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for Prosthetics and Orthotics

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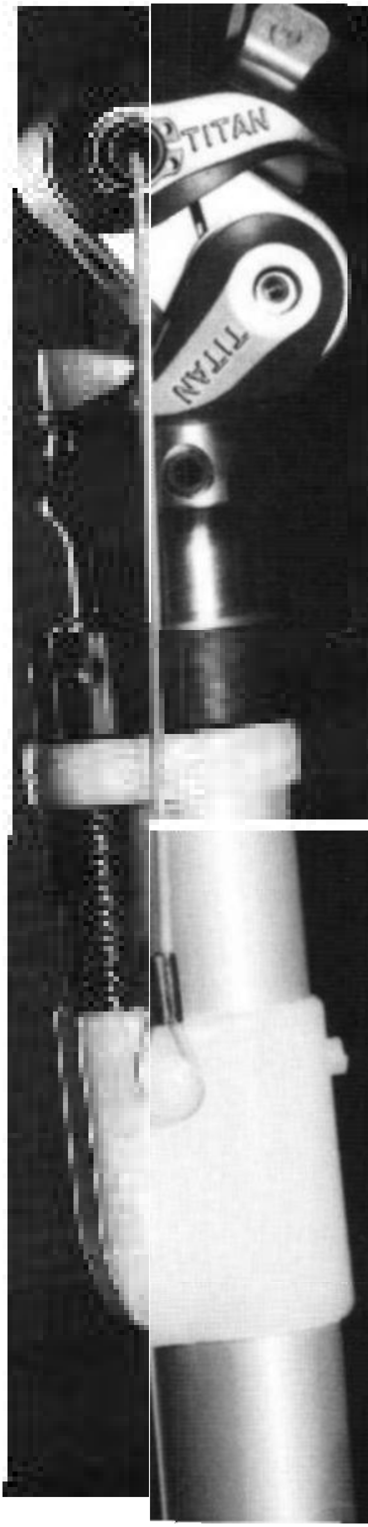
Including Supplement on Seating

December 1991, Vol. 15, No. 3



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The Journal of the International Society for Prosthetics and Orthotics

December 1991, Vol. 15, No. 3

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Prosthetics and Orthotics International, 1991, 15, 169–170

Editorial

Two years have passed since the new triennium started in Kobe with a new Executive Board. Many activities have taken place since then but in particular, I would like to emphasise the importance of those related to education and training in both the developed and the developing countries.

In Europe much work has been done by the ISPO/INTERBOR Joint European Education Committee. This committee is examining the implications of the open European market of 1992 with regard to the free movement of prosthetists and orthotists between the individual member states of the Community. At present prosthetists and orthotists are educated and trained to varying levels in the individual member states, ranging from University degree level on one hand to virtually nothing on the other.

The Committee has examined the levels of education and training that should be adopted within the Community and have recommended that the aim for the future should be University level or equivalent. This recommendation has been endorsed by both Societies. With this agreement the Committee approached the European Community to explore the possibility of having this level of education and training accepted. The Community view however is that individual professions should establish their own levels of education and training both nationally and community-wide before seeking acceptance by the European Community.

As a result of this, ISPO and INTERBOR agreed to conduct a study of the current situation in education and training and regulation within the different member states. This study has been partly funded by a grant from the ERASMUS Bureau of the European Community. A questionnaire was prepared and distributed to relevant groups and individuals throughout the European Community. Replies have been received and analysed and a first report has been prepared and submitted to the Community. Further study and analysis is necessary to improve the accuracy of the data and to provide a platform for the development of model curricula and planning information. A majority of countries have indicated that there is an intention to raise educational levels and to introduce more structure to the training.

These activities have concerned only the developed countries. The Society however has a great responsibility so far as education and training in the developing countries is concerned.

Each member of our Society must have been shocked to read the statistics displayed in the Editorial of our Past-President, Professor John Hughes, in the August 1990 issue of this Journal. The Society has been active during the last years trying to tackle these problems and a close collaboration has been established with the World Health Organisation (WHO). After the WHO Consultation on Training of Personnel in Developing Countries for Prosthetics and Orthotics in 1990 in Alexandria, Egypt, the Society has developed a proposal for one year courses in Lower Limb Orthotics Technology, especially related to poliomyelitis. The logic behind this would be to train professionals in a shorter space of time and for less money than is presently the case with, for example, the three year course for orthopaedic technologists in the Tanzania Training Centre for Orthopaedic Technologists (TATCOT), Moshi, Tanzania. As a result of this, a Meeting was held in Copenhagen attended by representatives of ISPO, the German overseas aid agency Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), WHO and TATCOT. The purpose was to examine a one year course proposed by TATCOT in Lower Limb Orthotics Technology, supplemented by 6 months of clinical work in an established orthotic centre in the candidate's home country. The proposal was finalised and put to WHO and the Tanzanian Ministry of Health for support.

It is a great pleasure to report that approval has now been given by WHO and the Ministry of Health. The Society is now also examining and preparing a proposal for a one year course in Lower Limb Prosthetics Technology.

Another important proposal on which we are making some progress is the organisation of courses to upgrade the "Short Course Trained Technician". The upgrading of the Short Course Technician (SCT) was discussed at length in the Workshop held at Strathclyde University in July, 1987.

Questionnaires had been developed and sent to 623 individuals in 79 countries on the basis of information obtained from the World Rehabilitation Fund. Much interesting information was obtained. Of particular relevance to this discussion were the following observations:

— all wanted further education and training and upgrading;
— virtually all were "qualified" in both prosthetics and orthotics;
— 40% also wrote letters most of which expressed concern at the prospect of time spent away from home.

The proposal is now that 25–30 SCT's will be trained at an institution like TATCOT. The general format of the course would be three 10 week periods of intensive training, education and revision at a training and education institute recognised by ISPO with intervening 10 month long supervised work experiences at the students' "home" base, supplemented by a distance learning course. It is envisaged that some 25–30 students at a time could enter this upgrading course which recognises that they already possess "adequate" skills acquired in the course of 6–10 years experience. The final assessment in both theory and practice will be as rigorous as the final examination of the orthopaedic technologist.

ISPO has to play a role in the education and training of prosthetists and orthotists all over the world. This is central to the implementation of the aims of our Constitution. It is my opinion that education and training in the developing countries and Eastern Europe is our primary task, now and in the immediate future. During the Seventh World Congress at Chicago 1992 these problems will have our highest priority in discussion.

Willem H. Eisma
President

Proposed amendment to the Constitution

The following amendment to ISPO's Constitution has been formulated by the Executive Board and published for comment in the April, 1991 edition of *Prosthetics and Orthotics International*. The UK National Member Society Committee have formulated a counter-proposal which is printed below.

These proposed amendments will be discussed and voted on by the International Committee at their meeting which will be held in association with the World Congress in Chicago.

Before the International Committee discusses these proposals, the Constitution requires that they be published to the International Committee and Members and Fellows for comment. Any such comments should be received by the Honorary Secretary before 1st February, 1992.

Original Clause
4.5.5 The Protocol and Nominations Committee shall comprise the President, the Past-Presidents, the President-Elect, two Fellows from the membership at large, the Honorary Secretary (ex officio).

Executive Board Proposal
4.5.5 The Protocol and Nominations Committee shall comprise the President, the Immediate Past-President, the President-Elect, two Fellows from the membership at large, the Honorary Secretary (ex officio) and up to two Past-Presidents nominated by the President.

UK National Member Society Committee Counter-proposal
4.5.5 The Protocol and Nominations Committee shall comprise the President, the Immediate Past-President, the President Elect, two Fellows from the membership at large, the Honorary Secretary (ex officio).

Prosthetics and Orthotics International, 1991, 15, 171–174

Executive Board Meeting

8 and 9 June 1991

The following paragraphs summarise the major discussions and conclusions of the Board Meeting held in Copenhagen in June. They are based on the draft minute of that meeting which has yet to be approved by the Board.

Interim Meeting of the International Committee Representatives

The Honorary Secretary reported on the action taken since the last Board Meeting with regard holding an Interim Meeting of the International Committee Representatives. The International Committee/Executive Board Working Group agreed that the Report of the Working Group, together with the comments of the individual members, should be circulated to the International Committee as the final Report of the Group. The Executive Board also finalised the paper on ISPO Policy and Activities. The Honorary Secretary had written to National Member Societies with the Report of the Working Group and also a draft Agenda seeking suggestions. At the time of the Executive Board Meeting only two written replies had been received from National Member Societies indicating their willingness to participate in the meeting although a further two National Member Societies had indicated verbally their intention to be represented at the meeting. Because of the low level of response it was agreed that the Honorary Secretary, when writing to the National Member Societies with the papers for the meeting, should indicate that in view of the high costs involved and the low response to date, the Executive Board felt that it would be irresponsible to go ahead with the meeting without first seeking the views of the National Member Societies as to whether or not the meeting should take place. If it was found that the majority of National Member Societies did not wish the meeting to be held, or would not be represented at the meeting, it would as a consequence be the intention of the Executive Board to cancel the arrangements already made.

(Honorary Secretary's Note: Since the Executive Board Meeting, the Honorary Secretary has written to the National Member Societies seeking their comments with regard the Interim Meeting of International Representatives. A minority responded positively and as a consequence the arrangements for the meeting were cancelled.)

Standing Committee Chairmen and Task Officer Reports

Bent Ebskov, the Chairman of the Finance Committee, reported on the statement of accounts for 1990. He was pleased to announce a positive result of more than 160,000DKK for the year. The Chairman presented a revised budget for 1991 which showed a small positive result, however, unexpected costs could take this into a deficit. He went on to warn against eating into the capital of the Society as at present the Society was depending on interest on the capital to achieve a positive financial result. He pointed out that if for example the sponsorship received from SAHVA and the War Amputations of Canada were to stop, the Society could run into long term financial difficulties. The Executive Board approved the budget for 1991. The Executive Board discussed a proposal from the German National Member Society that the Executive Board should consider the possibility of granting a temporary reduced international fee to new members from Eastern Europe. Information with regard East European economies would be obtained from the World Bank for the next Executive Board Meeting when this proposal would be reconsidered.

The Executive Board discussed the proposed amendment to the Constitution offered by the UK National Member Society Committee which would remove the limitation on the amount of time an International Committee Representative may continue to serve. While the Executive Board felt that there should be a limitation to the period served by International Committee Representatives, they agreed that the proposed amendment should be published to the membership and discussed and voted upon by the International Committee.

(Honorary Secretary's Note: This proposed amendment was printed in the August edition of Prosthetics and Orthotics International, page 164.)

The Executive Board endorsed the formation of a National Member Society in Finland and a Regional Member Society in the Carribean. Attempts to form National Member Societies in Thailand, Fiji, Indonesia, Turkey, Central America, France, Italy and Spain were still being pursued.

The Executive Board agreed to investigate the possibility of holding an ISPO Regional meeting in Africa directly after the Rehabilitation International Congress in Kenya which was scheduled for September 1992. It was suggested that this event could be held in either Kenya or Tanzania and it was anticipated that the subject of the meeting would be "Poliomyelitis". It was known that World Orthopaedic Concern (WOC) was also interested in holding a meeting in Africa on this subject and it was suggested that the Society should collaborate with WOC and also the World Health Organisation in organising such an event.

(Honorary Secretary's Note: Since the Board Meeting, it has been decided that the topic of the ISPO Regional Meeting should be "Lower Limb Amputation Surgery and Related Prosthetics". The Society explored the possibility of co-operation with WOC on Poliomyelitis, but unfortunately WOC have meantime postponed their plans.)

The Society had been in contact with the Peshawar Training Centre for Orthopaedic Technologists (PETCOT) with regard an inspection of their course leading to ISPO recognition. It was hoped that this inspection would take place during the examination of the final year students. Sepp Heim reported that the proposed course for Lower Limb Orthotic Technologists to be offered at the Tanzanian College for Orthopaedic Technologists (TATCOT) had been given approval by WHO and the Ministry of Health in Tanzania. WHO would distribute information regarding the course and still attempt to find scholarships for participants. A pilot course is likely to begin in 1992. A further proposal for a one-year course for the Lower Limb Prosthetics Technologist was in the process of being developed and it was hoped that this would also be approved by WHO in due course.

The special edition of *Prosthetics and Orthotics International* on the Limb Deficient Child was published in August. The special supplement on Seating was being prepared and is in fact included in this issue of the Journal. The Publications Committee is exploring the possibilities of offering bound volumes of *Prosthetics and Orthotics International* covering the past five years.

The meeting of ISO TC168, Prosthetics and Orthotics, was held in Berlin in May. Work was progressing well in this Committee, however, it has largerly been related to prosthetics. It was anticipated that in future, work would progress in the field of orthotics.

The first course on Amputation Surgery and Related Prosthetics would be held in Groningen from 30th January to 2nd February 1992. The announcement for this meeting appears elsewhere in this issue. The possibilities of holding a similar course in Thailand, Africa and Eastern Europe, are currently being explored.

The proposal that the Society should organise a Workshop on the Science and Practice of Socket Fit would be reconsidered after the World Congress in Chicago during which it was planned to hold a Symposium on Socket Fit.

To date there are 1400 entries in the Professional Register. A number of problems arising in the use of the Register were discussed, mainly those related to the description of profession and occupation. It was anticipated that all participants in the Register would be written to, with a copy of their entry for checking and asking for clarification of their entry with regard these points. A protocol for use of the Register was agreed. A number of searches on behalf of International Agencies had already been carried out.

The Executive Board discussed the need to establish the value to the community of good professional services in prosthetics and orthotics. It was recommended that a literature review be carried out in an effort to identify information with regard the cost-effectiveness of prosthetic and orthotic treatment and that work be carried out on developing a pro-forma to help generate case reports which would provide relevant information with regard the cost-effectiveness of prosthetic and orthotic treatment. A trial of the pro-forma will be conducted in Sweden and the results presented to the International Committee with the intention of soliciting information world-wide. It was also suggested that the Holte Report be reviewed in order to update its recommendations. This matter would be reviewed at the next Executive Board meeting after the pilot work is carried out in Sweden.

International Consultants

A. P. Kuzhekin has retired and will no longer be able to carry on as International Consultant to the USSR. Due to the political changes at present taking place in the USSR, it was decided to delay the appointment of a replacement. Seishi Sawamura reported on plans for a Special Forum on Aid to Asian Countries in Prosthetics and Orthotics, to be held in November 1991 in Tokyo. This Forum would investigate the present status of prosthetists and orthotists in the Philippines, Singapore, Malaysia, Thailand and China. The outcome would hopefully lead to the establishment of education and training courses. It was agreed that the President should represent the Society at this Forum.

International Organisations

The ISPO/INTERBOR Joint European Education Committee met in Berlin in May. The Committee discussed the response to the questionnaire on education and training of prosthetists and orthotists which had been distributed throughout European Community countries. It was agreed that a Report based on the responses should be made by John Hughes, Wieland Kaphingst and the Honorary Secretary.

(Honorary Secretary's Note: Since the Executive Board Meeting, a draft Report was discussed by the Committee and a finalised Report was presented to the ERASMUS Bureau at the end of October, together with a request for further funding in order to visit the individual countries to follow up the responses to the questionnaire.)

INTERBOR has organised a consortium of a number of Universities, manufacturing industries and small and medium enterprises which would look at the CAD CAM systems available within the European Community in order to evaluate their effectiveness within the fields of prosthetics, orthotics and seating. This consortium had applied for a grant to the TIDE programme to undertake this work. The TIDE programme is a Community initiative aimed at the socio-economic integration, through the application of modern technology, of people with difficulties or who are elderly. INTERBOR invited ISPO to participate in this application as an associate to INTERBOR. The Executive Board agreed to this participation.

(Honorary Secretary's Note: Since the Board Meeting, the application for a grant had been made to the TIDE programme but has subsequently been rejected. It was anticipated that the consortium may be re-formed in order to apply for funding for a project in Phase 2 of the TIDE programme.)

The Society have established a working relationship with WHO. The normal period of this status is two years. It has been suggested that it would be appropriate for the Society to apply for official relations with WHO in July 1992. The application would then be considered by WHO in January 1993. A draft proposal for upgrading short course trained technicians had been prepared and has been presented to WHO. WHO were now giving this consideration and would comment in the near future.

The Society had contacted Rehabilitation International offering to participate in their World Congress to be held in Nairobi, Kenya from 7th to 11th September, 1992. It was anticipated that the Society could make a presentation in a plenary session as well as organising a session on prosthetics and orthotics and an exhibition. It was hoped to use as many local members as possible for these presentations and Sepp Heim and Harold Shangali are presently making proposals for ISPO's participation at this meeting.

It was agreed that Ken Rankin, Zimbabwe, would represent the Society on the African Rehabilitation Institute's Technical Advisory Committee. The Executive Board discussed the matter raised by World Orthopaedic Concern (WOC) regarding the proliferation of agencies working in prosthetics and orthotics in individual countries and a suggestion that ISPO may help in co-ordinating these efforts. The Executive Board felt that it may be possible to collate information from the different agencies with regard the projects each was involved in, however, it was recognised that the problem was not only related to the individual agencies, but also to the small charitable and private organisations who involve themselves in the field. This matter would be reconsidered at the next Board Meeting.

The International Committee of the Red Cross had requested recognition of the courses for orthopaedic technologists which are offered in Mozambique and Afghanistan. It was agreed that ISPO should pursue the matter and that this may be done by general approval of the common course syllabus and then by an inspection of the results which would most appropriately be done at the times of the final examinations.

Congresses

Arrangements for the VII World Congress to be held in Chicago, USA from 28 June to 3 July 1992 are continuing to progress. Organisation for the programme and exhibit are well established and information would be given to exhibitors and participants in the near future. The Executive Board discussed the Knud Jansen Lecturer for the Congress and unanimously agreed that John Hughes should present this lecture.

The VIII World Congress is to take place in Melbourne, Australia from 2 to 7 April, 1995. A Committee structure for its organisation is being established and progress on this will be reported to the next Board Meeting.

Conferences and Meetings

It is proposed to hold a meeting on Prosthetics and Orthotics and Rehabilitation Engineering in Sicily in 1993 for all the Mediterranean Countries and the Gulf States. This meeting would be organised by INAIL (Italy) together with ISPO, however, all the financial responsibility would rest with INAIL. A Scientific Committee has been established comprising four ISPO and four INAIL representatives. The Executive Board discussed these initial plans and agreed the Society should collaborate on the condition there is no financial responsibility to ISPO.

Nominations for the Executive Board 1992

The Executive Board have proposed a slate of nominations for the Executive Board for the coming triennium as follows:

President:	Melvin Stills	USA	Orthotist
President-Elect:	Seishi Sawamura	Japan	Orthopaedic Surgeon
Vice-Presidents:	Per Christiansen	Denmark	Prosthetist/Orthotist
	Jean Vaucher	Switzerland	Orthopaedic Surgeon
Members:	Hans Arendzen	Netherlands	Rehabilitation Doctor
	Margaret Ellis	UK	Occupational Therapist
	Thamrongrat Keokarn	Thailand	Orthopaedic Surgeon
	Harold Shangali	Tanzania	Prosthetist/Orthotist
Hon. Treasurer:	J. Steen Jensen	Denmark	Orthopaedic Surgeon
Hon. Secretary:	Norman A. Jacobs	UK	Bioengineer

Norman A. Jacobs
Honorary Secretary

Prosthetics and Orthotics International, 1991, 15, 175–177

Orthoses of ventilative plastics

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Abstract
Plastics are extensively used as a material for orthoses. However, one remaining problem is the ventilation of the orthosis. This is a real problem in countries such as Japan, where it is hot and humid especially in summer.

The authors have invented a new orthosis "POROPLAST", which is made of mesh plastic sheets, combined in a cross-like weave.

These orthoses provide good ventilation and are very comfortable to wear. They have been fitted to seventy-four cases with satisfactory results.

Introduction

Plastics are extensively used as a material for orthoses. One problem which remains is that of the ventilation of the orthosis. Conventional plastic orthoses with substantial areas of skin contact have sometimes produced skin problems, for example, skin break-down, contact dermatitis, or pressure sores. This is a real problem in countries such as Japan, where it is hot and humid especially in summer.

Small holes may be punched-out of the plastic to decrease these kinds of problems, but this does not necessarily bring the desired results. Faulkner and Pritham (1973) reported the advantages of a below-knee prosthesis made from Light-cast® material, which has the ability to permit the flow of air. Nakamura (1988 and 1989) designed polyester hydrate resin sockets allowing the skin to breathe freely in order to improve the wearing conditions.

All correspondence to be addressed to Dr. H. Nagata, Department of Orthopaedic Surgery, Osaka Medical College, 2–7 Daigakumachi, Takatsuki, Osaka 569, Japan.

The authors have invented a new orthosis named "POROPLAST", which has good ventilation and is very comfortable to wear. So far, the record of the duration of wear of this orthosis is a maximum of six months. This orthosis is made of mesh plastic sheets, combined in a cross-like weave.

Materials and fabrication

A mesh sheet of thermoplastic high density polyethylene was chosen as the material. This can be moulded easily with heat. Three mesh sizes are used, large, medium and small (Fig. 1). The flexibility of an orthosis can be adjusted by changing the combination of these three types of plastic sheets. In practice, two kinds of sheets are used for an upper limb orthosis, and three for a lower limb orthosis or spinal orthosis.

The required number of sheets are placed on top of each other in such a manner that the meshes are crossed at a certain angle and held in place by cotton stockinette.

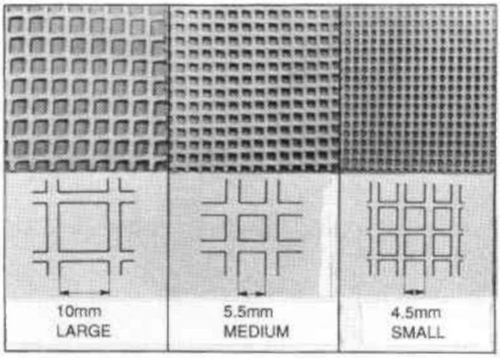

Fig. 1. Materials of mesh plastic sheets.

An OTTO BOCK® heating plate is usually used to soften materials. When the correct temperature is reached, they begin to melt and stick to each other.

Moulding is carried out immediately after the positive model has been covered with the softened material. When the material cools, a trim line is drawn on the moulded plastic and it is removed from the positive model.

Methods of cutting and trimming are the same as for conventional plastic materials. This is carried out after the cotton stockinette has been removed.

Finally the irregular margin of the orthosis is smoothed off around the edge using NEOPLANE® suede, and thereafter, the orthosis is completed by securing straps in the appropriate position.

Case presentations

These fabricated mesh plastic orthoses have been used in 14 cases for the cervical spine, for 26 thoracolumbosacral orthoses, for 6 upper limb and 26 lower limb cases, and for 2 others.

The patient shown in Figure 2 had skin problems which improved after the use of the mesh plastic orthosis. She initially wore a Philadelphia type collar after a cervical laminectomy with excision of a spinal tumour. After a few days she suffered from contact dermatitis. The collar was replaced with the mesh plastic orthosis and soon after her skin problem cleared up.

The cervical orthosis in Figure 3 was used after the tenth postoperative day for a patient with a fracture-dislocation at the fourth cervical vertebra. She was able to sit up and walk earlier with this type of orthosis and was comfortable even in a humid Japanese summer.

Fig. 2. Cervical orthosis.

The mesh plastic orthosis is used also for lumbosacral immobilization. It was used for a patient after a decompression and fusion operation for L4–L5 spondylolisthesis (Fig. 4). The contact surface of the skin could be observed directly through the mesh.

The new orthosis can be modified for use at the hip. It was used after resection and replacement of the femoral head for a malignant tumour. The area of the hip was reinforced by impregnating a fibrous bandage with acrylic resin and placing it between the mesh sheets.

POROPLAST can also be used for ankle-foot orthoses. It has been used after arthrodesis of the ankle joint for talipes equinus deformity as a sequel of cerebral palsy.

Comparative study on the ventilatory effects

In order to evaluate the ventilation effect of the new orthosis, it was compared with conventional orthoses in respect of differences in perspiration and skin surface temperature.

A polypropylene plastic orthosis and a mesh plastic one were put respectively on each foot of a patient under the same conditions for a certain duration of time.

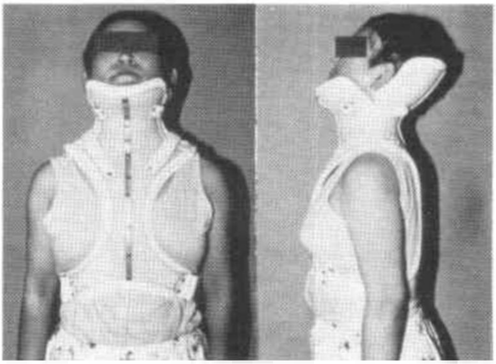

Fig. 3. Cervical orthosis.

Fig. 4. Orthosis for lumbosacral immobilization

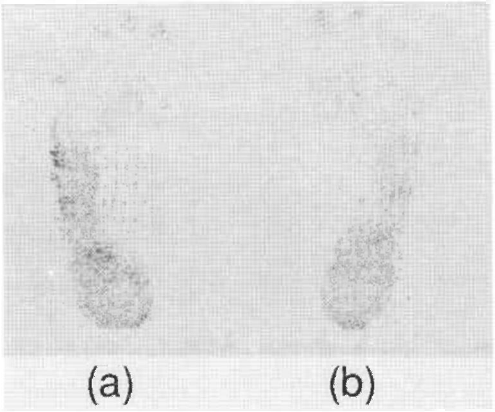

Fig. 5. Perspiration test.
(a) Conventional Orthosis (b) Mesh Plastic Orthosis

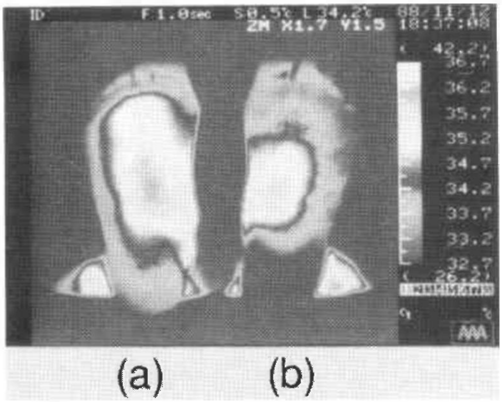

Fig. 6. Skin surface temperature using ultra-red thermogram.
(a) Conventional Orthosis (b) Mesh Plastic Orthosis

A special paper was used which indicates the degree of perspiration. The greater the quantity of perspiration the darker the paper is stained (Fig. 5). This displays that the mesh plastic orthosis reduces perspiration when compared with the conventional orthosis.

Next, the skin surface temperature was measured graphically using an ultrared thermocamera (Fig. 6). It can be clearly seen that the increase of skin temperature in the mesh plastic orthosis was lower than that in the conventional type.

Results

From these results it can be seen that the mesh plastic orthosis is more effective in ventilation. It has the additional advantage of permitting the observation of the contact surface of the skin. A further advantage is its light weight.

It is believed that this mesh plastic material can be adapted to produce orthoses for any part of the body and it may be utilized extensively in prosthetics as well as in orthotics.

Conclusion

This preliminary study demonstrates that this new type of orthosis has great advantages in ventilation and in weight. It has been tried clinically on 74 cases with satisfactory results particularly with regard to skin problems.

REFERENCES

Faulkner, V., Pritham, C. (1973). A below-knee prosthesis with a porous socket. *Orthot. Prosthet.* **27 (1)**, 1–5.

Nakamura, T. (1988). Process of development and application of porous plastic to prosthetic sockets. *Bull. Jap. Soc. Prosthet. Orthot.* **4 (2)**, 111–118.

Nakamura, T. (1989). Process of development and application of porous plastic to prosthetic sockets. *J. Prosthet. Orthot.* **1 (4)**, 202–210.

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A clinical evaluation of stumps in lower limb amputees

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Abstract

A study was carried out on 93 consecutive unilateral below-knee (BK) and 62 above-knee (AK) amputees. The dimensions of the amputation stumps were measured and the general condition and contralateral limb assessed at the time of prosthetic fitting. After one postoperative year, follow-up information for 124 (89%) of the surviving patients was obtained by personal contact. The observations were based on the standard formula for stump classification constructed by the International Society for Prosthetics and Orthotics.

The 93 BK stumps had a mean length of 16.0 cm and the 62 AK stumps a mean length of 28.0 cm. The scar on the stump was adherent in 13% of BK and 2% of AK stumps. The scar was deeply wrinkled in 7% of BK stumps and 10% of AK stumps. The scar on the stump was most frequently adherent or deeply wrinkled in trauma patients (33%). The skin was undamaged in 93% of all the patients at the first visit and in 94% at the time of follow-up. The mobility of the stump in the proximal joint was limited at the time of prosthetic fitting in 15% of cases. Phantom pain was reported by 59% and stump pain by 5% of patients at this time. Although the phantom pain was mild in most cases, it was usually still present after one year, and 53% of the surviving patients suffered from phantom pain. At the first visit, 20% of patients had problems in their contralateral leg. During the first postoperative year, 6 contralateral BK amputations were performed in the BK group and one contralateral AK amputation in the AK group. Thus, along with examination of the stump, attention must be paid to the contralateral limb with a view to preserving it. The study supports the usefulness of the standard form and classification of amputation stumps.

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Introduction

A systematic examination of the stumps following major amputation allows certain important characteristics to be identified, improving the chances of detecting problems and correcting malfunctions (Persson and Liedberg, 1983). The increasing number of amputations among elderly patients with occlusive arterial disease increases the need for an objective evaluation of stumps, since old patients are often not well-informed themselves (Persson and Liedberg, 1983). Many different systems of stump classification have been developed but none has achieved universal acceptance. The main reason for this may be that clinical teams in different countries have different patients, and technical problems and possibilities for treatment. They therefore develop their own descriptive categories to meet their individual needs (Wall, 1988). International systems need to be comparable if measurements are to be related to each other. The basic parameters and standard form of a classification system were accepted at the Third World Congress of the International Society for Prosthetics and Orthotics (ISPO) in Bologna, October 1980 (Persson and Liedberg, 1983).

The basic parameters of classification for stumps will include the following (Persson and Liedberg, 1983; Wall, 1988):

1. stump dimensions;
2. stump shape;
3. the scar on the stump;
4. the condition of the skin on the stump;
5. the firmness of the stump;

6. the condition of the end of the stump;
7. mobility of the stump on the proximal joint;
8. pain;
9. certain features of the contralateral leg.

This paper applies the basic parameters and a modified version of the standard form to the stumps of a series of Finnish lower limb amputees.

Materials and methods

The patient sample consisted of a total of 155 consecutive patients, sent by the operative units to the Prosthetic Factory of Helsinki for prosthetic fitting. Seventy-two per cent (112) of the patients were males and 28% (43) females. A total of 93 patients (60%) had undergone below-knee (BK) amputation and 62 patients (40%) above-knee (AK) amputation. The mean age of the patients was 62.8 years (range 14–87 years). The mean age was 73.0 for female BK and 62.8 years for female AK amputees. The corresponding figures for the men were 59.9 and 61.7 years. The majority of the patients, 107 (69%), were in the 60–79 years age group.

The reasons for amputation were vascular disease in 126 cases, trauma in 15 cases, tumour in 10 cases, frostbite in 3 cases and infection in one patient.

The amputations were mainly carried out in hospitals in Southern Finland. All the operations were performed between November 1985 and August 1988. Vacuum drainage of the wound was used to avoid the formation of a haematoma. All the stumps were kept in soft dressings to protect the wound and to apply pressure. The delay between the operation and the first permanent prosthesis was 16 weeks in BK amputees and 16.3 weeks in AK amputees. During the first visit, the patients were examined and interviewed and measurements made by the author and a certified prosthetist. The author also evaluated the medical records of the patients which were made by the operative units.

Out of the complete sample of 155 patients, 16 (10%) died during the first postoperative year. Follow-up information for 124 (89%) of the surviving patients was obtained by personal contact after one postoperative year, with patients being interviewed and examined by the author. Of the 124 follow-up patients, 78 were BK and 46 AK amputees.

The length of the stump was measured from the distal end of the stump to the medial joint space of the knee in BK stumps, and from the end of the stump to the crotch in AK stumps. The healing phase of the wound was recorded at the same time. The examinations were intended to describe size, shape and atrophy, allowing classification of stumps into cylindrical, conical or club-shaped.

Partial correlation coefficients were used to evaluate the relationship between stump variables and the walking functions.

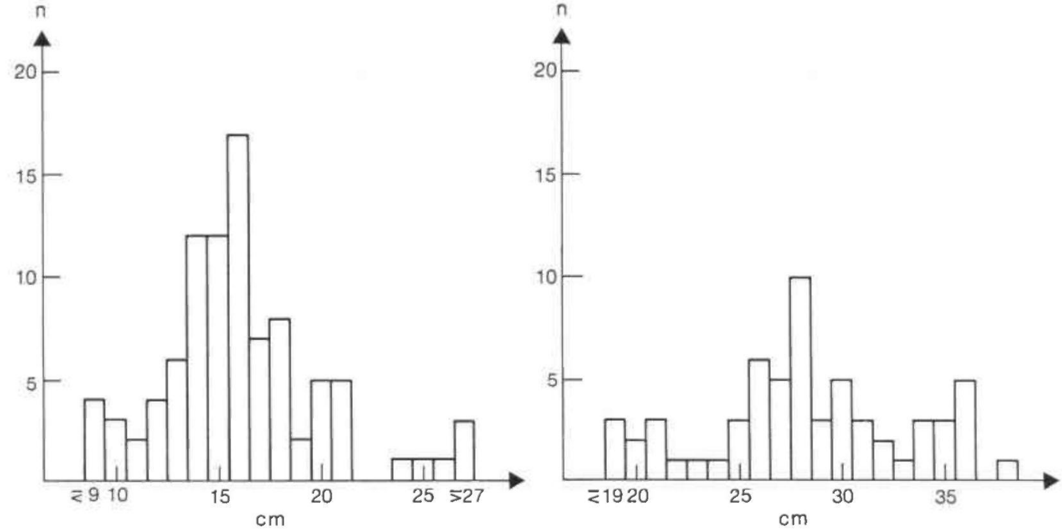

Figure 1. Left, length of below-knee stumps. Right, length of above-knee stumps.

Table 1. Shape of below and above-knee stumps at the time of prosthetic fitting and after one postoperative year.

Stump shape	Amputation level BK	%	AK	%
First visit				
Conical	39	42	36	58
Cylindrical	51	55	25	40
Club-shaped	3	3	1	2
Follow-up				
Conical	51	65	29	63
Cylindrical	27	35	17	37
Club-shaped	0	0	0	0

Results

The following results are presented in the order (1–9) of the standard form of ISPO (Persson and Liedberg, 1983).

The 93 BK stumps had a mean length of 16.0 cm, range 5–36 cm (Fig. 1, Left) and the 62 AK stumps a mean length of 28.0 cm, range 10–38 cm (Fig. 1, Right).

The shapes of the BK and AK stumps at the time of first visit and after the first postoperative year are presented in Table 1. At the first visit the shape was cylindrical in 49%, conical in 48%, and club-shaped in 3%. BK stumps became more conical during the first postoperative year and about two-thirds of BK and AK stumps were conical at the time of review.

The scar on the stump was adherent in 12/93 patients (13%) in the BK group and in 1/62 patients (2%) in the AK group. The proportions were the same after one postoperative year. The scar was deeply wrinkled in 7% of BK stumps and in 10% of AK stumps. The scar on the stump was adherent or deeply wrinkled in 5/15 trauma patients (33%).

The skin was undamaged in 93% of all the patients at the first visit and in 94% at the time of follow-up, with little difference between AK and BK levels (Table 2). At the time of prosthetic fitting, the skin of the stump was intact in 98% of all the 49 arteriosclerotics, in 90% of the 76 diabetics, in 90% of the 10 tumour patients and in 94% of the 15 trauma patients.

Table 2. Skin condition among above and below-knee stumps.

Condition	First visit BK	%	AK	%	Follow-up BK	%	AK	%
Undamaged	83	89	61	98	71	91	45	98
Abrasion	5	6	0	0	3	4	0	0
Ulcer	1	1	1	2	4	5	1	2
Scab	4	4	0	0	0	0	0	0
Total	93	100	62	100	78	100	46	100

After the first postoperative year the skin of the stump was normal in all the tumour patients, in 93% of the arteriosclerotics, in 96% of the diabetics and in 80% of the trauma patients. The most common skin lesion in the stump of the trauma patients was abrasion.

The BK stumps were soft in 30 cases (32%) and the AK stumps in 17 (28%) at the time of the first visit. At the time of follow-up, there were 5 (7%) soft BK stumps and 3 (6%) AK stumps.

Among the BK stumps the end of the stump was rounded and well protected in 81 (87%) of cases, slightly pointed in 9 (10%) and clearly pointed and poorly protected in 3 (3%). The corresponding figures for the AK stumps were 53 (85%), 8 (13%) and 1 (2%), respectively.

The mobility of the stump in the proximal joint was limited at the time of prosthetic fitting in 26 patients (15%), of whom 14 were AK and 12 BK amputees. The limitation of hip extension in AK amputees was mild (0 degrees of limitation) in 12 cases and moderate (0–12°) in 2 cases. The limitation of the knee joint in BK amputees was mild (5–10°) in 10 patients and moderate (10–20°) in 2 patients.

After the amputation phantom pain was a problem in 91 patients (59%), phantom limb in 64 (41%) and stump pain in 7 (5%) (Table 3). At the time of the review the corresponding figures were 66 (53%), 22 (18%) and 7 (6%). The severity of the stump symptoms is presented in Table 4. In one patient the stump pain was severe enough to limit walking. After amputation, 4% of patients experienced phantom pain coexisting with stump pain, while 30% experienced phantom pain with phantom

Table 3. Phantom limb, phantom pain and stump pain among BK amputees and AK amputees.

Symptoms	BK	%	AK	%
At the time of prosthetic fitting				
Phantom pain	53	57	38	61
Phantom limb	43	46	21	34
Stump pain	3	3	4	6
After one postoperative year				
Phantom pain	39	50	27	59
Phantom limb	16	21	8	17
Stump pain	6	8	1	2

Table 4. Severity of stump symptoms.

Stump symptom	At the time of prosthetic fitting n	%	After one post-operative year n	%
Phantom pain				
Mild (1)	66	73	46	70
Moderate (2)	25	27	20	30
Severe (3)	—	—	—	—
Phantom limb				
mild (4)	54	84	19	86
moderate (5)	10	16	3	14
severe (6)	—	—	—	—
Stump pain				
mild (1)	5	72	4	57
moderate (2)	1	14	3	43
severe (3)	1	14	—	—

1) Infrequent, mild pain, not requiring analgesics.
2) Fairly frequent pain, occasionally requiring analgesics.
3) Regular pain affecting the daily life of the amputee, requiring regular analgesics.
4) Infrequent sensation of lost limb.
5) A fairly frequent phenomenon causing occasional disturbance.
6) A regular phantom phenomenon causing regular disturbance.

limb. The corresponding figures at the end of the first postoperative year were 4% and 19%. Phantom pain and stump pain had a relationship with reduced walking distance ($p<0.05$) and reduced outdoor walking ($p<0.05$).

At the first visit, tenderness of the stump on palpation was found in 9 (10%) BK and in 8 (13%) AK stumps. The corresponding figures at the time of review were 6 (8%) and 4 (9%).

The state of the contralateral limb at the time of the first visit and after the first postoperative year is presented in Table 5. Of the 155 amputees, 124 (80%) had no problems in their contralateral leg at the time of the first visit. The most common pathological finding was a leg ulcer. During the first postoperative year, 6 contralateral BK amputations were performed among the 78 BK amputees and one contralateral AK amputation among the 46 AK amputees. After the first postoperative year, 110 (89%) of patients had no problem in their contralateral leg.

In the group of 124 follow-up patients, 42 (34%) suffered from ischaemic pain in the contralateral leg. The pain was mild in 19 amputees (15%), quite severe in 21 amputees (17%) and severe in 2 amputees (2%).

Table 5. Condition of the contralateral leg in below and above-knee amputees.

Condition	BK	%	AK	%
At the time of prosthetic fitting				
Normal	72	77	52	84
Ulcer	10	11	4	6
Oedematous	3	3	3	5
Eczema	2	2	2	3
Toe amputation	3	3	1	2
Foot amputation	3	3	—	—
After one postoperative year				
Normal	68	87	42	91
Ulcer	4	5	1	2
Oedematous	0	0	2	4
Toe amputation	1	1	—	—
Foot amputation	1	1	—	—
BK amputation	6	8	—	—
AK amputation	—	—	1	2

Discussion

There are relatively few publications on the general condition of amputation stumps. Many reports describe various problems of rehabilitation (Narang *et al.*, 1984; Steinberg *et al.*, 1985; Cumming *et al.*, 1987; Kullmann, 1987; Moore *et al.*, 1989) and pain in stumps (Steinbach *et al.*, 1982; Sherman and Sherman, 1983; Jensen *et al.*, 1985) but they do not deal with other parameters such as shape, firmness, strength, or range of motion.

There is no specific site of choice for BK amputation, but the lowest quarter of the leg is avoided, as the tibia and fibula are covered only by tendons and fascia in this area (Burgess, 1982). On measuring 58 BK stumps, Renström (1981) found a mean length of 14 cm. In another BK group, Persson and Liedberg (1983) reported a median length of 16 cm; the stump length was classified as normal in 81%, short in 13% and long in 6%. In the present study there was also a mean length of 16 cm for BK stumps. No allowance was made for shrinkage of the soft tissues by using circumferential measurements and the length-to-breadth proportion, as was done by Persson and Liedberg (1983), since the amputees came from other hospitals for examination, and prosthetic fitting took place as late as 16 weeks after amputation. In the BK material, 4 stumps were classified as short (<9 cm) and 6 as long (>24 cm) (Fig. 1). It is better to use proportional measures which take into account the diameter of the stump, and the new definition of long and short stumps employed by Persson and Liedberg (1983), than absolute measures in centimetres or relative measures expressed as a percentage of the unamputated side. The stump measures require no special equipment and can be made by any member of the amputee team.

Gonzales *et al.* (1974) studied energy expenditure of unilateral BK amputees with various stump lengths. Patients with long stumps had a 10% average increase in energy expenditure above normal, whereas those with short stumps had a 40% average increase. Thus as great a length as possible should be saved, consistent with the pathology present.

The techniques for AK amputation may vary widely depending on the aetiology. In the dysvascular patient the surgeon must make every effort to avoid AK amputation, in favouring instead knee disarticulation or BK amputation in order to preserve the advantages of having end-bearing or of retention of the knee joint, with increased possibilities for locomotion and a return to the community (Burgess and Matsen, 1981; Stirnemann *et al.*, 1987; Neff, 1988). The length of the stump affects the alignment of the prosthesis. There are no reports in the literature concerning the optimal measures of AK stumps. In the present study the mean length of the AK stump was 28 cm.

The size, shape and degree of atrophy of the stump determine the type of suspension. In the BK group of Persson and Liedberg (1983) the shape was cylindrical in 80% of cases, conical in 19% and club-shaped in 1%. Corresponding figures of the present study were 49%, 48% and 3%. In this series, the time lag between surgery and the first visit was rather long (16.4 weeks) and the fairly general use of shrinker socks could reduce limb volume and mould stump tissues. In the case of the BK amputation it is important to record whether the fibula is prominent or the distal end of the tibia is pointed or not.

The position of the scar is irrelevant as long as plastic principles are practised and the scar is non-tender, non-adherent and pliable (Burgess, 1982) and the incision is healed. In the present series the scar on the stump was more frequently adherent to bone tissue in BK (13%) than in AK (2%) stumps.

Moreover, skin lesions were more common in BK amputees (Table 2). Five out of 15 trauma patients had skin adherent to the bone at the time of prosthetic fitting; 2 of them had abrasions and one patient had an ulcer in the stump at the time of review. Adherent scars were most commonly found in the trauma group and seem to be a risk factor for skin problems in stumps.

Francis and Renton (1987) reported a 7% incidence of flexion contracture of the knee joint after BK amputation. In the BK amputation group of the present study there were 12 (13%) knee flexion contractures of which 10 were mild (5–10 degrees) limitations. Moffat *et al.* (1981) suggested that useful mobility with a prosthesis is still possible if the contracture is under 15°. In the AK group of the present study 12 out of 14 hip contractures were also mild, and joint contractures did not disturb rehabilitation during the first postoperative year.

In the literature there are various reports on the prevalence of phantom pain. Renström (1981) reported an incidence of 18% for phantom pain among 63 BK amputees. In the series of Persson and Liedberg (1983), stump pain was a problem in 18% and phantom pain in 21% of BK amputees. Sherman and Sherman (1983) reported an over 80% prevalence of phantom pain among more than 11,000 amputee veterans. Other researchers (Carlen *et al.*, 1978; Steinbach *et al.*, 1982; Jensen *et al.*, 1985) have found similar rates of occurrence in other populations. A study of persons with amputations or disarticulations proximal to the ankle revealed that phantom limbs were experienced by 55% of a group of 93 lower limb amputees (Otsuka, 1987). In the present study, there was a 59% prevalence of phantom pain at the time of prosthetic fitting, which diminished only to 53% during the first postoperative year and phantom pain and stump pain had a significant association with walking functions. Pain is always difficult to describe and is largely incapable of measurement. It is important to make the differentiation between spontaneous pain and tenderness. Accordingly the presence or absence of spontaneous pain, tenderness, presence of any palpable neuroma, pain after exercise, presence or absence of phantom pain and similarly of pain in the proximal joint are to be recorded.

In this study, 7 of the follow-up patients (6%) required major amputation of the contralateral limb during the follow-up year. All these patients were vascular patients. Other lesions of the contralateral limb were also fairly common. The end-stage nature of arteriosclerosis in these patients affects the entire arterial tree; similar end-stage disease is usually found in the contralateral limb and in other organs. This emphasises the need for systematic observation and a search for early lesions. Such patients must also be educated in avoiding injury to the contralateral limb and in reporting promptly any changes in symptoms in the contralateral limb. Prophylactic foot care should be encouraged and medical personnel should be taught to give attention to arteriosclerotic and diabetic feet.

There is a need for an objective evaluation and international classification of amputation stumps to compare one publication with another (Wall, 1988). The different clinic teams might use a standardised form of stump description and general acceptance of such a system would also be of interest to epidemiologists and government health officials (Wall, 1988). This study supports the usefulness of the ISPO standard form and classification of amputation stumps. However, many descriptions are determined in practice by inspection, palpation and questionnaire on pain. In order to make the system of stump classification more comparable it may be necessary to develop more definite scales for some elements in the description.

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REFERENCES

Burgess, E. M., Matsen, F. A. (1981). Current concepts review determining amputation levels in peripheral vascular disease. *J. Bone Joint Surg.*, **63A**, 1493–1497.

Burgess, E. M. (1982). Amputation surgery and postoperative care. In: Rehabilitation management of amputees, Ed. S. N. Banerjee. — Baltimore: Williams & Wilkins, 11–41.

Carlen, P., Wall, P., Nodvorna, H., Steinbach, T. (1978). Phantom limbs and related phenomena in recent traumatic amputations. *Neurology*, **28**, 211–217.

Cumming, J. G. R., Spence, V. A., Jain, A. S., Stewart, C., Walker, W. F., Murdoch, G. (1987). Fate of the vascular patient after below-knee amputation. *Lancet*, 12 September, 613–615.

Francis, W., Renton, C. J. (1987). Mobility after major limb amputation for arterial occlusive disease. *Prosthet. Orthot. Int.*, **11**, 85–89.

Gonzalez, E. G., Corcoran, P. F., Rodolfo, L. R. (1974). Energy expenditure in below-knee amputee: correlation with stump length. *Arch. Phys. Med. Rehabil.*, **55**, 111–119.

Jensen, T., Krebs, B., Nielsen, J., Rasmussen, P. (1985). Immediate and long-term phantom limb pain in amputees: incidence, clinical characteristics, and relationship to preamputation limb pain. *Pain*, **21**, 267–268.

Kullmann, J. (1987). Evaluation of disability and results of rehabilitation with the use of the Barthel index and Russek's classification. *Int. Disabil. Studies*, **9**, 68–71.

Moffat, L. E. F., Rainey, J. B., MacPherson, A. I. S. (1981). Major lower limb amputation reassessed. *J. R. Coll. Surg. Edinb.*, **26**, 50–53.

Moore, T. J., Barron, J., Hutchinson, F., Golden, C., Ellis, C., Humphries, D. (1989). Prosthetic usage following major lower extremity amputation. *Clin. Orthop.*, **238**, 219–224.

Narang, I. C., Mathur, B. P., Singh, P., Jape, V. S. (1984). Functional capabilities of lower limb amputees. *Prosthet. Orthot. Int.*, **8**, 43–51.

Neff, G. (1988). Surgery. In: Amputation surgery and lower limb prosthetics, Eds. G. Murdoch, R. Donovan. — Oxford: Blackwell Scientific Publications, 117–129.

Otsuka, T. (1987). Phantom limb, phantom pain and stump pain (Part II). Annual reports of the College of Medical Technology, Kyoto University, **6**, 1–8.

Persson, B. M., Liedberg, E. (1983). A clinical standard of stump measurement and classification in lower limb amputees. *Prosthet. Orthot. Int.*, **7**, 17–24.

Renström P. (1981). The below-knee amputee: a clinical study and experimental investigation on the circulation, muscle atrophy and strength of the amputated leg. Thesis. — Gothenburg, Sweden.

Sherman, R., Sherman, C. (1983). Prevalence and characteristics of chronic phantom pain among American veterans. *Am. J. Phys. Med.*, **62**, 227–238.

Steinberg, F. U., Sunwoo, I, Roettger, R. F. (1985). Prosthetic rehabilitation of geriatric amputee patients: a follow-up study. *Arch. Phys. Med. Rehabil.*, **66**, 742–745.

Steinbach, T., Nodvorna, H., Arazi, D. (1982). A five-year follow-up study of phantom pain in post-traumatic amputees. *Scand. J. Rehabil. Med.*, **14**, 203–207.

Stirnemann, P., Mlinaric, Z., Oesch, A., Kirschhof, B., Althaus, A. (1987). Major lower extremity amputation in patients with peripheral arterial insufficiency with special reference to the transgenicular amputation. *J. Cardiovasc. Surg.*, **28**, 152–158.

Wall, M. (1988). Lower limb amputation stump descriptions. In: Amputation surgery and lower limb prosthetics. Eds. G. Murdoch. R. Donovan. — Oxford: Blackwell Scientific Publications. 403–415.

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Lower limb intersegmental forces for below-knee amputee children during standing

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Abstract
The purpose of this investigation was to compare intersegmental knee and hip forces for below-knee amputee (BKA) and able-bodied children during standing. Three unilateral BKA children and 10 able-bodied children (7-9 years) were tested on four separate occasions at six month intervals. Three trials of external force and spatial data during standing were collected from each subject for each session. These data were utilised to determine the intersegmental forces at the knees and hips of the children using a static force analysis. Results indicated that in some instances the intersegmental forces for the BKA children were significantly greater than those of the able-bodied children and in other instances significantly lower ($p<0.05$). In all cases, however, the values were substantially less than corresponding values for walking and running. The effects of the forces upon spatial orientations indicated significant differences between the two groups of children. The frontal plane prosthetic knee angle, the sagittal plane prosthetic and non-prosthetic knee angles, and the sagittal plane trunk angle were all greater for the BKA children when compared to able-bodied children. These differences may be the result of the anatomical structure of the amputee and/or the construction of the prosthesis.

Introduction

It has been previously reported that the ground-shoe weight distribution for prosthetic and non-prosthetic limbs of below-knee amputee (BKA) children was not significantly different from that of able-bodied children (Engsberg *et al.*, 1989). However, the anterior-posterior weight distribution between the shoe and the ground for prosthetic and non-prosthetic feet was significantly different from able-bodied children (Engsberg *et al.*, 1989). More weight was applied to the forefoot of the prosthetic limb and more weight was applied to the rearfoot of the non-prosthetic foot than in the case of able-bodied children. It was concluded from this investigation that the benefit, detriment or irrelevance of these atypical loading patterns to the well-being of BKA children was unknown and that work should be conducted towards resolution of this issue.

The term detrimental load could refer to its magnitude, its direction or its distribution and could be detrimental from both short and long term perspectives. Short term perspective could be that the loads were related to pain, discomfort, premature fatigue. Long term perspective may indicate that the loads were related to degenerative joint disease. A direction towards understanding these loads and their potential effects could be to quantify them internally and compare them with similar values for able-bodied children. This quantification could be partially accomplished by considering the intersegmental forces at the joints of the lower limbs for these two groups of children. If the forces for the BKA children were significantly larger than those of able-bodied children and/or produced atypical spatial orientations then the possibility exists that they may be detrimental. If however, the

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loads were similar in direction and distribution to able-bodied children or were much smaller in magnitude than those occurring during other activities (e.g., walking or running) then they may not be detrimental. The purpose of this investigation was to compare intersegmental knee and hip forces for BKA and able-bodied children during standing.

Methods

Three unilateral BKA children and ten able-bodied children volunteered as subjects for this investigation. The children ranged in age from seven to nine years with the mean age being eight years. Each BKA child wore a SACH (solid ankle, cushioned heel) terminal device as a part of his/her prosthesis. The children visited the Human Performance Laboratory at The University of Calgary on four separate occasions at six month intervals. Three sets of data during standing were collected from each subject for each session. Ground reaction pressure data were collected from an EMED pressure system as previously described (Engsberg *et al.*, 1989). Spatial data were obtained from two Locam cameras (frontal and lateral views) operating at a rate of 20 Hz.

Joint centres and segmental endpoints were digitised from the film utilising a seven segment model (i.e., feet, legs, thighs, head-arms-trunk segment) and converted to three-dimensional data utilising the direct linear transformation (DLT) method (Abdel-Azis and Karara, 1975; Engsberg and Andrews, 1987). Figure 1 illustrates the right handed co-ordinate system (R) fixed (i) in the laboratory, (ii) to the distal aspect of the left leg, (iii) to the distal aspect of the left thigh and (iv) to the trunk segment. The latter three co-ordinate systems were used to describe the angular orientation of the three segments as a projection on to a plane. A left handed co-ordinate system (P) was used to describe the orientation of the right leg and thigh (Fig. 1). This left handed co-ordinate system was created in order that the positive Y axes always pointed laterally for the lower limbs and thus eliminate sign ambiguity in the data analysis in the frontal plane. For example, in the frontal plane (Fig. 1a) the angular orientation of the thigh was measured about the positive X_R or X_P axes from the positive Y_R or Y_P axes in the direction of the positive Z_R or Z_P axes, respectively.

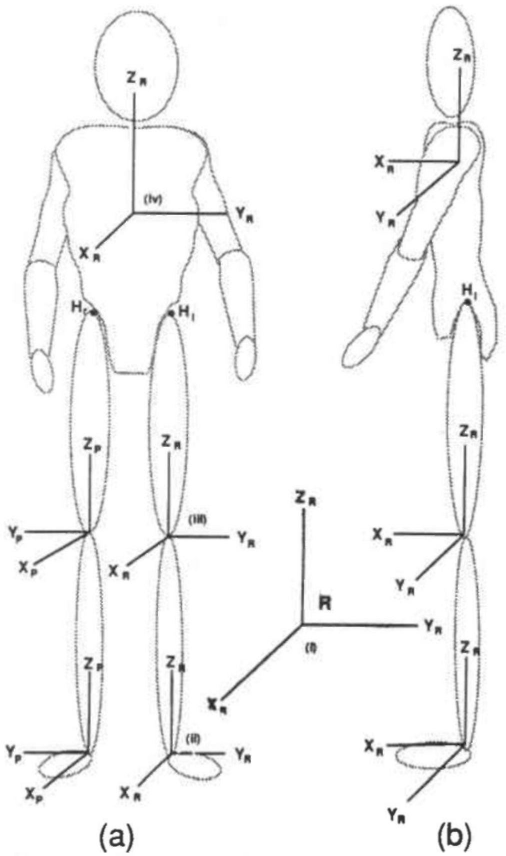

Fig. 1. The right and left handed laboratory co-ordinate system (i.e. R and P) fixed in the laboratory and at the distal aspects of the leg, thigh and trunk. This figure characterises the position of an able-bodied child from a frontal (a) and a lateral (b) perspective.

Pressure plate information was reduced to yield a resultant normal force and a point of application. It should be noted that in this analysis only normal forces were determined while shear forces were neglected. A dominant (D) and non-dominant (ND) foot was then declared for the limbs of the able-bodied children (Engsberg *et al.*, 1989). The dominant limb was defined to be the limb with larger average ground-foot force values. The non-dominant limb was the other limb.

Knowing the location of three points on the pressure plate allowed for transformation of the force data at its point of application to the same laboratory co-ordinate systems as the spatial data. The data were then transformed to local co-ordinate systems to provide for functionally relevant application of the data (Fig. 2). For

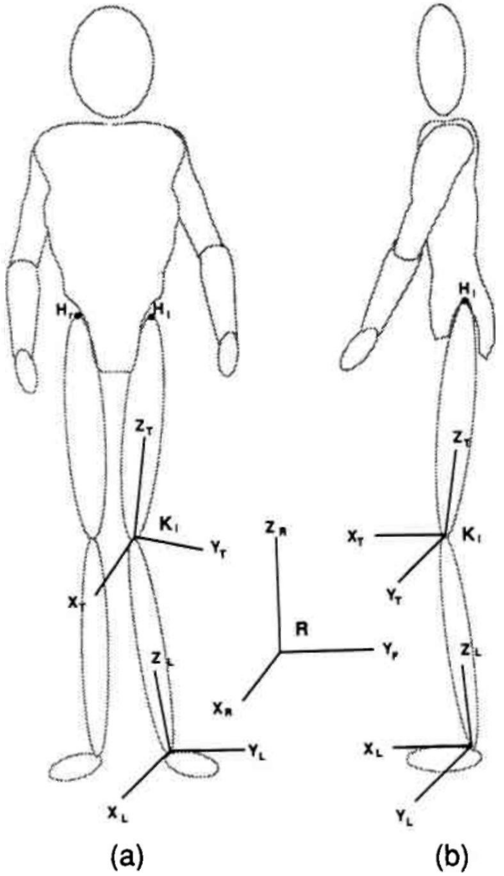

Fig. 2. The right and left handed local co-ordinate systems fixed on the segments at their distal ends. This figure characterises the position of a BKA child from a frontal (a) and a lateral (b) prosthetic leg perspective.

example, the local co-ordinate system produced an intersegmental force that was directed along the long axis of the segment. This force was identical to the intersegmental force obtained from the laboratory co-ordinate system (R) if the long axis of the segment was vertical. However, if the segment was not vertical the local co-ordinate system would continue to produce an intersegmental force that would be directed along the long axis of the segment, while the laboratory co-ordinate system (R) would produce a force that would still be vertical. This vertical force does not seem as functionally relevant in a non-vertical segment as would a force that was directed along the the segment's longitudinal axis. The local co-ordinate system (T) for the left thigh was determined in the following manner:

$$Z_T = r_{H_l/K_l} \quad (1)$$
$$X_T = Z_T \times r_{H_r/K_l} \quad (2)$$
$$Y_T = Z_T \times X_T \quad (3)$$

where X_T, Y_T, Z_T represents the thigh co-ordinate axes and r_{H_l/K_l}, r_{H_r/K_l} represent position vectors from the left knee (K_l) to the left hip (H_l) and from the left knee to the right hip (H_r). The local right handed co-ordinate system for the left leg and local left handed co-ordinate systems for the right leg and thigh were determined in a similar fashion. These co-ordinate systems were utilised to determine the intersegmental forces at the knees and hips of the children following the inverse dynamics approach as previously described (Andrews, 1974; Lewallen *et al.*, 1986; Miller, 1987; Verstraete and Soutas-Little, 1989). However, since the children were only standing the inertia force vector was equal to zero and the analysis was reduced to a static force analysis. In addition, the intersegmental forces were acting upon the proximal ends of the two segments and forces were normalised by dividing by body weight.

In order to present the spatial data of this investigation from a clinical perspective, an approximation of the Q angle (i.e., frontal plane acute angle of the patellar tendon and patellar ligament) was made for the able-bodied, non-prosthetic and prosthetic knees of the children. The Q angle was estimated by determining the frontal plane angle formed by the hip, knee and ankle joint centres. Zero degrees represented a straight limb. A positive value represented a valgus condition of the leg with respect to the thigh. A negative value represented a varus condition of the leg with respect to the thigh. In addition, knee flexion angles were also determined from the same joint centres, but in this case the orientation was the sagittal plane. Zero degrees represented full knee extension while a positive value represented a knee in flexion. It should be noted that the segmental analysis incorporated five degrees of freedom since only two points were used to represent each segment. Thus any abnormal angular orientation of one segment with respect to another about a longitudinal axis (i.e., Z_T or Z_L axis) was not recorded. However, it was speculated that any substantial amounts of external or internal rotation of the thigh or leg would be observed by atypical foot orientation.

One-way analysis of Variance (ANOVA) was used to determine significant differences between variables. A Tukey Post Hoc analysis then defined which of the variables were significantly different at the 0.05 confidence level. The intersegmental forces in the X, Y, and Z directions in the local co-ordinate systems for the dominant and non-prosthetic, non-dominant and prosthetic, and prosthetic and non-prosthetic limbs were evaluated. In addition, the projected angular orientations (i.e., frontal and sagittal planes) of the legs and thighs for the able-bodied, non-prosthetic and prosthetic limbs of the children and the angular orientations of the trunks for the two groups of children were compared. No significant differences existed between the angular orientations of the trunk, right and left legs and thighs of the able-bodied children and these were combined to form a single set of data.

Results

Figures 3-5 present the average normalised intersegmental forces and standard errors acting at the proximal end of the leg and thigh for each leg type of the BKA and able-bodied children. Figure 3 displays the results for both segments in the Z direction (i.e., longitudinal), Figure 4 in the Y (i.e., anterior-posterior) direction and Figure 5 in the X (i.e., medial-lateral) direction. Significant differences between non-prosthetic and prosthetic (*), between non-prosthetic and dominant (x) and

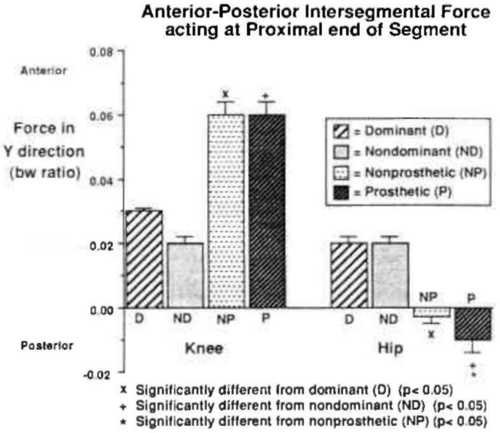

Fig. 4. Intersegmental forces normalised to a ratio of body weight (BW) acting in the Y direction (i.e. anterior-posterior) on the proximal end of the segment.

between prosthetic and non-dominant (+) are indicated. It was believed that these comparisons were most relevant since it was assumed that the non-prosthetic limb would be the dominant limb for the BKA children. This assumption seemed reasonable since two of the children were amputees due to a congenital abnormality and amputation occurred before one year of age. For the third BKA child, which foot was dominant prior to the amputation due to trauma was unknown. It was assummed that the non-prosthetic limb had become dominant if it had not been before the amputation. It should be noted that the changes from intersegmental knee forces acting on the leg to

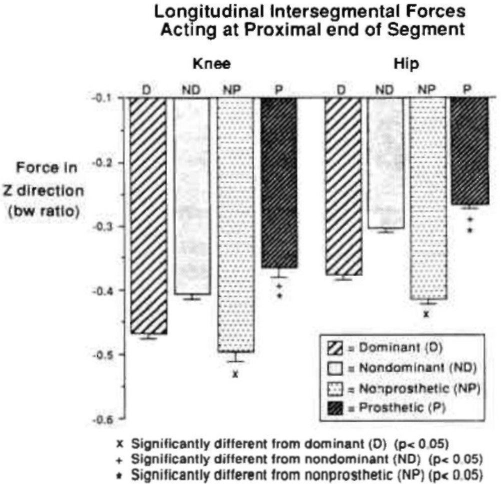

Fig. 3. Intersegmental forces normalised to a ratio of body weight (BW) acting in the Z direction (i.e. longitudinal) on the proximal end of the segment.

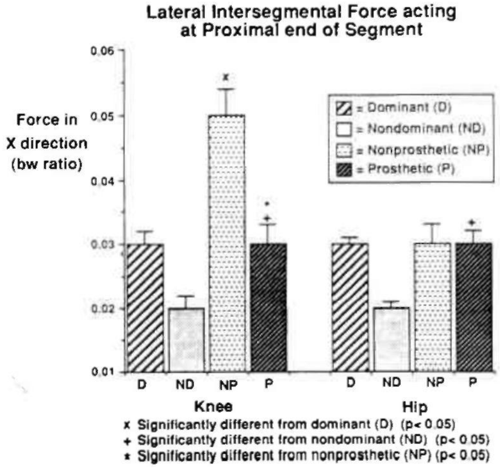

Fig. 5. Intersegmental forces normalised to a ratio of body weight (BW) acting in the X direction (i.e. medial-lateral) on the proximal end of the segment.

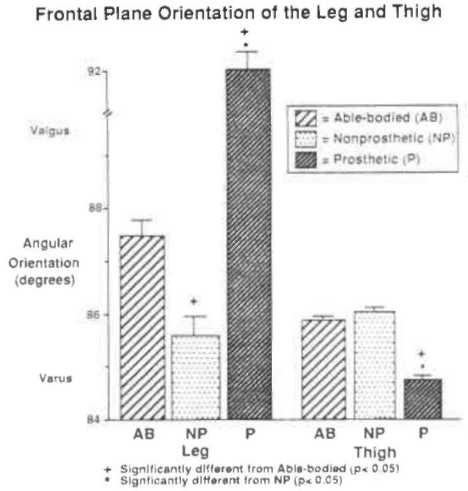

Fig. 6. Angular orientations of the leg and thigh in the frontal plane.

intersegmental hip forces acting on the thigh are not merely due to the subtraction of the weight of the distal segments. Since the results are presented with respect to the local co-ordinate systems they also reflect the change in segmental orientation. In addition, the intersegmental forces do not necessarily reflect the articular surface contact forces or forces due to muscular contractions.

The spatial effects of the intersegmental forces are presented in Figures 6-9. Frontal and sagittal plane leg and thigh angular orientations are indicated in Figures 6 and 7, respectively.

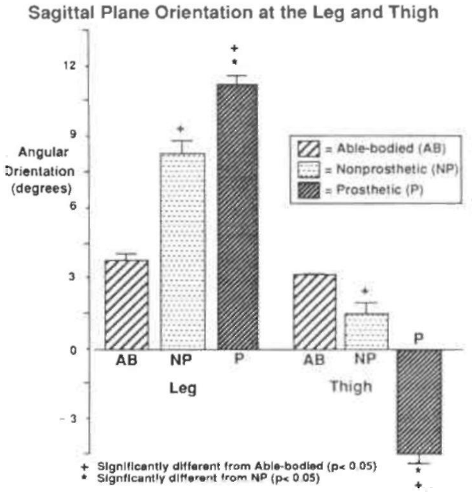

Fig. 7. Angular orientations of the leg and thigh in the sagittal plane.

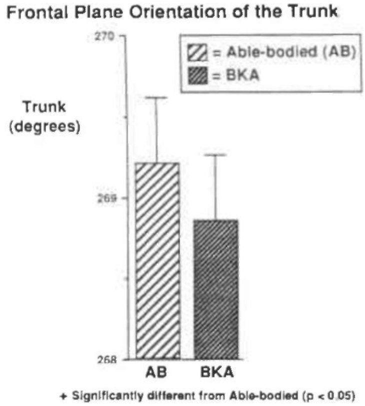

Fig. 8. Angular orientations of the trunk in the frontal plane.

Significant differences from able-bodied (+) and from non-prosthetic (*) are indicated.

Q angles and sagittal plane knee flexion angles for the able-bodied, non-prosthetic and prosthetic knees of the children are presented in Table 1. The slight valgus condition of the prosthetic leg relative to the knee (i.e., the prosthetic leg was oriented lateral to the knee) is pictorially displayed in Figure 2a. For comparison, the same orientation for the able-bodied children is displayed in Figure 1a. The sagittal plane orientation of the prosthetic leg and thigh of the BKA children is pictorially displayed in Figure 2b and that for able-bodied children is presented in Figure 1b.

Discussion

The intersegmental forces for the non-prosthetic and prosthetic knees and hips were significantly different from the dominant and non-dominant joints of the able-bodied children, respectively. In some instances they were slightly greater than able-bodied and in others slightly less than able-bodied. If the magnitudes of the intersegmental loads are considered, the values reported here do not appear to be substantially large when compared with other activities. The present investigation

Table 1. Q-angles and sagittal plane knee flexion angles for able-bodied, non-prosthetic and prosthetic limbs of subjects.

Leg type	Q-angle (degrees)	Knee flexion angle (degrees)
Able-bodied	1.0	0.2
Non-prosthetic	-0.3	7.2
Prosthetic	7.3	14.2

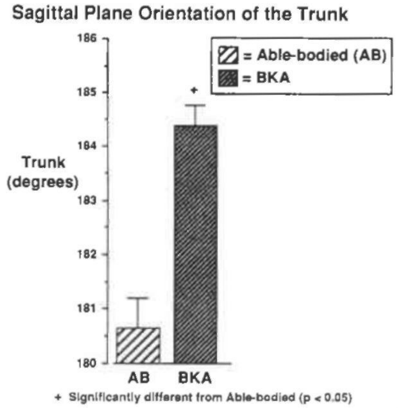

Fig. 9. Angular orientations of the trunk in the sagittal plane.

derived intersegmental forces of up to about 0.5 body weight for standing. However, it has been reported that intersegmental joint forces for walking of BKA children may be up to about 1.5 body weight (Lewallen *et al.*, 1986; Engsberg *et al.*, In Press). In addition, intersegmental forces for running may be about 2.0 body weight (Miller, 1987) for BKA adults. Thus it would not appear that the intersegmental forces during standing would be detrimental to the well-being of BKA children. Nevertheless it should be noted that the two additional factors, articular surface contact forces and their distribution, were not considered in this analysis and could prove to be detrimental to these children. Further investigation in this area is warranted.

The spatial results from the forces displayed differences between the two groups of children. Primarily, (1) the frontal plane prosthetic knee angle (i.e. Q angle), (2) the sagittal plane prosthetic and non-prosthetic knee angles and (3) the sagittal plane BKA trunk angle were different from those of the able-bodied children. A number of possible conditions may exist to explain these orientation differences. Two of the three BKA children in the present investigation were congenital amputees with fibular hemimelia. This condition often results in a valgus orientation of the leg with respect to the thigh (Fig. 2a) and thus a larger than able-bodied Q angle. It could be therefore speculated that these observed differences may not exist if additional subjects without this valgus condition were measured.

The greater than able-bodied sagittal plane prosthetic knee flexion angle (i.e., 14.2 degrees) could be the result of the socket design. For example each of the three subjects were fitted with PTB (patellar-tendon-bearing) sockets. It has been reported that if a PTB socket is so constructed that slight knee flexion is imposed, then the patellar ligament is better able to accept larger vertical loads during activities than if flexion was not imposed (New York University Medical Center, 1987). In addition, prosthetists often impose knee flexion when they construct the sockets to reduce the valgus condition of the leg with respect to the knee of some amputee patients. This was the case for two of the BKA children. Finally, while it was not the case for any of the three subjects in this investigation, a knee flexion contracture would create a sagittal plane flexion condition. Explanations for the sagittal plane non-prosthetic knee flexion did not abound, however this condition could be related to stability, leg length discrepancy, improperly aligned prosthesis or an uncomfortable socket. No measure of these factors was performed. The sagittal plane forward trunk angle of the amputees (Fig. 9) could be related to the prosthetic knee flexion.

It is apparent from these spatial results that the BKA children assume a distinctly different posture from that assumed by able-bodied children. The forces producing this postural orientation are different from able-bodied and may be the result of the imposed structure of the prosthesis and the lower limb. It would appear that monitoring the posture of the group of BKA children for an extended period of time to determine if this trend would continue may be valuable. In addition, measuring the posture of BKA adults to consider if the postural orientation of this population is the same as BKA children may also prove helpful.

Summary

This investigation measured the intersegmental knee and hip forces for BKA and able-bodied children. The significant differences observed for the internal force systems between groups of children may not be harmful to the BKAs since their magnitudes were substantially lower than those for walking and running. However, contact forces between articulating bones and their distribution were not determined. The effect of the loads on the posture of the BKA children produced

significant differences from able-bodied children. Without additional information from BKA adults and longitudinal information from BKA subjects, the influence of this atypical posture cannot be determined at this time.

Acknowledgement

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REFERENCES

ABDEL-AZIZ, Y. I., KARARA, H. M. (1975). Direct linear transformation from comparator co-ordinates into object-space co-ordinates in close range photogrammetry. Proceedings of the symposium on close-range photogrammetric systems. – Falls Church, VA: American Society of Photogrammetry.

ANDREWS, J. G. (1974). Biomechanical analysis of human motion. Kinesiology IV. – Washington, DC: American Association for Health, Physical Education and Recreation, p 32–42.

BROUWER, B. J., ALLARD, P., LABELLE, H. (1989). Running patterns of juveniles wearing SACH and single-axis foot components. *Arch. Phys. Med. Rehabil.*, **70**, 128–134,

ENGSBERG, J. R., ANDREWS, J. G. (1987). An analysis of the combined talocalcaneal/talocrural joint during running support. *Med. Sci. Sport. Exerc.*, **19**, 275–284.

ENGSBERG, J. R., ALLINGER, T. L., HARDER, J. A. (1989). Standing pressure distribution for normal and below-knee amputee children. *Prosthet. Orthot. Int.*, **13**, 152–155.

ENGSBERG, J. R., LEE, A. G., PATTERSON, J. L., HARDER, J. A. (In Press). External loading comparisons between normal and below-knee-amputation children during walking. *Arch. Phys. Med. Rehabil.*

LEWALLEN, R., DYCK, G., QUANBURY, A., ROSS, K., LETTS, M. (1986). Gait kinematics in below-knee child amputees: a force plate analysis. *J. Pediatr. Orthop.* **6**, 291–298.

NEW YORK MEDICAL CENTER. POSTGRADUATE MEDICAL SCHOOL (1987). Lower-Limb Prosthetics. – New York: NYU, p 119.

MILLER, D. I. (1987). Resultant lower extremity joint moments in below-knee amputees during running stance. *J. Biomech.*, **20**, 529–541.

VERSTRAETE, M. C., SOUTAS-LITTLE, R. W. (1990). A method for computing the three-dimensional forces and moments in the lower limb during gait. Proceedings of the XII International Congress of Biomechanics 76. – Oxford: Pergamon Press.

Prosthetics and Orthotics International, 1991, 15, 192

Seating Supplement Foreword

This supplement on Seating follows a similar supplement on Wheelchairs published in the April 1991 issue of this Journal. Both are drawn from material presented at "Dundee 88" an International Conference on Wheelchairs and Seating.

This supplement commences with a discussion of the surprisingly wide-ranging physiological considerations involved in seating. An understanding of the causes of deformity is an essential foundation to the provision of seating and is described in the second paper.

The need for detailed assessment of childrens' needs in the provision of seating is emphasised in a paper extending from the biomechanics of sitting to prescription practice. These themes are developed further to encompass people of all ages, with practical examples from specific case studies.

The final papers tackle the important problem of pressure sores, first discussing their causes and measurement of interface conditions leading into an evaluation methodology for cushions.

Together with that of the April 1991 issue, this supplement provides valuable additions to the written body of knowledge concerning wheelchairs and seating. I am grateful to the authors for their hard work in preparing these papers and making these supplements possible.

Geoffrey Bardsley
Guest Editor

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Physiological considerations in seating

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Abstract
Physiological changes occur with change of posture.

Seating imposes significant effect on the cardiovascular, respiratory, abdominal, renal and neurological systems.

The presence of severe skeletal deformities can significantly alter the physiological responses of the individual to changes in posture. In the case of severe kyphoscoliosis profound haemodynamic changes may occur. Lung perfusion has been shown to be posture dependent and the imposition of a specific seated position may have profound effects. This may compound existing lung problems for example bronchiectasis, which is not uncommon in these individuals, leading to hypoventilation.

Abdominal compression which can occur with the patient in a flexed position can exacerbate a hiatus hernia, which can be both uncomfortable for the patient and may lead to feeding difficulties. The flexion at the hips of the lower limbs may also lead to problems of renal drainage especially where there is a catheter or other drainage appliance.

Seating significantly affects many neurological reflexes. For example the presence of an extensor pattern can be helped by the adoption of a flexed position. The presence of pain can also influence the neurological response to a spe•ific position.

Those providing seating systems must consider the physiological effects that occur and compromise between these and the other requirements.

Cardiovascular and respiratory systems

Normal ventilation consists of an equilibrium between air flow through the lungs and perfusion of the lung parenchyma with blood allowing gaseous exchange to occur. Oxygen is removed from the inspired air and carbon dioxide laden air is expired.

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In the normal lung, atmospheric oxygen diffuses into the blood and thereafter to cellular mitochondria as the partial pressure of oxygen (pO_2) in the cells is lower than in the blood. If the arterial pO_2 falls, cellular pO_2 will also fall with a consequential rise of tissue pCO_2 (partial pressure of carbon dioxide). The oxygen balance in the body is dependent on both the ventilation and the metabolic demands of the tissues.

In situations where hypoventilation occurs,

a) there is an increase in alveolar and arterial pCO_2
b) there is a reduction in the alveolar, arterial and cellular pO_2

In these circumstances the patient can become hypoxic.

For efficient gas exchange, ventilation and alveolar perfusion must be balanced. Ventilation-perfusion is the ratio of alveolar ventilation over pulmonary blood flow and is used as a measure of ventilation and blood flow changes in various situations. If, for example, ventilation and blood flow are mismatched, then the ventilation-perfusion ratio alters giving an indication of the oxygen and carbon dioxide changes that can be expected, which may have a profound effect on the body.

The lung has been found to have considerable regional differences in gas exchange.

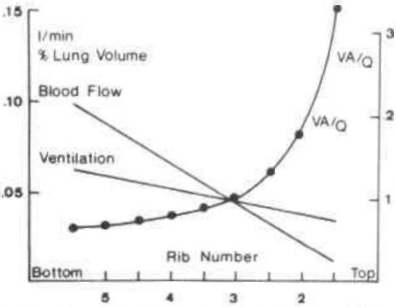

Fig. 1. Distribution of ventilation and blood flow down the upright lung. Ventilation-profusion ratio (VA/Q) decreases down the lung. (From J. B. West, Ventilation: blood flow and gas exchange/3rd edition. — Oxford: Blackwell.)

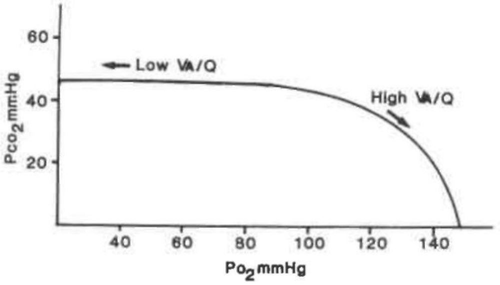

Fig. 2. Oxygen and carbon dioxide diagram, showing that pO_2 and pCO_2 (partial pressure) of all lung units have different ventilation perfusion ratios. (From West, 1987.)

Ventilation increases from the lung apex to the lung base primarily due to the anatomical shape of the lung, there being more lung parenchyma at the base than at the apex. Similarly, pulmonary blood flow increases rapidly from lung apex to lung base due partly to the anatomical shape and also to the hydrostatic and gravitational forces acting on that blood. As a result the ventilation-perfusion ratio is high (> 1.0) at the lung apex and low (< 1.0) at the lung base (Fig. 1).

This in turn results in different blood gas concentrations in different regions of the lung. At the lung apex where the ventilation-perfusion ratio is high the pO_2 is high while pCO_2 is low. This is because the relative blood flow is low and gaseous exchange can take place at a more leisurely pace. The opposite is true of the lung base (Fig. 2). These regional differences can be quite marked (Fig. 3). In comparison with oxygen, carbon dioxide levels have less regional differences and are more affected by ventilation. This can be seen by reference to the "dissociation curve" of carbon dioxide (Fig. 4). Increase in ventilation raises the carbon dioxide output with high or low ventilation ratios. This contrasts with the oxygen dissociation curve which shows that with low ventilation-perfusion ratios some benefit

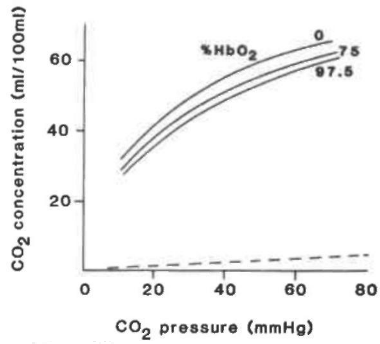

Fig. 4. Carbon dioxide dissociation curve for blood of different oxygen saturation. Note that oxygenated blood carries less CO_2 for the same pCO_2. (From West, 1985.)

is obtained by increasing the ventilation, but in normal situations ventilation itself has little effect on pO_2 level (Fig. 5).

The regional ventilation of the lung can be demonstrated to vary according to the posture adopted. As described above, ventilation in the standing position increases from lung apex to base whereas in the supine position these differences disappear with apical and basal ventilation being similar. In the lateral position the dependent lung becomes the better ventilated (James, 1976).

In deformed chests, for example kyphoscoliotic chests, the anatomical dead space gains greater importance as does the residual volume. The anatomical dead space is "the volume of respiratory system exclusive of alveoli" (Fig. 6). The deformed chest cannot expand normally and thus lessens the amount of gas exchanged. The effective aveolar ventilation also becomes reduced with less fresh inspired air available for gaseous exchange. In severe deformity, the effective respiration can be reduced dramatically leading to the development of pulmonary emphysema. This is found frequently in kyphoscoliosis (Bergofsky *et al.*, 1959).

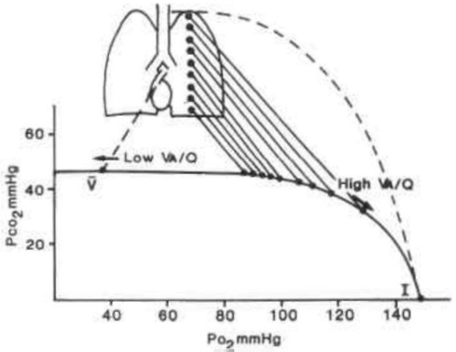

Fig. 3. Regional differences in blood gases in different parts of the lung. (From West, 1987.)

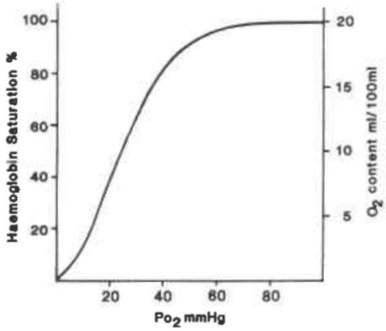

Fig. 5. Oxygen dissociation curve. (Haemoglobin concentration of 14.5g/100ml). (From West, 1987.)

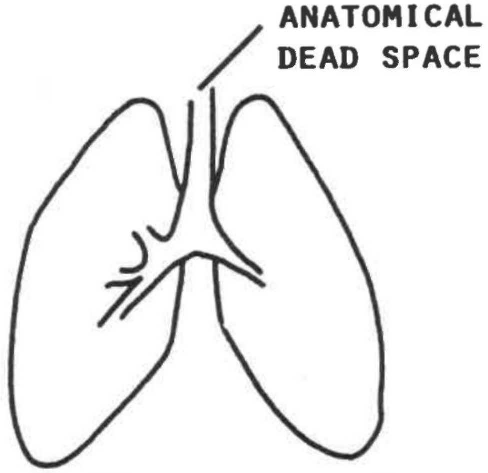

Fig. 6. Anatomical dead space. (The volume of the respiratory system exclusive of the alveoli.)

The deformed chest has, as a consequence of the deformed skeletal shape, a lower than normal lung volume. This can be as much as 63% of the predicted level (James, 1976). The vascular resistance may be raised due to the extra-aveolar vessels becoming narrowed. This results in a linear reduction in blood flow which can be very poor at the apex. When supine the apical blood flow improves with no great change in the basal flow. There may be some change in the antero-posterior plane with posterior (dependant) blood flow exceeding the anterior flow. The changes are explained by the hydrostatic differences of blood in the blood vessels compounded by the increased vascular resistance.

Dollery and his colleagues (1965) reported that some of the changes with regard to the differences in ventilation from apex to the base were not found in ten studied cases of kyphoscoliosis. The ventilation was found to be fairly even although in some older patients ventilation reduction was found in the lower zone. In the younger cases, ventilation was found to be remarkably even, despite gross skeletal deformity (Bake *et al.*, 1972; Dollery *et al.*, 1965). X-rays of kyphoscoliotic chests showed translucent lungs on the concave side suggesting more efficient lungs. The anteroposterior diameter of the lung on the concave side was found to be reduced and thus so also was the lung volume.

No evidence of air entrappment occurs but poorly ventilated spaces have been described. Blood flow is abnormal not due to the kinking in the blood vessels but probably due to the foreshortened chest reducing the total height of the lung tissue. Under-perfusion of lung tissue may however occur and over a period of time, pulmonary vascular resistance may rise and pulmonary hypertension may follow. This may lead to right ventricular loading with the imbalance of ventilation and blood perfusion, with carbon dioxide retention (Bergofsky *et al.*, 1959; James, 1976). The resulting development of chronic hypoventilation may ultimately lead to cor pulmonale. However this complication is rare under the age of 20 (James, 1959). Later, there may develop a reduced ventilation response to carbon dioxide further reducing the efficiency of ventilation.

Increasing scoliosis reduces lung vital capacities. In addition increased rib cage rigidity has been found to occur with increasing age (Caro and Du Bois, 1961) and may be compounded in spinal disease, such as ankylosing spondylosis and kyphoscoliosis. This coupled with the evidence that chest wall compliance rises with age may suggest an increased difficulty with breathing, requiring more effort. Increasing scoliosis has also been shown to result in a fall in the total lung capacity and vital capacity. These changes are significantly greater if a paralytic scoliosis has occurred. Despite increasing kyphoscoliosis with the haemodynamic ventilation changes that follow as deformity progresses, many do not develop problems until later. "Young patients with idiopathic kyphoscoliosis are often symptom free and remain so until middle age when those with severe deformity may become breathless on exertion and develop respiratory, or less often, cardiac failure" (Dollery *et al.*, 1965). During the early years the lungs can cope with the deficiency but as individuals grow older pulmonary resistance increases and some regional hypoventilation may occur and this may be in the scoliotic concavity (Dollery *et al.*, 1965).

There are some for whom respiratory function becomes severely compromised as a result of bronchiectasis. Bronchiectasis is an abnormal and irreversible dilation of the bronchi, usually associated with inflammation and can be caused by the blocking of a bronchus by either mucous or inhaled matter. This often occurs in individuals with severe skeletal deformity and mental deficiency. This plug occludes part of the bronchus trapping air and secretion leading to recurrent infection, ultimately resulting in dilation of the bronchi. Fibrosis of the lung occurs with recurrent infection leading to some arterial-venous shunting. This may be as a result of the haemodynamic changes occurring with enlargement of the bronchial arteries and the development of bronchopulmonary anastomoses. This loss of vital functional lung tissue may be crucial and in those with severe handicap it may be extensive, producing an extraordinarily inefficient lung.

The posture achieved by a seating system can have a direct effect on the cardio-respiratory system. Posture can be seen to affect the physiology of the respiratory system. The maintenance of a good respiratory shape by controlling spinal curvature is in the interests of maintaining a good cardio-respiratory function and long term future (Zorab, 1976). In addition, the seated position may be important in the case of severely handicapped individuals in whom normal physiological swallowing and coughing reflexes may be abnormal. If the individual chokes on food it may become inhaled leading to the development of bronchiectasis which can hasten the development of cardio-respiratory distress.

In the case of paralytic scoliosis, the patient's ability to ventilate is significantly reduced, both due to severe deformity and respiratory muscle weakness. In these circumstances postural problems can lead to respiratory distress requiring extremely careful positioning.

A patient that has been cared for in a supine position will find that postural hypotension may occur if they are suddenly placed in the sitting or standing position. Gradual elevation is therefore needed to counteract this effect, thus allowing the sympathetic nervous system time to readjust to the new position.

The cardio-respiratory system maintains a delicately balanced equilibrium which has considerable reserves. However in the event of skeletal deformity significant changes may occur which can lead to severe cardio-pulmonary disease and premature death. The posture of the individual can be shown to influence directly some of the haemodynamic factors involved and can play an important role in maintaining normal cardio-respiratory integrity.

Abdominal system

The abdomen contains three main physiological systems,

1. Alimentary tract
2. Hepatic system
3. Renal system

Alimentary tract

The alimentary tract is a self regulating digestive system and its function is not significantly affected by posture. Physical inactivity, imposed by a sedentary or wheelchair lifestyle, encourages constipation and the difficulty of transferring can compound this problem making bowel evacuation difficult. Bowel habits with regular evacuation is the norm for fit and healthy adults and disabled individuals require to develop similar regularity if severe physiological changes are not to occur since chronic constipation, and possibly spurious diarrhoea can be a severe physiologically disturbing problem.

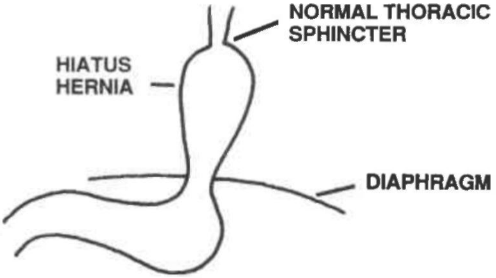

Fig. 7. Herniation of the stomach through the diaphragm resulting in hiatus hernia.

The seated posture itself does not directly affect the digestive system, but reflux oesophagitis may be encouraged by a supine posture. This appears to be common in the severely disabled individual. This is due both to the neuromuscular imbalance and the severe skeletal deformities which may distort the diaphragm, encouraging herniation of the abdominal contents into the thorax (Fig. 7). The supine position encourages reflux of gastric contents into the oesophagus which is extremely uncomfortable and if a chronic problem can lead to peptic ulceration, oesophageal stricture or oesophageal carcinoma. The reflux of gastric contents may lead to aspiration of this material causing either pneumonia or bronchiectasis which, as described above, can have serious consequences. This problem may be helped by careful positioning which may require a compromise.

Ileostomy or colostomy stoma and drainage bags require special consideration. In much the same way as described in constipation, obstruction of these stomas can lead to severe physiological changes. Drainage of these stomas must occur unimpeded and thus the posture adopted is worthy of thought. Ileal conduits which may have been provided to control urinary incontinence require the same consideration since poor drainage can lead to hydronephrosis, recurrent infection and the potential for serious renal damage.

Immobility can lead to obesity exacerbating the problems of transferring in and out of a seat. The very large or very weak require careful positioning if the independence of the individual is to be maintained. In addition the required hip flexion needed to sit can be a problem in very obese people since increased intra-abdominal pressure may compromise the respiratory excursion of the diaphragm, encouraging the development of a hiatus hernia.

Hepatic system

No significant changes appear to occur in this system in relation to seating and therefore no further comment will be made.

Renal system

Incontinence is a major social and hygienic problem. For the wheelchair dependent individual the problems are aggravated by the difficulties of access and transfer into and out of the wheelchair. Inability to transfer may make the incontinence worse since the individual may be aware of the need to micturate but by the time they have got out of the chair it may be too late and involuntary emptying of the bladder may have occurred. Childrens' nappies and incontinence pads can be socially acceptable. These are however bulky, often unhygienic, and present the skin with an environment which encourages bacterial and/or fungal proliferation and, with the moist environment, may lead to skin maceration and breakdown. The efficiency of an intimately fitting seat can be lessened by the bulky incontinence pad which interferes with the seat function and limits its usefulness. The intimacy of the seat and problem of skin breakdown require consideration. These problems can be compounded by anaesthetic skin and pressure loading which may encourage the development of pressure sores.

Those patients with a bladder catheter, urodomes or other incontinence devices require careful positioning. Free drainage of these devices is essential if urinary obstruction is to be avoided. There must not be any "uphill" stretches of conduit as these could compromise bladder drainage leading to potentially damaging urine reflux or hydronephrosis.

Consideration should be given to the individual who has to empty a drainage bag independently since his posture may make this task difficult or impossible thus reducing his level of independence.

Central nervous system

A very significant number of individuals requiring special seating have some form of cerebral inability whether congenital, biochemical or post-natal. The wide range of abnormalities presenting with seating problems are found with considerable variation in clinical findings and difficulties.

The various neurological deficits and ensuing reflexes are discussed by Trefler and Taylor in this supplement.

The problems however that require special seating often require special solutions since the pathology imposes constraints on the ultimate solution. The presence of an extensor pattern of reflexes which appears to be the most frequent can often be overcome by flexion in the hips. However considerable flexion may be required and this in time may encourage the development of permanent flexion contractures, which may or may not be important depending on the person's circumstances.

Flexor patterns may conversely require a more extended position. The presence of primitive reflexes such as the asymmetrical tonic reflex, may require very specific location to reduce them to allow both comfort and function to be achieved.

Involuntary movements present great difficulties for those individuals requiring special seating. These may be athetoid in nature or may present in the form of epilepsy.

Epilepsy imposes its own problems since rapid extraction of the individual from the chair may be necessary. This requires rapid release fasteners if restraints are necessary. Obviously the seat design must avoid potential danger to the occupant if the epilepsy is to be adequately managed.

Pain can severely limit an individual's lifestyle. This pain may be skeletal in origin due to skeletal collapse (e.g. osteoporosis or spinal disease) or pressure on nerves (e.g. osteophyte pressures on spinal nerves) or it may be due to joint damage (e.g. subluxation of the hip). Cutaneous damage as seen in a pressure sore, may lead to severe pain, where the dressings themselves may interfere with the seating system. Positioning must take account of potential pressure points. The severely disabled often find it difficult to explain to those caring for them that they are in pain. The carer in turn however may learn a person's responses to discomfort. Consequently, the carer should be closely involved in the provision of seating since the seating team may not readily be aware of the individual's problems.

The presence of chronic pain can be debilitating and interfere with the quality of life. The position imposed by a seating system may result in the occupant remaining in a predetermined position for many hours. This being so, the seating team must be alert to the possibility of painful postures and these should be avoided whenever possible.

Positioning of an individual in specialised seating can have a profound effect on that individual. The position may affect the tone of the body and the ability of the individual to function independently. Therefore great consideration is needed when supplying a chair. With modern technology a significantly increasing number of individuals have communication aids. The link with the therapist and engineer is crucial if this technology is to be utilised to its maximum potential. Positioning of the individual must take the above into consideration as well as many of the problems mentioned earlier in this text if the person requiring the special seat is to obtain the maximum benefit from the system supplied.

Conclusion

The objectives of seating may involve conflicts with the many medical considerations.

Successful provision of special seating requires the identification of the priorities of these conflicting requirements and subsequent selection of the compromise to achieve a practical solution.

REFERENCES

Bake, B., Bjure, J., Kasalichy, J., Nachemson, A. (1972). Regional pulmonary ventilation and perfusion distribution in patients with untreated idiopathic scoliosis. *Thorax*, **27**, 703–712.

Bergofsky, E. H., Turino, G. M., Fishman, A. P. (1959). Cardio respiratory failure in kyphoscoliosis. *Medicine* (Baltimore), **38**, 263–317.

Caro, C., Du Bois, A. B. (1961). Pulmonary function in kyphoscoliosis. *Thorax*, **16**, 282–290.

Dollery, C. T., Gillan, P., Hugh-Jones, P., Zorab, P. A. (1965). Regional lung function in kyphoscoliosis. *Thorax*, **20**, 175–181.

James, J. I. P. (1976). Scoliosis/2nd edition. — Edinburgh: Churchill Livingstone.

West, J. B. (1985). Respiratory physiology: the essentials/3rd edition. — Baltimore: Williams and Williams.

West, J. B. (1987). Pulmonary pathophysiology/3rd edition. — Baltimore: Williams and Williams.

Zorab, P. A. (1976). The medical aspects of scoliosis. In: Scoliosis/2nd edition. Ed. J. I. P. James. — Edinburgh: Churchill Livingstone.

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The causes of developmental deformity and their implication for seating

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Abstract
This article attempts to touch upon several different aspects of developmental deformity. It is intended to show that the position in which children are placed and the time these postures are maintained are important in preventing fixed and structural deformity. These are considered to be the prime causes of deformity. Whilst surgery is often necessary, it should be seen as complementary to an early postural regime, one part of which is the position in which a child sits.

Introduction

When designing or fitting seating there are many factors to consider. A particularly important factor is deformity and the problem of accommodating and supporting existing deformity whilst preventing further deterioration.

The causes of deformity are legion (Fig. 1) This paper will consider those often referred to as "developmental deformities" and in particular those caused by cerebral palsy and profound mental retardation.

Deformity

Understanding of the mechanisms involved in the appearance of developmental deformity is not complete, but it is beginning to look as though it is sufficient to form a rationale for action. Even less than twenty years ago, many people considered that disparity of muscle strength was the sole cause of deformity in growing children and cited polio as the example. It was said that a difference of two muscle grades on the Oxford strength scale between agonist and antagonist would produce deformity as the child grew. Yet what did that scale measure? Not the absolute strength of a muscle group in relation to its opposing group, but its strength relative to its normal strength as measured by its ability to move the appropriate body segment in relation to gravity and load. Thus on the Oxford scale a normal person's

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CONGENITAL *Born with deformity*
- Shape
- Number
- Size
- Joint mobility

Born with defect tending to deformity
- e.g. Muscular dystrophy
  - Spinal muscular atrophy
  - Brittle bones
  - Spina bifida
  - Retts
  - Cerebral palsy
  - Profound mental retardation

ACQUIRED *Trauma*
- Shape, number, size, joint mobility
- Neurological – Peripheral
  - – Spinal
  - – C.N.S.

"Disease"
- e.g. Stroke
  - Multiple sclerosis
  - Rheumatoid arthritis
  - Idiopathic scoliosis
  - Polionyelitis
  - Meningitis/encephalitis

Therapeutic
- e.g. Frog plasters

Fig. 1. The causes of deformity.

plantarflexors and dorsiflexors both score 5 (and so are "equal") in spite of the fact that usually, the platarflexors can exert 17 times the torque of the dorsiflexors (Perry, 1985). Why then does a normal person remain undeformed? Considerations such as this led some physiotherapists working with cerebral palsy and profound mental retardation to assume that *posture* was involved in some way (Scrutton and Gilbertson, 1975). The normal person was seen as having postural "balance" across each joint (whatever that might mean) and so does not deform. Whether deformity was caused directly by a central process (the "imbalanced" central nervous system (CNS) directly dictating a body shape to match its postural needs) or by a peripheral process (secondary to the postural imbalance) was not clearly agreed or often even discussed.

Sharrard (1971) has shown very clearly how he pictured the mechanism, believing that the growing bone applied a force to the muscles and all other structures which grew in response. In the case of muscle strength imbalance, this produced greater growth in one muscle group than another owing to different forces being applied to them (Fig. 2). Very little was ever

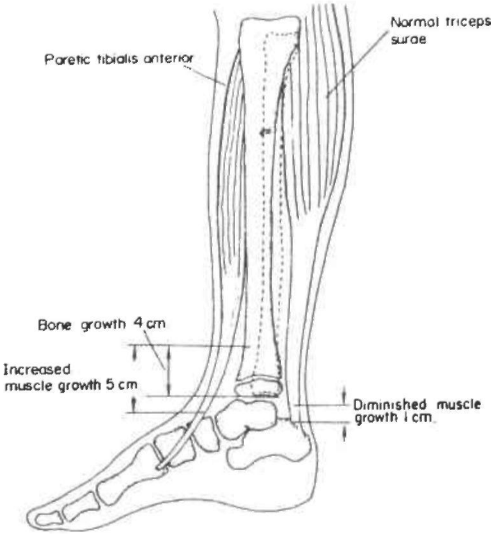

Fig. 2. Tension as a factor in muscle growth. The normal muscle is under diminished tension from its antagonist and receives less stimulus to grow; the paretic muscle is effectively under increased tension and shows abnormal growth in length.
(Figure reprinted from Paediatric Orthopaedics and Fractures, W. J. W. Sharrard, 1971 by kind permission of Blackwell Scientific Publications.)

written about the growth of any tissue other than bone and often it was referred to as "hypertrophy of length" on the assumption, often stated, that no new muscle tissue grew, it simply lengthened; although sarcomeres in "contracted" muscle are seen to be elongated but fewer in number (Tabary, 1971). It may seem unlikely that the CNS should *directly* dictate muscle length, but it was the hypothesis favoured by the writer at that time. This was partly because of the analogous skeletal undergrowth (hemihypoplasia) seen in most children with congenital hemiplegia. This hypoplasia appears to bear no relationship to the degree of movement disability or to the circulation in those limbs (Holt, 1961) and cannot be explained as a peripheral phenomenon secondary to under-use. The author considered that the likely mechanism was an example of the le Chatelier-Braun principle that a system in equilibrium always tends to regain its equilibrium when any constraint is applied to it. The "constraint" in this case is bone growth and the equilibrium in the normal person requires a balanced muscle growth response. In cerebral palsy an unequal growth response is needed to match the incorrect equilibrium determined by the damaged CNS (Scrutton and Gilbertson, 1975). This principle still appears to apply to these mechanisms, but peripherally. At the time it led the author to some (now) unlikely conclusions regarding treatment.

However, to complicate the issue, it can be observed that actual contracture of muscle and other tissue can also occur in the absence of growth. So any growth-related mechanism is not the only one which might affect children's muscles. This introduces the word "contracture" and some clarification of terminology is probably needed. In this article, several terms relating to the length of muscle (that is muscle and tendon together) will be used:

Contracture	Shortening of a muscle which consequently can no longer extend to the length it once could.
Mobile deformity	A posture maintained by a patient which can nevertheless be fully corrected by the

	examiner. It is a deformity of posture rather than of anatomy.
Fixed deformity	A limitation of range of movement (i.e. angular movement at a joint) caused by a muscle or group of muscles not being sufficiently extensible. There can be causes of fixed deformity other than muscular but that is not immediately part of this discussion.
Structural deformity	Change of bony shape or loss of joint integrity (subluxation or dislocation).
Developmental deformity	A fixed or structural deformity which occurs while the body is still growing as a consequence of the forces applied (i.e. the manner in which the body is used).

The gastrocnemius muscles of normal mice lengthen or grow, like human muscle, to accommodate bone growth and consequently a full range of ankle dorsiflexion is maintained. However, the gastrocnemii of (congenital) paraplegic mice do not. From birth to maturity the muscle/tendon growth is only 55% of bone growth and thus fixed deformity limits dorsiflexion significantly (Ziv *et al.*, 1984). Furthermore, Ziv and his colleagues demonstrated that — in this muscle — approximately ⅓ of the growth occurred in the Achilles tendon and ⅔ in the muscle; but nearly 70% of the muscle growth occurred at the distal musculo-tendinous junction, which they refer to as the "muscle growth-plate". The growth occurs by the creation of sarcomeres (the contractile unit of myofibrils) which can be thought of as the "transient element" of the muscle, that is the element which comes and goes as circumstances dictate.

What happens if a muscle is fixed in one position? Inactivity might (and does) cause changes, but there is more involved than the effect of inactivity (Williams and Goldspink, 1984); for the changes vary depending on whether the muscle is fixed in a lengthened or shortened position. Williams and Goldspink go on to suggest that the changes seen (a proportional increase in connective tissue) in muscles immobilised in the shortened position are "likely to result in the reduced elasticity observed in immobilised muscles. Similar changes may occur whenever muscle is working at a shortened length".

For how long does a muscle need to be stretched (and what is meant by "stretched"?) to maintain its fully functional length. Tardieu *et al.* (1988)* studied the range of movement of the soleus muscle throughout the day in 10 children whith cerebral palsy — 5 with hemiplegia and 5 with diplegia — as well as 5 children who were not handicapped. They concluded that 6 hours stretch in 24 hours was needed to maintain length and described precisely how they defined "stretch".

Structural deformity is usually associated with fixed deformity and within these disorders refers primarily to the hip joint — a major problem in seating. Once again, the mechanism of producing hip dysplasia is not fully understood but the prime cause could be summed up as persistently abnormal forces acting on the femoral head/acetabulum interface probably during the first four years of life. These are brought about by delayed weightbearing and by abnormal posture usually adduction with internal rotation or, less often, abduction with external rotation of the femur. Undoubtedly fixed deformity is strongly associated with hip dysplasia in these children but it is doubtful that it is strictly speaking a cause. Rather, the same circumstances that produce fixed deformity also produce dysplasia and, because persistence of posture causes dysplasia, surgical correction of fixed deformity may be necessary to prevent it. Reimers (1980) in an exhaustive monograph on hip dysplasia in cerebral palsy found that anterior obturator neurectomy on its own was as effective in correcting dysplasia as neurectomy combined with adductor tenotomy.

The age at which those abnormal forces act is also important. Vidal (1985) found in his series of 292 hips in 158 cerebral palsied children that acetabular obliquity (one way in which acetabular dysplasia can be seen on x-ray) did not appear until 30 months, or unless the

*See subsequent correspondence in *Developmental Medicine and Child Neurology*, 1989, **31**, 117–118.

femoral head had migrated lateral to the bony acetabular margin by more than 20% of the head's (bony) width (Vidal, 1985). This is not always so, but was for his series and probably for the majority of cerebral palsy children. Harris *et al.* (1975) amongst others showed that natural corrective remodelling of the acetabulum gets increasingly less likely after 4 years; and Kalen and Bleck (1985) found that soft tissue surgery was less effective in producing hip stability after age 5 years. For a more detailed review see Scrutton (1989).

Thus this period from birth to (say) 5 years — and perhaps more particularly from 30 months to 4 years — is critical for hip development and early weight-bearing should be encouraged with avoidance of a persistent posture. Fortunately, both these aims are consistent with basic seating aims as follows:

1. the pelvis needs to be correctly positioned for both spinal and lower limb posture;
2. correct femoral and foot position gives a more secure base;
3. ease of transfer is necessary to allow standing.

REFERENCES

HARRIS, N. H., LLOYD ROBERTS, G. C., GALLIEN, R. (1975). Acetabular development in congenital dislocation of the hip, with special reference to the indications for acetabuloplasty and pelvic or femoral realignment osteotomy. *J. Bone Joint Surg.*, **57B**, 46–52.

HOLT, K. S. (1961). Growth disturbances. In: Hemiplegic cerebral palsy in children and adults, a report of an international study group, Wills Hall, Bristol, 1961. (Little Club Clinics in Developmental Medicine, No 4). — London: The National Spastics Society.

KALEN, V., BLECK, E. E. (1985). Prevention of spastic paralytic dislocation of the hip. *Dev. Med. Child Neurol.*, **27**, 17–24.

PERRY, J. (1985). Personal Communication cited. In: Orthopaedic management in cerebral palsy E. E. Beck. Clinics in Developmental Medicine, No 99/100. – London: MacKeith Press, Blackwell Scientific, 1987.

REIMERS, J. (1980). The stability of the hip in children: a radiological study of the results of muscle surgery in cerebral palsy. *Acta Orthop. Scand. Suppl.*, 184.

SCRUTTON, D. R., GILBERTSON, M. (1975). Physiotherapy in paediatric practice. – London: Butterworth.

SCRUTTON, D. R. (1989). The early management of hips in cerebral palsy. *Dev. Med. Child Neurol.*, **31** 108-116.

SHARRARD, W. J. W. (1971). Paediatric orthopaedics and fractures. – Oxford: Blackwell Scientific Publications.

TARDIEU, C., LESPARGOT, A., TABARY, C., BRET, M. D. (1988). For how long must the soleus muscle be stretched each day to prevent contracture? *Dev. Med. Child Neurol.*, **30**, 3–10.

VIDAL, J., DEGUILLAUME, P., VIDAL, M. (1985). The anatomy of the dysplastic hip in cerebral palsy related to prognosis and treatment. *Int. Orthop.*, **9**, 105-110.

WILLIAMS, P. E., GOLDSPINK, G. (1984). Connective tissue changes in immobilised Muscle. *J. Anat.*, **138**, 343-350.

ZIV, I., BLACKBURN, N., RANG, M., KORESKA, J. (1984). Muscle growth in normal and spastic mice. *Dev. Med. Child Neurol.*, **26**, 94-99.

The following two papers provide essential guidance in their subject areas. They are not referred to in this paper as they appeared subsequent to its writing.

O'DINGER, N. J., NEILSON, P. D., NASH, J. (1989). Mechanisms of muscle growth related to muscle contracture in cerebral palsy. *Dev. Med. Child Neurol.*, **31**, 543-552.

WRIGHT, J., RANG, D. M. (1990). The spastic mouse and the search for an animal model of spasticity in human beings. *Clin. Orthop.*, **253**, 12-19.

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Development of sitting ability, assessment of children with a motor handicap and prescription of appropriate seating systems

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Abstract

The prescription of appropriate seating for children and young adults with a motor handicap is a complex issue requiring a clear identification of the child's physical ability in all postures. Recent work by Pountney *et al.* (1990) has shown how the development of lying ability is linked to sitting ability. This emphasises the importance of the total approach to assessment and prescription of seating systems and of not isolating seating needs from other postural considerations.

This article summarises the work undertaken in recent years at Chailey Heritage to improve knowledge about prescriptive, adaptive seating for children with a motor handicap. The results are being increasingly applied throughout the United Kingdom.

Postural stabilisation

Postural stabilisation is a vital prerequisite to the establishment of a functional sitting posture. Able-bodied people have the postural ability to compensate for the inadequacies of the many seats that are in use and are able to change position to avoid discomfort or to improve function whilst in the sitting position.

People with physical disabilities who lack postural ability therefore need seating which is far superior to that used by the able-bodied population. The seating has to compensate for the lack of postural stability whilst also enhancing the functional and postural ability that each individual has. It will be recognised that every person with a disability will have a very individual need and great demands are placed on the designers and producers of seating systems in order that each individual reaches his or her full potential in terms of postural and functional ability.

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It is accepted that very few children with physical disabilities receive all the therapy time that each requires. It is very important therefore that therapeutic principles are carried over between therapy sessions if the valuable gains achieved during therapy are not to be lost. Indeed, equipment used by the children should be seen as part of their therapy. All prescribed equipment must provide the required postural control, postural stabilisation and the postural accommodation compatible with the programme and goals of treatment and management for that child.

It is convenient to divide the biomechanics and the equipment which achieves the biomechanical support into two categories: Posture Accommodation and Posture Stabilisation.

Posture accommodation involves the accommodation and support of an existing posture. This is usually the approach used when the child has a fixed deformity or a progressive deformity or is at risk of tissue trauma from anaesthetic skin. The primary consideration is not the application of biomechanical principles to achieve significant improvements but to provide comfort, to protect the child from damage such as tissue trauma or from fractures as in the case of osteogenesis imperfecta and to maintain maximum functional ability in the case of conditions such as Lesch Nyhan syndrome where self protection is also a consideration. Posture accommodation is usually the primary consideration when there is little potential for long term improvement. The physical problems associated with the advanced stages of muscular dystrophy and Lesch Nyhan syndrome together with those associated with severe cases of spinal muscular atrophy and spina bifida are examples of when posture accommodation is considered as a priority. Quite often, the initial posture presented is not greatly modified by the equipment produced but the child's arms may be relieved of weight-bearing and hence function is improved, head control may be improved or at least maintained and the child can be protected from himself and the environment. In many cases, the equipment will be a complex compromise perhaps consisting of a spinal orthosis with a built-in, inconspicuous headrest which the child uses in conjunction with special cushioning and thoracic pads or perhaps a very carefully and precisely made moulded seating system or Matrix seat. The principles of posture stabilisation described below need to be considered in this type of seating in order to ensure that maximum function and comfort can be achieved but they will not be the priority in the final design.

Posture stabilisation involves the use of appropriate biomechanical principles to take a pro-active approach to the production of seating systems to provide stabilisation and control compatible with therapy programmes and which facilitate and improve function in both the short term and the long term. Seating for posture stabilisation thereby achieves both immediate and long term improvements in postural ability. It is essential that each child is carefully assessed to determine his level of ability from which the prescriptive needs can be clearly defined. It is equally important to review these needs constantly during the use of the equipment in order that it may be adjusted to maintain the gains and achieve further improvements.

Without a stable platform from which to operate, no one is able to function properly or to their maximum ability and full concentration is required to prevent sliding or falling. Able-bodied people need only to walk on ice or sit on a greasy pole to experience this! For seating systems to be of benefit they must, therefore, provide postural stability and follow biomechanical and therapeutic principles to optimise function and potential for improvement. They must also meet orthopaedic requirements and be easy to use. It is often difficult to meet all of these objectives but current efforts in design and development are improving on solutions to these problems. It should be recognised that all equipment provided for all children is inevitably a compromise. It is therefore essential that the parents, carers, teachers, treating professionals and others who need to know are involved in the assessment and prescription process in order that all needs are clearly identified. It is then possible to reach a satisfactory compromise where the objectives are understood and any limitations of use are accepted.

It is extremely important that the performance of a seating system is measured. The performance should be measured in terms of the short term and long term improvements in postural ability achieved by the child. If the correct biomechanical principles have been adopted, then improvements should be possible or at least abilities should be maintained through growth spurts or other periods of difficulty. If deterioration in ability is observed then attention should be directed to both the seating system and its adjustment and to the child's lying ability. The importance of correct and frequent adjustment to seatings and the relevance of the child's lying ability is addressed later.

The biomechanics of the upright sitting posture

There are many "sitting" postures that may be adopted but the one that most frequently comes to mind and around which most of our activities and furniture are designed is the "upright" sitting posture. This is defined as one of balance in which the hips and knees are flexed at 90° and the ankles are in the plantargrade position or 0° of flexion. The biomechanics described here will be related to achieving this posture.

When sitting in a chair it is important that as much contact as possible is made with the chair's support surface to achieve comfort through distribution of supporting forces and to achieve stability through the largest base of support. An upright, right-angled chair cannot, therefore, provide an upright posture without some degree of discomfort, instability or a great deal of postural muscle activity (Fig. 1). The discomfort

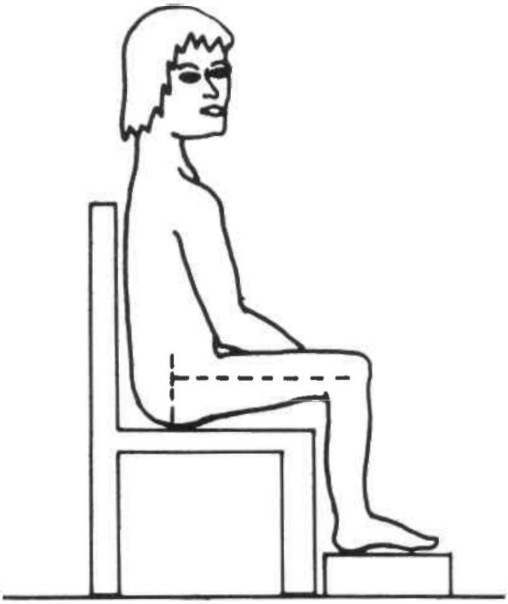


Fig. 1. Upright posture with pelvis in neutral position, hips and knees at 90° of flexion and ankles at 0° showing incompatibility of upright right angled chair.

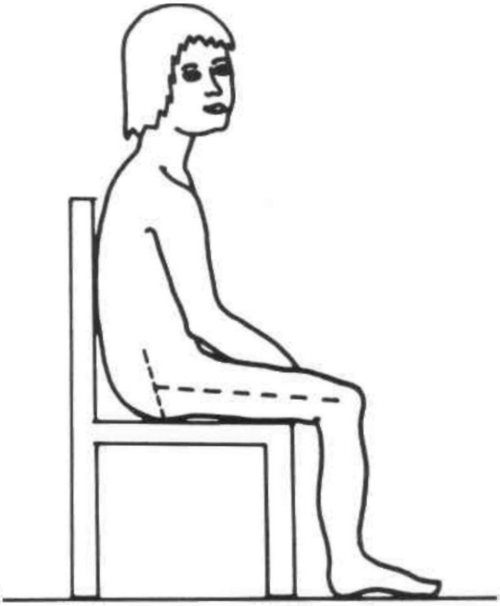


Fig. 2. Slumped, "chin poking" posture normally adopted on upright, right angled chair.

will arise from support only being provided to the ischial tuberosities when the femurs are horizontal which will also lead to instability if this is the only area of contact for support. The feet need to be supported at the right height to keep the femurs horizontal. This may require resting on tip-toes and postural ability will be required to maintain the pelvis in the neutral plane, with the trunk upright and also to stay in position on the chair. The posture most likely to be adopted on a flat, right-angled chair, is one with the thighs in contact with the seat surface and hence the femurs sloping forwards and the pelvis posteriorly tilted. There will be loss of lumbar lordosis and an accentuation of the thoracic kyphosis and cervical lordosis leading to a slumped, "chin poking" posture (Fig. 2). This is not a stable posture and frequent repositioning is required to prevent falling. Discomfort will be a continuous feature of any posture on this type of chair.

The first objective is to provide appropriate support and control for the pelvis and thighs to hold the femurs horizontally and provide a stable, horizontal platform for the ischial tuberosities. There are different ways of achieving this and the easiest and most successful is the ramped cushion (Mulcahy and Pountney, 1987). Made from the correct grade of high resiliance, combustion modified foam, the flat surface provides stability for the pelvis and the 15° ramp starting just anteriorly of the gluteal crease provides support for the thigh to maintain the femur horizontal. The 15° angle suits most anatomical shapes but may need to be varied to meet specific needs. In general, larger people require a larger angle but this may lead to difficulties in getting in and out of the seat. To ensure that the cushion will work properly the feet must be supported at the correct height to maintain and ankles at 0°, the knees at 90° and the femurs supported horizontally. This may be achieved by adjusting footrests or by adjusting the height of the chair if the feet are on the ground.

With this provision, the pelvis is still not controlled and postural ability is required to maintain the neutral pelvis position and the upright posture. It should be noted that the natural, upright curvature of the spine can only be adopted when the pelvis is in the neutral or slightly anteriorly tilted position. This is most easily achieved in the standing position. When sitting, tight hamstrings and general relaxation or lack of tone or control lead to posterior tilting of the pelvis which in turn leads to flattening of the lumbar lordosis and accentuation of the thoracic kyphosis and cervical lordosis. The conventional correction for this posture has been the introduction of lumbar support to reintroduce the lumbar curve but this has disadvantages.

Firstly, children who have not yet developed the ability to achieve independent sitting will probably not have developed a lumbar lordosis. Introduction of a lumbar curve with lumbar support is therefore inappropriate and can result

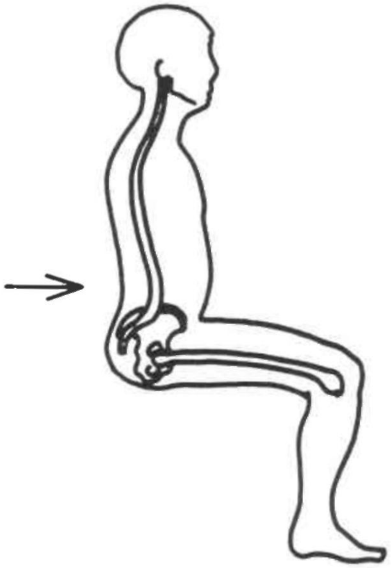


Fig. 3. Lumbar spine being used as a lever by a lumbar support to bring the pelvis to the neutral position to restore a lumbar lordosis.

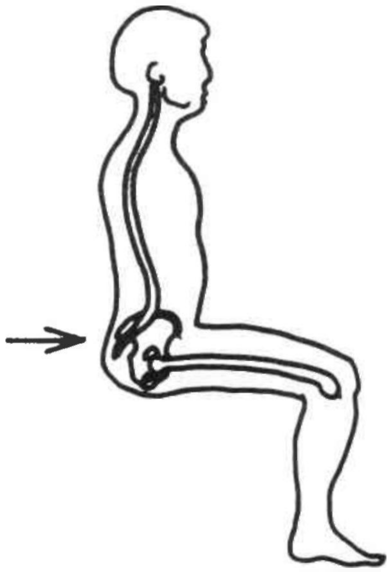


Fig. 4. Force applied to the pelvis by a sacral pad to bring the pelvis to the neutral position thus restoring or facilitating a lumbar lordosis.

in the child extending against the lumbar pad or being pushed into a flexed posture by it.

Secondly, the lumbar curve can only exist if the pelvis is in the neutral plane and a lumbar pad alone, therefore, uses the lumbar spine as a lever to bring the pelvis to the neutral plane (Fig. 3). This can cause high shear forces on the L5/S1 joint and discomfort can result.

A more appropriate method of achieving the correct spinal curvature is to apply a force directly to the pelvis (Fig. 4) to bring it to the neutral plane and this is achieved with the sacral pad (Mulcahy and Pountney, 1986). The sacral pad extends the full width of the pelvis, it is curved in the horizontal plane to provide comfort when applying a force to the pelvis and it extends no higher than the L5/S1 joint. That is, it acts on the full width of the pelvis over the length of the sacral spine, hence its name. The thickness of the pad is chosen to compensate for the different anteroposterior dimension of the trunk and the pelvis, typically 18mm to 36mm but this may vary according to the material of the backrest support and any deformity that may be present. The upright posture and natural curvature of the spine are now attainable but the biomechanical system is not yet complete.

When the sacral pad exerts a force on the posterior aspect of the pelvis the child is still able to move foward away from the pad returning to the slumped posture with the pelvis posteriorly rotated. A pelvic strap pulling back and down at 45° is an essential component of any seating system but is not the solution to this particular problem. The main purposes of the strap are to prevent the child "standing" or extending up and out of the seat and for safety purposes in a wheelchair or vehicle. The solution lies in the application of an equal and opposite force on the pelvis to that exerted by the sacral pad and this is achieved through correct use of the kneeblock.

The force applied to the pelvis by the sacral pad is not equal throughout the length of the sacral spine but is at a maximum at the top of the pad where most force is required on the posterior, superior iliac spines to prevent posterior tilting of the pelvis. The kneeblock, when correctly adjusted and used with correctly positioned feet and ramped cushion, applies a force to the pelvis via the femurs and the hip joints. The hip joints lie below the level of the L5/S1 joint and thereby below the level of the top of the sacral pad. Accordingly, the force of the sacral pad and the force of the kneeblock applied equally and in opposite directions serve to rotate the pelvis forward from the posteriorly tilted position towards the neutral position. As the pelvis moves

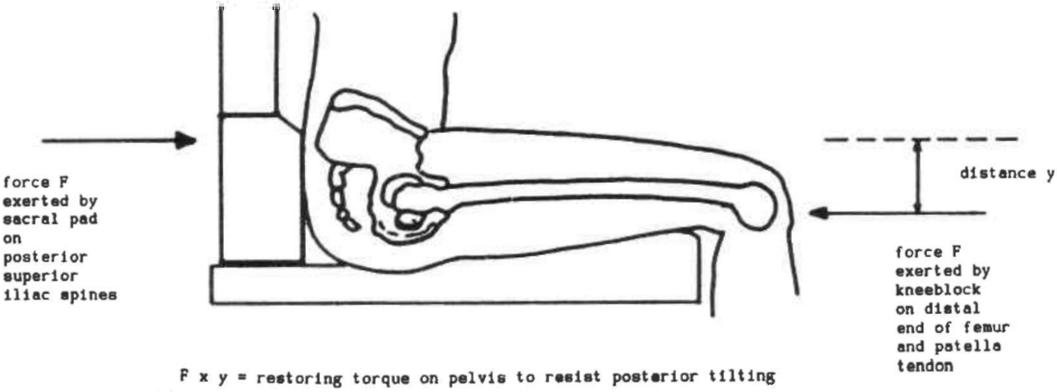


Fig. 5. Forces applied to the pelvis by the sacral pad and the kneeblock and the distance between them, y, producing the torque to hold the pelvis in the neutral position.

towards the neutral position so the distance between the line of action of the two forces is increased (Fig. 5). The forces applied to the child by the sacral pad and the kneeblock are therefore at a minimum when the pelvis is in the neutral plane and increase to a maximum, possibly intolerable level if the adjustment is incorrect and a slumped posture is allowed.

The correct application of these biomechanical principles is embodied in the design of the Chailey Adaptaseat and its successor the CAPS II. The essential feature of both designs is the easy adjustment of the components to achieve the desired result. If adjustment is not possible or cannot be carried out quickly and easily without workshop facilities and whilst the child is sitting in the seat, then the seating system is unlikely to provide ongoing postural control and the initial gains in ability will not be maintained. Once the postural stability has been achieved using these biomechanical principles, the trunk and head support required are often less than expected. After a short period of use the headrest can often be dispensed with and then only used for safety when travelling or perhaps when eating. As a child's abilities are consolidated and improve so the lateral supports can be adjusted to reduce the control provided allowing the child to be more active in the seat. The control and stabilisation provided by the correctly adjusted base of the seat allows dissociation of upper trunk movement and the lateral supports become limit stops. Thus static seating permits a dynamic child to remain dynamic but in a controlled manner such that he can regain his correct posture through the stabilisation of the base of support.

The kneeblock arrangement can also be used to correct or control a "windswept" posture (Fig. 6) by pushing back on the femur of the previously abducted hip and derotating the pelvis against the sacral pad. The other hip is then adducted to reduce the risk of dislocation. No force is applied

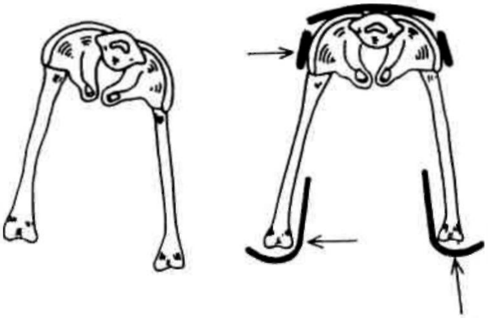


Fig. 6. Control and correction of the windswept hip posture by means of the sacral pad, kneeblock and lateral pelvic pads.

along the femur of the previously adducted hip, i.e. the one in danger of dislocating or already dislocated. A gap between the kneeblock pad and knee ensures this.

Development of sitting ability

The ability to sit unsupported develops in the normal child as part of the sequence of motor development of lying, sitting, standing, walking and running. This developmental sequence involves a mixture of neurological postural reactions and changes in the biomechanics of the spine, shoulder and pelvic girdles. At birth the majority of normal full term babies are able to anchor their bottoms when they are pulled from lying supine into a long sitting position. Head control during the manoeuvre is poor, the baby being unable to stop his head falling backwards as he is pulled up into a sitting position.

Motor development during infancy has long been described as occurring in a cephalocaudal direction, that is head control is noticeable first in the developmental sequence, followed by improvement in trunk control seen in sitting and total body control seen in standing. However this head to toe progression is an illusion. In fact all parts of the infant's body can be seen to be developing control simultaneously throughout infancy (Prechtl, 1984; Pountney *et al.*, 1990).

Motor development in infancy may be assessed in two complementary ways; assessment of neurological development and assessment of motor ability.

Assessment of neurological development

Neurological assessment of the infant consists of observation of the infant, and assessment of early automatic responses and reflexes such as the Moro response, asymmetrical and symmetrical tonic neck reflexes, with the righting and equilibrium reactions. Further details may be obtained from Baird and Gordon (1983). Neurological assessment requires skill and experience, is dependent upon the "state" of the child as defined by Prechtl (1974), and still has a considerable level of inter-examiner variability.

Assessment of motor ability

An alternative method is to use an observational approach to determine the highest level of ability a child can demonstrate in his normal environment. The child may adopt a lower level of postural ability to achieve a stable base for functional activity. A scale of levels of lying ability (Table 1) (Pountney *et al.*, 1990) and of sitting ability (Table 2) (Mulcahy *et al.*, 1988) have been described. These levels of ability may be used when describing the normal infant as well

Table 1. Levels of lying ability.

Supine

Level 1

Unable to maintain supine when placed except momentarily and then very asymmetrically. Rolls into and maintains side lying — body following head turning in a total body movement. Weightbearing through lateral aspect of head, trunk and thigh. Neck extended with chin poke.

Level 2

Settles on back when placed. 'Top heavy'. Weightbearing through upper trunk, head. Pelvis tilted posteriorly. Shoulder girdle retracted. Asymmetrical posture — head to one side, difficulty in turning it side-to-side — bottom moves laterally as the head is turned giving 'corkscrew' appearance.

Level 3

Maintains supine position with neutral pelvic tilt, hip abduction, shoulder girdle neutral. Symmetrical posture but 'top heavy'. Chin tucked, not retracted — head in midline and able to move freely side-to-side without lateral movement of bottom. Able to track visually and make eye contact. Weightbearing through pelvis and shoulder girdle giving general curvature to trunk — with 'pot belly' lateral profile. Beginning of unilateral grasp to side of body and takes fists and objects to mouth. May roll into prone due to lack of lateral weight shift.

Level 4

Symmetry of posture and movement is first seen at this level. Pelvis anteriorly tilted, shoulder girdle protracted. Shoulders flexing and adducting allowing midline play above chest with hands together and feet together. Symmetrical posture. Weightbearing through upper trunk and pelvis. Definite lordotic curve. Chin retracted. 'Free' pelvic movement beginning, allowing child to touch knees with flexed hips (but not toes). Alternatively can extend hips and knees; rests in crook lying.

Beginning of lateral weight shift.

Beginning unilateral leg raise — independence of limbs from trunk.

Adept finger movements towards end of this stage.

Level 5

'Free' movement of shoulder girdle and pelvis on trunk. Pelvis has full range of movement allowing child to play with toes with legs extended and rolls into side lying. Side lying functional. Can return to supine. Weightbearing either on shoulder girdle and pelvis or central trunk only and playing between these postures. Efficient limb movement — hand play and prehensile feet — crossing midline.

Level 6

Pelvic and shoulder girdle moving freely. Consistent ability to roll into prone by achieving side lying as in level 5 and then anteriorly tilting pelvis on trunk and extending hips.

Prone

Level 1

'Top heavy'. Weightbearing through chest, shoulders and face. Pelvis posteriorly tilted. Hips and knees flexed. Shoulder girdle retracted, shoulders flexed and adducted. Asymmetrical posture and head to one side.

Level 2

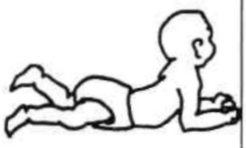
Settles when placed. More generalised weighbearing than level 1. Weightbearing through chest, upper abdomen. Pelvis posteriorly tilted. Shoulder girdle retracted, shoulders flexed and adducted. Head to one side but beginning to lift it from floor with 'flat back' profile but not sustaining. Asymmetrical posture, bottom moving laterally as head turns side-to-side.

Level 3

Maintains prone position with neutral pelvis, shoulder girdle beginning to protract. Symmetrical weightbearing through abdomen, lower chest and knees and thighs. Maintains head lift from floor with total trunk curvature — head in line with spine. Rocking antero-posteriorly. No lateral weight shift and therefore often topples into supine as lifts head and chest up.

Level 4

Pelvis anteriorly tilted but not 'anchoring'. Shoulder girdle protracted, weightbearing through abdomen and thighs, varying between forearm and hand propping, with shoulders elevated. Head and upper trunk movement dissociated from lower trunk allowing lateral trunk flexion with lateral weight shift = a beginning of pivoting. Angular lateral profile of upper chest and bottom. Unilateral leg kicking. Hand and foot play is midline.



Level 5

Pelvis anteriorly tilted. Shoulder girdle protracted — hand propping with extended elbows and lumbar spine extension. Weightbearing through iliac crests and thighs and lower abdomen. Pelvic anchoring and upper body movement (extension and rotation) upon it. Deft pivoting with lateral trunk flexion and moving backwards on floor. Purposeful roll prone into supine.

Level 6

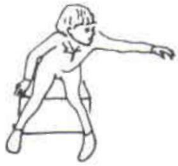
'Free' movement of pelvis and shoulder girdle. Beginning to weight-bear on all fours/antero-posterior, rocking on all fours.

Reproduced by kind permission of the Editor from Pountney, T. E., Mulcahy, C., Green, E. (1990). Early development of postural control. *Physiotherapy*, **76 (12)**, 799–802.

as those with a postural impairment, as seen in cerebral palsy and diseases with neurological degeneration or neurological injury. A definite link has been observed between a child's lying ability and his sitting ability. It has been found that a child has to achieve level 4 lying ability in both prone and supine positions before he can achieve level 3 sitting ability, i.e. maintaining independent sitting. In addition level 5 lying ability is achieved before level 5 sitting ability, i.e. maintaining sitting and moving out from his base (Pountney *et al.*, 1990).

Table 2. Levels of sitting ability.

When placed on a flat box, feet on the floor:-

1. UNPLACEABLE	A child who wriggles & slides and cannot be placed in a sitting position.	
2. PLACEABLE, NOT ABLE TO MAINTAIN	A child who can be placed in a sitting position but needs holding to stay in position - at best he can balance momentarily.	
3. ABLE TO MAINTAIN POSITION BUT NOT MOVE	A child who when placed in a sitting position can just keep his balance as long as he does not move.	
4. ABLE TO MAINTAIN POSITION AND MOVE WITHIN BASE	A child who once placed in a sitting position can sit independently and can move his trunk forward over his sitting base but cannot recover his balance after reaching to one side.	
5. ABLE TO MAINTAIN POSITION AND MOVE OUTSIDE BASE	A child who can sit independently, can use either hand freely to the side of his body and can recover balance after leaning or falling to either side.	
6. ABLE TO MOVE OUT OF POSITION	A child who can sit independently and can transfer weight across the surface of a seat but cannot regain a correct sitting position.	
7. ABLE TO ATTAIN POSITION	A child who can regain his sitting position after moving out of it.	

Reproduced by kind permission of the Editor from Mulcahy, C. M., Pountney, T. E., Nelham, R. L., Green, E. M., Billington, G. D. (1988). Adaptive seating for motor handicap: problems, a solution, assessment and prescription. *Br. J. Occup. Ther.*, **51 (10)**, 347–352.

Assessment of postural ability and for postural support requirements

The assessment process is a comprehensive one which considers the whole child, his family, the home environment, the school environment, modes of travel, mobility and daily living issues. The assessment should define both treatment and complementary equipment needs in all postures. The complexitites and importance of correctly designed equipment, especially adaptive seating, and the need for compromise necessitates that everyone involved with the child, i.e. parents, carers, therapists, doctor, rehabilitation engineering personnel, teachers, nurses, etc., has to become involved or at least have an input to the process. It is also important that they realise that whilst the child is learning a new posture, finer activities such as those used for eating or for driving a powered chair or operating a computer, may deteriorate. This is especially so if a child has been using obligatory patterns of movement associated with an asymmetrical posture with inadequate stabilisation and control. The child will require both physical and mental support as well as re-education of these skills once a symmetrical posture with stability and control has been achieved. All those involved with the child have to understand this in order to provide the support the child needs. Progress in relearning the lost skills will result if the process is fully understood. Communication is therefore an extremely important and probably the most time consuming aspect of the assessment procedure often taking on an educational emphasis. Without communication, a great deal of effort and expensive equipment may be wasted.

The assessment therefore has the following main objectives:

(a) to identify and record a child's abilities in different postures and provide a means of improving these through treatment and provision of appropriate equipment;

(b) to identify and measure where possible any postural deformity and further define the equipment required, especially adaptive seating, to control and, if possible, improve these deformities and to prevent progression to fixed deformity;

(c) to establish and record a baseline of measures and abilities as a reference for subsequent reviews and assessments and as a means whereby the performance of the treatment and equipment can be monitored, e.g. the child's ability in an adaptive seating system should be measurably better than with no postural support;

(d) to communicate with and, where appropriate, educate all those involved with the child in the aims and objectives of the treatment and equipment, the details of the use of the equipment and the expected outcomes both positive and negative;

(e) to achieve agreement by all to the most practical solution(s) to the problems being addressed and to encourage participation in the attainment of the child's potential.

Assessment procedure

The procedure by which the assessment is undertaken is divided into three stages which are fully documented with both written and photographic records to include measurable data.

1) The child is observed and, preferably, photographed in his current seat or wheelchair. The reasons for requiring a new seat are established together with how the child is currently growing and any consequential changes in ability. The way in which the child uses his existing posture to eat, operate his wheelchair and/or computer and whether any obligatory patterns of movement are being used that may need re-educating are all observed and noted.

2) The seat or wheelchair is examined after the child has been removed or has transferred to another surface. This can provide information about how the existing seat or wheelchair is used by the tell-tale areas of wear or permanent depression or even breakage in extreme cases. It can focus attention on particular problems to be taken into consideration. It also allows the transfer procedure to be observed and assessed.

3) The child's abilities are established in different postures without support. This is the most important stage of the assessment which begins with the observations of how easily the child is to handle and an assessment of the contribution that the existing seat or wheelchair has made to a pattern of movement, i.e. has the seat contributed to an extensor pattern of movement or an asymmetric posture?

The child's abilities are then established:

(a) in the positions of lying supine, lying prone and side-lying,
(b) during the pull to sit,
(c) in long sitting,
(d) sitting on a flat box,
(e) sitting on a ramped cushion, and
(f) standing.

In each of these positions or manoeuvres observations are made on the following:

(i) how symmetrical the child is and how he distributes weight and anchors himself on the support surfaces,

(ii) how the child orientates body segments, i.e. is the pelvis posteriorly or anteriorly tilted? is the spine extended or flexed? is the shoulder girdle protracted or retracted? how does the child position or make use of head and arms?

(iii) the ability the child has to conform to positions, maintain positions, move within positions and move into and out of positions all with minimum or zero assistance and support,

(iv) the degree of postural or fixed deformity or contractures present or the potential for developing any.

Whilst the child is sitting on the ramped cushion, the support required to improve his abilities is simulated by hand and the effect of doing this is noted.

Lying in the supine, prone and side lying positions

The child's level of lying ability is assessed by observing the child in the prone and supine positions. The symmetry or asymmetry of posture, anteroposterior tilt of the pelvis, retraction or protraction of the shoulder girdle and the areas of the body used to weight bear in these positions are assessed and noted. The child's ability to move within the posture and into and out of the posture are also assessed together with the functional ability. From these observations the level of lying ability of the child is determined. This will indicate the problems the child is likely to have in the sitting posture, e.g. children with lying ability below level 4 will not achieve level 3 sitting ability. Also, poor pelvic and truck control will be indicative of the child's difficulties in organising his body and in weight bearing adequately through his bottom and thighs in the sitting posture.

During the assessment, the child's pelvis is placed into a neutral position and the effect of this on the child's ability to align or position his head, truck, shoulder girdle and limbs is observed and noted. The pelvis and trunk are then organised into alignment and the effect of this on the child's movement of head, shoulder girdle and limbs is noted.

Thus a complete picture of the child's abilities in the lying position is obtained together with an indication of problems likely to be encountered in the sitting posture.

Pull to sit

The child is pulled by his hands from the supine position towards a long sitting position. The child's ability to dissociate his trunk movement from the lower part of his body is assessed and noted. This is reflected in the child's ability to anchor his bottom on the support surface and flex at the hip joints. If the child is able to do this then he should be at least placeable in the sitting position, i.e. at least level 2 sitting ability. If the child cannot anchor his bottom and instead slides along the surface and generally curves his body forwards with little or no hip flexion, i.e. his body behaves as one single structure, then he is likely to be unplaceable, i.e. level 1 sitting ability.

Long sitting

The long sitting position is often difficult to achieve or maintain but it is an important position because it emphasises any contractures or tendencies towards deformity that may not be apparent in other positions. The hamstrings, spine, hips, knees and ankles are examined to establish whether they will physically prevent the child from attaining the upright sitting posture. The importance of emphasising these problems is that treatment and postural control equipment can be defined to correct these tendencies. For example, an internally rotated and adducted hip leading to pelvic obliquity will also result in postural scoliosis. The scoliosis could be the focus of attention but by simply abducting and externally rotating the hip, the pelvic obliquity can often be eliminated and the scoliosis corrected. Naturally, if the adductor muscles are too tight, the problem has to be remedied by therapy before the postural equipment can be supplied to maintain the corrected posture. In extreme cases, surgery may be required and then therapy and the appropriate equipment during the post-operative period are essential to maintain the surgical correction. A rigorous assessment of need in the long sitting position is therefore just as important as, if not more so than, the remainder of the sitting positions.

Sitting on a flat box

The height of the assessment boxes is adjusted such that the child can sit with thighs supported throughout their length on the surface of the box and the feet flat on the floor. The ease with which the child can be placed on the box is noted. The child's ability to maintain the sitting position with minimum or no support is noted. The symmetry of the child's posture anteroposteriorly as well as laterally is assessed and noted. The child's level of sitting ability is determined whilst he is sitting on a flat box.

Sitting on a ramped cushion

The height of the assessment boxes is readjusted to allow the child to sit on the ramped cushion on top of the boxes with his thighs supported throughout their length on the ramp, his femurs horizontal and feet flat on the floor. The child's ischial tuberosities should be supported on the flat, horizontal section of the cushion. The effect of the ramped cushion is to improve the child's sitting ability and bring the upper body forward over the sitting base.

The symmetry of the child's posture both anteroposteriorly and laterally is assessed and the effect of the cushion on the child's ability to maintain the sitting posture and move within it is noted.

Standing

When considering prescriptive seating systems it is important to know whether the child can assist with transfers to the standing posture or even transfer independently. The height of the seating system may be important and the ease with which the child can move footplates and other components out of the way has to be assessed.

First, the child's ability to move across the cushion and to stand up is assessed. His ability to lean forwards and sideways whilst on the cushion will give an indication of the ease with which he should be able to move the seat and wheelchair components. The type and amount of support required for these manoeuvres has to be assessed and it may be different from that required for other functions in the sitting position. Compromise or easily adjustable support may be required.

Prescription

A baseline level of achievement and needs are recorded for each child, both for treatment and for postural support sufficient to maintain his abilities throughout the day. Hare's work (Hallett *et al.*, 1987) has been extremely useful and an adaptation of her classification led to the description of seven levels of sitting ability (Table 2). These levels describe the ease with which a child can be placed in a sitting posture, how he anchors his bottom in a sitting posture and how well he can ajdust his body over and out of his sitting base. The prescription of seats follows from the information gained from assessment of sitting ability.

Children with sitting ability from level 1 to 3 have poor postural ability. Without seating support they remain physically dependent and often are unable to observe what is happening around them. Seating systems incorporating the biomechanical principles described above to achieve the upright posture are essential. Full postural stabilisation and an improved functional ability can be achieved leading to improvement in postural ability. In addition, it is particularly important to adjust the environment around the child whilst he is in the seating system. For example, the schoolwork, the television or the computer and monitor must be positioned to allow for the child's line of vision compatible with the current and expected abilities.

Children with greater postural ability, that is, level 4 and above, require postural stability to encourage independence. Seating systems which incorporate the biomechanical principles described above but with reduced trunk support will allow both work and rest positions for the child. The dimensions of the seat cushion and sacral pad are crucial as incorrect sizes, for example excessive length, may induce sacral sitting. The cushion requires securing, as a sliding cushion can also induce a sacral sitting position. The consideration of work heights must not be forgotten.

Sitting ability level 1

Even if the child cannot be placed in a sitting posture, this is still recorded as a positive level of ability because it defines a major need for treatment and postural support. At this ability level a child cannot achieve or maintain a sitting posture, that is he cannot anchor his pelvis or dissociate the movement of his trunk from his lower body. Prescriptive seating is required to provide postural fixation, especially stabilisation of the pelvis. The biomechanical principles described above will achieve this.

An upright position must be introduced as early as possible to reduce the de-stabilizing effect of a posteriorly tilted posture. If the child remains at this low level of ability, he will become increasingly difficult to handle particularly as he approaches adolescence. When increased tone and primitive reflexes compound the postural instability in the tilted position, the child may become "unmanageable". It is therefore important that the child experiences frequent handling and changes of position if he is going to be able to improve his postural ability. Posture is dynamic, and consideration of alternative ways of introducing upright posture with symmetrical weight bearing should be undertaken. Pope (1988) has successfully simulated the posture adopted by motorcyclists in an adult population of low postural ability. The pelvis is stabilised by using a scooter saddle with knee support and the trunk supported forwards over the base. Stewart and McQuilton (1989) have also shown preference for this type of posture for the lower ability child. A useful alternative seating support can be provided by the Controller Chair (Stowaway Furniture and Design Ltd, Bedford) particularly as its components can be varied to offer comfortable and corrective support in the lying position. If a child cannot take weight through his pelvis in the lying position, he will not become placeable and manageable in the sitting position.

Sitting ability level 2

In order to maintain an upright sitting posture, a child at level 2 ability needs a very supportive seat with the full biomechanical principles described above. The seat base must be horizontal. The child may be helped to learn to maintain an upright posture by providing a variable trunk support, including a narrow anterior support pad which will not impede protraction of the shoulder girdle.

Lateral trunk support should align with the chest contours, an anterior thoracic strap giving alternative or additional trunk security if necessary. Stabilisation of the shoulder girdle can be encouraged by using the anterior support pad with a tray at elbow height. This posture can be assisted by arm gaiters especially constructed to hold the elbows flexed for arm propping on the tray surface.

Sitting ability level 3

It must be remembered that a child at sitting level 3 is dependent on his hands for support or will only be able to adopt a fixed position unless he is given adequate support to enable him to participate in life. A stable, symmetrical sitting base needs to be provided as described in the biomechanical principles.

The child should be able to regain an upright sitting position, after leaning forwards, the seating system lateral supports being spaced and shaped appropriately to facilitate this. Variations of postural support should be made throughout the day, such as limiting the use of a headrest to travel in a vehicle or a power chair or adjusting the lateral supports to encourage lateral trunk movements.

Sitting ability level 4

Children with a greater ability, that is level 4 sitting ability and above, require postural stability using the biomechanical principles for the upright posture to encourage independence. In this way a child is able to work, rest and play. The dimensions of the seat cushion and sacral pad continue to be crucial as incorrect sizes may induce sacral sitting. The cushion must be secured as a sliding cushion reduces postural stability by inducing a sacral sitting posture. An appropriate work height should be arranged.

At sitting ability level 4, the child still has an immature rounded spinal posture, and lacks adequate pelvic stability upon which to adjust his trunk and raise his arms to shoulder level. He is not able to counterpoise efficiently and, in order to reach out to one side, he will either reach forward and down, or may alternatively adjust his entire sitting base by swinging his legs to one side, so that his outstretched arm does not extend far beyond his sitting base.

The most important feature of prescriptive seating for level 4 ability is a stable sitting base upon which he feels secure enough to achieve a straight back posture and the ability to reach out from his seating base. It may be necessary to add a pommel following the contours of the thighs in order to widen the sitting base and perhaps a kneeblock if asymmetry is predominant. Anterior thoracic support should not be necessary for this child but he will need some lateral control, such as armrests. These can be removed as soon as the child becomes more able.

Sitting ability level 5

Stability of the child's sitting base must be provided, with an orthogonal base (horizontal ramp cushion and probably a sacral pad). His feet should be on the floor when sitting on a school chair or reach the floor from a wheelchair if possible, to encourage him to reach further from his base and eventually acquire the ability to transfer out of his seat. His independence skills will depend to some extent on both a correct sitting height and a correct working height.

A child at level 5 sitting ability will probably find it easier to counterpoise to one side than the other and may initially need lateral support to allow side propping to either side or a pommel as described in level 4. Armrests should be removeable, but can help to boost a child's security when he is mobile in his seat, such as when he is driving a power chair or being pushed in a manual wheelchair, and may help with transfers.

Sitting ability level 6

A child who can get out of his seat by adjusting his trunk weight sideways or forwards over his sitting base will need a stable sitting base upon which he can develop a more mature sitting posture and from which he can transfer. An orthogonal base as described above can provide this. His feet should be on the floor to help with transfers. Desk height should be appropriate for his visual and manual abilities as well as to assist him reaching out of base and transferring. The child needs to be able to undo any security straps himself, such as the pelvic strap, if he is to maintain his independence in transferring.

Sitting ability level 7

Although a child at this level of ability can sit he is probably still learning to walk. His independence may still depend on the height and depth of his seat and on his work height. A stable seat with a rest position is required. He will need to be able to fasten and release his straps.

Non right-angled postures

For the more able child, therapists may wish to try out seating solutions that have been developed for people suffering from back pain, such as forward sloping seats with or without knee pads. It is important to remember that people with normal ability can adopt an upright posture and lordosis. To provide a similar solution for the child with sitting ability level 7, it is necessary to maintain his ability to get into his seat himself. The seat may, therefore, require modification.

This type of seat, when used for physically handicapped children will only facilitate the correct spinal posture if the child has the physical ability to attain it. It does not induce a lordotic posture if the child has not yet developed it.

Monitoring seat performance

It is necessary to monitor the effect of the seat on the child's ability and to check that his sitting ability remains better in the seat than out of it. As the child's pelvis changes to a neutral position, the seat length required will reduce. If the seat is not shortened, the excessive seat length will permit a sacral sitting posture to remain with consequent loss of potential for further improvement. The child may require additional support during some activities, for example, driving his power chair, in order to assist his postural adjustment to the movement of the chair and of the joystick. At other times, reduced support may provide an opportunity for the child to contribute actively to his postural control.

A permanent record of the child's achievement can be made by documentation of the child's lying ability and sitting ability in and out of the seat, and by using polaroid pictures and video.

Loss of sitting ability

If a child apparently loses sitting ability, it is important to check whether this is a genuine loss of ability or one provoked by poor positioning, such as a tilted or reclining seating system or maladjusted seating system.

Genuine loss of physical ability

This may be present in degenerative disorders of the nervous system and of the muscles. If sitting ability is becoming less for these reasons, it is essential that a balanced seating posture is maintained from the outset as the effects of gravity on a weak system cause severe postural deformity. Whilst it is important to allow the full possible range of free movement, postural stability may be maintained by providing an outer limit of movement for the trunk and stability for the pelvis. An example of this is in boys with muscular dystrophy whose function is often achieved by trunk movement so that intimate support would reduce function. Carefully positioned lateral supports may permit enough lateral movement to maintain function while still preventing excessive lateral lean.

Tilted or reclined postures

It has been shown by Nwaobi (1986) with EMG studies that both hip extensors and hip adductors exhibit a significant increase in tone when the child is reclined or tilted from an upright posture, thus promoting extensor thrust. In addition, in a reclined position, the child's hands become positioned in "high guard" and are not in a practicable position for use. Nwaobi (1987) has demonstrated that upper extremity function is not maximised in the reclined position.

Children with motor handicap who are placed in a reclined or tilted position feel that they are falling and often try to counteract this feeling by trying to come forward. This is often interpreted as flopping forwards so that the child is given further restraints and/or reclined further in an attempt to correct this (Hare, 1988). For people with poor protective reactions, backward or reclined positioning is not preceived as a position of comfort (Motloch, 1977).

The reclined or tilted posture is not a functional position for vision. Either the line of vision is upwards towards the sky or ceiling, or the person has to continually lift his head forward from the reclined position — a difficult manoeuvre — in order to see.

Eating and drinking skills are best established and maintained in an upright position. Swallowing is neurologically a flexor activity. Laryngeal elevation during normal swallow requires generation of adequate shortening of the muscles above the larynx with some simultaneous lengthening of muscles below the larynx. An increase in tension in the lower group such as when the neck is extended, increases difficulty in swallowing. Flexing the neck, on the other hand, facilitates laryngeal elevation by decreased length and tension of the lower group of muscles. In addition, a reclined position increases the risk of choking because anatomical closure of the larynx may not occur during swallowing.

An investigation into the effect of orientation on the cognitive ability of children with cerebral palsy shows that while the tilted seated position had no effect on simple perceptual tasks, complex tasks involving inter-system processing were significantly worse when the children were in a correctly fitted seat tilted backwards by 20° than when they were in a wheelchair alone. The children performed best when correctly seated in an upright sitting position (Green, 1987).

Normal infants develop their ability to recover sitting balance from a forward prop position before developing the ability to side prop and then returning to a balanced sitting position from a reclined position (Illingworth, 1975). It is therefore a developmentally later ability to learn to sit forward from a reclined position, than to learn to sit forward in a propped position.

Deformity

Increasing deformity even to a small extent may compromise sitting balance. An early windswept deformity of the pelvis with pelvic tilt may reduce the area of the sitting base, and change the forces of gravity acting on the body. Asymmetrical forces may potentiate scoliosis, increasing deformity and loss of sitting balance. Increasing posterior tilt of the pelvis may lead to loss of the usual spinal curves of the mature posture, and loss of a balanced sitting position. The individual may eventually take up the C-shape within the chair or an extended position with the head extended backwards over the back of the chair (Pope, 1985).

Growth

An increase in the length of the trunk may lead to changes of forces acting on the shoulder and pelvic girdles, compromising sitting balance. Femoral growth leads to an increased seat depth requirement. If seat depth is not adjusted with growth, the reduced support the thighs and control of the pelvis in sitting may lead to reduction in sitting ability.

Maladjustment of the seat

A poorly adjusted seat or a seat requiring adjustment for growth or changes in ability can reduce a child's sitting ability or his potential for improvement. Regular checks of adjustment must be made even if no further growth is expected.

Conclusions

Seating must contribute actively to encourage a child's postural development. It should allow the child to be dynamic and permit a higher level of sitting ability than the child exhibits out of the seat. The seat must also continue to complement both treatment principles and the child's abilities as these improve. Seating is part of postural management in all postures and postural management must be considered as part of the child's overall management programme.

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REFERENCES

BAIRD, M. W., GORDON., E. C. (1983). Neurological evaluation of infants and children. Clinics in developmental medicine. — Oxford: SIMP, Blackwell Scientific.

GREEN, E. M. (1987). The effect of seating position on cognitive function in children with cerebral palsy: 59th Annual Meeting of British Paediatric Association (Abstract G158). — London: The Association, p108.

HALLETT, R., HARE, N., MILNER, A. D. (1987). Description and evaluation of an assessment form. *Physiotherapy*, **73**, 220–225.

HARE, N. (1988). Children keep you thinking, interview with Dorothy Henham. *Therapy Weekly*, March 24, 6.

ILLINGWORTH, R. S. (1975). The development of the infant and young child, normal and abnormal/6th edition. — Edinburgh: Churchill Livingstone.

MOTLOCH, W. M. (1977). Seating and positioning for the physically impaired. *Orthot. Prosthet.*, **31 (2)**, 11–21.

MULCAHY, C. M. (1986). An approach to the assessment of sitting ability for the prescription of seating. *Br. J. Occup. Ther.*, **49**, 367–368.

MULCAHY, C. M., POUNTNEY, T. E. (1986). The sacral pad — description of its clinical use in seating. *Physiotherapy*, **72**, 473–474.

MULCAHY, C. M., POUNTNEY, T. E. (1987). Ramped cushion. *Br. J. Occup. Ther.*, **50**, 97.

NWAOBI, O. M. (1986). Effects of body orientation in space on tonic muscle activity of patients with cerebral palsy. *Dev. Med. Child Neurol.*, **28**, 41–44.

NWAOBI, O. M. (1987). Seating orientations and upper extremity function in children with cerebral palsy. *Phys. Ther.*, **67**, 1029–1212.

POPE, P. M. (1985). A study of instability in relation to posture in the wheelchair. *Physiotherapy*, **71**, 124–129.

Pope, P. M., Booth, E., Gosling, F. (1988). The development of alternative seating and mobility systems. *Physiotherapy Practice*, **4**, 78–93.

Pountney, T. E., Mulcahy, C., Green, E. (1990). Early development of postural control. *Physiotherapy*, **76**, 799–802.

Prechtl, H. R. F. (1974). The behavioural states of the newborn infant: a review. *Brain Res.*, **76**, 185–212.

Prechtl, H. R. F. (1984). Continuity and change in early neural development. In: Continuity of neural functions from prenatal to postnatal life. Ed. H. R. F. Prechtl. Clinics in Developmental Medicine, 94. – Oxford: SIMP, Blackwell Scientific, p1–15.

Stewart, P. C., McQuilton, G. (1987). Straddle seating for the cerebral palsied child. *Physiotherapy*, **73**, 204–206.

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Prescription and positioning: evaluating the physically disabled individual for wheelchair seating

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Abstract

Within the past 10 years, technology has provided members of the seating team with new approaches in dealing with severely physically disabled children and adults. Positioning is often the first step in overall provision of technical aids. Before physically disabled individuals can operate augmentative communication devices, computer keyboards or other assistive or rehabilitative devices, they should be provided with the optimum seated posture from which to operate. The proximal stability provided by a therapeutically designed seating system will enhance motor potential. Presently, there are many approaches to providing dynamic seating. A thorough evaluation, with input from all team members including the client and his family is necessary to define clearly the goals for the seating device. Once these goals are defined, the team can investigate the possible technical solutions. Thorough ongoing re-evaluation and follow-up of both the client's needs and the possible technical solutions will ensure that persons with physical disabilities will be in the best possible posture to perform the tasks of daily living.

Introduction

A stable posture enables persons with physical disabilities to participate more fully in everyday activities be they educational, vocational, recreational or related to the challenge of independent living. For many children and adults with severe physical disabilities, positioning equipment, especially therapeutically designed and prescribed seating systems in mobility bases, can make a dramatic difference at home, school, work and in the community.

Twenty years ago, the field of wheelchair seating was just emerging. There were perhaps two types of standard folding wheelchairs in a few sizes and one or two adult-size powered wheelchairs. The extent of the seating that was commercially available included several cushions for pressure management and a few special order items such as flat wooden upholstered seats for wheelchairs. Most seating modifications were hand fabricated plywood and foam inserts done in therapy departments of paediatric hospitals or schools. In the intervening years, the available technology has changed incredibly. In fact, there are so many choices that consumers and professionals alike can be overwhelmed. There are lightweight chairs from at least fifteen companies, powered chairs, folding and non-folding, a myriad of different control options for many of the chairs with some applicable for some chairs and not for others, many three wheeled carts, powered scooters and specially designed childrens devices that stand have seats that rise and so on. There are also many commercially available seating options. There are planar and contoured systems. Some are custom made while others can be purchased from standard modules in a catalogue. There are different materials used, and a variety of delivery systems in place such as catalogue order, central fabrication or custom fabrication on site. It only becomes more confusing for clinicians, engineers and therapists as time goes on.

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However, one thing has not changed. Before the selection of the type of technological solution is begun, a thorough evaluation of the client's skills, problems and goals must be completed. With that information well established, the choice of appropriate technology becomes much easier. The focus of the choice is centred on the functional requirements of the client and not the glamour of the new technology.

Evaluation process

Goals for seating will vary for each client. The basic considerations become ranked by priority as the evaluation is performed and as the team listens carefully to the client, the family, the caretakers and other involved professionals. Basic goals for seating can be to:

- facilitate motor abilities to maximize function,
- alleviate abnormal muscle tone,
- prevent, delay or accommodate deformity,
- increase comfort,
- manage pressure,
- improve self image,
- facilitate physiological function,
- enhance quality of life,
- promote care giving or independent activities of daily living.

If the client is elderly and wheelchair bound, the first priority may be comfort. If the client has had a spinal cord lesion and has insensitive tissue, the first priority would be pressure management. An eight year old child with cerebral palsy who attends school may need to have functional use of a computer and therefore must be seated so that control of the keyboard is as efficient as possible. Adults at work may need seating not only for functional considerations but also for the aesthetics of presenting themselves well in the marketplace. Of course, all the above clients would wish to be as comfortable as possible, but other priorities may come into play in the decision making as to which system is best, especially if any compromise is necessary.

The evaluation by the therapist should contain neuromotor and orthopaedic summaries, sensory status, fine and gross motor abilities, strength especially as it relates to the performance of functional activities, work/ educational status, psychological implications and environmental considerations. Each of these areas of evaluation is presented below in more depth.

Neuromotor summary

The neuromotor summary includes an evaluation of tone and the presence of primitive postural reflexes, particularly as they influence tone during functional activities. The reflexes usually involved include the asymmetric tonic neck reflex, symmetric tonic neck reflex, tonic labyrinthine reflexes and positive supporting reaction. In evaluating tone one determines if the individual is generally hypotonic, hypertonic, athetoid, or if they have a mixture of tone present. Most individuals diagnosed as being spastic quadriplegics actually have hypertonic extremities with a hypotonic trunk. Also noted are the changes in tone which result from functional activities. For example, a marked increase is seen in tone in some persons with neuromotor disabilities when they attempt speech or when they reach for the controls of their powered wheelchair. If a person with an asymmetric tonic neck reflex (ATNR) to the left looks to the left, there will be an increase in extensor tone in the left upper limb and an increase in flexor tone on the right upper limb. Finally it is important to note if the person is able to alter tone voluntarily through postural adjustments or alternatively is locked into the abnormal patterns with no volitional control once reflex patterns occur.

Orthopaedic summary

When examining a client's orthopaedic status, it must be determined which deformities are realistically correctable and which simply must be accommodated. This decision is often based on whether the deformity is fixed or flexible, what the underlying cause of the deformity is and the degree of the deformity. For example, an individual with a slight (10°) scoliosis can be supported in a fairly upright position, whilst correcting the curve of the spine. An individual with a 30° or greater scoliosis would need to be reclined to either correct or comfortably accommodate the curve. Someone with a fixed scoliosis of 20° would have to be accommodated but if the same curve was still flexible, then a goal would be to try to partially correct the deformity. If a rotational scoliosis is part of a total ATNR pattern that is reinforced constantly during the day, it is unlikely that the magnitude of the problem can be lessened by seating. In many cases, the line between accommodation and attempts at correction is a fine one. If correction is the goal, then realistically orthotic intervention or surgery must be considered.

Sensation status

In this evaluation, particular attention is paid to areas of impaired or absent sensation, and especially bony areas, such as over the ischial tuberosities, which will be contacted by the seat and/or backrest. Individuals with normal sensation and severe orthopaedic deformities with many bony prominences who cannot accomplish weight relief are treated as if they have no sensation. Also of concern are the forces applied to the trunk by the back components of the seating system. For persons with scoliosis, especially when there is a rotational component, the seating components can put tremendous pressure on non-weightbearing surfaces of the trunk. The risk of pressure problems should be avoided or minimised by the design of the seating components including shape and materials used.

The length of time that an individual sits in one chair during the day, the responsibility for the supervision of skin care and how frequently this is carried out are additional issues to consider. A person who stays in their seating system for the entire day requires a different type of sitting surface than one who is in their system for only a half hour at a time. People who can alter their position are at much less risk than those who must rely on others for position change.

Activities of daily living (ADL), gross and fine motor abilities

The individual's ability to independently carry out ADL skills is evaluated primarily so the seating provided assists, not hinders independence. For example, if the person can independently pivot transfer forward out of the wheelchair from a certain seat height from the floor, it would be essential to ensure that the seat height is maintained when modifying the wheelchair with a seating system. Occasionally, there must be compromises between the clients independence and the therapeutic goals which have been established for the seating system. In almost all cases, independence must be maintained unless long term complications of considerable magnitude are anticipated if seating goals are compromised. For example, a person with a severe rotational scoliosis should be discouraged from using an ATNR to accomplish reach if over years it is anticipated that the scoliosis would worsen to the extent of precluding sitting at all. Once an appropriate seating system is implemented, the ADL and fine motor skills can be re-evaluated to determine possible strategies in the performance of functional activities.

Educational/work history

An educational history includes the client's current educational level as well as the long term goals of the school personnel/family/individual. Severely physically disabled clients without the abilities to communicate, write, or independently access a computer should be given opportunities to interact meaningfully with their appropriate academic environment. In these situations, receptive communication skills are carefully evaluated by a speech pathologist/occupational therapist/educator team to determine the need for an augmentative communication system. The need for computers and other educational aids such as special trays for communication systems, page turners, and other technology used to assist the client in the academic environment are addressed as part of the client's overall seating system.

Transportation to and from school must also be considered. If a child is to be transported in the seating system several issues must be considered. The wheeled base must be crash tested and an approved tiedown system must be used to ensure compliance with safety standards. Many school districts and colleges provide vans or buses with lifts and wheelchair tie downs. If the child is in a stroller base, then an alternative mode of transportation such as a safety approved car seat and a secured storage space for the base is recommended. If powered mobility is a consideration, both school and home transportation must be able to accommodate the device and environmental accessibility must be evaluated.

If the client has entered the work place, both the environment and the job characteristics are evaluated to ensure that the recommended technical aids will be compatible. This is particularly important in reference to wheelchair height versus work space heights, transportation accessibility and environmental considerations for ADL such as entrance ramps, accessibility of bathrooms, location of eating facilities.

Psycho-social considerations

Functional seating systems, must be "user friendly". Systems which require continuous adjustments, which come out of adjustment easily, have removable parts that are easily lost, or are difficult to transport, are less likely to be used in the intended manner. Cosmesis is an important consideration especially when dealing with children. Choices such as the colour of the seat, the fabric of the cover and the material of the tray are very important to the clients and their families. The seating system should be considered an extension of the individual's tastes and self image.

Prescription process

Before a specific piece or method of seating technology is matched to a client's individual needs positioning goals are established. There are established therapeutic guidelines of positioning in sitting (Bergen and Colangelo, 1985). Positioning usually begins at the pelvis, then continues to the lower limbs, the trunk, head, and shoulder/upper limbs. Guidelines assist in establishing a systematic approach for the seating team.

Professionals ultimately rely upon observation skills, evaluation results, the ability to try the client in a number of positions (simulate) during the evaluation process and also rely upon the input from the client.

Positioning principles

The general goals of seating have already been stated. The decision making process as to the specific seating components and the body position, almost always begins with the pelvis.

The pelvis

With few exceptions, positioning begins with support at the pelvis as this generally dictates what happens in the rest of the body. The pelvis is positioned and held as close to midline as feasible. This will encourage a stable base of support on which the remainder of the body may be positioned. A lap belt mounted at about 45° is used to maintain pelvic positioning. For those clients with fixed posterior pelvic rotation the lap belt mounted closer to an 80–90° angle to the horizontal may work better to keep the child from sliding forward and under it. Fixed deformities about the pelvis should, for the most part, be accommodated within the seating system with the goal of a balanced trunk and head position. More flexible deformities should be addressed by unilateral seat height buildups, custom contouring or with other unique solutions. At all times, care should be taken not to compromise trunk and head position through creative problem solving at the pelvis.

Lower limbs and feet

The lower limbs are positioned in neutral rotation at the hips and with 90° flexion at the hips, knee, and ankles. An angle greater than 90°, particularly at the hips and knees, encourages a posterior pelvic rotation posture, which results in the client sliding out of the seat. This is especially noticeable in clients with increased lower limb extensor tone. Failure to maintain 90° or less at the hips and knees often results in a lower limb extensor pattern with posterior pelvic rotation, internal rotation, adduction and extension at the hips, and extension at the knees. Because the hamstring muscles pass over both the knee and hip joints, knee flexor tightness (hamstring tightness) is accommodated to avoid posterior rotation at the pelvis. If efforts are made to place the feet on wheelchair footrests when the hamstrings are tight, the stretch on the muscles will pull the pelvis into a posterior tilt. In this case, flexion of greater than 90° at the knees will allow the pelvis to maintain a more neutral tilt.

Deformities such as a "windswept" deformity (adduction contracture of one hip, abduction of the opposite hip) are all too often present in the lower limbs. If correction is not feasible, the deformity is accommodated at the pelvis and the head and trunk are positioned as forward facing as possible.

Tendencies toward adduction of both hips is discouraged by positioning in abduction. This is particularly important in clients with the potential for, or history of, hip dislocation or subluxation. Pommels (abductors) are placed distally, so as not to facilitate adduction by stimulating the medial thighs. The feet are optimally positioned at a neutral ankle angle. Foot straps placed at a 45° angle encourage pressure towards the heel rather than only the ball of the foot. This inhibits elicitation of the positive supporting reaction. Extreme deformities are either accommodated or braced.

The trunk

Depending on the degree of active trunk control, midline support can range from a "low profile" trunk support, for those who simply need a tactile reminder of where midline is, to rigid trunk support for those who have little or no trunk control. Support for those with spinal deformities, such as scoliosis and kyphosis is carefully evaluated to ensure that corrective forces applied to the individual are tolerable. Scoliosis is managed with the three point pressure technique. Support pads are placed under the apex of the curve, high on the opposite side and bilaterally at the pelvis. Severe deformities should always be accommodated comfortably, using a seating technique that allows for contact with as much surface area as possible. Usually, when supporting a scoliosis, some degree of tilt (maintaining 90° hip angle) is necessary to alleviate some of the effects of gravity on the spine. Also, if the client is not forced to counteract gravity, the lateral supports do not need to be as aggressive and can be made more comfortable and tolerable.

Persons with a flexible kyphosis are managed with a custom contoured back component and an anterior support, usually a flexible anterior harness. The custom component is particularly important in the region of the apex of the curve. If the curve is fixed, the spine is accommodated. In either case it is often advisable to tilt the system in space to decrease the effects of gravity.

Anterior trunk support is necessary for individuals who cannot maintain an upright position independently for an extended period of time, but require a more upright position for functional or therapeutic reasons. Chest belts are helpful for those who simply require a gentle assist into upright. Chest panels, harness, or other four point supports (over the shoulders and laterally around the trunk) are useful for those who tend to come forward with their shoulders, or who tend to elevate at the shoulders to obtain stability.

The shoulders/upper limbs/head

Shoulder protraction is provided occasionally to assist in relaxing extensor tone. Shoulder protraction "wings" added to the back or the lap tray, encourage a more midline upper limb posture. However, before any se ting modification is done, it is suggested that the child's head position in space is re-evaluated as the problem may be the presence of the tonic labyrinthine supine reflex. If this is the case, the tilt of the seating system should be altered (probably brought closer to the vertical) and often the degree of protraction is lessened.

Head position can dictate overall body tone, particularly in the trunk and upper limbs/ shoulder girdle. Reclining or tilting an individual often results in increased trunk and shoulder girdle extensor tone, because of the effects of the tonic labyrinthine supine reflex. In addition, the symmetrical and asymmetrical tonic neck reflexes can affect positions of the trunk and upper limbs. In situations where the ATNR is very dominant, the overriding abnormal tone and asymmetries must be dealt with before any pelvic positioning can be started.

A hyperextended position of the neck, with a kyphotic posture of the upper trunk is a difficult positioning problem. This indicates overall trunk hypotonicity, resulting in a tiring and non-functional position of the head. Tilting the individual, maintaining hip angle and at the same time bringing the head to a more upright position can alleviate the effects of gravity on a hypotonic spine, while providing a more functional head position.

Another difficult functional problem is when a child has a flopping head or a head that pulls into flexion. Individuals with this problem are observed with their heads "hanging down", no matter what the angle of tilt. Some individuals cannot be reclined or tilted because their functional position is vertical. Many devices, including snugly fit head straps, chin cups, and soft cervical collars have been used to resolve this problem. Any device about the head needs to be carefully applied and observed, as it can affect tone, neck position, and swallowing. In unattended situations when the lap belt is not well secured, the resultant problems can prove dangerous.

The seating simulator

The ability to simulate postures and positions in space is an important part of the evaluation for a seating system. Holding someone on an examining table or taking measurements in the lying position is an inaccurate assessment and does not provide adequate information. The effects of position on tone, realistic forces which can be applied, initial acceptance of positioning, and effects of positioning on the individual's function can only be accurately evaluated with the client in the sitting position. Also, the child's reaction to the upright position in a seating system is not well observed unless he can be seated without the assistance of therapists and parents holding hands. The use of a seating simulator helps provide the seating team with the technical information required for assembly of an individually designed seating system.

Simulators should have angular adjustments, adjustments in thigh length, hip angle, and back height, as well as varying shapes and sizes of seat and back components, both planar and contoured, lap belts, head rests, chest supports and footrests. In addition, a variety of powered and manual chairs should be used for the evaluation. Manual or powered bases should not be recommended purely on the basis of catalogue information. Especially when dealing with evaluating powered wheelchair controls for the severly physically disabled, the patient should be allowed to actually try the proposed solution. When a child does not yet have his own seating system, the simulator components can be used to "simulate" the desired combination of seating components. This is the only way that it is possible to provide needed proximal trunk support so that the child can use their limited distal control to operate a powered device. By using a simulator, the therapist can know by the end of the evaluation what the functional position is, and what types of equipment may be appropriate and possible.

Matching devices to needs

Once the desired posture is found through evaluation, the therapist investigates which commercial devices will achieve the desired goals. Again, functional and therapeutic goals are defined before deciding what hardware to use. Whenever possible, commercially available devices are chosen. A second choice is to modify a commercially available product and the last choice is to custom fabricate a device. In most cases, custom fabrication is more costly that the commercially available options if all factors are considered.

Fastening the seating components into the wheeled base must also be considered. Fastenings must be easy to use, durable and safe. It is also important to be able to locate a seating system in more than one base if powered mobility is a consideration.

A number of factors which must be coordinated to form a basis for decision-making toward a specific seating device include: the presence and degree of abnormal tone and reflexes; the amount of postural control that can be obtained and sustained by the individual; functional skills resulting from external postural control; the potential for, or existence of orthopaedic deformities; and sensory status (Hobson, 1984). For the purpose of a frame of reference, individuals will be defined in terms of three groups; mildly involved, moderately involved, and severely involved (Fig. 1).

A mildly involved individual is one with mild tone/strength problems (the ability to readily maintain symmetrical postures) and minimal orthopaedic involvement (no limitations in range of motion in sitting).

A moderately involved individual is one with moderate tone problems manifested by an inability to maintain functional or symmetrical postures; and moderate orthopaedic

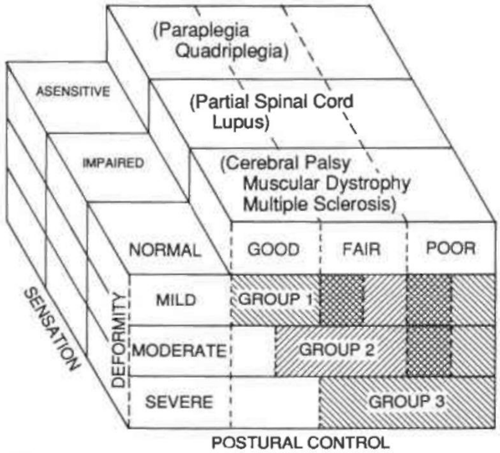

Fig. 1. A three-dimensional representation of the key intrinsic factors (control, deformity and sensation) that guide decision making in specialised seating.

involvement which could include a flexible scoliosis of less than 30°; flexible kyphosis; dislocated hip with a leg length discrepancy of less than two inches; contractures of the hips/knees of less than 110°; and feet which are unable to maintain a plantigrade position.

A severely involved individual has severe tone/strength problems which would prevent obtaining or maintaining symmetrical postures; severe, fixed curvatures of the spine (greater than 30°) and/or fixed deformities about the pelvis or lower limbs greater than those previously described.

A person need not fit all of the descriptions to fall into a category. For example, a person could be defined as severely involved if only tone were severely impaired, but no orthopaedic deformities were present; such is the case with many individuals with athetoid cerebral palsy.

Sensation is considered separately. Aside from the obvious categories of "absent", "impaired", and "normal", one also considers the individual's ability to relieve pressure independently and move away from discomfort. Many severely involved individuals are categorised as having impaired sensation because of the combination of severe, bony deformities combined with the inability to move away from discomfort.

In choosing hardware, no one piece of equipment is appropriate for everyone. Careful evaluation of an individual's needs combined with knowledge of available equipment can assure an appropriate match.

Mildly involved

Generally, mildly involved individuals can be seated using planar, commercially available components. These are systems which have modular, interchangeable parts which can be readily adjusted for growth or change. Functionally, they provide midline stability and encourage maintenance of midline postures.

Examples of mildly involved individuals would include:

A child with spastic diplegic cerebral palsy who is partially ambulatory, but requires a wheelchair for distance mobility. With a flat seat, the child can have the proximal stability necessary for her/him to obtain upper limb function to propel the chair.

A low level paraplegic who requires a simple pressure relieving cushion in a lightweight wheelchair to provide pelvic stability and assist in maintaining skin integrity.

Moderately involved

Moderately involved individuals can be seated using custom-contoured systems, or combinations of planar and contoured systems. The main goals with this group are to correct/accommodate orthopaedic deformities and provide enough stability for the individual to be functional.

Examples of moderately involved individuals would include:

A child with spinal muscular atrophy with no orthopaedic deformities. Although the child has no deformities, he requires very aggressive midline support to obtain distal function. In addition, the child cannot weight relieve and is very bony, and needs a surface which can assist in providing pressure relief. While a midline linear back could be used, customisation of the seat would be necessary to provide pressure relief.

A head-injured adult with hip and knee extension contractures, kyphotic trunk posturing, poor head and trunk control, and a dominance of overall extensor tone. An intimately contoured approach would allow accommodation of deformity, control of tone, and provide the ability to control resiliency of the sitting surface to decrease the possibility of pressure sore development.

Severely involved

With few exceptions, severely involved individuals require a total customised approach to control severe tone; accommodate severe deformities which often result in bony prominences; and/or accommodate for sensation problems. The sitting surface which contacts the body must closely approximate the individual's body contours, particularly if severe orthopaedic deformities are present, to prevent pressure areas over bony deformities.

Examples of severely involved individuals include:

A high tone athetoid with minimal orthopaedic deformity. Although minimal deformity is present, very aggressive contouring is necessary to provide midline stability because of the high tone. In addition, the retained abnormal reflexes can dictate the need for a less resilient sitting surface to protect integrity of the skin.

A young man with advanced Duchenne Muscular Dystrophy, with severe pelvic obliquity and spinal deformity. He requires a contoured seat to comfortably accommodate the orthopaedic deformities. The back, however, can be less contoured providing some midline stability because some trunk movement is necessary to obtain upper limb movement and placement.

An adult with severe spastic quadriplegic cerebral palsy, with multiple, severe orthopaedic deformities, and no head or trunk control. The main goal with this individual is to provide a contoured seating system to comfortably accommodate deformities.

REFERENCES

BERGEN, A., COLANGELO, C. (1985). Positioning the client with CNS deficits. — Valhalla, NY: Valhalla Publications Ltd., p3–23.

HOBSON, D. A. (1984). Matching client needs with specialized seating options. In: Seating for children with cerebral palsy — A Resource Manual. — Memphis, TN: University of Tennesee, Rehabilitation Engineering Program.

TAYLOR, S. J., TREFLER, E. (1984). Decision making guidelines for seating and positioning children with cerebral palsy. In: Seating for children with cerebral palsy — a resource manual. — Memphis, TN: University of Tennessee, Rehabilitation Engineering Program.

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Pressure management

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Abstract
The prevention or minimisation of the occurrence of pressure sores is an important consideration in the rehabilitation of physically disabled people, especially for the wheelchair user with a spinal cord injury.

Although there is little definitive information on the cause of pressure sores, several intrinsic and extrinsic factors have been highlighted. Probably the most significant causative factor is the application of force to the skin surface. The relationship between the magnitude of pressure and its duration; the temperature and humidity at the interface; and the physiological effects that this has on the microcirculation and lymphatic drainage are discussed in this article.

It is suggested that a rationale for the prevention of pressure sores includes the limitation of the duration of pressures applied to the skin surface and the reduction of the peak pressures particularly at vulnerable sites. In this context the design criteria for a clinical interface pressure measurement system, and the uses and limitations of the commercially available options, are considered. The development of a structured programme of wheelchair and support surface provision, assessment and follow-up is required.

Introduction

Pressure sores are a major problem for people who have areas of tissue which lack sensation or who have limited natural mobility. These deficits affect very many who use wheelchairs and the prevention of pressure sores is a key consideration in the rehabilitation of patients who require a wheelchair and in the provision of a suitable chair and cushion.

There is little reliable information on the incidence or prevalence of sores related to the use of wheelchairs. A survey of 995 patients in the Borders Health Area in Scotland showed that 24% of the 121 wheelchair users had a pressure sore compared to to 7.4% of the 874 patients who did not use a wheelchair (Barbenel, 1985), a highly significant difference.

Spinal-cord-injured wheelchair users are at special risk of developing sores and it has been estimated that pressure sores affect 5-10% of such wheelchair users each year (Ferguson-Pell *et al.*, 1980). The same study showed that the average duration of hospital in-patient treatment for ischial sores was 70 days. These figures imply that pressure sores in wheelchair users represent a considerable financial cost and medical and nursing burden. In addition the sores are a source of major discomfort and disruption to the lives of the patients who have them and recurrent sores may make it impossible for them to gain employment.

Reliable, definitive and objective information on the cause of pressure sores remains limited and fragmentary. The prevention of sores is based both on this limited scientific evidence and empirical experience. The development of a structured programme of wheelchair and support surface provision, assessment and follow-up, within which the idea of pressure sore prevention can be implemented, is the key to the successful prevention of the majority of pressure sores.

Causation

Pressure sores are a form of non-specific damage which can be caused in many ways. The results of systematic programmes of pressure sore prevention for wheelchair users (Barbenel, 1989) suggest that there is an unavoidable minimum number of sores which may be caused by trauma during transfer, friction etc. Nevertheless, the major cause of pressure sores is the application of forces to the skin surface for prolonged periods of time. Additional extrinsic factors include the presence of abnormally high temperatures and moisture accumulation at the loading area of the skin. Intrinsic factors such as the thickness and conditions of the skin and subcutaneous tissues, the presence of scars and the nutritional status of the patient may also be of great importance. Posture may also greatly influence the magnitude and distribution of forces acting on the tissues.

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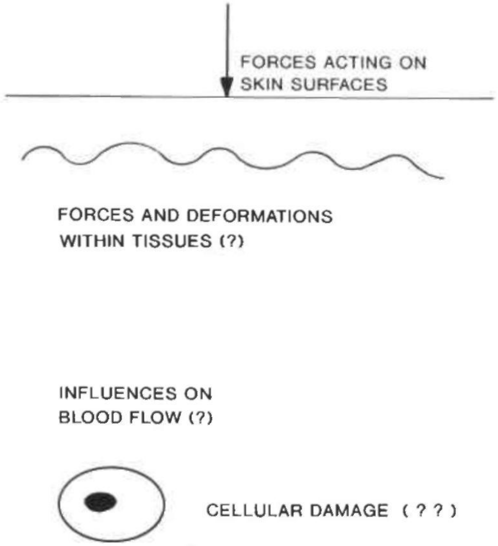

Fig. 1. Forces acting on the skin surface may produce cellular damage, but details of the effects of pressure on the tissues become increasingly uncertain (indicated by the question marks).

Ultimately, pressure sores are produced by damage to, and destruction of, cells within the tissues. There is clearly a chain of cause and effect, linking forces applied to the skin surface with cellular damage (Fig. 1), but it is also a chain of increasing ignorance. The forces applied to the skin surface can be measured with some degree of precision. The local forces and deformation which the surface forces produce within the tissues are much less well understood, and physical or finite element models which might produce detailed information are extremely difficult to validate. The effect of these local forces and deformations on the microcirculation and lymphatic drainage of the tissues have been investigated, but only the most general information has been obtained which appears to be both subject and device dependent. Finally, the response of the cells to the unfavourable mechanical and nutritional environment produced by the surface forces is particularly ill-understood. Damage can occur to a variety of target cells which may be within the muscle or overlying fat and skin or the cells of the dermal-epidermal junction, but it is not known which type of cell will be damaged by which combination of causative factors.

Pressure and time

The force applied to the surface of the skin can be resolved into two components. One acts at right angles to the skin and is generally called the pressure; the other acts parallel to the skin surface and is known as shear. Devices for measuring the forces on the skin measure the pressure (although the shear forces may affect the measurement). There is no satisfactory method of measuring the shear forces. Consequently, quantitative investigation and discussion of forces acting on the skin refer to the effects of pressure.

Pressure has been known to be a causative factor in pressure sores for many years (see historical references in Silver, 1990). Kosiak *et al.* (1958) were the first to systematically investigate the magnitude and duration of pressures required to produce tissue damage. Forces of various magnitudes were applied to skin over the femoral trochanters and ischial tuberosities of dogs for variable durations and the condition of the loaded tissues examined histologically. It was found that tissue damage occurred after the application of high forces for a relatively short time, or lower forces for longer times. The experiments have been repeated and the general conclusion that both magnitude and duration of force are critical in developing pressure sores has been verified by other workers (Lindan, 1961; Daniel *et al.*, 1981). The work was, inevitably, carried out on animals (dog, rat, rabbit and pig) and within the overall verification of the general conclusion, it is clear that there are major differences in the magnitudes and duration of forces which the various workers have reported as being necessary to produce tissue damage.

Although there have been no controlled investigations of the forces and times needed to produce tissue damage in humans, there is some limited data. Trumble (1930) found that local pressures of about 78mmHg applied to the skin of patients produced complaints of pain and he was able to show the collapse of capillaries and veins. The most clinically useful results are those of Reswick and Rogers (1976) who measured the pressures over the bony prominences of 980 seated subjects. The tolerance curve they produced (Fig. 2) confirms the inverse relationship between pressure and duration, and has been widely used. The authors themselves warn that it should, however, be used as a general guideline rather than being taken as absolute.

Physiological effects of pressure

Applying even moderate pressures to the skin surface results in blanching. This observation has led to the interaction between pressures and microcirculation being given a central role in the causation of pressure sores. There have been numerous investigations of the response of the superficial microcirculation to load. In addition, it has been suggested that the lymphatic drainage of tissues may be disrupted by pressure.

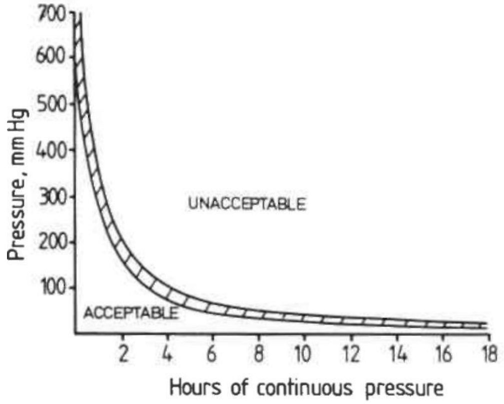

Fig. 2. Pressure-time tolerance curve, after Reswick and Rogers (1976).

The effect of external loading on the skin microcirculation has been assessed using radioisotope clearance (Daly *et al.*, 1976; Larsen *et al.*, 1979), photoplethysmography (Barbenel *et al.*, 1976; Bennet *et al.*, 1984), transcutaneous oxygen tension measurements (Newson and Rolfe, 1982; Bader, 1990) and laser Doppler flowmetry (Sacks *et al.*, 1988). Transcutaneous oxygen measurements have the major drawback that they can only be realistically carried out at elevated skin temperatures, and it is unclear whether the results of such tests can be extrapolated to more normal conditions. Optical methods have the advantage of rapid response time and allow tests to be completed in a shorter timescale.

The results reported by the individual groups are highly variable and difficult to summarise, but there is no evidence of the existence of the critical closing pressure, analogous to the capillary blood pressure, at which a marked discontinuity in the pressure-microcirculatory response occurs. The results do, however, confirm that higher pressures produce greater disruption of the microcirculation, providing an underlying causation for the inverse relationship between pressure and time required to produce tissue damage which is found experimentally. Although it has been suggested that the microcirculation in the denervated skin of paraplegic patients is more sensitive to load than normal skin, little evidence has been found to support this except during repetitive loading (Barbenel *et al.*, 1976).

The lymphatic drainage of the subcutaneous tissues of dogs has been investigated by Miller and Seale (1981) who injected Tc-99m labelled sulphur. Lymphatic clearance rates were measured with the tissue unloaded and under external compression. Clearance was found to be normal until the external pressures reached 60-70mmHg, after which the lymphatic flow rates were reduced almost to zero. A mathematical model of a lymphatic drainage and the effects of external pressure on interstitial fluid dynamics has been presented by Reddy *et al.*, (1981). The simple linear model appears to predict an inverse relationship between the magnitude of pressure and loading duration required for the interstitial fluid volume to reach any given proportion of its initial volume. The relationship is similar to that in Figure 2 and has led Reddy and co-workers to suggest that lymphatic fluid flow may play a significant role in the physiological response of tissues to load, which ultimately leads to tissue damage.

Temperature and humidity

Most wheelchair cushions are made of materials which are poor conductors of heat and which disrupt the normal heat loss from the skin surface. This results in temperature elevations in the tissues at the contact areas, which will increase the local metabolic rate and may further exacerbate the deleterious effect of pressure. The interface temperatures have been shown to depend both on the thermal properties of the support surface and the ambient temperature (Brattgard *et al.*, 1976). Materials with a high heat capacity, such as gel cushions, will take a considerably longer time to reach their equilibrium elevated temperature than will foam cushions. Movements which disrupt the contact between the skin and support surface will immediately change the interface forces, but the tissue temperature will remain elevated for some time (Barbenel *et al.*, 1978).

Temperature elevations at contact areas are commonly associated with sweating and a high local relative humidity. As with temperature, the magnitude of the effect depends both on the nature of the support surface and the environmental conditions (Brattgard *et al.*, 1976).

Tissue thickness and condition

Skin thickness can be measured using both A and B scan ultrasound. Magnetic resonance has been used to produce images of the cross-sectional anatomy of test subjects (Reger *et al.*, 1990). These images show the skin, subcutaneous tissue and muscle and allow the influence of load on tissue thickness to be evaluated.

There is a wide variety of devices for measuring the mechanical properties of the skin in vivo (Barbenel, 1987) but the complexity of the measurement and analysis and doubts about the utility of the measurements has limited such tests.

Tissue condition can be measured by a variety of biochemcial tests and spinal injury patients have been shown to have collagen breakdown (Claus-Walker *et al.*, 1973), protein deficiency (Kermani *et al.*, 1970; Moolton, 1972) and reduced leucocyte ascorbic acid concentration (Burr and Rajan, 1972).

Measurement of interface pressure

The multiple factors associated with pressure sore formation, which have been outlined in the previous section, provide the rationale and potential for the measurement of many variables. Interface pressure is the only variable which has been routinely measured and shown to be of practical significance.

The requirements which an interface pressure sensor must satisfy have been understood in general qualitative terms for some time (Pressure and Force Measurements, 1968). More recently these have been used to provide estimates of design parameters (Ferguson-Pell, 1980), but it has proved difficult to design and construct usable devices which satisfy these guidelines.

A key problem is that placing a sensor between the skin and the soft support surface, such as a cushion, disturbs the conditions which determine the pressure and which the sensor is required to measure. Obviously a large rigid sensor will indent both surfaces and the measured pressure will depend much more on the device than on the interface pressures under the resting conditions. It is obvious that the sensor should be as thin as possible, and it appears that both the thickness and diameter of the device are important. It has been suggested that the diameter to thickness ratio should not be less than 10:1. In order to produce least disturbance of the original pressure and geometry of the interface, it is also desirable that the sensor be flexible.

The sensor of choice depends on the use to which it is to be put. For routine clinical use, sensors which provide a static pressure measurement which is essentially a snapshot of the pressure distribution at a single instant, have proved very useful. Simple pressure mapping methods using pressure-sensitive, dye-releasing capsules (Brand and Ebner, 1969) or sheets impregnated with chemicals which react at a rate modified by the applied pressure (Frisina and Lehneis, 1970) have been described. Unfortunately these very simple systems are sensitive to temperature and other factors, in addition to pressure, and this has made the pressure values obtained unreliable and limited their use.

Simple electropneumatic sensors, first described by Mooney *et al.* (1971) have been extremely useful for routine measurement of interface pressures. They are closed systems which are inflated by a standard sphygmomanometer. The sensors consist of flat capsules with thin flexible walls which have electrical contacts on the opposing internal surfaces. The sensor is placed at the patient-support surface interface and inflated until the pressure is sufficient to separate the walls of the capsules and electrical contacts, producing a signal commonly shown by the switching of a LED. The capsule is then allowed to slowly deflate until the indicator shows that the walls are once again in contact. The pressure at which this occurs is then taken as the interface pressure. The major advantage of these sensors is their simplicity and commercial availabilty (Talley Surgical Instruments Ltd., Boreham Wood, Herts, UK).

The simple elecropneumatic sensors have formed the basis of more complex systems. Multiple sensors can be constructed in sheet form to produce pressure mapping systems (Garber *et al.*, 1978; Mayo-Smith, 1980; Pratt *et al.*, 1980; Bader and Hawken, 1986). A commercial system (Talley Surgical Instruments Ltd.) has proved popular for clinical use.

Continuous output sensors are useful if the pressure-time history occurring at the patient support interface is being investigated, and also have applications for routine use. Strain-gauged diaphragm transducers for measuring hydrostatic pressure are readily available commerically, as is the necessary signal-conditioning equipment. The sensors themselves can be obtaned in very small sizes and with diameters of less than 3mm and thickness less than 1mm, although they are rigid. A major drawback for their routine use is their considerable cost.

There are few other sensors suitable for measuring interface pressure which are regularly available commerically. Numerous specially constructed devices have been described in the literature. These generally rely on pressure induced changes in either the resistance or the capacitance of materials within the sensor which produces an electrical output; both types suffer from two major defects. The pressure sensitive material in the sensor has to be relatively soft in order to obtain sufficient sensitivity. Most soft materials are however time-dependent, showing such behaviour as hysteresis and creep. The electrical output produced by such time dependent devices depends not only on the load but also previous load history to which the device has been subjected and it is extremely difficult to obtain an unambiguous measurement of pressure. Under these circumstances the devices usually have a non-linear relationship between the output and the applied pressure and are commonly sensitive to temperature and curvature (Barbenel, 1983).

A recently described combination of a fluid filled sensor bag and pressure transducer (Barbenel and Sockalingham, 1990) has been used to measure the interface pressure beneath elastic bandages, and has considerable application in measuring interface pressures including the interface between the subject and the support surfaces.

All the sensors described above appear to be sensitive to the interface conditions and will generally not produce the same output reading under identical test conditions. This makes the quantitative comparison of the work of different groups using different sensors difficult. In addition care must be taken in interpreting the absolute values of pressure-time tolerance curves (as in Fig. 2) as these measurements will depend on the sensors used for carrying out the initial research.

Pressure sore prevention

The pressure beneath a subject seated in a wheelchair is not uniformly distributed, but is highest over the bony prominences of the ischial tuberosities and the greater trochanters, the sites at which pressure sores are most prevalent (Barbenel *et al.*, 1977). The assessment of patients, available support devices and the matching of the two are discussed in Choosing a Wheelchair System (1990) and elsewhere in this supplement. The starting point for pressure sore prevention must be the provision of a suitable wheelchair, correctly adjusted for the patient. The rationale for pressure sore prevention consists of three aims:

i) to limit the duration for which pressure acts,
ii) to reduce the peak pressures at vulnerable sites by distributing the pressure beneath the patient more uniformly or selectively unloading at-risk sites,
iii) to eliminate as far as possible such unfavourable factors as friction, poor posture and malnutrition.

Patients who can make regular movements should be trained and encouraged to provide regular pressure relief by push-ups or rocking from side to side. The preferred frequency and duration of pressure relief is largely a matter of personal opinion and values which have been suggested include ten seconds relief every ten minutes (Noble, 1981), to one or two minutes relief every hour (Watson, 1983). Measurements suggest, however, that patients actually make relief movements at irregular intervals and that the periods of relief are of variable duration (Fisher and Paterson, 1983; Barbenal *et al.*, 1984; Merbitz *et al.*, 1985; Ferguson-Pell *et al.*, 1990).

The magnitude of the peak pressures is less amenable to simple modification. Since it is not possible to make any great reduction in the weight supported by the wheelchair seat, the average interface pressures cannot be reduced to any great extent. Major alterations can only be achieved by redistributing the pressure to make it more uniform and to reduce it over the "at-risk" sites. These aims can be achieved by the provision of a suitable wheelchair cushion and the aim of any pressure sore prevention programme for seated wheelchair users must be the choice, provision and maintenance of a suitable wheelchair cushion.

The specific wheelchair cushion is probably of secondary importance, compared to its ability to redistribute the pressure, and expert systems have shown promise as an aid for selecting an appropriate cushion (Ferguson-Pell *et al.*, 1989).

The correct support surface is that which can achieve as satisfactory a pressure distribution as is possible and produces no tissue trauma. The primary objective in providing a cushion for wheelchair users to prevent pressure sores is to ensure that the pressures over sites at high risk of developing sores, particularly the ischial tuberosities, are as low as possible and preferably less than 40mmHg. This can only be established by interface pressure measurements with the patient sitting on the chosen cushion. Failure to achieve the desired interface pressure on the cushion selected should logically lead to the evaluation of other cushions. It is, however, not always possible to reach the desired low pressure level and it may be necessary to provide the patient with cushions producing higher than the desired pressures. This should always be associated with special care to ensure that the patients carry out routine pressure relief exercises.

There is considerable variation between patients in their tolerance of pressure. This is reflected in the shaded area of Figure 2 which is in an area of uncertainty and doubt. The suitability of a wheelchair cushion for a patient can only be assessed by inspection of the tissues after the patient has used it. Localised areas of erythema or elevated temperatures are warning signs of tissue trauma and action should be taken to prevent further tissue damage.

Wheelchair cushions have limited durability and after continual use often show a degradation of performance with a danger of increased ischial pressures. As part of any wheelchair and wheelchair cushion provision service, follow-up procedures are essential. The provision of a satisfactory wheelchair and support surface requires considerable skill, but change with time in the condition of both the devices and the patients, makes it mandatory to recognise that the provision of such assistive devices is the first stage of a programme of continuing care rather than an end in itself.

REFERENCES AND BIBILOGRAPHY

Bader, D. L. (1990). Effects of compressive loading regimens on time viability. In: Pressure sores – clinical practice and scientific approach, Ed. D. L. Bader. – London: Macmillan Press, p191–201.

Bader, D. L., Hawken, M. B. (1986). Pressure distribution under the ischium of normal subjects. *J. Biomed. Eng.* **8,** 353–357.

Barbenel, J. C. (1983). Measurement of interface pressures. In: Pressure sores, Eds. J. C. Barbenel, C. D. Forbes, G. D. O. Lowe. – London: Macmillan Press, p67–78.

Barbenel, J. C. (1985). The prevalence of pressure sores. In: National symposium on care, treatment and prevention of decubitus ulcers. – Arlington: Veterans Administration, p1–11.

Barbenel, J. C. (1987). Biomechanics of skin. In: Systems and control encyclopaedia: theory, technology, application (Vol. 1), Ed. M. Singh. – Oxford: Pergamon Press, p478–482.

Barbenel, J. C. (1989). Pressure sore prevention for spinal injured wheelchair users. In: Progress in bioengineering; proceedings of an international seminar held on the occasion of the 25th anniversary of the Strathclyde Bioengineering Unit, Glasgow, September, 1988, Eds. J. P. Paul, J. C. Barbenel, J. M. Courtney, R. M. Kenedi. – Bristol: Adam Hilger, p62–67.

Barbenel, J. C., Davies, R. V., Ferguson-Pell, M. W. (1984). Movements made by paraplegic patients in wheelchairs. *Care Sci. Prac.,* **3 (2),** 60–64.

Barbenel, J. C., Evans, J. H., Gibson, F. (1976). Alteration of blood content of superficial tissues subject to load. In: Digest of papers: 11th International Conference on Medical and Biological Engineering, Ottawa, Canada, 2–6 August, 1976, p48–49.

Barbenel, J. C., Evans, J. H., Jordan, M. M. (1978). Tissue Mechanics. *Eng. Med.,* **7,** 3–9.

Barbenel, J. C., Gibson, F., Turnbull, F. (1976). Optical assessment of skin blood content and oxygenation. In: Bedsore biomechanics; proceedings of a seminar on tissue viability and clinical applications, Eds. R. M. Kenedi, J. M. Cowden, J. T. Scales. – London: Macmillan, p83–93.

Barbenel, J. C., Jordan, M. M., Nicol, S. M., Clark, M. O. (1977). Incidence of pressure sores in the Greater Glasgow Health Board area. *Lancet,* **ii,** 548-550.

Barbenel, J. C., Sockalingham, S. (1990). A device for measuring soft tissue interface pressure. *J. Biomed. Eng.,* **12,** 519–520.

Bennett, L., Kavner, D., Lee, B. Y., Trainor, F. S., Lewis, J. M. (1984). Skin stress and blood flow in sitting paraplegic patients. *Arch. Phys. Med. Rehabil.,* **65,** 186–190.

Brand, P. W., Ebner, J. D. (1969). Pressure sensitive devices for denervated hands and feet. *J. Bone Joint Surg.,* **51A,** 106–116.

Brattgard, S. O., Carlsoo, S., Severinsson, K. (1976). Temperature and humidity in the sitting area. In: Bedsore biomechanics; proceedings of a seminar on tissue viability and clinical applications, Eds. R. M. Kenedi, J. M. Cowden, J. T. Scales. – London: Macmillan, p185–188.

Burr, R. G., Rajan, K. T. (1972). Leucoyte ascorbic acid and pressure sores, in paraplegia. *Br. J. Nutr.,* **28,** 275–281.

Choosing a Wheelchair System (1990). *J. Rehab. Res. Dev. Clin. Suppl.,* **2.**

Claus-Walker, J., Campos, R. J., Carter, R. E., Chapman, M. (1973). Electrolytes in urinary calculi and urine of patients with spinal cord injuries. *Arch. Phys. Med. Rehab.,* **54,** 109–114.

Daly, C. H., Chimoskey, J. E., Holloway, G. A., Kennedy, D. (1976). The effect of pressure loading on the blood flow rate in the human skin. In: Bedsore biomechanics; proceedings of a seminar on tissue viability and clinical applications, Eds. R. M. Kenedi, J. M. Cowden, J. T. Scales. – London: Macmillan Press, p69–77.

Daniel, R. K., Priest, D. L., Wheatley, D. C. (1981). Etiological factors in pressure sores: an experimental model. *Arch. Phys. Med. Rehabil.,* **62,** 492–498.

Ferguson-Pell, M. W. (1980). Design criteria for the measurement of pressure at body/support interfaces. *Eng. Med.,* **9,** 209–214.

Ferguson-Pell, M. W., Cardi, M., Hurwitz, D. E. (1989). Expert systems, a promising tool for patient assessment. In: Progress in bioengineering; proceedings of an international seminar held on the occasion of the 25th anniversary of the Strathclyde Bioengineering Unit, Glasgow, September, 1988, Eds. J. P. Paul, J. C. Barbenel, J. M. Courtney, R. M. Kenedi. – Bristol: Adam Hilger, p68–72.

Ferguson-Pell, M. W., Hurwitz, D. E., Burn, T. G., Masiello, R. (1990). Remote monitoring of wheelchair sitting behaviour. In: Presure sores – clinical practice and scientific approach, Ed. D. L. Bader. – London: Macmillan Press, p261–273.

Ferguson-Pell, M. W., Wilkie, I. C., Reswick, J. B., Barbenel, J. C. (1980). Pressure sore prevention for the wheelchair-bound spinal injury patient. *Paraplegia,* **18,** 42–51.

Fisher, S. V., Paterson, P. (1983). Longterm pressure recordings under the ischial tuberosities of tetraplegics. *Paraplegia,* **21,** 99–106.

Frisina, W., Lehneis, H. R. (1970). Pressure mapping: a preliminary report. *J. Biomech.,* **3,** 526.

Garber, S. L., Krouskop, T. A., Carter, R. G. (1978). A system for clinically evaluating wheelchair pressure relief cushions. *Am. J. Occup. Ther.,* **32,** 565–570.

Kermani, S. R., Siddique, M., Zain, S., Kazi, K. (1970). Biomechanical studies on pressure-sore healing in paraplegics. *Paraplegia,* **8,** 36–41.

Kosiak, M., Kubicek, W. G., Olson, M., Danz, J. N., Kottke, F. J. (1958). Evaluation of pressure as a factor in the production of ischial ulcers. *Arch. Phys. Med. Rehabil.,* **39,** 623–629.

Larsen, B., Holstein, P., Lassen, N. A. (1979). On the pathogenesis of bedsores. Skin blood flow cessation by external pressure on the back. *Scan. J. Plast. Reconstr. Surg.,* **13,** 347–350.

Lindan, O. (1961). Etiology of decubitus ulcers; an experimental study. *Arch. Phys. Med. Rehabil.,* **42,** 774–783.

Mayo-Smith, W. W. (1980). Pressure measurements: device for obtaining readouts from multiple sites using pneumatic transducers. *Arch. Phys. Med. Rehabil.,* **61,** 460–461.

Merbitz, C. T., King, R. M., Bleiberg, J., Grip, J. (1985). Wheelchair push-ups: measuring pressure relief frequency. *Arch. Phys. Med. Rehabil.,* **66,** 433–438.

Miller, G. E., Seale, J. (1981). Lymphatic clearance during comprehensive loading. *Lymphology,* **14,** 161–166.

Moolton, S. E. (1972). Bedsores in the chronically ill. *Nursing Mirror,* Feb., 65–67.

Mooney, V., Einbund, M. J., Rogers, J. E., Stauffer, E. S. (1971). Comparison of pressure distribution qualities in seat cushions. *Bull. Prosthet. Res.,* **10 (15),** 129–143.

Newson, T. P., Rolfe, P. (1982). Skin surface PO_2 and blood flow measurement over the ischial tuberosity. *Arch. Phys. Med. Rehabil.,* **63,** 553–556.

Noble, D. C. (1981). The prevention of pressure sores in persons with spinal cord injuries. – New York: World Rehabilitation Fund.

Pratt, D. J., Bowker, P., Wardlaw, D., McLaughlin, J. (1980). A monitor for plotting pressure contours inside a plaster cast. *Eng. Med.,* **9,** 147–149.

Pressure and Force Measurements (1968). National Research Council, Committee of Prosthetic Research and Development. – Washington D.C.: National Academy of Sciences.

Reddy, N. P., Cochran, G. V. B., Krouskop, T. A. (1981). Interstitial fluid flow as a factor in decubitus ulcer formation. *J. Biomech.,* **14,** 879–881.

Reger, S. I., McGovern, T., Chung, K. C. (1990). Biomechanics of tissue distortion and stiffness by magnetic resonance imaging. In: Pressure sores – clinical practice and scientific approach. Ed. D. L. Bader. – London: Macmillan Press, p177–190.

Reswick, J. B., Rogers, J. E. (1976). Experience at Rancho Los Amigos Hospital with devices and techniques to prevent pressure sores. In: Bedsore biomechanics; proceedings of a seminar on tissue viability and clinical application. Eds. R. M. Kenedi, J. M. Cowden, J. T. Scales. – London: Macmillan, p301–310.

Sacks, A. H., Ksander, G., O'Neill, H., Perkash, I. (1988). Difficulties in laser Doppler measurements of skin blood flow under applied external pressure. *J. Rehabil. Res. Dev.,* **25 (3),** 19–24.

Silver, J. R. (1990). Spinal injury. In: Pressure sores – clinical practice and scientific approach, Ed. D. L. Bader. – London: Macmillan Press, p97–115.

Trumble, H. C. (1930). The skin tolerance for pressure and pressure sores. *Med. J. Aust.,* **ii,** 724–726.

Watson, N. (1983). Skin care and long-term rehabilitation. In: Pressure sores, Eds. J. C. Barbenel, C. D. Forbes, G. D. O. Lowe. – London: Macmillan Press, p95–102.

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Evaluation of cushions using dynamic pressure measurement

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Abstract

Reduction of pressures generated in the tissues overlying the ischial tuberosities is an important measure for predicting a cushion's effectiveness. In particular, the pressure-time relationship is significant in the prevention of pressure sores. In this study a dynamic pressure monitoring system was used to obtain pressure-time profiles for 25 spinal cord injured subjects. Each subject tested three types of cushion (Foam, Gel (Aberdeen) and Roho) for periods of two hours each during which routine activities were performed. Results obtained were broadly comparable with previous studies. Average pressures were: Foam 87.6mmHg (11.6kPa); Gel 68.6mmHg (9kPa) and Roho 54.6mmHg (6.7kPa). Pressure-time histograms are presented for three subjects for each cushion. These show inter-subject variability on the same cushion as well as intra-subject variability on different cushions. Therefore individual patient assessment is important in providing the most appropriate cushion. Dynamic pressure monitoring allows the pattern of pressure variation to be determined and hence the potential effectiveness of the cushion.

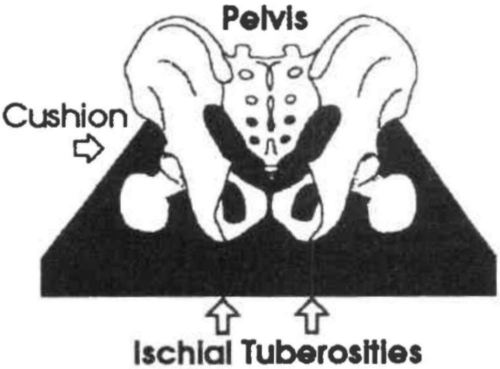

Fig. 1. Ischial tuberosities.

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Introduction

When a person sits, the highest pressures are generated in the tissues overlying the ischial tuberosities (Fig. 1). This pressure is dependent on the bony configuration, the depth of the soft tissues and the support surface or cushion on which that individual sits. Numerous cushions (Fig. 2) are available which are made from different materials such as foams or gels, or may be filled with water or air (flotation). Some of these cushions have composite structures combining more than one of these basic materials. All of the cushions are designed to reduce pressure beneath the ischial tuberosities. The materials and geometry of a cushion are important variables that affect its ability to distribute pressure. Usually an estimate of this pressure is made by taking a single static reading with a pressure transducer placed between the tissues (overlying the bony prominence) and the support surface. This pressure reading is then used as a guideline to predict the effectiveness of the cushion for a given point.

Pressure alone cannot cause a sore and it has been known for many years that it is the pressure-

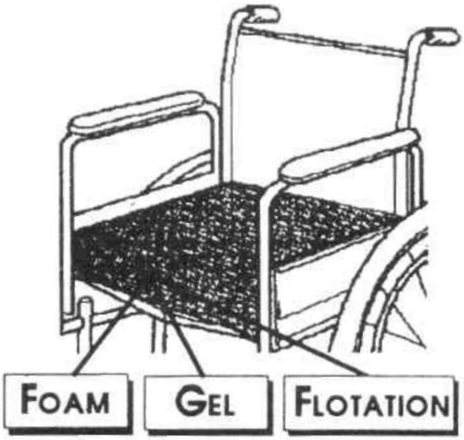

Fig. 2. The wheelchair cushion.

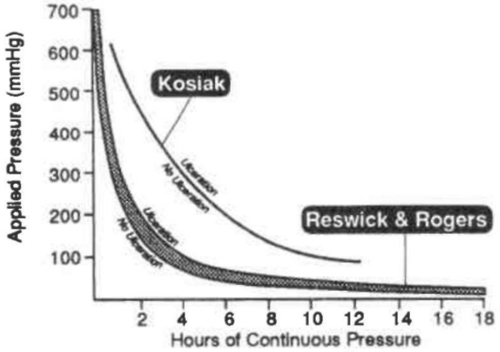

Fig. 3. Tissue tolerance guidelines (Reswick and Rogers, 1976; Kosiak, 1959).

time relationship that is of fundamental importance. Many studies have investigated the relationship between the level and duration of static pressure required to initiate pathological changes in animals (Brooks and Duncan, 1940; Groth 1942; Husain, 1953; Kosiak, 1959 and 1961; Lindan, 1961 and 1965; Dinsdale, 1973 and 1974; Daniel, 1981).

In the classic study of Kosiak (1959) an inverse relationship was shown to exist between the amount and duration of pressure required to render pathological changes in tissues. Reswick and Rogers (1976) have accumulated data from actual patient experience which confirms the shape of the curve produced by Kosiak but has a different gradient (Fig. 3). These experimental data have been useful in classifying the general form of the pressure-time relationship for a damage threshold (Fig. 4). However, the problem of using this relationship as a guideline for cushion prescription is that it ignores the variability of pressure that can occur over a period of time. Evidence for the presence of large numbers of movements in wheelchair-bound individuals has been reported in studies of the movement of the centre of gravity (Bardsley, 1977), wheelchair patient activity (Davies, 1978) and pressure relief patterns (Patterson and Fisher, 1980). This is particularly important when prescribing a cushion. The ability of a cushion to dampen movement and distribute the pressures generated can only be assessed accurately with dynamic measurement and the true effects of pressure beneath the ischial tuberosities can only be understood if the pressure-time distribution is investigated over a period sufficient to allow patterns of pressure variability to be established for a given support surface.

Method and materials

A portable battery operated dynamic monitoring system employing two electro-pneumatic type sensors (28mm in diameter) was developed for measuring simultaneously pressures beneath both ischial tuberosities (Bar, 1988). This system had a constant sampling rate of 10Hz for each channel. The dynamic pressure signal was analyzed on the basis of a cumulative frequency distribution represented graphically as a histogram (Fig. 4b). This enabled the large masses of pressure data collected to be described with little loss of significant information. The pressure-time curve (Fig. 4a) was divided into 6 class intervals of 30mmHg width based on the fact that 30mmHg (4kPa) represents capillary pressure (Landis, 1929), 60mmHg (8kPa) is a frequently used threshold for pressure ischaemia and 120/90mmHg (16/12kPa) represents systolic/diastolic pressures. The histogram was constructed by counting the number of times an observation fell or was distributed into each class (e.g. T1+T2+T3 ... in the 30-60 interval) as illustrated in Fig. 4a.

Some 25 active Spinal Cord Injured subjects were selected for this study (17 paraplegics and 8 quadriplegics). Pressures were monitored simultaneously beneath both ischial tuberosities for a period of 2 hours. Subjects were free to wheel and move about in the test wheelchair during this period. No restriction was placed on pushup or other pressure relief behaviour.

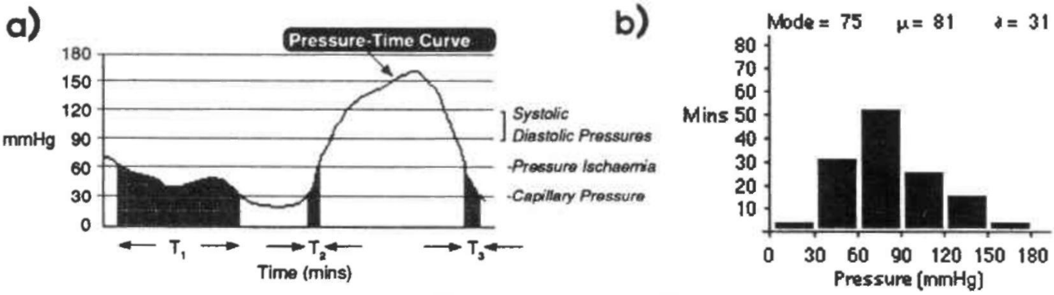

Fig. 4. The pressure histogram. For each pressure histogram the mode, the mean (μ) and the standard deviation (δ) were calculated. These parameters, together with the direction of skew, allow an estimation of the ability of the cushion to dampen movement, equalise and minimise pressures. Differences between left and right side histograms indicate posture.

Three cushions based on foam, gel and air-filled mediums were used in this study as follows:

Foam with vinyl cover

This cushion comprises a 100mm (4″) thick polyurethane foam inner with a vinyl cover. The density of the foam is 96kg/m^3 (6lb/cu.ft) (Fig. 5a).

Aberdeen Gel Cushion

A gel inner, enveloped in a vinyl cover, is contained within a foam border which is also covered in vinyl. The gel inner is 50mm (2″) thick and the foam surround is 25mm (1″) thick (Fig. 5b).

The Roho

Multiple inter-connected air-filled tufts form the basis of the Roho cushion. The inflation pressure is adjusted for each individual via an air inlet (Fig. 5c).

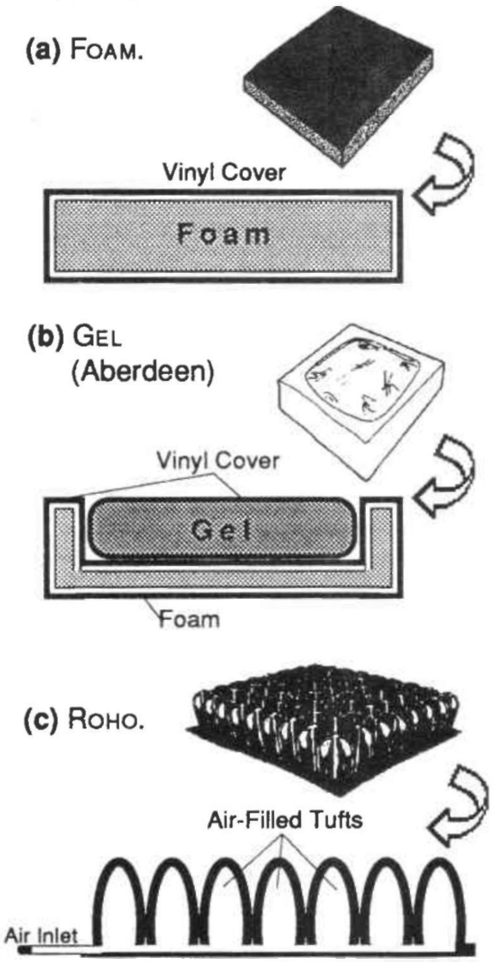

Fig. 5. Cross-sectional view of test cushions.

Fig. 6. Repositioning.

Results and discussion

Movement

Pressures generated at the interface were dependent on the complex interaction of three factors namely: bodily movements, the type of cushion and wheelchair motions. Common characteristics appeared in the pressure-time traces obtained from all the cushions tested and it was possible to isolate a number of features related to these three factors.

Postural changes or repositioning were characterized by significant changes in pressure lasting longer than a few minutes (macro-movements). In this study both tetraplegic subjects as well as paraplegic subjects were observed to adopt a number of different positions in the wheelchair such as hooking an arm behind the backrest handle of the wheelchair (Fig. 6).

Changes in pressure generally of a few seconds duration were frequently identified in the pressure-time records and were classed as micro-movements. These changes were probably a result of variations in trunk position. All pressure traces contained spikes of pressure of short duration i.e. $\leq$5 seconds (short transients). These spikes were of varying amplitude ranging from a few mmHg to changes approaching 200mmHg (26.6kPa) and were the result of upper limb movements, fast trunk movements and wheelchair motions. Frequencies up to 1Hz were recorded for the fastest bodily movements tested which included playing table-tennis, computer games (with a joy-stick on the lap) and propulsion of a wheelchair.

The effects of wheelchair motions were found to be relatively minor for a given cushion compared to the effects of bodily movements. Either micro-movements or short transients could be superimposed on macro-movements. In other words, a change of posture could occur, represented by a large shift in pressure distribution, followed by the presence of small pressure oscillations indicating further small trunk or limb movements or wheelchair movements.

Cushions

Pressures varying between 50 and 150mmHg (6.7kPa–20kPa) were recorded on the three types of cushions tested in this study which is consistent with the results of previous pressure studies on cushions when allowances are made for differences in measurement technique including the fact that all previous studies have measured pressure statically (Houle, 1969; Mooney *et al.*, 1971; Cochran, 1973; Souther, 1974; Palmieri, 1980; Garber *et al.*, 1978; Krouskop *et al.*, 1986). Unfortunately achieving interface pressures less than capillary pressures appears difficult from the practical point of view and, although there have been many attempts at cushion design, no cushion has been found to keep pressures below capillary pressures at all points.

In this study, the characteristics of the cushions were found to influence the interface pressures. Their effectiveness depended on their ability to distribute pressure and reduce peaks caused by movements so that average pressure over time was minimized. The differences between these cushions just reached statistical significance across the subject group ($p<0.1$). The mean pressures recorded for the subject group on each cushion were: Foam=87.6mmHg (11.6kPa); Gel=68.6mmHg (9kPa); Roho=50.6mmHg (6.7kPa).

The pressure distributions recorded for the individual subjects depended on the cushions on which they were obtained. Three examples are given (Figs. 7, 8 and 9) that illustrate the variability of pressure that can occur with time for a given subject as well as between subjects on different cushions.

Subject 1: A foam cushion could be potentially hazardous because this subject demonstrated a tendency to sit with high pressures under one buttock. Since foam is not a fluid material this pressure difference was not accommodated. This pressure difference improved on the Gel cushion, but still tended to be high (105mmHg or 14kPa) under the left buttock. On the Roho the pressures under the left and right buttocks were equalised and reduced to near capillary levels.

Subject 2: On all three cushions, pressure was distributed approximately equally between buttocks but tended to be high on foam. Both the Gel and Roho cushions produced acceptable pressures.

Subject 3: Acceptable pressures were obtained on all cushions for this subject with similar distributions of pressure for all cushions. For such a person, the need for a special cushion is not vital and a standard 100mm (4") foam would be acceptable in terms of pressure. It is of interest to note that, at the time of testing, this subject had retained much of his muscle bulk and tone in the buttock and posterior thigh regions which provided a relatively well padded sitting area compared to many disabled persons.

For all subjects the pressure histograms for Foam and Gel tended to be broad and flat (Fig. 10). An explanation for these shapes may, in part, be obtained by reference to the nature of the damping effects of each type of cushion. Similar damping ratios for Foam and Gel type cushions have been demonstrated by Cochran and Palmieri (1980) using a flat indenter in "bench tests". This finding reinforces observations made in the present study. It was apparent from an inspection of the pressure-time traces that transient pressures of short duration occurred more frequently on the Foam and Gel cushions than on the Roho. Relatively small changes in position could produce large changes in pressure and possible "bottoming-out" on Foam. The same picture was not always true of Gel: the temperature of the Gel, the subject's anatomical shape and the rate of change of movement all appeared to affect the degree of damping afforded by the Gel. With regard to movement, rapid changes (short transients) tended to generate high pressure spikes but slower motions could be absorbed to some extend by the "flow" of the Gel. If the supporting Gel medium was allowed to flow freely it would, according to the laws of fluid dynamics, distribute pressure evenly throughout the entire supporting medium. However, the cover enveloping the Gel limits flow owing to its elastic limits i.e. surface tension. This means that ideal pressure distributions are in fact difficult to achieve on Gel type cushions and explains why dynamic pressures are not easily dampened resulting in broad frequency distributions for this type of cushion. It is of interest to note that high static pressure readings on Gel type cushions ranging from averages of 70 to 95mmHg (9.3–12.7kPa) have also been the surprising finding of several other authors (Mooney *et al.*, 1971; Souther *et al.*, 1974;

Palmieri *et al.*, 1980). These figures compare favourably to the mean pressures obtained for the Gel cushion in this study i.e. 69±18mmHg (9.2±2.4kPa).

The Roho was more efficient at permitting movement and distributing pressure than either the Foam or Gel cushions. The distribution of pressure on the Roho was approximately symmetrical for left and right sides for all subjects. In addition pressures were contained in the lower

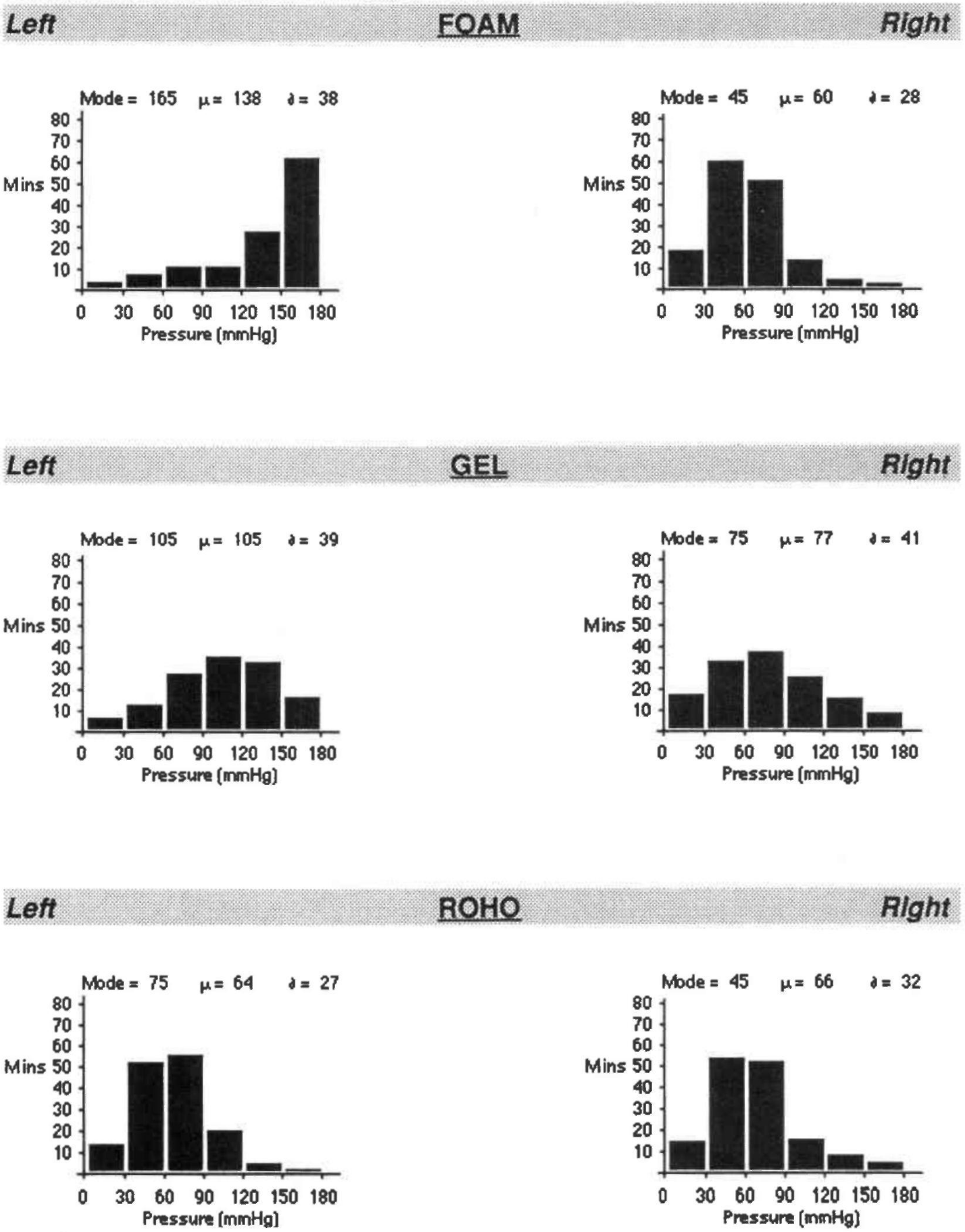

Fig. 7. Subject No. 1 — Tetraplegic (C2). Sex: Male — 36 years. History of sores: None. Push-ups: Yes.

class intervals of the pressure histograms with the result that narrower distributions were obtained for the Roho. Fisher and Kosiak (1979) have reported static pressures on the Roho when tested on twelve able-bodied individuals to be in the range of 53 to 55mmHg (7.0–7.3kPa) which agrees closely with the mean pressure of 51±10mmHg (6.8±1.3kPa) obtained in this study. However, these authors compared a 100mm (4") Foam cushion to the Roho and could

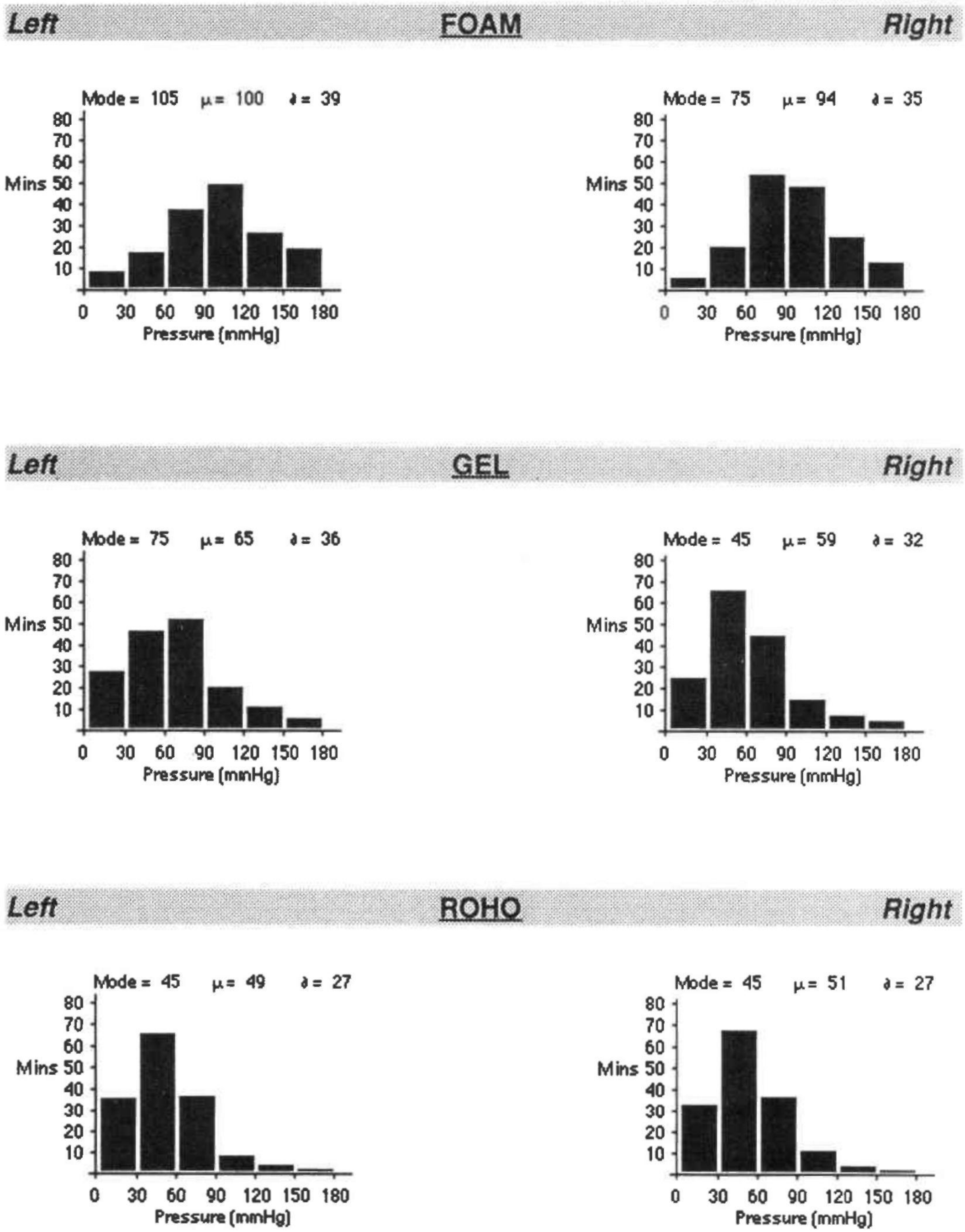

Fig. 8. Subject No. 2 – Tetraplegic (T3/T4). Sex: Male – 34 years. History of sores: None. Push-ups: Yes.

find no statistical difference between static pressure readings for the same subjects. There may be two reasons for this finding. Firstly static readings were made which, according to the results of this study, may not give an accurate assessment of the interface relationship for a wheelchair-bound person. Secondly, the authors used able-bodied subjects who may not provide realistic interface pressures owing to the muscle tone and bulk in the buttocks region. In this study

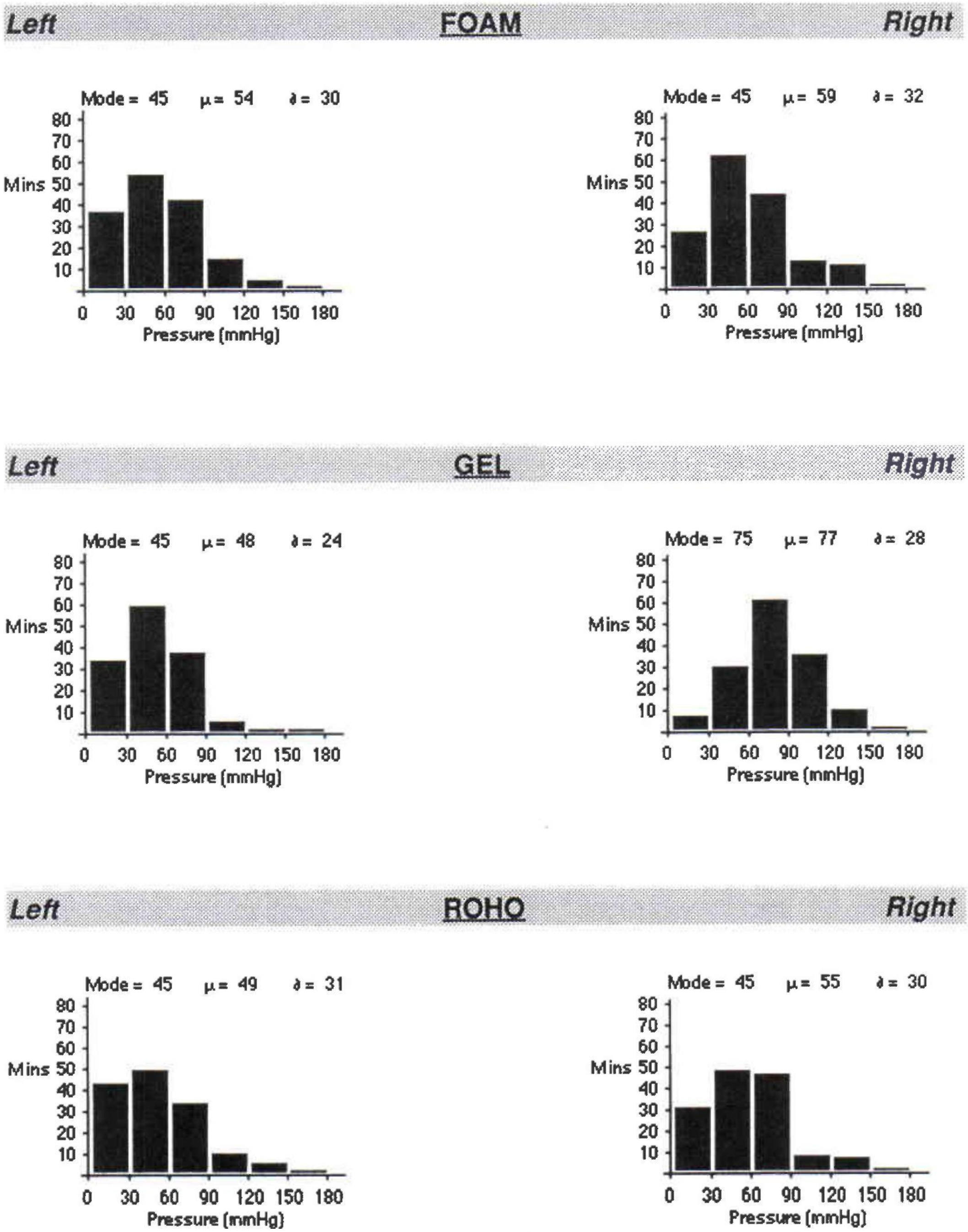

Fig. 9 Subject No. 3 — Paraplegic (L2). Sex: Male — 31 years. History of Sores: None. Pushups: Yes.

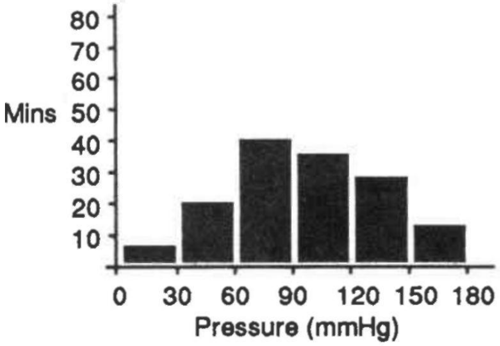

Fig 10. Broad pressure histograms for foam and gel.

all those subjects with significant muscle bulk in the lower limbs recorded low pressures on all cushions confirming the view that able-bodied subjects should not be used for the evaluation of supports designed for the disabled. The findings in this study demonstrate for a large number of disabled individuals the potential ability of the Roho to equalise and distribute dynamic pressures provided the inflation pressures are correctly established before sitting.

Conclusions

In general pressures beneath the bony prominences tend to be higher on foam than on other types of cushions. Gel cushions also tend to generate higher pressures because these are stiff materials which tend to deflect less beneath the patient with movement. The Roho, with its flotation properties, is able to distribute pressure in the sitting area more effectively than either of these other types of cushions provided the correct amount of air for optimal suspension is maintained in the cushion. The variability of pressure observed for these different cushions in this study confirms the view that the selection and fitting of cushions to patients must be done on an individual basis. It is common clinical practice to take single readings of pressure as part of the assessment process but this may not be sufficient for some patients especially young active wheelchair bound individuals. These patients require a more detailed assessment which should include dynamic pressure measurement to determine the extent of the pressure variation with time. Furthermore, clinical verification of the effectiveness of a cushion after a period of sitting is recommended since pressure alone may not account for all the factors causing a pressure sore.

REFERENCES

Bar, C. A. (1988). The response of tissue to applied pressure. Ph.D. Thesis, University of Wales.

Bardsley, G. I. (1977). Investigations into movement related to the aetiology of pressure sores. Ph.D. Thesis. — Glasgow: University of Strathclyde.

Brooks, B., Duncan, G. W. (1940). Effects of pressure on tissues. *Arch. Surg.*, **40**, 696–709.

Cochran, G. V. B., Palmieri, V. (1980). Development of test method for evaluation of wheelchair cushions. *Bull. Prosthet. Res.*, **10 (33)**, 9–30.

Cochran, G. V. B., Slater, G. (1973). Experimental evaluation of wheelchair cushions; report of a pilot study. *Bull. Prosthet. Res.*, **10 (20)**, 29–61.

Daniel, R. K., Priest, D. L., Wheatley, D. C. (1981). Etiological factors in pressure sores: an experimental model. *Arch. Phys. Med. Rehabil.*, **62**, 492–497.

Davies, R. V. (1978). The long term monitoring of wheelchair patient activity with special reference to the pressure sore problem. M.Sc. Thesis. — Glasgow: Univeristy of Strathclyde.

Dinsdale, S. M. (1973). Decubitus ulcers in swine: light and electron microscopic study of pathogenesis. *Arch. Phys. Med. Rehabil.*, **54**, 51–56.

Fisher, S. V., Kosiak, M. (1979). Pressure distribution and skin temperature effect of the Roho wheelchair balloon cushion. *Arch. Phys. Med. Rehabil.*, **60**, 70–71.

Garber, S. L., Krouskop, T. A., Carter, R. E. (1978). A system for clinically evaluating wheelchair pressure relief cushions. *Am. J. Occup. Ther.*, **32**, 565–570.

Groth, K. D. (1942). Experimental study of decubitus ulcers. *Acta Chir. Scand. (Suppl.)*, **87**, (Suppl. 76).

Houle, R. J. (1969). Evaluation of seat devices designed to prevent ischaemic ulcers in paraplegic patients. *Arch. Phys. Med. Rehabil.*, **50**, 587–594.

Husain, T. (1953). Experimental study of some pressure effects on tissues with reference to the bed sore problem. *J. Pathol. Bact.*, **66**, 347–358.

Kosiak, M. (1959). etiology and pathology of ischaemic ulcers. *Arch. Phys. Med. Rehabil.*, **40**, 62–69.

Kosiak, M. (1961). The etiology of decubitus ulcers. *Arch. Phys. Med. Rehabil.*, **42**, 19–29.

Lindan, O. (1961). Etiology of decubitus uclers: experimental study. *Arch. Phys. Med. Rehabil.*, **42**, 774–783.

Mooney, V., Eribund, M. J., Rogers, J. E. Stauffer, E. S. (1971). Comparison of pressure distribution quantities in seat cushions. *Bull. Prosthet. Res.*, **10 (15)**, 129–143.

Palmieri, R., Haelen, T., Cochran, G. V. B. (1980). A comparison of sitting pressures on wheelchair cushions measured by air cell transducers and miniature electronic transducers. *Bull. Prosthet. Res.*, **10 (33)**, 5–8.

Patterson, R. P., Fisher, S. V. (1980). Pressure and temperature patterns under the ischial tuberosities. *Bull. Prosthet. Res.*, **10 (34)**, 5–11.

Reswick, J. B., Rogers, J. (1976). Experience at Rancho Los Amigos Hospital with devices and techniques to prevent pressure sores. In: Bedsore biomechanics. Eds. R. M. Kenedi, J. M. Cowden, J. T. Scales. — London: McMillan, p301—310.

Souther, S. G., Carr, S. D., Vistnes, L. M. (1974). Wheelchair cushions to reduce pressure under bony prominences. *Arch. Phys. Med. Rehabil.*, **55**, 464—466.

International Newsletter
Winter 1991

Australian National Member Society announced its Annual Scientific Meeting which was held in Melbourne on October 11 and 12, 1991. A pre-conference Workshop on October 10 addressed the theme, Prosthetic and Orthotic Production Methodologies, including CAD CAM, and their clinical implications. The Workshop displayed current CAD CAM systems, thermoplastic moulding techniques, clinical applications, and components and equipment. At the Scientific Meeting, a trade display featured prosthetic components, custom shoes, surgical supports, new prosthetic and orthotic materials, bandages, modular seating systems, orthoses, and orthotic components.

Society members are volunteering to assist with the 1995 ISPO World Congress.

The 1992 Upper Limb Course, under joint sponsorship with ISPO, has been accredited by the Australian College of Rehabilitation Medicine.

The new Constitution and Rules enables the society to incorporate.

New Zealand National Member Society announced that the Artificial Limb Board invites applications for places in the 1992 course in Prosthetic Technology offered in collaboration with Christchurch Polytechnic. The course is full-time, of two years duration. For the first four academic terms, teaching takes place at the Polytechnic and at Christchurch Artificial Limb Centre. The final two terms are spent on clinical affiliation at one of the Board's limb centres, situated in Auckland, Hamilton, Wellington, Christchurch, and Dunedin. Student progress is monitored by means of log books, in-service assessments, and periodic examinations. On completion of the course, students qualify for joint certification by the New Zealand Artificial Limb Board and the Christchurch Polytechnic. Mr. G. J. Flanagan, Christchurch Artificial Limb Centre, Burwood, Christchurch can provide details.

Joan E. Edelstein
Editor

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CANADA

The University of Münster/Germany celebrates the 25th Anniversary of its Centre for Prosthetics, Orthotics and Rehabilitation

René Baumgartner welcomes the many guests from the University and from professional organisations, including ISPO represented by G. Fitzlaff.

In Germany the only chair exclusively for prosthetics, orthotics and rehabilitation exists in the University of Münster. With 50,000 students, the University is the third largest one in Germany and also plays a leading role in German orthopaedics. As far back as 1955, the late Professor *Hepp* established a special department for prosthetic fitting and training for upper limb amputees, victims from World War II. In 1966, an extension was built especially for children with thalidomide deformities.

From the very first day, the history of the Centre has been connected with the name of Professor *Götz-Gerd Kuhn*. After Professor *Hepp* died in 1967, *G. G. Kuhn* became his successor until he retired in 1983. Among his numerous inventions, his socket for below-elbow and below-knee amputees became world-known and are still called the Münster-type socket for below-elbow and the KBM (Kondylen-Bettung Münster) for the lower limb.

In 1985, Professor René Baumgartner was appointed director of the Centre. He introduced surgical treatment for patients who are to be fitted with prosthetic and orthotic devices. Amputation surgery, stump correction and diabetic foot care became one of the main topics of the Centre. Research in prosthetics and orthotics was further continued and published mostly in the German language.

The Centre was established in the spirit of ISPO. It still plays an important role in the life of ISPO Germany in organising seminars and publishing papers all based on the philosophy of interdisciplinary action.

Prosthetics and Orthotics International, 1991, 15, 243–244

ISPO Update Course on *Lower Limb Amputations and Related Prosthetics*

30th January–2nd February, 1992
Groningen, The Netherlands

Introduction

The format of this first **up-date** course following the Consensus Conference in Glasgow, October 1990 will be **review lectures** based on the presentations at the consensus conference and the points from the discussions leading to contemporary recommedations.

Ample time will be allocated for elucidation and discussion with the participants. The course is aimed at vascular surgeons, general surgeons, orthopaedic surgeons, rehabilitation specialists, prosthetists and other members of the amputation team.

Place

Martinihal Congress Centre Groningen, the Netherlands.

Time

January 30–February 2, 1992. Lecture programme starting from Thursday 14.00 hrs till Sunday 12.00 hrs.

Course fee

Covers lectures and consensus materials and will be 3,800DKK for ISPO-members and 4,500DKK for non-members. Refunds will be available until December 15, 1991, with a retention of 800DKK to cover administrative costs.

The course fee will also include coffee, tea, lunches and two receptions which will be offered on Thursday and Friday. On Saturday February 1, 1992 a dinner will be organized (optional).

Hotel

A reduced price covering three nights (incl. breakfast) will be 1,245DKK.

Registration form

Mail to ISPO, Borgervænget 5, DK-2100 Copenhagen Ø, Denmark. Payment will be due together with registration form as a bank-cheque in DKK-currency or copy of post-giro draft mailed to giro account 1 61 93 30. Personal cheques are not accepted. The number of participants is limited and will be served on a first come basis.

(continued over)

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Course fee:

☐ ISPO Member 3,800DKK

☐ Non-member 4,500DKK

☐ Dinner, Saturday February 1 300DKK

Altea Hotel fee:

☐ Single room 1,245DKK

☐ Double room 1,245DKK

Name of accompanying person

____

☐ Dinner 300DKK

Payment is enclosed as ☐ Bank-cheque ☐ Postgiro-draft amounting to: ____________

Date: ____________________ Signature: ____________________

Preliminary Programme

Day 1

Tissue Viability and Level Selection

Stump Environment

Patient Management

Free Papers

Day 2

General Principles

Above-Knee Amputations

Above-Knee Prosthetics

Amputations in Congenital Deformities and the Growth Period

Free Papers

Day 3

Knee Disarticulation

Through-Knee Prosthetics

Below-Knee Amputations

Below-Knee Prosthetics

Amputation in Trauma

Free Papers

Day 4

Ankle and Foot Amputations

Neuropathic Foot

Free Papers

Course organizers

Prof. Emeritus George Murdoch, Scotland.
Dr. J. Steen Jensen, Denmark.
Dr. H. C. Thyregod, Denmark.

Faculty

Denmark: J. Steen Jensen MD, E. Lyquist CPO, H. C. Thyregod MD.
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USA: J. Bowker MD, F. Gottschalk MD, M. Stills, CO.

Description of resort

Groningen is a 950 years old city with many historical spots. The 375 years old University is one of the basic elements in the city with its 18,000 students. Many fine restaurants, pubs and typical Dutch locations guarantee a pleasant stay in Groningen.

Accommodation

Rooms have been reserved in Hotel Altea, next door to the Martinihal Congress Centre. This hotel is a Pullman International Hotel with an indoor swimming pool. A reduced price has been arranged for participants of this course. Partners are welcome without any additional charge for hotel accommodation.

Transport

By plane to Amsterdam; there is a train every 30 minutes from Amsterdam Airport to Groningen.

Organizing Committee the Netherlands

Dr. J. H. Arendzen
Prof. W. H. Eisma
Mrs. P. H. Zweerts de Jong

This form should be posted on completion to:

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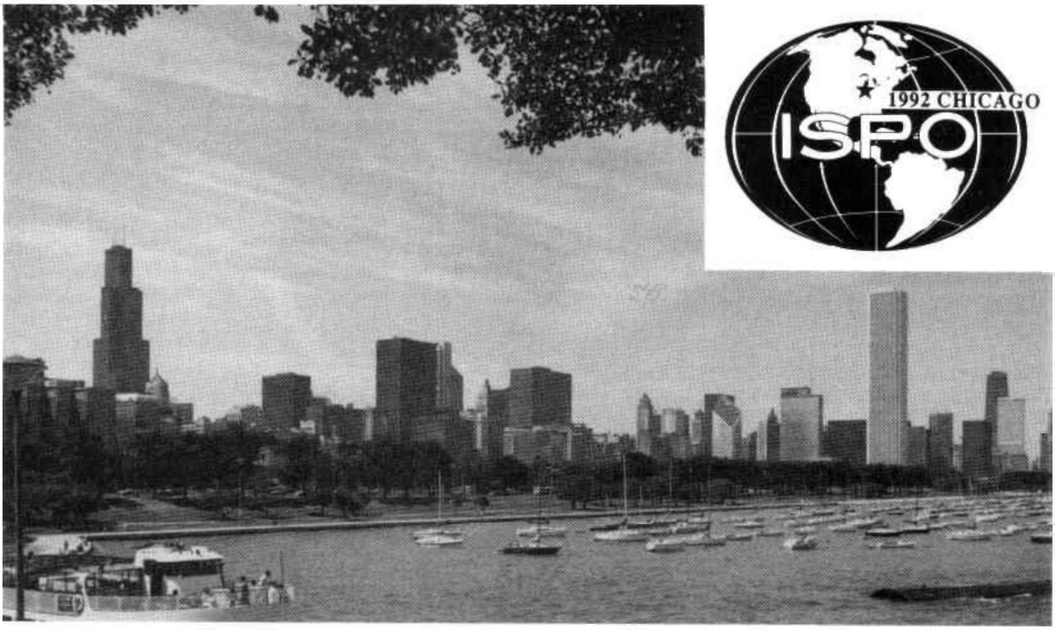
Prosthetics and Orthotics International, 1991, 15, 245–258



VII World Congress

28 June—3 July, 1992, Chicago, Illinois, USA

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President's Message

The Triennial World Congress is the most important event in the Society's calendar of seminars, symposia and courses. This is the second time that it will be held in the United States of America. The first time the Congress was held in the USA, it took place in New York, and it is now appropriate that the seventh Congress will be in Chicago, a place which can be easily reached from all the continents of the world. I know that the membership at large is pleased that this international event is being organized by the US National Member Society.

The International Congress Committee has assembled an excellent program with the theme, "Find the World of Prosthetics and Orthotics Developing Around the Globe." The seventh World Congress will consist of scientific, technical, clinical and surgical papers, general sessions, symposia and instructional courses; scientific and commercial exhibits; poster sessions; a video and film program; and technical tours. It is important to emphasize that the scientific program is enhanced by the commercial exhibitors' and manufacturers' presentation within the scientific program itself. The activities of the practitioners and industry are of great importance and can lead to a better understanding of the patient and the consumer. The state of the art will be presented as far as prosthetics, orthotics and rehabilitation technology is concerned. It is evident that this World Congress, more than ever, will be focused on developing countries as well as on that fact at the end of 1992, the borders of Europe will be open.

Education to achieve the highest possible level of practice in each profession in this field has to be our goal. Standards and professional levels are seen to be of great importance to protect the quality of care, education and research, both nationally and internationally. The Seventh World Congress in Chicago functions to facilitate these aims.

Besides all the scientific activities, a wonderful social program has been organized. This program shows the hospitality of several institutes and several societies who are supporting the Seventh World Congress. The Congress ends with the American celebrations of the 4th of of July. I would like to urge you and all the Society's members, as well as the membership of our collaborating organizations, to take part in this unique event. Come and join us in Chicago in 1992.

William H. Eisma
President, ISPO

An Invitation to Attend

The International Society for Prosthetics and Orthotics (ISPO) cordially invites you to attend its Seventh World Congress in Chicago, Illinois, USA, June 28 to July 3, 1992. The Congress, a triennial event, provides a rare chance for you to meet practitioners and researchers of the field from all over the globe. The Society's multidisciplinary nature means that attendees can hear and interact with the world's leaders in orthotics and prosthetics, whether they be physical therapists, prosthetists, orthotists, surgeons, physicians, engineers, nurses, occupational therapists, consumers, or rehabilitation specialists.

In addition, the Congress' Scientific and Commercial Exhibition enables everyone to become aware of what is available worldwide in prosthetics and orthotics technology, tools, and practice.

The Congress will feature a daily program that begins in the morning with instructional courses (basic and advanced) and commercial workshops; followed by commercial and scientific exhibits, video and film programs, review sessions where world-renowned specialists present state-of-the-art practice, and poster and paper sessions that cover a range of advancements in the fields of prosthetics and orthotics.

A full social program is planned, as well as activities for accompanying persons. For attendees, social highlights include:

- A Welcoming Reception following the opening ceremonies sponsored by the Orthotics and Prosthetics National Office
- A reception and tour of the Rehabilitation Institute of Chicago, including Northwestern University's laboratories and educational facilities
- Heartland Night
- Chicago sightseeing and technical tours
- the Congress Banquet
- the World Assembly of ISPO.

We invite you to plan your vacation schedule around the Congress. Chicago is a great place for a vacation. It is a cosmopolitan, but very American, city. Catch the spirit that Lorenz Hart describes in his song, "Chicago" –

There's a great big town
On a great big lake
Called Chicago.
When the sun goes down
It is wide awake.
Take your ma and your pa,
Go to Chicago.
Boston is England
N'Orleans is France,
New York is anyone's
For ten cents a dance.
But this great big town
On that great big lake
Is America's first
And Americans make
Chicago. *

*"Chicago", Music by Richard Rogers, Lyrics by Lorenz Hart, from John O'Hara's musical *Pal Joey,* Act I Scene III.

Join us in Chicago in 1992!

Dudley S. Childress
General Secretary
VII World Congress

Program At A Glance

	JUNE 28, 1992 Sunday	JUNE 29, 1992 Monday	JUNE 30, 1992 Tuesday	JULY 1, 1992 Wednesday	JULY 2, 1992 Thursday	JULY 3, 1992 Friday
07.30 HOURS		Registration (until 17.00 hrs) Continental Breakfast for Course Attendees	Registration (until 17.00 hrs) Continental Breakfast for Course Attendees	Registration (until 17.00 hrs) Continental Breakfast for Course Attendees	Registration (until 17.00 hrs) Continental Breakfast for Course Attendees	Registration (until 10.00 hrs) Continental Breakfast for Course Attendees
08.00 HOURS	Registration (until 17.00 hours)	Instructional Courses Tutorial Courses Manufacturers' Workshops	Instructional Courses Tutorial Courses Manufacturers' Workshops	Instructional Courses Tutorial Courses Manufacturers' Workshops	Instructional Courses Tutorial Courses Manufacturers' Workshops	Instructional Courses Tutorial Courses Manfuacturers' Workshops
09.30 HOURS		Coffee Break in Exhibit Hall Exhibits Open (until 17.00 hrs)	Coffee Break in Exhibit Hall Exhibits Open (until 17.00 hrs)	Coffee Break in Exhibit Hall Exhibits Open (until 17.00 hrs)	Coffee Break in Exhibit Hall Exhibits Open (until 17.00 hrs)	Coffee Break in Exhibit Hall Exhibits Open (until 17.00 hrs)
10.00 HOURS	Instructional Courses Tutorial Courses Manufacturers' Workshops	Posters, Video and Film Prog (until 17.00 hrs) Overview Sessions	Overview Sessions	Video and Film Prog. (until 12.00 hrs) Overview Sessions	Posters, Video and Film Prog (until 17.00 hrs) Overview Sessions	Overview Sessions
11.00 HOURS		Overview Sessions	Overview Sessions	Overview Sessions	Overview Sessions	*(11.15 hours)* World Assembly Prize Presentations Australian 8th World Congress Official Closing Ceremonies
12.00 HOURS		Luncheon in Exhibit Hall	Luncheon in Exhibit Hall	*Afternoon and Evening:* Sightseeing and Technical Tours See details on following pages	Luncheon in Exhibit Hall	
13.00 HOURS						Congress Ends
13.30 HOURS		Scientific, Technical and Clinical Sessions Symposia and Paper Sessions	Scientific, Technical and Clinical Sessions Symposia and Paper Sessions		Scientific, Technical and Clinical Sessions Symposia and Paper Sessions	American celebration of the 4th of July (American Independence Day), Grant Park and other locations.
14.00 HOURS	Opening Ceremonies Official Opening Knud Jansen Lecture Prof. John Hughes					
15.00 HOURS		Coffee Break in Exhibit Hall	Coffee Break in Exhibit Hall		Coffee Break in Exhibit Hall	
15.30 HOURS		Scientific, Technical and Clinical Sessions Symposia and Paper Sessions	Scientific, Technical and Clinical Sessions Symposia and Paper Sessions		Scientific, Technical and Clinical Sessions Symposia and Paper Sessions	
16.00 HOURS	Exhibits Open					
17.00 HOURS		Sessions End	Sessions End		Sessions End	
18.00 HOURS		Reception and Open House at Rehab Institute of Chicago and Northwestern University				
18.30 HOURS	Welcoming Reception Sponsored by Orthotics and Prosthetics National Office					
20.00 HOURS					World Congress Banquet Entertainment, Music, and Dancing until 24.00 hours	
21.00 HOURS						

Program

Sunday — June 28, 1992

08.00 hrs	Registration (until 17.00 hours)
10.00 hrs	Instructional Courses Manufacturers' Workshops
14.00 hrs	Opening Ceremonies Official Opening Knud Jensen Lecture — Professor John Hughes
16.00 hrs	Exhibits Open
18.30 hrs	Welcoming Reception *Sponsored by Orthotics and Prosthetics National Office*

Monday — June 29, 1992

07.30 hrs	Registration (until 17.00 hours)
07.30 hrs	Continental Breakfast for Instructional Course Attendees
08.00 hrs	Instructional Courses Tutorial Courses Manufacturers' Workshops
09.30 hrs	Coffee Break in Exhibit Hall Commercial and Scientific Exhibits (until 17.00 hours)
10.00 hrs	Posters (until 17.00 hours) Video and Film Program (until 17.00 hours)
10.00 hrs	Overview Sessions
11.00 hrs	Overview Sessions
12.00 hrs	Luncheon in Exhibit Hall
13.30 hrs	Technical and Clinical Sessions Symposia Scientific Sessions
15.00 hrs	Coffee Break in Exhibit Hall
15.30 hrs	Technical and Clinical Sessions Symposia Scientific Sessions
17.00 hrs	Sessions End
18.00 hrs	Reception and Open House *Hosted by the Rehabilitation Institute of Chicago and Northwestern University*

Tuesday — June 30, 1992

07.30 hrs	Registration (until 17.00 hrs)
07.30 hrs	Continental Breakfast for Instructional Course Attendees
08.00 hrs	Instructional Courses Tutorial Courses Manufacturers' Workshops
09.30 hrs	Coffee Break in Exhibit Hall Commercial and Scientific Exhibits (until 17.00 hours)
10.00 hrs	Posters (until 17.00 hours) Video and Film Program (until 17.00 hours)
10.00 hrs	Overview Sessions
11.00 hrs	Overview Sessions
12.00 hrs	Luncheon in Exhibit Hall
13.30 hrs	Technical and Clinical Sessions Symposia Scientific Sessions
15.00 hrs	Coffee Break in Exhibit Hall
15.30 hrs	Technical and Clinical Sessions Symposia Scientific Sessions
17.00 hrs	Sessions End
21.00 hrs	Heartland Night *A fun-filled social occasion allowing you to enjoy square dancing, and music from the American Midwest*

Wednesday — July 1, 1992

07.30 hrs	Registration (until 17.00 hrs)
07.30 hrs	Continental Breakfast for Instructional Course Attendees
08.00 hrs	Instructional Courses Tutorial Courses Manufacturers' Workshops
09.30 hrs	Coffee Break in Exhibit Hall Commercial and Scientific Exhibits (until 12.00 hours)
10.00 hrs	Video and Film Program (until 12.00 hours)
10.00 hrs	Overview Sessions
11.00 hrs	Overview Sessions
Afternoon and Evening	*Sightseeing Tours:* • Life along the North Shore • Museum of Science and Industry • Field Museum — Adler Planetarium — Shedd Aquarium • Frank Lloyd Wright Architecture Tour • Baseball Game • Architectural River Tour • Jazz and Blues Clubs • Ravinia Theatre and Box Supper *Technical Tours:* • VA/Hines Hospital • Rush Presbyterian St. Lukes Hospital • Pritzker Institute for Medical Engineering • Select Private P&O Facilities

Thursday — July 2, 1992

07.30 hrs	Registration (until 17.00 hrs)
07.30 hrs	Continental Breakfast for Instructional Course Attendees
08.00 hrs	Instructional Courses Tutorial Courses Manufacturers' Workshops
09.30 hrs	Coffee Break in Exhibit Hall Commercial and Scientific Exhibits (until 17.00 hours)
10.00 hrs	Posters (until 17.00 hours) Video and Film Program (until 17.00 hours)
10.00 hrs	Overview Sessions
11.00 hrs	Overview Sessions
12.00 hrs	Luncheon in Exhibit Hall
13.30 hrs	Technical and Clinical Sessions Symposia Scientific Sessions
15.00 hrs	Coffee Break in Exhibit Hall

15.30 hrs Technical and Clinical Sessions
Symposia
Scientific Sessions
17.00 hrs Exhibits End; Sessions End
20.00 hrs Banquet of 7th World Congress
Entertainment by "The New Generation" Gospel Singers
Music & Dancing until 24.00 hours

Friday — July 3, 1992
07.30 hrs Registration (until 10.00 hrs)
07.30 hrs Continental Breakfast for Instructional Course Attendees
08.00 hrs Instructional Courses
Tutorial Courses
Manufacturers' Workshops
09.30 hrs Coffee Break in Exhibit Hall
10.00 hrs Overview Sessions
11.15 hrs World Assembly
Prize Presentations
Australian 8th World Congress
Official Closing Ceremonies
13.00 hrs Congress Ends

American Celebration of the 4th of July (American Independence Day), Grant Park and other locations

Program Details

Overview Sessions

The Overview Sessions will consist of 30 minute oral presentations followed by a pre-arranged ten minute response, the presenter will have an additional five minute response time. After the presentations and responses, ten minutes will be available for questions.

Topics to be presented include:

- To Amputate or Preserve the Severely Injured Limb
- Surgical Management of Limb Deficient Children
- Limb Salvage vs. Amputation and Rehabilitation in Dysvascular Patients
- Tissue Conserving Amputation
- Below-Knee Suspension Variants
- Conservative Management of the Diabetic Foot
- Tone Reducing Orthoses: Myth or Reality?
- Above-Knee Socket Design
- CAD/CAM in Prosthetics
- Prosthetic Foot Mechanisms
- Pediatric Myoelectric Fittings
- Advances in Upper Limb Prostheses
- Upper Limb Orthotic Management
- Seating and Service Delivery: Orthotics or Engineering
- Lower Limb Orthotics: Walking or Wheelchair
- Stroke Management
- Prosthetics in the Third World — The Vietnam Experience
- Geriatric Amputation and Prosthetics Management
- Orthopaedic Footwear
- The Limb Deficient Person: Fitting and Care

Overview Sessions Program

	Mon, June 29	Tues, June 30	Wed, July 1	Thurs, July 2	Fri, July 3
	Hall A	*Hall A*	*Hall A*	*Hall A*	*Hall A*
10.00-11.00	To amputate or preserve the severely injured limb	Surgical management of limb deficient children	Paediatric myoelectric fittings	Conservative management of the diabetic foot	Stroke management
11.00-12.00	Limb salvage versus amputation and rehabilitation in dysvascular patients	Tissue conserving amputation	Advances in upper limb prostheses	Orthopaedic footwear	(11.15) World Assembly Prize Presentations Australian 8th World Congress Official Closing Ceremony
	Hall B	*Hall B*	*Hall B*	*Hall B*	*Hall B*
10.00-11.00	Prosthetic foot mechanisms	CAD/CAM in prosthetics	Tone reducing orthoses, myth or reality?	Upper limb orthotic management	Seating and service delivery (orthotics or engineering)
11.00-12.00	Below-knee suspension variants	Prosthetics in the Third World — the Vietnam experience	Lower limbs orthotics, walking or wheelchair	The limb deficient person (fitting and care)	
	Hall C	*Hall C*	*Hall C*	*Hall C*	*Hall C*
10.00-12.00			Above-knee socket design		
11.00-12.00			Geriatric amputation and prosthetics management		

Symposia

Symposia papers have the same scientific value as posters and contributed papers; however, symposium papers have been solicited.

Symposia topics include:

- Orthotic Management of Lower Back Pain
- Pain Management
- Above-Knee Surgery
- P&O Education Worldwide
- Management of Spasticity
- Tone Reducing Orthoses
- Limb-Socket Modelling
- Management of Severe Limb Trauma
- Spinal Biomechanics
- Occupational Therapy in P&O
- Orthopaedic Foot Care
- Physical Therapy in P&O
- Sports and Recreation
- Club Feet
- Knee Disarticulation
- CAD/CAM of Sockets
- Active Knee Mechanism Development
- Pediatric Prostheses
- Prehensor Design and Use
- Cineplasty and Variants
- Advances in Vascular and Plastic Surgery Related to Amputation and Limb Salvage
- Limb Viability
- Advances in Hand Management
- Geriatric Amputee Management
- Prosthetics and Orthotics in History
- Clinical Applications of Gait Analysis
- New Locomotion Aids
- Tissue Mechanics and Socket Design
- Control of Upper Limb Prostheses
- Biomechanical Modelling of Locomotion
- Orthotics and Functional Electrical Stimulation (FES)
- P&O International Status
- Consumer Symposium
- Measurement of Pressure and Shear
- Mechanical Design in P&O
- Gait Training for the Leg Amputee
- Hip Disarticulation Fittings
- Early Post Trauma Management of Persons with Spinal Cord Injury (SCI)
- Management of the Arthritic and Deformed Foot
- Orthotic and Therapeutic Management of Stroke Patients
- Orthotic Management of Bone Fractures
- Seating and Positioning
- Lower Limb Orthotics
- Upper Limb Orthotics
- Management of Brachial Plexus Injuries
- Management of the Upper Limb in Spinal Cord Injuries
- Introductory Biomechanics
- Advanced Biomechanics
- Biomechanics of Human Locomotion
- Wheelchair Biomechanics and Prescription
- Amputation Surgery
- Hand Surgery and Prosthetic Replacement
- Post-Surgical and Early Management of Below-Knee and Above-Knee Amputations
- CP Surgical Management
- Mangement of the Diabetic Foot
- Surgical Management of Spinal Fractures
- How to Run a Small Business with CAD/CAM
- Clinical Applications of Gait Analysis
- Survey of Modern Motion Analysis Equipment
- Sockets for Upper Limb Prosthetics
- Upper Limb Prosthetics
- Clinical Fitting and Care of High Level Bilateral Amputees
- Training of Upper Limb Amputees
- Myoelectric Training of Children

Instructional Courses

Instructional courses in prosthetic/orthotic topics will be offered as part of the Congress. The cost of each course is $50 (in US dollars), payable at the time of registration.

The program of courses is shown on side 2 of the Congress Registration form.

To enroll in a course, specify your choice(s) on side 2 of the Congress Registration form. Enrollment is on a first-come, first-served basis.

Upon receipt of your registration, you will be notified as to which course you are enrolled in, and the time and place of the course session.

Courses include:

- Advanced Below-Knee and Symes Fitting Practice
- Management of the Geriatric Amputee
- Above-Knee and Through Knee Fitting Practice
- CAD/CAM in Small Private Practice

Papers and Presentations

Knowledge in the field of prosthetics, orthotics, and rehabilitation engineering is expanding at a rapid rate and one of the objectives of the Congress is to provide an international forum for the sharing of clinical, technical, and scientific advances in these fields. This will be accomplished in part by regular paper sessions, symposia, poster sessions, and an audiovisual program. All papers and presentations will be summarised in the Congress Proceedings. Each applicant will be notified in writing by March 15, 1992 as to the acceptance of his/her application.

Papers

Papers will be presented in contributed paper sessions and organised symposia. Oral presentations in regular paper sessions and in symposia will be limited to 15 minutes, including discussion. All papers must be presented in English. A single 35mm slide and overhead projecters will be available to presenters.

Substantive content and new findings in the covered fields are criteria for paper acceptance.

Papers will concisely present the objective, methodology, results and significance of the work reported. Preliminary results may be reported. All papers will be represented in the Congress Proceedings.

To submit a paper for the Congress, contact the Congress Secretariat, Moorevents, Inc., for an application and Author's Kit. The deadline for receipt of papers and applications is January 15, 1992.

Posters

Oral and poster presentations are considered of equal scientific value. Posters will be displayed for one day each in the Exhibit Hall of the hotel. Presenters will be on hand when their posters are displayed to answer your questions and to promote discussion. Poster summaries will be represented in the Congress Proceedings.

To submit a poster for the Congress, contact the Congress Secretariat, Moorevents, Inc., for an application and Author's Kit. The deadline for receipt of poster applications is also January 15, 1992.

Audiovisuals

An audiovisual program of film, video, and slides will be a highlight of this Congress. Each audiovisual presentation will be 30 minutes long. Audiovisual presentation summaries will be represented in the Congress Proceedings.

To submit an audiovisual for the Congress, contact the Congress Secretariat, Moorevents, Inc., for an application and Author's Kit. The deadline for receipt of audiovisual applications is January 15, 1992.

Awards

The Brian Blatchford Prize

This prize was established by the Blatchford family to honour the memory of Brian Blatchford. It is awarded every three years at a World Congress of ISPO for an outstanding innovation in prosthetics and/or orthotics practice. The innovation should be related to a piece of prosthetic and/or orthotic hardware, or a scientifically based new technique which results in a better prosthesis or orthosis. The innovation should have reached a sufficiently advanced stage to ensure that it can be used successfully on patients.

The prize to be awarded at the Seventh World Congress of ISPO will be £2200. The prize-winning innovation will be presented at the Congress and published in *Prosthetics and Orthotics International.*

To be considered for this prize, the applicant or nominator should present evidence detailing the innovation, together with a sample of the device if appropriate, to the President of ISPO by February 29, 1992.

Applications and nominations should be sent to:

Professor W. H. Eisma
Elswout 2
9301 TS Roden
The Netherlands

The President and Executive Board of ISPO and the Blatchford family reserve the right to withhold the prize should no suitable applicant be found.

The Forchheimer Prize

This prize was established by the Forchheimer family to honour the memory of Alfred Forchheimer. It is awarded every three years at a World Congress of ISPO for the most outstanding paper on objective clinical assessment, clinical evaluation, or clinical measurement published in *Prosthetics and Orthotics International* during the three years prior to the Congress.

The President and Executive Board of ISPO and the Forchheimer family reserve the right to withhold the prize should no suitable paper be published.

Exhibits

The Congress offers a unique opportunity for manufacturers and distributors of prosthetic and orthotic products to show these products to a worldwide audience of prosthetists, orthotists, nurses, rehabilitation specialists, and others.

The Congress gives international exhibitors a chance to investigate the large market for prosthetic and orthotic products that exists in the USA. Likewise, American exhibitors can explore international business opportunities. All exhibitors can use the Congress to meet and hear the leading practitioners and researchers of the field from all over the globe.

The Congress gives attendees a chance to see first-hand the marketing, production, and distribution of prosthetic/orthotic products and to talk with the manufacturers of these products.

The Congress Exhibition will take place in Wacker Hall, adjacent to all the Congress meeting rooms. Viewing of the exhibits will be encouraged by a special Exhibits Opening Ceremony on one of the first days of the Congress. Lunches and coffee breaks will take place in the exhibit area, and generous exhibit hours will be provided so you can view the exhibits at your leisure.

For more information on the Congress Exhibition, contact the Congress Secretariat, Moorevents, Inc.

Special Events

Opening Reception

All Congress attendees are invited to attend this gala reception, sponsored by the Orthotics and Prosthetics National Office, following the official Opening Ceremonies of the Congress and of the Exhibition Hall. At the reception, you will be introduced to American sports, complete with an opportunity to try your luck at baseball, basketball, golf, and soccer. Sample Chicago's popular "ball park" snack food and join the festivities as a uniformed marching band performs for your pleasure. The Opening Reception will be held in the West Tower Lobby and Plaza of the Hyatt Regency. Dress is casual.

Heartland Night

Experience some "down home" music and dancing. Learn to square dance, a popular form of American folk dance, and enjoy an evening of fun and friendship. Dress is casual.

Reception and Open House at the Rehabilitation Institute of Chicago (RIC)

Hosted by the RIC and Northwestern University (NU). Open to all Congress attendees and accompanying persons. Visit the Northwestern University Prosthetic-Orthotic Education Center, the Prosthetics and Orthotics Clinical Services Department of the RIC, the Prosthetics Research Laboratory, the Rehabilitation Engineering Program, RIC Occupational & Physical Therapy Departments, NU Physical Therapy School, and other facilities of the RIC and NU.

Closing Banquet

On Thursday evening, enjoy a lovely dinner and dance to the music of one of America's top dance bands. You will be entertained by the *New Generation*, one of America's foremost gospel singing groups, who regularly appear on television and in concert all over the United States. They are Chicago's own and we are proud to present their unique music to you. To attend this banquet, you must purchase a ticket. See the registration form. Dress is semi-formal.

Technical Tours

All offered Wednesday afternoon, July 1, 1992. Note: If a minimum number of persons is not reached, the tour will be cancelled. Registration for these tours will occur upon your registration and check-in at the Congress site.

Technical Tours include:

- Veterans Administration/Hines Hospital (Rehabilitation Engineering Center)
- Rush Presbyterian St. Lukes Hospital (Gait Analysis Laboratories)
- Pritzker Institute for Medical Engineering (Illinois Institute of Technology)
- Select Private Prosthetic & Orthotic facilities

Accompanying Persons Program

Included in their Congress registration fee, accompanying persons can visit the Congress Exhibition Hall, attend the Welcoming Reception and reception at the Rehabilitation Institute of Chicago, and attend Heartland Night and the Congress Banquet.

Accompanying persons also have access to *The Sporting Club*, a private health and fitness club adjacent to the Hyatt and available to all hotel guests for a daily fee. The facilities include fitness machines, a running track, a climbing wall, a complete European spa, racquetball and squash courts, a swimming pool, and a basketball court. The hotel concierge can assist you in making reservations.

Daily tours and activities for accompanying persons consist of a choice of five tours of Chicago sights and landmarks all offered on Monday, Tuesday, and Thursday mornings for a separate fee. Accompanying persons may also register for sightseeing and technical tours on Wednesday afternoon and evening as described below. Note: If a minimum number of persons per tour is not reached, the tour will be cancelled.

Tour A: Architectural River Cruise. Same as Tour B under Sightseeing, below.

Tour B: Frank Lloyd Wright Architectural Tour. Same as Tour F under Sightseeing, below.

Tour C: Life Along the North Shore. Same as Tour A under Sightseeing, below.

Tour D: Art Institute. Cost: $30.00 US. Time: 3 hours. Includes transportation, guide, admission.

A world class institution, the Art Institute is best known for its collection of Impressionist and Post-Impressionist paintings. However, with collections that span 40 centuries, the museum has much more to offer in its many collections and exhibits. The tour will include a guided walk, time for browsing, and if desired, tickets to the current special exhibit.

Tour E: Museums of the Magnificent Mile and River North Galleries. Cost: $42.00 US. Time: 5.5 hours. Includes transportation, guides, admissions, and lunch.

The Magnificent Mile is home to two small jewel-like musuems — the Museum of Contemporary Art and the Terra Museum of American Art. Tour them both and then we will bus over to River North for lunch and a walk through the city's most exciting art galleries. The area is the center of Chicago's bustling art scene.

Sightseeing Tours

All offered Wednesday afternoon, July 1, 1992. Note: If a minimum number of persons per tour is not reached, the tour will be cancelled. Please register for these tours using the Congress Registration form at the back of this booklet.

Tour A: Life Along the North Shore. Cost: $42.00 US. Time: 6.5 hours. Includes transportation, guide, lunch.

To many people, the North Shore area is synonymous with a lifestyle of comfort and ease. This bus tour will look at some magnificent homes on the North Shore, along with Northwestern University, the Bahai Temple, the North Shore Congregation Israel, and the Chicago Botanic Gardens. Stops will be made to see the interiors of Bahai and North Shore Congregation. Another stop will be at the Botanic Gardens to take a stroll through the gardens and to have lunch.

Tour B: Architectural River Cruise. Cost: $45.00 US. Time: 2.25 hours. Includes transportation, guided cruise, lunch.

Chicago has a magnificent architectural heritage. What better way to explore it than on a comfortable cruise on the Fort Dearborn. We will supply a box lunch and an architectural guide will supply "food for thought", an informed narrative focusing on Chicago's skyline as viewed from the river. Photographers, this one's for you!

Tour C: Chicago's Major Museums in the Park. Cost: $50.00 US. Time: 5 hours. Includes transportation, admissions, guide, literature, and lunch.

Chicago's merchant princes have endowed her with three world class museums clustered at the periphery of Grant Park. Visitors on this tour will see the sky show at the Adler Planetarium, the show featuring the whales and porpoises in the new Oceanarium at the Shedd Aquarium, and an Egyptian tomb at the Field Museum. There will be ample time to explore the other exhibits at each museum and to enjoy lunch.

Tour D: Take Me Out to the Ball Game. Cost: $34.00 US. Time: 4 hours. Includes admission and transportation.

Have your peanuts, popcorn, and crackerjack either at the new Comiskey Park to cheer the White Sox, or at Wrigley Field, home of the Chicago Cubs. If the White Sox play in the evening, this tour will be offered on Wednesday evening.

Tour E: Museum of Science and Industry. Cost: $31.00 US. Time: 3.5 hours. Includes transportation, movie, guide, maps, and literature.

The Museum of Science and Industry is a thoroughly modern "hands on" museum housed in a building built for the 1893 Columbian Exposition. Among the exhibits are a German submarine captured in WWII, a coal mine, the famous whispering gallery, Coleen Moore's Doll House, and the Henry Crown Space Center. The tour will also include a film in the Omnimax Theater — a movie projected on a 70 foot domed screen that makes the viewer part of the scene.

Tour F: Frank Lloyd Wright Architectural Tour. Cost: $30.00 US. Time: 3.5 hours. Includes transportation, guide, admissions, and literature.

This is an opportunity to see the work of the genius who revolutionised residential architecture. We will trace the development of the Prairie House from our bus as we view the many Frank Lloyd Wright houses in Oak Park and River Forest. We will also have an interior tour of Wright's completely restored home and studio and his famous Unity Temple.

Tour G: An Evening at Ravinia. Evening tour. Cost: $60.00 US. Time: 6 hours. Includes transportation, ticket, box supper, and guide.

Located 45 minutes from the heart of Chicago, Ravinia provides the perfect summertime setting for exceptional music under the stars in a beautiful 35 acre park. This evening will include a gourmet basket supper, cash bar, transportation, and reserved concert seats.

Tour H: A Little Night Music. Evening tour. Cost: $45.00 US. Time: 3 hours. Includes transportation, guide, all cover and entertainment charges.

Some of Chicago's best musicians will introduce you to jazz and blues music, Chicago style. During the 1920s, Chicago was the jazz capital of the nation. Today the jazz scene is still a vital part of the city's cultural life. The first half of this century also brought Mississippi Blues to Chicago's south side, home of legends Muddy Waters and Jimmy Reed. You will visit two of Chicago's best jazz and blues clubs.

Travel Information

A special travel program offering significant savings on air travel to Chicago is available for Congress participants.

Please make your travel arrangements as early as possible. Seating will be limited in some discount categories. These special discount fares are available only to VII World Congress of ISPO participants traveling to Chicago between 25 June and 6 July, 1992.

Official Congress airlines
American Airlines.

Official Congress travel agency
Carlson Travel Network.

For North American Attendees

To take advantage of the special rates described below, call Carlson Travel Network's toll free reservation number: 1-800-311-8132. Identify yourself as an ISPO Congress participant. This number is available from 08.30 to 17.00 hours, Monday through Friday, Chicago time.

Canadian participants may call on 312-372-3313.

All travel requests may also be faxed on 312-372-3499.

Options

- 5% discount off all published fares, ranging from first class to the deeply discounted super-saver fares. All restrictions on the fare must be met to qualify for the discount.
- 45% discount off the unrestricted, full fare domestic round trip coach fare. Three-day advance purchase is required, and there are no cancellation or change fees.
- 40% discount off the unrestricted full coach fare for trips originating in Canada. Seven day advance purchase is required, and there are no cancellation or change fees.

For International Attendees

Special airfare rates are also available in conjunction with international travel to the Congress.

For more information, call 312-329-0330 or fax your request by calling 312-329-0533. Identify yourself as an ISPO Congress participant. These numbers are available from 08.30 to 17.00 hours, Monday through Friday, Chicago time.

American Airlines Star Number

If you plan on calling American Airlines directly, without going through Carlson Travel Network, you must refer to the following Star Number to get the special Congress travel rates:

Star # S7562KT

Pre- and Post-Congress Travel

Carlson Travel Network has developed an attractive program of travel tours throughout North America designed for international delegates. These tours are offered by Carlson Travel Network's special ISPO vacation department at the same discounted fares offered for travel to and from the Congress. To obtain copies of the brochures, call the number above.

Visa Regulations

Most travellers to the United States must obtain visas at home before beginning their trip. Exceptions are made for some travellers from countries included in the Visa Waiver Pilot Program. Information on US visa requirements is available from all United States embassies and consulates.

Special Assistance for Persons with Disabilities

Assistance for persons with disabilities is available. If you have a special need for transportation, lodging, or seating, please indicate this to Carlson Travel, the airlines, and on your registration and hotel forms.

Additional General Information

Climate

High temperatures in Chicago during early summer average 28°C (83°F); however, the continental weather is highly variable and deviations of ±10°C (±18°F) from the norm may occur.

Language

The official language of the Congress is English.

Electrical Current

The electrical current in the United States is 110/220 volts and operates on 60Hz.

Shopping

Chicago is a shopper's paradise, all within walking distance to the Hyatt Regency Chicago. Stores are generally open 10.00—18.00 hours Monday through Staturday. Speciality malls (mostly indoors with multiple shops within) along Michigan Avenue and in suburban areas are open on Sundays from 12.00 hours until 17.00 hours.

Foreign Currency

Foreign currency may be exchanged in the International Terminal at O'Hare International Airport, at the Hyatt Regency Chicago Hotel, or at the numerous banks in close proximity to the hotel at a more favourable exchange rate.

Congress Registration Information

To register for the Congress and Congress functions fill out the form at the end of this announcement. Accompanying person registrations are also included on this form.

Registration as an attendee (member, non-member, student, one-day) includes entry to all Congress events (with the exception of lunches, the Banquet and sightseeing tours). Registration as an accompanying person includes items previously described.

The Congress site at the Hyatt Regency Chicago Hotel is accessible to persons with disabilities. If you have special needs, please note this on your registration form.

The Early Registration deadline is April 1, 1992. Please allow adequate time for mail delivery so as to meet this deadline. Upon receipt of your form and proper fees, you will be sent a confirmation of your registration.

Full payment of all fees is included when you send in your registration form. Checks and money orders must be payable to "VII World Congress of ISPO" in US dollars drawn on a US bank. Failure to do so will result in bank charges that will be invoiced to the attendee. You may also charge your fees to VISA or Mastercard.

Mail all forms and fees to:
Secretariat, VII World Congress of ISPO
c/o Moorevents Inc.,
676 North St. Clair St., Suite 1765
Chicago, IL 60611 USA

Congress Registration Fees and Dates for Regular Attendees (Members)

If you register . . .	Your fee is . . .
Before April 1, 1992	$400 (in US dollars)
After April 1, 1992	$500
One-day registration	$180

Social functions for one-day registrants are available for an additional fee.

Congress Registration Fees and Dates for Regular Attendees (Non-Members)

If you register . . .	Your fee is . . .
Before April 1, 1992	$520 (in US dollars)
After April 1, 1992	$620
One-day registration	$220

Social functions for one-day registrants are available for an additional fee.

Congress Registration Fees and Dates for Students

If you register . . .	Your fee is . . .
Before April 1, 1992	$200 (in US dollars)
After April 1, 1992	$250
One-day registration	$100

Proof of student status required.
Social functions for one-day registrants are available for an additional fee.

Congress Registration Fees and Dates for Accompanying Persons

If you register . . .	Your fee is . . .
Before April 1, 1992	$150 (in US dollars)
After April 1, 1992	$200

Instructional Course Fees

The fee for each instructional course is $50 (in US dollars).

Fees for Meals, Banquet, Tours and Accompanying Persons Program

See the registration form and the appropriate pages in this announcement.

Hotel Registration Information

The Congress Hotel is the Hyatt Regency Chicago. The hotel is accessible to persons with disabilities, and a limited number of special accessible rooms exist. If you have special needs or need a special room, please note this on the hotel reservation form. Accessible rooms are available on a first-come, first-served basis.

Hotel guests have access to *The Sporting Club*, a private health and fitness club adjacent to the Hyatt, available for a daily fee. The facilities include fitness machines, a running track, a climbing wall, a complete European spa, racquetball and squash courts, a swimming pool, and a basketball court. The hotel concierge can assist you in making reservations.

A special hotel room rate is available to attendees of the Congress. The rate is $102 United States Dollars per night plus applicable taxes (currently 12.4%). This room rate applies to single or double occupancy.

The special room rate is available *only* by using the hotel reservation form at the back of this announcement.

The Early Registration deadline is June 3, 1992. Please allow adequate time for mail delivery so as to meet this deadline. Upon receipt of your form and proper fees, you will be sent a confirmation of your registration.

Mail all forms to:
Secretariat, VII World Congress of ISPO
c/o Moorevents, Inc.
676 North St. Clair St., Suite 1765
Chicago, IL 60611 USA

Late News

Full Announcement

In addition to these pages a separate full announcement of the Congress will be distributed by post within the next few weeks.

Manufacturers' Workshops

A number of Manufacturers' Workshops are being organised at present. It is the intention that they will be held in association with the Instructional Courses. Details of these Workshops will be circulated in the near future.

HOTEL RESERVATION FORM

Seventh World Congress of ISPO, June 28 to July 3, 1992
Hyatt Regency Chicago Hotel, Chicago, Illinois, USA
Deadline for *Receipt* of Early Registrations: June 3, 1992
After June 3: Reservations accepted as space available.

Personal Information

Name (Family Name, Given Name, Initial)

Title or Position

Company or Organisation

Mailing Address

Telephone/Fax

Accompanying Person(s) or other Attendees in room with you *(limit 2 persons per room):*

Registration Category *tick one*

☐ *Member* ☐ *Non-Member* ☐ *Student* ☐ *Exhibitor*

Would you like a room for persons with disabilities? Tick this box ☐ *(Special rooms are limited. Please request early.)*
Do you need other assistance because of a disability? Tick this box ☐ and describe needed assistance below:

Room Stay Information

Arrival Date: ______________ Estimated Time of Arrival: ______ am pm *(circle)*

Departure Date: ______________ *(Tickout is at 11.00 hours)*

Tick type of room desired:
☐ SINGLE $102 US plus tax per night How many rooms? ______
☐ DOUBLE $102 US plus tax per night How many rooms? ______
(All room rates are subject to state and local taxes, currently equivalent to 12.4%.)

Reservation Fees

One night's deposit is required to guarantee your hotel reservation. You may charge the fee ($102.00 US per room) to a major credit card, or you may issue a check, to be paid in US dollars, drawn on a US bank, payable to the "Hyatt Regency Chicago Hotel". Please note that bank charges will be incurred and you will be invoiced for those charges unless your check is drawn on a US bank. If you must cancel your reservation, contact the hotel directly, before 16.00 hours on the day of arrival.

Please charge my credit card for $102.00 US per room to reserve my accommodations:

Credit Card Name *(VISA, Mastercard, American Express, Diners Club, Discovery Card):* ______________

Expiration Date: ______________

Card Number ______________ Name as it appears on Card ______________

Cardholder Signature ______________

Send all forms and fees to: Moorevents, 676 N. St. Clair St., Suite 1765, Chicago IL 60611 USA

For Office Use Only:

Date Received ____ Date Acknowledged ____ Amount Received ____ Amount Due ____ Special Needs Y_ N_

CONGRESS REGISTRATION FORM

Seventh World Congress of ISPO, June 28 to July 3, 1992
Hyatt Regency Chicago Hotel, Chicago, Illinois, USA
Deadline for *Receipt* of Early Registrations: April 1, 1992 (Late after April 1)

Personal Information

Name (Family Name, Given Name, Initial)

Title or Position

Company or Organization

Mailing Address

Telephone/Fax

Accompanying Person(s) *name as it should appear on badge*

Registration Category *tick one*

☐ *Member* ☐ *Non-Member* ☐ *Student* ☐ *Exhibitor*

Do you need assistance because of disability? Tick this box ☐ and describe needed assistance below:

Fee Worksheet	**TOTALS**
1. Congress Registration Fee *tick all applicable and write total in column at right.*	
☐ 1a Member Early $400 ☐ 1a Member Late $500 ☐ 1a Member One Day $180	1a
☐ 1b Non-Member Early $520 ☐ 1b Non-Member Late $620 ☐ 1b Non-Member One Day $220	1b
☐ 1c Student Early $200 ☐ 1c Student Late $250 ☐ 1c Student One Day $100	1c
☐ 1d Accompanying Person Early $150 How many? _ ☐ 1d Accompanying Person Late $200 How many? _	1d
2. Instructional Courses *ticked on reverse side of this page* How many? _ × $50 each course. Write total in column at right.	2
3. Activities *tick all applicable and write totals in column at right.*	
3a Meals: ☐ Lunch-Monday $10 How many? _ ☐ Lunch-Tuesday $10 How many? _ ☐ Lunch-Thursday $10 How many? _	3a
3b Tours: ☐ Tour A $42 How many? _ ☐ Tour B $45 How many? _ ☐ Tour C $50 How many? _ ☐ Tour D $34 How many? _ ☐ Tour E $31 How many? _ ☐ Tour F $30 How many? _ ☐ Tour G $60 How many? _ ☐ Tour H $45 How many? _	3b
3c Banquet: ☐ For All Attendees and Accompanying Persons $75 each. How many? _	3c
3d Accompanying Persons Tours ☐ Tour A $45 How many? _ ☐ Tour B $30 How many? _ ☐ Tour C $42 How many? _ ☐ Tour D $30 How many? _ ☐ Tour E $42 How many? _	3d
TOTAL FEES DUE *add lines 1a, 1b, 1c, 1d, 2, 3a, 3b, 3c, 3d and write total in space at right.*	

Full payment is due at time of registration. Checks and money orders must be payable to "VII World Congress of ISPO" in US dollars drawn on a US bank. Failure to do so will result in bank charges that will be invoiced to the attendee.

Or charge to VISA or Mastercard: *tick one* ______ VISA ______ Mastercard Expiration Date: ____________

Card Number ______________________ Name as it appears on Card ______________________

Cardholder Signature ____

Send all forms and fees to: Moorevents, 676 N. St. Clair St., Suite 1765, Chicago IL 60611 USA.

For Office Use Only:

Date Received ____ Date Acknowledged ____ Amount Received ____ Amount Due ____ Special Needs Y_ N_

Instructional Courses

(please tick boxes to enrol in course)

Sunday, June 28 (10.00–12.00 hrs)	Monday, June 29 (08.00–09.30 hrs)	Tuesday, June 30 (08.00–09.30 hrs)	Wednesday, July 1 (08.00–09.30 hrs)	Thursday, July 2 (08.00–09.30 hrs)	Friday, July 3 (08.00–09.30 hrs)
IC 101 Amputation surgery	*IC 102* Amputation surgery (cont.)	*IC 103* Mangement of the diabetic foot	*IC 104* Management of the arthritic and deformed foot	*IC 105* Postsurgical and early management of BK and AK amputations	*IC 106* Orthotic management of bone fractures
	IC 202 Early post trauma management of persons with spinal cord injury	*IC 203* Surgical management of spinal fractures	*IC 204* Management of the upper limb in spinal cord injury	*IC 205* Management of brachial plexus injuries	*IC 206* Orthotic and therapeutic management of stroke
IC 301 Seating and positioning	*IC 302* Introductory biomechanics	*IC 303* Introductory biomechanics (cont.)	*IC 304* Advanced biomechanics	*IC 305* Biomechanics of human locomotion	*IC 306* Wheelchair biomechanics and prescription
IC 401 Advanced below-knee and Syme fitting practice	*IC 402* Advanced below-knee and Syme fitting practice (cont.)	*IC 403* Above-knee and through knee fitting practice	*IC 404* Above-knee and through knee fitting (cont)	*IC 405* CAD/CAM in a small clinical practice	*IC 406* Hip disarticulation and hemipelvectomy fitting
	IC 502 Survey of modern gait analysis equipment	*IC 503* Clinical applications of gait analysis	*IC 504* Surgical management of cerebral palsy	*IC 505* Gait training for the leg amputee	*IC 506* Gait training for the leg amputee (cont.)
IC 601 Upper limb prosthetics	*IC 602* Sockets for upper limb prostheses	*IC 603* Myoelectric training of children	*IC 604* Hand surgery and prosthetic fitting	*IC 605* High level upper limb fittings	*IC 606* Upper limb amputee training
IC 701 Upper limb orthotics	*IC 702* Lower limb orthotics	*IC 703* Lower limb orthotics (cont.)	*IC 704* Management of the geriatric amputee		

(Continental breakfast will be provided 07.00–07.30 Monday–Friday)

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Calendar of Events

National Centre for Training and Education in Prosthetics and Orthotics
Short Term Courses, 1992

Courses for Physicians, Surgeons and Therapists

NC505 Lower Limb Prosthetics; 3–7 February, 1992.
NC502 Upper Limb Prosthetics and Orthotics; 24–28 February, 1992.
NC510 Wheelchairs and Seating; 3–5 March, 1992.
NC511 Clinical Gait Analysis; 11–13 March, 1992.
NC506 Fracture Bracing; 11–15 May, 1992.

Courses for Prosthetists

NC211 PTB Prosthetics; 10–21 February, 1992.
NC218B Ischial Containment Prosthetics; 16–20 March, 1992.
NC212 Hip Disarticulation Prosthetics; 27 April–8 May, 1992.

Course for Orthotists and Therapists

NC217 Ankle-Foot Orthoses for the Management of the Cerebral Palsied Child; 1–3 April, 1992.

Further information may be obtained by contacting Prof. J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, Curran Building, 131 St. James' Road, Glasgow G4 0LS, Scotland. Tel: 041-552 4400 ext. 3298.

19–24 January, 1992
ACOPPRA II, the 2nd International Conference of the Central American Association of Orthotists, Prosthetists, Rehabilitation Professionals and Affiliates, Panama City, Panama, Central America.
Information: Rita Chan de Lee, Secretary ACCOPRA, PO Box 26, Zona 1, Panama City, Republic of Panama.

30 January–2 February, 1992
ISPO Course on Lower Limb Amputations and Related Prosthetics, Groningen, The Netherlands.
Information: ISPO, Borgervænget 5, 2100 Copenhagen Ø, Denmark.

31 January–2 February, 1992
International Congress and Workshop of the German Society of Orthopedics and Traumatology on the Thumb and Wrist, Dusseldorf, West Germany.
Information: Dr. C. L. Jantea, Sec. Handsurgery and Rheumatology, Orthopaedic Dept. of the Heinrich Heine University, Moorenstr. 5, D-4000 Dusseldorf, Germany.

20–25 February, 1992
Annual Meeting of the American Academy of Orthopaedic Surgeons, Washington, USA.
Information: AAOS, 222 South Prospect, Park Ridge, IL 60068, USA.

5–9 April, 1992
Biomedical Engineering Society Annual Meeting, Anaheim, California, USA.
Information: BES, PO Box 2399, Culver City, CA 90231, USA.

7–12 April, 1992
American Academy of Orthotists and Prosthetists Annual Meeting and Scientific Symposium, Miami, USA.
Information: AAOP, 717 Pendleton Street, Alexandria, VA 22314, USA.

8–10 April, 1992
ISPO (UK) Annual Scientific Meeting, Manchester, England.
Information: B. McHugh, NCTEPO, University of Strathclyde, Curran Building, 131 St. James' Road, Glasgow G4 0LS, Scotland.

22–25 April, 1992
Independence '92 – International Congress and Exposition on Disability, Vancouver, Canada.
Information: Suite 2000, 1176 W. Georgia Street, Vancouver, B.C., V6E 4A2, Canada.

7–10 May, 1992
Annual Meeting of the American Board of Physical Medicine and Rehabilitation, Rochester, MN, USA.
Information: American Board of Physical Medicine and Rehabilitation, Suite 674, Northwest Center, 21 First Street SW, Rochester, MN 55902, USA.

15–17 May, 1992
Annual Meeting of the American Spinal Injury Association, Toronto, Canada.
Information: American Spinal Injury Association, 2020 Peachtree Road NW, Atlanta, GA 30309, USA.

21–24 May, 1992
Meeting of the International Society for the Study of the Lumbar Spine, Chicago, USA.
Information: Prof. Alf Nachemson, Dept. of Orthopaedics, Sahlgren Hospital, S-413 45, Goteborg, Sweden.

6–11 June, 1992
15th Annual Conference of RESNA Rehabilitation Technology, Toronto, Canada.
Information: RESNA, Suite 700, 1101 Connecticut Avenue NW, Washington, DC 20036, USA.

21–22 June, 1992
European Spinal Deformities Societies Meeting, Lyon, France.
Information: Eric Bancilhon, 29 Rue President Ed. Herriot, 69002 Lyon, France.

21–24 June, 1992
8th Meeting of the European Society of Biomechanics, Rome, Italy.
Information: ESB '92, Istituto di Fisiologia Umana, Universita "La Sapienza" Piazzale Aldo Moro, 5, 00815 Rome, Italy.

28 June–3 July, 1992
7th World Congress of ISPO, Chicago, USA.
Information: 7th World Congress of ISPO, Moorevents, Inc., 400 North Michigan Avenue, Suite 2300, Chicago, Il 60611, USA.

29–30 June, 1992
Annual Meeting of the National Association of Rehabilitation Facilities, Chicago, USA.
Information: National Association of Rehabilitation Facilities, PO Drawer 17675, Washington, DC20041, USA.

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