 | 2 | 3 | 3 | 15 | 27 | 9 |
| Combination of prosthesis | 76 | 35 | 20 | 27 | 3 | 15 | 100 | 32 |
| No prosthesis | 25 | 11 | 18 | 24 | 8 | 40 | 51 | 16 |
| Total | 220 | 100 | 74 | 100 | 20 | 100 | 314 | 100 |

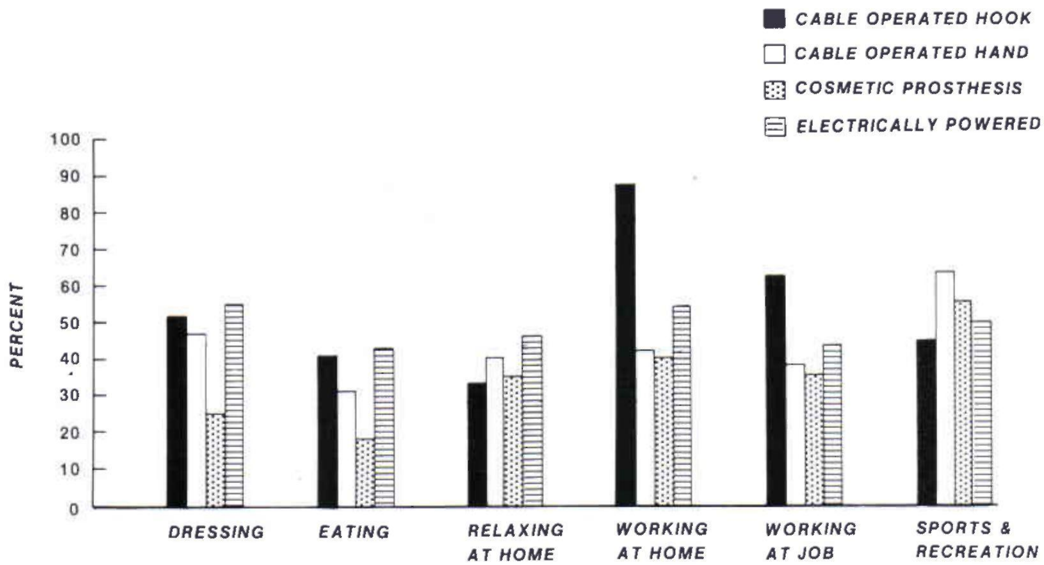


Fig. 2. Prosthetic use-functional activities.

activity. Figure 2 reflects a wide range of responses indicating a very varied preference by amputees.

*At work*

Sixty-six per cent of upper limb amputees reported using their prostheses at work. The choice of using a cable operated hook/hand, cosmetic prosthesis or electrically powered prosthesis depended on the requirements of the amputee. Amputees who used the electrically powered prostheses primarily had jobs that involved office work, supervisory work or contact with the general public. They were able to utilize the electrically powered prosthesis in their work tasks because of their light activities in a relatively clean environment. Those amputees who used a cable operated prosthesis had jobs that required heavy lifting or their work environment was unsuitable. It was generally dirty, materials to be handled were greasy or sharp and the danger of damaging the glove or prosthesis was high. For these jobs, the cable operated hook was more suitable because of its ruggedness and durability.

Exposure to extremes of weather can be a problem with the electrically powered prosthesis. Very cold weather will interfere with the function of the battery, and outdoor work in winter time can be uncomfortable because the stump may become very cold. Hot humid weather conditions or working strenuously can cause excessive sweating, leading to the loss of myoelectric control.

*Activities of daily living*

The extent to which body powered or electrically powered prostheses were used for activities of daily living was quite diverse. Below and above-elbow amputees found both types useful for eating, personal care and dressing. However, most high level amputees found their prosthesis less useful and used it only occasionally for activities of daily living.

*Recreational use*

Both body powered and electrically powered prostheses were used for a variety of sports and recreational activities. The most popular activities for which prostheses were beneficial included golf, fishing, gardening and minor home and car repairs.

Some amputees played baseball, broomball, or pool, while some were active in camping, canoeing, hunting and curling or hockey. The cable operated hook was preferred for heavier and more vigorous activities and some used the cable operated hand for specific sports.

*Social use*

The amputees liked the cosmesis of the electrically powered prosthesis and wore it for many social events. It was found to be considerably more acceptable in the social sphere than the cable operated hook. It was quite often not noticed or if noticed, it elicited amazement, interest and more positive comments than the hook. The electrically powered prosthesis was used most often for eating, holding objects and occasionally driving a car. High level amputees tended not to make active use of it often in a social setting as they felt the use would lead to greater attention directed toward them. However, they appreciated the availability of function when they desired it, combined with increased comfort. A few amputees did not mind wearing their cable operated hook in a social setting. However, many preferred using the cable operated hand and cosmetic prosthesis rather than the hook if they did not possess an electrically powered prosthesis.

In an attempt to ascertain which prosthesis satisfied our amputees' needs the most, calculations were made to determine how many amputees used one prosthesis exclusively and how many used a combination of two or more prostheses (Table 1). Approximately 1/3 (102/314) of amputees used the cable operated hook exclusively and approximately 1/3 (100/314) used a combination of more than one prosthesis.

Although only 9% (27/314) of amputees used the electrically powered prosthesis exclusively, the majority of amputees have been fitted with cable operated hook/hands whereas considerably fewer have been fitted with electrically powered prostheses. Amputees predominantly used the cable operated hook and electrically powered prosthesis in combination relative to their functional requirements. Only 5% (16/314) and 6% (18/314) respectively of amputees used the cable operated hand and cosmetic prosthesis exclusively.

**Acceptance**

For any prosthesis to be accepted and used by the amputee, it must be comfortable, functional and have a pleasing appearance. Other contributing factors that influence acceptance, are the quality of the stump, the level of the amputation, manual dexterity and motivation of the amputee.

Complete or useful acceptance of an upper limb prosthesis was reported in 89% (196/220) of below-elbow amputees, 76% (56/74) of above-elbow amputees and 60% (12/20) of high level amputees. The majority of amputees used more than one prosthesis for their functional needs at work, home, recreation and social events.

Amputees indicated that the most preferred prosthesis was the electrically powered prosthesis. The cable operated hook was the second most favoured followed by the cosmetic and cable operated hand.

Figure 3 illustrates the acceptance and use of the four types of prostheses. Since the majority of amputees have more than one prosthesis, there were multiple responses to this question.

For the cable operated hook the acceptance

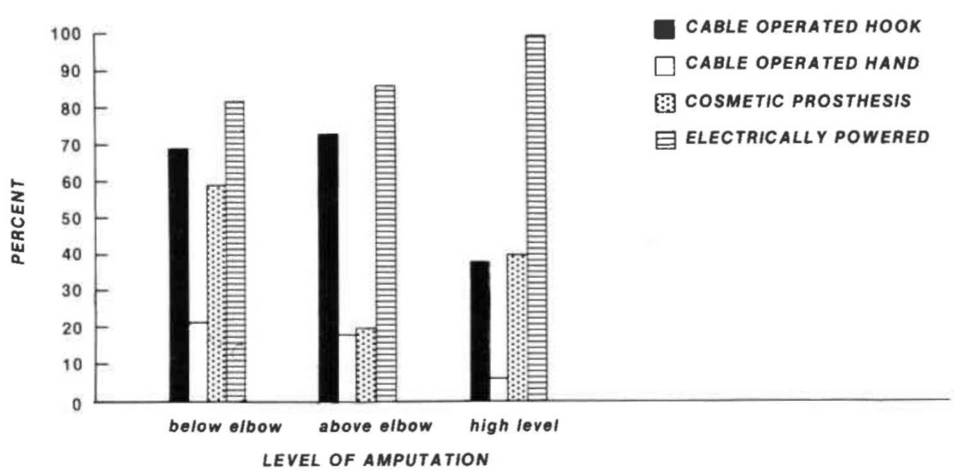


Fig. 3. Acceptance of body powered and electrically powered prostheses.

rate was 69% (145/209) at the below-elbow level, 73% (47/64) at the above-elbow level and 38% (6/16) at higher levels. The low acceptance rate by high level amputees is due to the high energy expenditure necessary to achieve limited function with a cable operated prosthesis. A wide range of acceptance rates for body powered prostheses exists in the literature from 34% (73/213) at the below-elbow level and 28% (29/103) at the above-elbow level by Vitali et al, (1978) to 90% (18/20) by Chan (1984).

The cable operated hook is especially advantageous for hobbies and jobs which require manual skills because of the following properties: it provides good sight of the grasped object; it is not easily damaged; it is designed for rugged conditions; it is easy to clean. An obvious disadvantage of the cable operated hook is the lack of cosmetic appeal. It is also difficult to stabilize some objects with the split hook, due to its shape and sometimes insufficient gripping force. To overcome some of these shortcomings, amputees may interchange their split hook with other hooks or terminal devices that have been designed for use in specific tasks or hobbies.

The cable operated hand has a very low acceptance rate at 21% (44/209), 18% (12/66) and 6% (1/16) for the various levels. Amputees have found the hand difficult to operate, awkward, and heavy. It is not durable and has a weak grip. This prosthesis is occasionally used for specific sports or work activities or as a nonactive prosthesis for cosmesis.

The acceptance of the cosmetic passive prosthesis covers a wide range from 59% (34/58) for below-elbow amputees to 20% (4/20) for above-elbow and 40% (2/5) for high levels. Amputees reported using this prosthesis primarily for social events. It is gradually being discarded in favour of the electrically powered prosthesis which offers cosmesis combined with function.

The high acceptance rate of 82% (59/72) at the below-elbow level, 86% (6/7) at the above-elbow level and 100% (4/4) for high level amputations for the electrically powered prosthesis is very positive (Fig 3), and it appears that amputees strongly favour this prosthesis, especially high level amputees. However, as yet, at this Centre only 33% of below-elbow amputees, 9% of above-elbow amputees and 20% of high level amputees have been fitted with the electrically powered prosthesis. A review at this Centre that followed up all 164 amputees fitted with electrically powered prostheses, resulted in an 80% (104/130) acceptance rate at the below-elbow level, 69% (11/16) at the above-elbow level and 72% (13/18) at the high level. (Heger et al, 1985). A $Chi^2$ test was done and the difference between acceptance rates for the three levels of amputation between the two studies was not statistically significant. Our acceptance rate at the below-elbow level compares favourably with the acceptance rates reported by Herberts (1980) and Stein and Walley (1983), who reported 37% (14/38) and 60% (14/23) at the below-elbow level respectively.

The advantages of electrically powered prostheses are:

1. Increased comfort because of lack of harness suspension for below-elbow amputees and simpler harnesss for higher level amputees.
2. Cosmetic acceptance by amputees and the general population. Although for some amputees, the lack of a large-sized prosthetic hand in comparison to the amputee's hand (largest available size is 8) may lead to unsatisfactory cosmetic appeal.
3. Superior pinch force (15 to 251bs.) compared with the cable operated hook (7 to 81bs.).
4. Control of the myoelectric prosthesis is more natural and less strenuous; movements of the hand and elbow units are independent of the position of the body.
5. For high level amputees, whose physical impairment is severe, the electrically powered prosthesis is a viable alternative to the cable operated prosthesis, because it provides a greater range of function and requires less energy expenditure.
6. Some sensory feedback has been reported by some amputees between the stump and prosthesis, the vibration of the motor and controlling muscle contraction.
7. Short below-elbow stumps can be provided with good function through skillful fitting of the Muenster socket.

The disadvantages of electrically powered prostheses at the present time are:

1. High cost factors in initial fitting (approximately twice as expensive as cable operated) and ongoing repairs (average of two repairs per year for our amputees).

2. Myoelectric service must be carried out in a specialized Centre.
3. The electrically powered prosthesis is not as durable as the cable operated prosthesis because it has not been designed for heavy work in regard to its suspension, wrist connection, handframe and glove. Many amputees were reluctant to' use the electrically powered prosthesis for some specific activities for fear of damaging the glove or its components. The current electric elbows have been criticized because they are too noisy, have limited strength, and move too slowly for functional purposes.
4. The shape of the hand makes some precise tasks more difficult.
5. The prosthesis requires more maintenance, eg. recharging the battery regularly and cleaning the glove.
6. The suspension of the Muenster socket and resultant weight distribution may cause discomfort and magnify the apparent weight of the prosthesis for some amputees.

The acceptance of prosthetic devices by upper limb amputees is a very complex process in which several important factors interact. Prosthetic fit and reliability are of special importance, but psychological and socioeconomic factors play important roles. Another review at this Centre on employment patterns of industrial amputees included the 314 upper limb amputees in this study. It was found that 88% of these upper limb amputees were employed at the time of review (Millstein et al, 1985). Prosthetic use by upper limb amputees was positively associated with return to work. Our experience shows that good acceptance figures for body powered and electrically powered prostheses can be obtained if prosthetic fitting and training is combined with the services of a multidisciplinary team. Patients must be followed up regularly and prosthetic fitting changed according to the changing needs of patients.

## Conclusions

The findings of this review of 314 upper limb amputees confirm that complete or useful acceptance of an upper limb prosthesis was reported in 89% of below-elbow amputees, 76% of above-elbow amputees and 60% of high level amputees. Prostheses are well used and essential to the amputees' personal and employment activities. Most upper limb amputees should be fitted with both a body powered and electrically powered prosthesis to meet their various functional requirements. The benefits of these prostheses far outweigh their costs.

The cable operated hook is well accepted and used by the majority of amputees for heavy work and precision tasks at work and at home. It provides good sight of the grasped object, is not easily damaged and is easy to clean. The cable operated hand and cosmetic prosthesis are used by a small number of amputees primarily for cosmesis at social occasions. In spite of the high initial cost and continued maintenance and repair, improvement in comfort, cosmesis and function have led to good levels of acceptance of the electrically powered prosthesis. For high level amputees, it provides better function, superior pinch force and requires less energy expenditure than the body powered prosthesis.

The multidisciplinary team approach, at the Amputee Clinic, patient follow-up and service have contributed to the very positive results of this review. These findings, combined with daily interaction with patients at the Amputee Clinic, suggest that upper limb amputees have the motivation and the ability to overcome the loss of a hand.

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# Bouncy knee in a semi-automatic knee lock prosthesis

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**Abstract**

The Bouncy Knee concept has previously proved of value when fitted to stabilised knee units of active amputees. The stance phase flex-extend action afforded by a Bouncy Knee increased the symmetry of gait and also gave better tolerance to slopes and uneven ground. A bouncy function has now been incorporated into a knee of the semi-automatic knee lock design in a pilot laboratory trial involving six patients. These less active patients did not show consistent changes in symmetry of gait, but demonstrated an improved ability to walk on slopes and increased their walking range. Subjective response was positive, as noted in the previous trials.

**Introduction**

Many knee mechanisms in above-knee prostheses are rigidly locked by some means while the limb is weight-bearing. This ensures the security of the knee against collapse into flexion. However the rigidity of the locking causes an asymmetry in gait, since the natural knee undergoes a flex-extend-flex action while under load in the walking cycle. In contrast, the rigidly locked prosthetic limb becomes a pole over which the pelvis must vault between heel strike and toe-off.

In 1981, Judge and Fisher described the concept of a 'bouncy' knee, a way to provide a more natural flex-extend-flex action in the knee unit of a prosthesis during the stance phase of gait. The absolute security of the knee is guaranteed by the conventional locking device, but an additional torsional spring incorporated into the knee still permits some degree of flexion. Torques naturally generated by the foot-floor reaction force during stance phase cause a flex-extend action 'bounce' in the torsional spring, which the authors demonstrate to approximate the natural knee action. Tests with an experimental knee unit on a single subject were favourable.

The Bouncy Knee concept was subsequently incorporated into a commercial knee unit for a six patient trial. The unit selected was the Blatchford Stabilised Knee (B.S.K.), a unit with a mechanism which automatically locks the knee when the limb is subjected to an axial load. This device is most frequently fitted to the prostheses of reasonably active patients, who can make use of its facility to allow free swing of the knee during swing phase of gait with automatic locking during stance phase. The B.S.K. trial (Fisher and Judge, 1985) established the predicted potential to improve symmetry of gait, by both subjective assessment and biomechanical measures. Additionally, the volunteer users reported a number of other benefits which they felt to be major. Among these were improved ability to walk on rough ground or slopes, improved balance lifting heavy loads, and improved socket comfort due to shock absorption (presumably in the rubber torsional spring).

The extremely positive response of the pilot volunteers encouraged the United Kingdom Department of Health and Social Security to initiate a 25 patient field trial with the Bouncy Knee/B.S.K. units. This is now completed and the findings were similar to that of the pilot trial, with the main advantages being a more natural gait, more tolerance of rough and sloping ground, and improved comfort. These advantages are all gained from a unit which carries insignificant overhead in terms of limb cost or weight.

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It had been intended from the onset to explore the use of the Bouncy Knee with different types of knee mechanisms, particularly the category of Semi-Automatic Knee Lock (SAKL). The knees of these prostheses automatically lock when fully extended, as for example when the wearer rises from a chair. During standing and gait, the knee remains locked in the fully extended position. The lock is released manually when the wearer wishes to flex the limb again, usually to sit down. This type of knee unit is used mostly with less active patients who need the confidence of a locked knee at all times. It was possible that the advantages of improved symmetry from the Bouncy Knee would not be realised in a limb which is predominantly used with less active patients, whose gait is perhaps too impaired to approach a natural rhythm. The results of the trial with the B.S.K. units indicated, however, that the additional bonus of improved comfort and slope tolerance were important benefits which might also be achieved for the SAKL users. This report describes the pilot trial which was conducted with SAKL prostheses wearers.

**Bouncy Knee action on non-level ground**

One of the major problems of lower limb amputees in walking in the natural environment is the intolerance of prostheses to ground which is not level and even. Compensation for irregular ground is made by the non-amputee by adjustments in posture denied to the amputee by the mechanics of their prosthesis. In this context, the Bouncy Knee can assist to restore stability when the ground is inclined or changes level in the line of progression of gait.

Consider the plight of an above-knee amputee standing on an incline with a rigidly locked knee and a fixed ankle joint. When the prosthetic foot is flat on the ground with a symmetrical stance, the line of bodyweight is necessarily thrown towards the anterior of the support base by the physical geometry of the fixed limb. Unless a counterbalancing force is provided through arm support via rails or sticks, or the natural limb and body posture are used to compensate, the person is in danger of toppling over forward. In walking down a slope a similar effect is imposed, whereby the line of bodyweight is too far forward over the base of support for stability whenever the prosthetic foot is flat on the ground. The patient must resort to an unnatural gait in order to negotiate even a moderate slope in safety, frequently edging down the slope sideways.

By allowing the knee to flex during load bearing, the Bouncy Knee can assist the amputee to do with his prosthesis what the natural limb would do on the same incline—bend the knees in order to allow the centre of gravity to stay over the base of support. Consequently in mid-stance phase on the prosthetic limb, the pelvis is not forced to move precariously anterior. In practice, a flexible ankle such as on the uniaxial foot will also affect the anterior-posterior stability on an incline.

Similar biomechanical arguments explain the increased tolerance to walking on rough ground. A locally inclining surface under the prosthetic foot has less tendency to topple the person over forwards. Lifting heavy loads is another instance where the non-amputee normally compensates by leaning posteriorly, and the Bouncy Knee flexion can assist the. amputee to sit back on his prosthesis. In the B.S.K. trial, subjects reported that they were able to mount kerbs without breaking step; normally the natural limb is preferred for the first step onto the higher level, whereas either limb was acceptable with the Bouncy Knee unit fitted. This is again a feature of the Bouncy Knee, which allows the prosthetic foot to go flat earlier on the pavement by flexion at the knee.

**The SAKL Bouncy Knee**

The design has been based on the VIP Mk.2 SAKL limb currently produced by Vessa Ltd. who have cooperated throughout this trial. The VIP knee enables a simple spring design to be housed within its hemi-spherical knee ball. The pivot of the Bouncy Knee unit is placed 50mm anterior to the knee axis bolt with a neat appearance and ease of production (Fig. 1). For simplicity twin helical compression springs were used to provide the bounce function. Three different pairs coupled with nesting springs of the opposite helix were available to provide a range of torsional stiffness. A simple hook attached to the pivoted plate and engaging with the knee bolt of the prosthesis acts as a back check to prevent hyperextension of the bounce unit. Maximum bounce flexion is 15°. This unit is experimental only.

The knee unit was fitted to a prosthesis made to the identical prescription as the normal

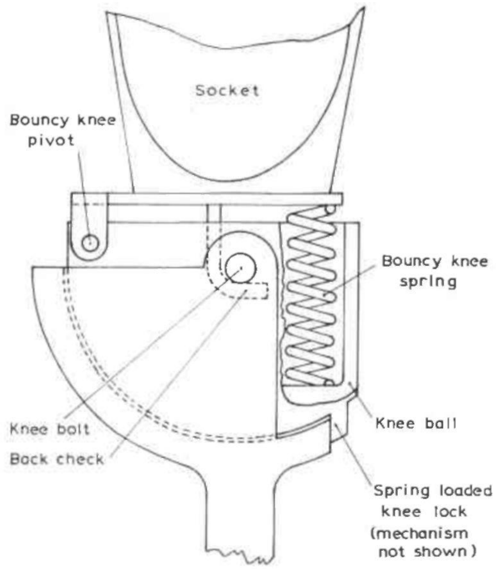


Fig. 1. The experimental Bouncy Knee/SAKL unit, based on the Vessa VIP knee.

service prostheses, all of which had uniaxial feet. The cosmesis was not fitted since the trial was to be conducted entirely intramurally; by this means the weight of the experimental and the service prostheses were kept the same.

The action of the Bouncy Knee depends on the line of the floor reaction force passing behind the bounce axis during stance phase, and thereby causing flexion. For the B.S.K. it was established that this condition could be met when the knee axis and bounce axis are coincident. However the B.S.K. knee alignment is set 'lively' with the axis forward for ease of swing. For the SAKL limb this alignment criterion is not relevant, and the line of the reaction force may possibly fall anterior to the knee bolt. To ensure that the floor reaction force falls behind the bounce axis, it was decided to place this axis well forward in the SAKL knee unit.

**Trial procedure**

The trial was conducted entirely in the laboratory and the walking training school. Six patients who were accustomed SAKL wearers were selected to represent a whole spectrum of activity level. This was to establish a 'cut-off point if it occurred. All were in reasonable health, had a medium length stump, and were reasonably happy with the fit of their current prosthesis. The subjects completed the trial sequentially from the most active to the least. Subjects 1 and 2 used one walking stick, Subjects 3 and 5 used two walking sticks, Subject 4 used two forearm crutches and Subject 6 used a Zimmer walking frame.

An experimental SAKL/Bouncy Knee limb was made for each subject, incorporating a facility to activate or disable the bounce with all other factors remaining constant. The gait of each subject was assessed subjectively by a physiotherapist, first with the service limb and then with the experimental limb (bounce inoperative). This confirmed that the gait of the subject was similar with both limbs. The gait of each subject was then monitored wearing the experimental limb (bounce inoperative) to give a baseline.

The bounce function was then activated. A force platform (Lord and Smith, 1984; Smith and Lord, 1985) was used to assess static alignment, particularly the centre of foot pressure and the line of the foot-floor force at knee level. The subjects' limbs were realigned to check whether any adjustment was beneficial to the Bouncy Knee action; however the final alignments were not measurably different from the starting service alignments, although this might not always be the case. The gait was reassessed after a period of familiarization comprising a few days walking training (level, slope and stairs). The gait was then monitored in the laboratory. The patient's comfort and confidence were assessed by questionnaire. The trial was then terminated.

The biomechanical assessment techniques used were a simple instrumented fishing reel line to monitor speed of walk along the level or down a slope; a footswitch on each heel to record heel strike; heel markers onto a strip of paper in order to measure stride and step lengths during level walking; and a special-purpose goniometer on the bounce axis to record bouncy knee flexion when operative. Measurements on a forceplate inserted in a walkway were discontinued as less active subjects experienced difficulty. Parameters calculated included length of stride, speed of walk, and maximum flexion of the Bouncy Knee in level walking and when walking down a slope of 1 in 7. The subjective reactions were assessed by questionnaire.

**Experimental results**

All six subjects completed the trial. The results of the biomechanical analysis are shown in Table 1. Statistical confidence levels are not given, since the numbers on the trial were small and the sample non-uniform in ability. The table demonstrates that, with the exception of subject 5,

stride lengths were increased,
walking on a slope was enabled or facilitated,
the bounce function was active in level and slope walking,
step length asymmetries were improved (S2 & S3), remained the same (S1 & S4), or worsened (S6).

The questionnaire and physiotherapist assessments indicated that,

it was much less effort to walk,
distance of walking before tiring increased 25% to 50% (S2, S3, S4 & S5), and 150% (S6),
although sometimes no changes in walk pattern were detected, the subjects stated that it was more comfortable to walk.

The physiotherapist assessed that subject 1 felt unsure of the bounce when first fitted as it gave him a feeling of insecurity.

It was noted that subjects who walked down the slope with a locked knee did so hesitatingly with a physiotherapist in front and at the side to increase confidence. With the bounce operative this was not necessary and the subjects walked unaided.

A consistent static alignment by the project prosthetist ensured that the line of bodyweight supported by the prosthesis fell posterior to the bounce axis; this was indicated by the centre of pressure under the foot.

**Discussion**

Improved symmetry of gait was not the major benefit sought from the Bouncy Knee in the SAKL prosthesis; indeed analysis of the ratio of left to right step lengths shows that the asymmetry was reduced in two subjects who were the most asymmetrical at outset (S2, S3); remained unchanged in the two subjects who were fairly symmetrical at outset (S1, S4); and increased in the last two cases (S5, S6). Subject 5 shows a deterioration in all the biomechanical measures which might not be ascribable to the bounce function since this was nearly unutilized throughout (Table 1).

With the exception of subject 5, all other subjects increased their stride length with the speed of level walking remaining about the same or increasing.

Regarding the additional benefits noted in the earlier trials, it was again shown that the ability to walk down a slope is considerably enhanced by a Bouncy Knee. The increased bounce

Table 1. Stride lengths and step lengths are the mean of the central 8 to 10 strides along a level walkway. 'Bounce' is defined as knee flexion during stance phase. A slope of 1 in 7 was used.

| Subject No. | | Stride Length mean,mm L-L R-R | Step Length mean,mm L-R R-L | Speed mean, Level | m/s Slope | Bounce maximum, degs. Level | Slope | Age; Date Side Amp |
|---|---|---|---|---|---|---|---|---|
| 1 | FIXED KNEE | 565:582 | 288:277 | 0.38 | — | — | — | 80 yr |
| | BOUNCY KNEE | 652:653 | 318:333 | 0.57 | 0.32 | 6.0 | 9.5 | 3/84 L/AK |
| 2 | FIXED KNEE | 659:651 | 501:149 | 0.49 | — | — | — | 73 yr |
| | BOUNCY KNEE | 697:695 | 457:238 | 0.52 | 0.30 | 3.5 | 7.0 | 10/82 R/AK |
| 3 | FIXED KNEE | 536:540 | 96:441 | 0.31 | 0.15 | — | — | 71 yr |
| | BOUNCY KNEE | 552:557 | 143:409 | 0.33 | 0.20 | 5.5 | 7.0 | 4/84 L/AK |
| 4 | FIXED KNEE | 440:439 | 199:241 | 0.23 | — | — | — | 68 yr |
| | BOUNCY KNEE | 520:514 | 232:289 | 0.24 | 0.11 | 12.5 | 15.0 | 6/84 L/AK |
| 5 | FIXED KNEE | 459:461 | 304:164 | 0.25 | — | — | — | 83 yr |
| | BOUNCY KNEE | 385:383 | 289: 93 | 0.23 | — | 1.8 | — | 11/83 R/AK |
| 6 | FIXED KNEE | 385:381 | 277:109 | 0.12 | 0.08 | — | — | 68 yr |
| | BOUNCY KNEE | 411:423 | 307:105 | 0.14 | 0.08 | 1.0 | 7.0 | 5/84 R/AK |

showed the extent to which bounce flexibility was being utilized in this activity. Walking on rough ground was not tested in the laboratory.

Subjective assessments by the physiotherapist and amputees were again favourable, especially with regard to 'making walking easier'. Even subjects 5 & 6, at the most disabled end of the spectrum and with a lack of entirely positive biornechanical outcome, liked the experimental limb with its bounce function.

It has been proposed that knee flexion during the stance phase of gait is energy-efficient (Bresler et al, 1957). Flexion of the knee and consequent shortening of the limb at mid-stance phase assists the centre of gravity of the body to pass forward approximately in a level horizontal plane, and minimizes the cyclical variation of kinetic energy in the vertical direction which would otherwise occur. This hypothesis may partially explain the frequent observation of the subjects that they could walk further-up to 150% in distance—without tiring. Other factors to take into account are that the Bouncy Knee has an energy storage capability, absorbing energy during early stance phase and releasing it during mid-to-late stance phase; and that the altered symmetry of gait reduces energy losses in other modes (not investigated).

## Conclusion

This pilot trial of the Bouncy Knee incorporated into a SAKL design has demonstrated the potential benefit of the device to less active amputees. The benefits are particularly evident in an increased tolerance of uneven ground and slopes, and in the increase in distance which the subjects could walk without tiring. The loss of rigidity at the knee did not cause these subjects any great concern, with only one subject showing an initial hesitation—later overcome. The trial has opened the way for further design work to develop a production unit.

## Acknowledgements

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# The Danish Amputation Register 1972-1984

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**Abstract**

The DAR was established in 1972 for the purpose of collecting data on major upper and lower extremity amputations as well as details on corresponding prosthetic fitting in Denmark. During phase 1 (1972-1980) voluntary reports were submitted by surgical departments and prosthetic manufacturers, totalling about 5000. During phase 2 (1978-1984) data on all amputations in Denmark were supplied on a yearly basis by the National Patient Register, a division of the National Health Board. The information collected during phase 1 is rather detailed, but does not represent the entire national output. The phase 2 data are less detailed, but yield full national coverage. The information is compatible as to distribution of age, sex and etiology. The methods and present status of dataprocessing are described and the planning for the foreseeable future is outlined.

## Introduction

Despite the centralized character of Danish government and a long tradition of medical statistics, no details were available in the early seventies on the number and types of amputations performed, nor on the size and composition of the amputee population. For many years the delivery of prostheses for amputees was recorded centrally, but unfortunately this work was abolished in 1970, and for reasons unknown the accumulated records were maculated. The situation was no better in other countries, in fact one of the best documented studies at that time was that of Hansson (1964) on the amputee population of Gothenburg City, Sweden. This work, like all other available studies built on small or modestly sized groups is more often than not unrepresentative and biased. Small wonder then, that information on standard parameters like types of amputation, etiology, complications, reamputation and contralateral amputation as well as mortality varied to a degree that rendered it impossible to obtain a valid picture of the quantitatively and qualitatively serious problems of amputation.

Consequently the Danish Amputation Register (DAR) was founded in 1972 in order to

1. Permit analysis of etiological factors, operative details, incidence and type of complications and reamputation, per- and postoperative death, duration of hospitalization, degree of mobility on discharge and certain basic social information.
2. Facilitate the selection of well-defined groups of amputees for the purpose of in-depth analysis.
3. Generate statistics on the number and type of prostheses delivered (initially and later) and to analyse technical aspects relative to the prostheses.
4. Permit trend analysis for prognostication of future needs in personnel, facilities and economy.

The present work is a report on the activities of the DAR from 1972 through 1984.

## The administrative infrastructure

By 1972 the Danish population numbered about 5 million. Since the mid-sixties all Danes were given a 10-digit "person number", composed of birth data plus four check-digits, the last representing sex. The system was monitored by the Central Person Register (CPR), which also recorded all births and deaths continuously. The entire hospital system was publicly owned and run and every hospital and department had a numeric code. In the individual hospitals diagnoses were recorded according to the International Classification of Diseases (ICD- nr.).

Since 1972 operations were coded locally according to a nationally adopted classification system. There was *n*o central recording. All counties and townships were systematically

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numbered. The CPR was accessible to professionals with a legitimate (e.g. scientific) interest in the information contained. The other code systems mentioned were publicly available upon request.

**Method — phase 1**

Because no centralized patient recording existed in 1972, a set of standard reports was designed, i.e. 1 - Hospital Report, 2 and 3 - Prosthetist's Reports on respectively, upper and lower extremity prostheses delivered. Each report was one sheet (quarto) which could be folded to constitute a letter, postage prepaid.

***Hospital Reports***

By early 1973 an appeal detailing the purpose and set-up of the DAR was issued to all Danish surgical and orthopaedic departments, as well as to all prosthesis establishments. Also all departments received sets of reporting forms with accompanying step-by-step instructions for filling in the forms.

The hospital reports (type 1) contain information on the individual patient's personal data; the hospital and department where the amputation was performed; the dates of admission, discharge and disposal (home, nursing home etc); further information on previous amputation(s), including when and where; as well as details on the actual amputation such as etiology, method of operation, the limbs involved, complications, eventual revisions or reamputation during the same admission; plus details on the state of mobilization on discharge. In-patient death and its cause was also recorded. The reporting being voluntary, nationwide coverage was not possible during the period from 1973 to 1980 when the collection of this type of data was terminated. However, approximately 70 per cent of all operating hospital departments were involved in reporting for shorter or longer periods. In most departments the recording was handled by senior residents, who received a small remuneration for the services rendered. Upon receipt in the DAR the reports were validated for completeness and, as far as possible, for coherence. Immediately upon the foundation of the DAR, concomittantly with the design and printing of the reporting forms, work was initiated on a data-processing system, based upon the OSIRIS data-base management system for mainframes. The data were transferred to magnetic tape via punch cards. The tape was then encoded in compliance with the exigencies of law. The data processing was carried out on the Northern Europe University Computing Centre (NEUCC) in Copenhagen.

During the project period a total of more than 5000 reports were processed in this way. A number of preliminary computations were carried out for ad hoc reporting and presentations. Moreover the long term mortality was established in comparison with the general population in the CPR. A preliminary report on the occurrence of ipsilateral reamputation, contralateral amputation and death was published earlier (Ebskov & Josephsen, 1980).

***Prosthetist's reports***

Until 1972 almost all upper and lower extremity prostheses in Denmark were manufactured in the workshops of "The Home and Society for Crippled Children" (SAHVA). Due to certain political complications the reporting did not get well under way until 1974, but thereafter functioned very satisfactorily for all but one establishment.

The prosthetists' reports (types 2 and 3) contain information on the individual patient's personal data, previous amputation(s) and general hospital information identical with the hospital reports, and, in addition, the prosthetist's code + number, details on time of stump measurements, delivery of the prosthesis at the fitting stage, the outcome of the ensuing training, adjustments and the final result. Finally the technical details regarding type of prosthesis and the components used in the production were recorded. Besides information on the lower extremity prosthesis supplied (type 2), information on the eventual postoperative immediate fitting, and other aids to mobilization employed prior to the delivery of the definitive prosthesis was recorded.

During the period up to 1980 a total of more than 5000 reports were received and processed.

**Method — phase 2**

As already mentioned, the DAR never succeeded in obtaining national coverage on a voluntary basis. In 1976 the Danish National Health Board established the National Patient Register (LPR), and decreed a duty for all hospitals, other than mental hospitals, to submit certain standardized information on all patients admitted. After a slow start the LPR was productive by 1978. As is the case with the CPR, persons and organizations with a documented legitimate scientific interest may obtain access to the information contained in the LPR. The DAR has had such access since 1978 and has subsequently received an annual report on all patients amputated during the preceding year. Whereas the individual patient records correspond to those of the DAR system in a number of respects, they lack information with regard to the side involved as well as finer deatils of the operative procedures and any complications.

By 1980 it was evident that the mainframe-based data analysis was too rigidly schematic to profitably utilize the increasing wealth of information contained in the DAR. Further, because of the complexity of the OSIRIS software we were depending upon expensive programmer's assistance.

Consequently a study was undertaken of the feasibility of using microcomputers for future analysis. By December 1981 the DAR acquired the first Apple microcomputer with the presently best available analytical tools. It soon became evident that whereas the principle was right, the realization was far too cumbersome to be realistic in the long run. Consequently by 1983 the Apple was replaced by an IBM PC/XT. This tool has proved fully satisfactory for handling the LPR data with a combination of compatible software packages (Infostar, Lotus 123 and Wordstar). In fact it has been possible upon short notice to process random segments of the data base for the purpose of specific presentations with a minimal consumption of time. Because of the very large amount of data now present, it has been necessary to establish connection to the hospital mainframe which is used for storage.

Until now it has not been possible to co-analyse corresponding pairs of hospital and prosthetist's records on the same individual. Very recently the advent of a sophisticated data base management tool (R-base 4000) has eliminated this obstacle to utilizing the hitherto inaccessible information contained in the phase 1 records.

## Discussion

The data collected during the two phases complement each other. The sets are compatible inasmuch as a comparison demonstrates equal distribution as to age, sex and etiology.

The phase 1 data permit a detailed analysis of reamputation and mortality. One such study, based on part of the entire material, was previously published (Ebskov, 1980). Further, these data are accessible to very detailed analysis of the relationships between age, sex, etiology, surgical procedure, complications, mortality and type of department where the amputation was performed. The realtionships between these parameters and the types of prostheses fitted, the duration of training with the prosthesis and the incidence of failure is also accessible.

The phase 2 data permit an analysis of the nationwide picture. A preliminary study has been published (Ebskov, 1983). At present inexplicable geographical differences have been isolated, and are now being subjected to further study. Because of the yearly reporting from the LPR, trend analyses as well as a reasonable approximation of the total amputeee population is possible, and at the planning stage.

## Conclusion

It may be argued that the information contained in the DAR should have been continuously published. However the author feels that the proper basis for valid reporting has not been established until now.

At present recruiting of interested colleagues is under way for a coordinated utilization of the DAR for the purpose of establishing "the natural history of amputation in Denmark''.

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*Prosthetics and Orthotics International, 1986, 10, 43-45*

# Technical note

# Assessment of some shock absorbing insoles

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**Abstract**

Due to the increase in prescription of insoles to relieve symptoms due to skeletal shocks at heel strike a pilot study was initiated to look at some materials used for this purpose. Five materials were examined (Plastazote, Spenco, Sorbothane, Poron (PPT) and Viscolas) by two methods. The first method used an accelerometer mounted between the teeth of one of the authors (PR) to record skeletal shock. The second method used a force plate to record the shock produced by dropping a ball-bearing onto the insoles from a standard height. The results showed that Plastazote is poor at absorbing shock with Spenco and Sorbothane being quite good. The best insole materials tested were Poron (PPT) and Viscolas with the latter being marginally superior. No account was taken of degradation of the materials in use except that Plastazote worn for 72 hours was also used in the study, this producing the worst results.

## Introduction

There has been a trend towards the prescription and supply of shock absorbing insoles not only for proven clinical/medical conditions but also, as a result of the increase in popularity of sports and other leisure activities, for the non-specific painful heel or foot. This has resulted in many new products being introduced and many older products being used in this new context.

A recent publication (Campbell et al, 1984) examined the compressive behaviour under simulated use of foamed orthotic shoe insoles. These foams were all considered to be "cushioning" or "pressure-distributing" (Albert, 1981; Wood, 1981) and are generally felt to function as a soft-tissue supplement. The matching of the mechanical characteristics of the soft tissues of the foot to those of a material inserted into footwear has already been reported to be of value (Beach and Thompson, 1979).

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The small study reported here does not try to examine the effects upon the insole material due to heat, perspiration and any mechanical degradation due to continuous stress reversals but looks simply at two methods of assessing the shock absorbing value of five materials, four newer products (Spenco, Sorbothane, Poron (PPT) and Viscolas) and medium density ($45 kgm^{-3}$) Plastazote as a reference. Plastazote was included in this study as locally it is being used as a shock absorbing insole material although it is generally felt that this is a poor choice for this application.

## Materials and methods

The five materials tested vary in their form. Plastazote and Poron are available in sheet form and are cut to size. Viscolas is available both as a ready made contoured insole and in sheet form. Spenco and Sorbothane are available as ready made insoles with Spenco being of a uniform thickness and Sorbothane being contoured. Sorbothane has a slight longitudinal wedge and Viscolas has a medial arch support and a thicker perimeter. Plastazote is well known to suffer from rapid compression set (bottoming). The other materials apparently do not suffer this to the same extent. It was thus decided to carry out an extra test on old Plastazote (Plastazote worn by one of the authors (PR) for 72 hours). The ready made insoles were nominally 5-6mm thick in the heel region and so in the cases of Plastazote and Poron the closest match was used, 6mm for both.

Two tests were used to assess the materials for their shock absorbing properties. Firstly an accelerometer (Bell and Howell — 25g) was attached to an orthodontic impression plate (Fig. 1) and held firmly in the teeth of one of the

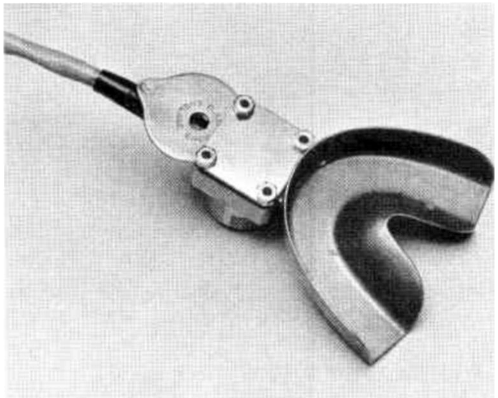

**Fig. 1 The accelerometer shown attached to the orthodontic impression plate.**

authors (PR). He then walked along the length of a gait laboratory with each insole in turn and then without any insole and on each pass he stepped onto a Kistler force plate. The accelerations and vertical foot/floor reaction forces were recorded on a storage oscilloscope and dumped onto a chart recorder for analysis. At least five sets of data were collected for each insole before proceeding with the next. The use of an accelerometer attached to the teeth in assessing skeletal transients has been well documented (Light et al, 1980). This does give a lower signal than that provided via attachment direct to the tibia but is less invasive and preferred in this context.

The second test method was to drop a 0.056kg ball-bearing from 1.02 metres onto each sole in turn placed on top of the Kistler force plate. The vertical force was recorded on a storage oscilloscope and again dumped onto a chart recorder for analysis. The traces were averaged by the oscilloscope for each insole prior to dumping.

## Results

Figure 2 (left) shows the results from the gait assessment method of insole assessment. They are all expressed in multiples of g and are normalized to a standard vertical foot/floor reaction force. The accelerations ranged from about 0.6g to about 1.15g with a fairly even spread. Without an insole the acceleration was 1.08g (±0.06) which was very similar to old Plastazote (1.07g ±0.05). New Plastazote was better at 1.02g (±0.12) with Spenco and Sorbothane both at 0.92g (±0.07 and ±0.08 respectively). Poron had a value of 0.86g (±0.06) and Viscolas had the best value of 0.74g (±0.13). There is considerable overlap between many adjacent groups although the underlying trend is clear.

If these results are compared to those in Figure 2 (right) almost the same order is observed. This figure shows the results expressed in terms of the height of the first peak after contact of the ball-bearing but this is directly related to the absorption of the shock impact. Old Plastazote is still worse than the other insoles at 60mm (±5.5) but new Plastazote, Spenco and Sorbothane have very similar values of 50.0mm (±5.3), 48.25mm (±7.2), and 49.5mm (±6.8) respectively. Poron and Viscolas again perform the best with values of 41mm (±4.0) and 39.9mm (±4.9) respectively.

## Discussion

For a shock absorbing insole to be of clinical value it must provide good absorption and its properties should last for a long time. The work of Campbell et al, (1984) has indicated that the probable useful life of materials such as Plastazote and Spenco may not be long when compared to Sorbothane and Poron. They did not test Viscolas but the indications are that it should perform as well as Sorbothane in this respect. So although the tests reported here show the shock absorbing properties of the materials at their best, except for Plastazote, these may not last for long if compression set is marked. In this context the best materials seem to be Sorbothane, Poron and Viscolas with a preference for the last two. In addition, a strongly damped response to impact is to be preferred and this is the sort of behaviour exhibited by all of the materials except Plastazote. These results do not mean that Plastazote should not be used as an insole material but it should not be used as a shock absorbing material.

Plastazote is a closed-cell foam and as such should exhibit shock absorbing properties. This is because each cell forms a small "cushion" against the impact forces. However a slow compression takes place over a few days use because the closed cells are not impermeable, but allow gas to escape. Potential energy stored in the deformed matrix causes air to be drawn back into the cells when unloaded but a permanent set is produced due to damage to

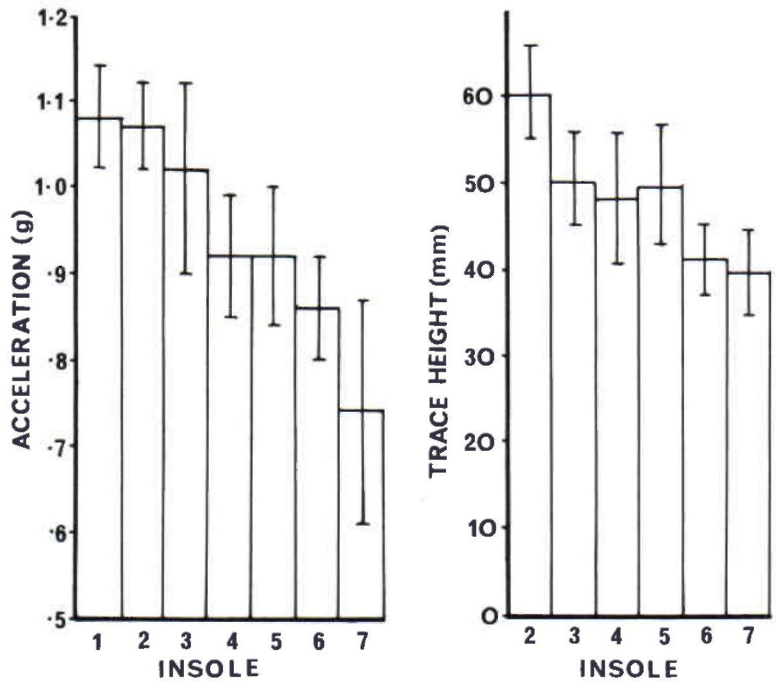


**Fig. 2. Left, the results from the gait assessment of the insoles. The accelerations are quoted as multiples of g and the vertical bars represent ± one standard deviation from the data. The numbers along the x-axis indicate the following insoles:- 1—footwear only, 2—"old" Plastazote, 3—"new" Plastazote, 4—Spenco, 5—Sorbothane, 6—Poron (PPT), 7—Viscolas. Right, the results from the impact assessment of the insoles. The impact peak is measured in millimetres and the vertical bars represent ± one standard deviation for the data.**

some of the cells. This effectively limits the useful life of the material which, when new, is not a good choice as a shock absorbing material in this application.

This study is a small preliminary one aimed at identifying some aspects of shock absorbing insole characteristics which will be of value in selecting the most appropriate material to use in a given clinical situation. The effects on these insoles by other factors (other than loading, static and repetitive) such as perspiration, scuffing and torsional wear need to be assessed before any definite conclusions can be drawn. However, this contribution illustrates that there are some basic differences between the insoles studied which may make selection of a suitable material a little easier.

**Acknowledgements**

The authors wish to thank British Rail Engineering for the loan of the accelerometer; Miss Anna Baker and Mrs Vivienne Rees for typing the manuscript; Department of Medical Illustration, Derbyshire Royal Infirmary for the diagrams.

Viscolas is a new shock absorbing insole material and is available from the Chattanooga Corporation, 101 Memorial Drive, P.O. Box 4287, Chattanooga, TN 37405, U.S.A.

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# Calendar of Events

**25 April, 1986**
International Back Pain Society. One day conference "The lumbar spine and back pain". London.
Information: Congress Team International (UK) Ltd., 30 Deane Way, Ruislip, Middlesex, HA4 8SX, England.

**7–9 May, 1986**
Second Annual Course in Practical Upper Extremity Prosthetics (in conjunction with the Rehabilitation Institute of Detroit), Nassau County Medical Center, East Meadow N.Y.
Information: Dr. Daniel Shapiro, Department of Physical Medicine and Rehabilitation, Nassau County Medical Center, 2201 Hempstead Turnpike, East Meadow, NY 11554, USA.

**7–10 May, 1986**
Annual Meeting of the Association of Children's Prosthetic/Orthotic Clinics, Milwaukee Children's Hospital–Medical College of Wisconsin.
Information: Francis J. Trost, Programme Chairman, 2545 Chicago Avenue S. Minneapolis, MN, 55404, USA.

**26–27 May, 1986**
Workshop on Internatinal Developments in Hip Disarticulation and Hemipelvectomy Prostheses, Health Sciences Building, University of Ottawa.
Information: Education Department, Royal Ottawa Regional Rehabilitation Centre, 505 Smyth Road, Ottawa, Ontario K1H 8M2.

**28–30 May, 1986**
The S. M. Dinsdale International Conference in Rehabilitation. "Towards the 21st Century".
Information: Education Department, Royal Ottawa Regional Rehabilitation Centre, 505 Smyth Road, Ottawa, Ontario, K1H 8M2.

**1–6 June, 1986**
WFOT 9th International Congress "Occupational Therapy 1986, Health and Development Through Action and Activities" Copenhagen, Denmark.
Information: DIS Congress Service, Linde Alle 48, DK–2720, Vanløse, Copenhagen, Denmark.

**16–21 June, 1986**
Study Institute and Conference on Biomechanics of Human Movement — Applications to Ergonomics, Sports and Rehabilitation. Formia (Latina), Italy.
Information: Conference Secretariat: Mrs. Letizia Lombardi, CSR-FIDAL, Via Po 50, 00198 Rome, Italy.

**23–36 June, 1986**
American Orthopaedic Association, Hot Springs, VA.
Information: AOA, 444 N Michigan Avenue, Chicago, IL, 60611.

**23–27 June, 1986**
RESNA, 86, 9th Annual Conference on Rehabilitation Technology, Minneapolis.
Information: RESNA, Suite 700, 1101. Connecticut Ave., NW, Washington, DC 20036.

**25–27 June, 1986**
XVth Symposium of the European Society of Osteoarthrology, Venue, Kuopio-Finland.
Information: Dr. H. J. Helminen, Managing Chairman, University of Kuopio, Department of Anatomy, P.O. Box 6, SF-70211, Kuopio, Finland.

**26–28 June, 1986**
International Medical Society of Paraplegia.
Information: IMSP Annual Scientific Meeting in Scandinavia 1986, Department of Neurology, Rikshospitale, University Hospital, Oslo, S., Norway.

**29 June–4 July, 1986**
ISPO 5th World Congress, Copenhagen.
Information: DIS Congress Service, Linde Allé 48, DK 2720 Vanløse, Copenhagen, Denmark.

**6–11 July, 1986**
VI International Congress on Neuromuscular Diseases, Los Angeles.
Information: Post-Graduate Division — KAM 318, USC School of Medicine, 2025 Zonal Avenue, Los Angeles, CA 90033.

**18–19 July, 1986**
American Academy of Orthotists and Prosthetists Continuing Education Conference 3–86, "Spina Bifida," Cincinnati, Ohio.
Information: American Academy of Orthotists and Prosthetists, 717 Pendleton St., Alexandria, VA 22314.

**21–23 July, 1986**
4th International Conference on Mobility and Transport for Elderly and Disabled Persons. Vancouver, British Columbia.
Information: Susan Barker, Transport Canada, DGCR/X Floor 26, Tower C, Place de Ville, Ottawa, Ontario, K1A 0N5, Canada.

**24–26 July, 1986**
Back Pain Current Concepts and Recent Advances–1st. European Congress. Helsinki.
Information: Congress Team International (UK) Ltd., 30 Deane Way, Ruislip, Middlesex HA4 8SK. England.

**4 August, 1986**
Canadian I.S.P.O. Seminar.
Information: Patricia Hayston, C.O. (C). Nova Scotia Rehabilitation Centre, Orthotics/Prosthetics Unit, 1341 Summer Street, Halifax, N.S. B3H 4K4.

**5–7 August, 1986**
Halifax Atlantic Canada '86, C.A.P.O. Convention. Nova Scotia, Canada.
Information: Nova Scotia Rehabilitation Centre, Orthotics/Prosthetics Unit, 1341 Summer Street, Halifax, N.S. B3H 4K4.

**11–15 August, 1986**
Myoelectric Controls — Course and Symposium, University of New Brunswick, Canada.
Information: Director, Bioengineering Institute, University of New Brunswick, Fredericton, NB Canada, E3B 5A3.

**17–22 August, 1986**
The 7th AOA International Symposium: Frontiers in Low Back Pain. Venue: Chicago-USA.
Information: William J. Kane, M.D., PhD., Symposium Chairman, 845 N. Michigan Avenue, Chicago, Illinois, 60611, USA.

**18–22 August, 1986**
Seminar on UCLA Total Surface Bearing BK Prosthesis, Los Angeles, California.
Information and applications: UCLA Prosthetics Education Program, Room 22–46 Rehabilitation Center, 1000 Veteran Avenue, Los Angeles, California 90024, USA.

**25–27 August, 1986**
North American Congress on Biomechanics combined with the 10th Annual Conference of the American Society of Biomechanics and the Fourth Biannual Conference of the Canadian Society of Biomechanics. Le Grand Hotel, Montreal, Quebec, Canada.
Information: Conference Secretariat of NACOB, Dept. of Physical Education, University of Montreal, 2100 Edouard-Monpetit Blvd., Montreal (Quebec), Canada H3C 3J7.

**31 August–3 September, 1986**
Joint Congress of the Hungarian Orthopaedic Association and the Hungarian Society of Traumatology, Budapest, Hungary.
Information: Ortopediai Klinika Congress Bureau, Budapest PF 45 H-1502 Hungary.

**4–5 September, 1986**
The Biomechanics and Orthotic Management of the Foot, Nene College, Northampton.
Information: Dr. D. J. Pratt, Technical Director, Orthotics and Disability Research Centre, Derbyshire Royal Infirmary, London Road, Derby DE1 2QY, England.

**4–6 September, 1986**
3rd European Conference on Biomaterials, Paris, France.
Information: Dr. P. S. Christel, Conference Chairman, Laboratoire de Recherches Orthopédiques, Faculté de Medicine, Lariboisiere — Saint-Louis 10, Avenue de Verdun, 75010 Paris, France.

**8–10 September, 1986**
5th Meeting of the European Society of Biomechanics, Berlin, West Germany.
Information: Conference Secretariat, Oskar-Helene-Heim, Biomechanics Laboratory, Clayallee 229, D–1000 Berlin 33 (West), West Germany.

**9–12 September, 1986**
MECOMBE '86, IV Mediterranean Conference on Medical and Biological Engineering, Sevilla, Spain.
Information: Prof. Dra. Laura Roa, Escuela Superior Ingenieros Industriales, Avda. Reina Mercedes, s/n, 41012 Sevilla, Spain.

**10–12 September, 1986**
Sixth Annual Advanced Course in Lower Extremity Prosthetics, Nassau County Medical Center, East Meadow, NY.
Information: Dr. Daniel Shapiro, Department of Physical Medicine and Rehabilitation, Nassau County Medical Center, 2201 Hempstead Turnpike, East Meadow, NY 11554, USA.

**15–17 September, 1986**
10th Anniversary Meeting of the European Society of Biomaterials, Bologna, Italy.
Information: Dr. G. Ciapetti, Instituto Orthopedico Rizzoli, via Codivilla 9, 40136, Bologna, Italy.

**15–20 September, 1986**
8th Asia and Pacific Regional Conference of Rehabilitation International, Bombay, India.
Information: Hon. Secretary, Rehabilitation International Regional Conference, A–2, Rasadhara Co-op. Housing Society Ltd. 385 S.V.P. Road, Girgaum, Bombay 400 004, India.

**19–20 September, 1986**
American Academy of Orthotists and Prosthetists Continuing Education Conference 4–86, "Powered Limb Prosthetics", Newington, Connecticut.
Information: American Academy of Orthotists and Prosthetists, 717 Pendleton St., Alexandria, VA 22314.

**21–24 September, 1986**
2nd Vienna International Workshop on Functional Electrostimulation, Vienna, Austria.
Information: Christine M. Jancik, Bioengineering Laboratory, Van Swieten-Gasse 1, A–1090, Vienna, Austria.

**21–26 September, 1986**
Scoliosis Research Society, Bermuda, West Indies.
Information: SRS 444 N Michigan Avenue, Chicago IL 60611.

**29 September–2 October, 1986**
Pediatric Orthopedic Update, Palm Beach, FL.
Information: AAOS, 444 N Michigan Avenue, Chicago, IL 60611.

**7–10 October, 1986**
IX Congress of the Yugoslav Orthopaedic and Traumatologic Association. Venue, Novi Sad-Yugoslavia.
Information: JOUT'86, c/o Drustvo lekara Vojvodine, Vose Stajica, a 21000 Novi Sad, Yugoslavia.

**24–25 October, 1986**
American Academy of Orthotists and Prosthetists Continuing Education Conference 5-86, "Lower Limb Prosthetics" Kansas City, Missouri.
Information: American Academy of Orthotists and Prosthetists, 717 Pendleton St., Alexandria, VA 22314.

**27–31 October, 1986**
Course on Advanced Prosthetics Techniques, Los Angeles, California.
Information and applications: UCLA Prosthetics Education Program, Room 22–46 Rehabilitation Center, 1000 Veteran Avenue, Los Angeles, California 90024, USA.

**1–6 November, 1986**
American Academy of Pediatrics Annual Meeting, Washington, DC.
Information: AAP PO Box 927 EIK Grove Village, IL 60007.

**1987**

**22–27 January, 1987**
American Academy of Orthopaedic Surgeons Annual Meeting, San Francisco, C.
Information: AAOS, 444 N Michigan Avenue, Chicago, IL 60611.

**3–8 May, 1987**
American Orthopaedic Association Annual Meeting, Washington, DC.
Information: AOA, 444 N Michigan Avenue, Chicago, IL 60611.

**17–20 May, 1987**
Pediatric Orthopaedic Society, Toronto, Canada.
Information: POS, PO Box 11083, Richmond, VA 23230.

**18–20 May, 1987**
"Toward 2000" The World Confederation for Physical Therapy — 10th International Congress, Sydney, Australia.
Information: Frank Allendar APTA, 1111 N. Fairfax Street, Alexandria, VA 22314.

**5–10 July, 1987**
International Conference on Disability Education, Jerusalem, Israel.
Information: Israel Rehabilitation Society, 18 David Elazar Street, Tel Aviv 61901, Israel.

## New Zealand Artificial Limb Board
## Course in Prosthetics—September 1986

The New Zealand Artificial Limb Board is offering a course in prosthetics, designed for surgeons, prosthetists and therapists, and commencing on Monday, 8th September 1986.

The principal guest speaker will be Professor John Hughes, Director of the National Centre for Training and Education in Prosthetics and Orthotics in the University of Strathclyde, Glasgow, and President-elect of ISPO.

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Course numbers will be limited to 25 so that all members may participate fully in practical aspects of training, and have the fullest opportunity for the sharing of experience.

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Applications or enquiries are invited from interested professionals in New Zealand, Australia and other parts of the Pacific Basin, or from further afield.

**A draft programme and application forms are available from the Course Secretary, Wellington Artificial Limb Centre, P.O. Box 7281, Wellington South, New Zealand.**

**Information for Contributors**

Contributions should be sent to Prosthetics and Orthotics International, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, Curran Building, 131 St. James' Road, Glasgow G4 0LS, Scotland. In the meantime considerable difficulty and delay is entailed in processing contributions in languages other than English. Authors are asked to provide three copies of text, tables and figures. Papers are accepted on the understanding that they may be subject to editorial revision and that no substantial part has been, or will be published elsewhere. Subsequent permission to reproduce articles must be obtained from the publishers. Manuscripts should be typewritten in double line spacing on one side of paper only with margins of 25 mm. **Papers must commence with an abstract not exceeding 250 words.** On a separate sheet must be:

(1) Title and short title. The short title should appear at the head of each page and should not exceed forty-five characters including spaces.
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**Illustrations**

All illustrative material should be lightly marked on the back in pencil with the figure number in Arabic numerals, title of paper, authors' names and a clear indication of the top of the figure. The approximate location in the text should be marked. Figure captions should be typed on a separate sheet. Tables should be used only when necessary to clarify important points. Each table should be typed on a separate sheet and numbered consecutively in Arabic numerals.

**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.*

**Reprints**

Ten reprints will be supplied free of charge to the first named author. Additional reprints may be ordered from the publishers at time of acceptance.

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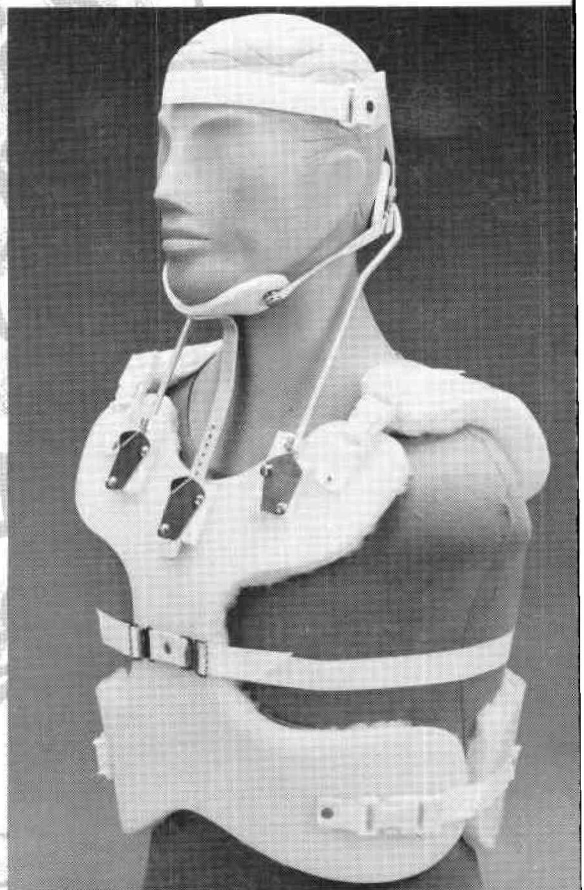

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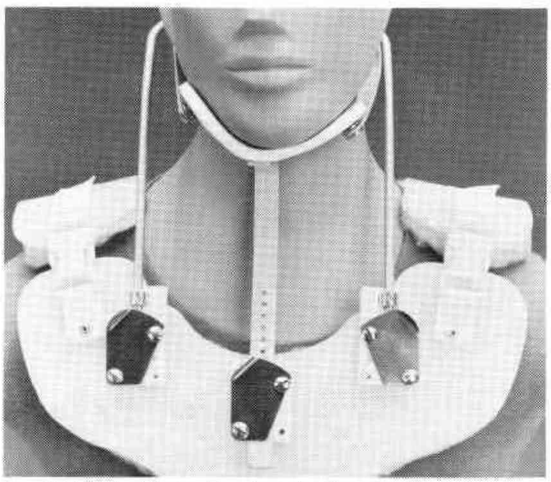



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