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Prosthetics and Orthotics International

December 1994, Vol 18, No. 3

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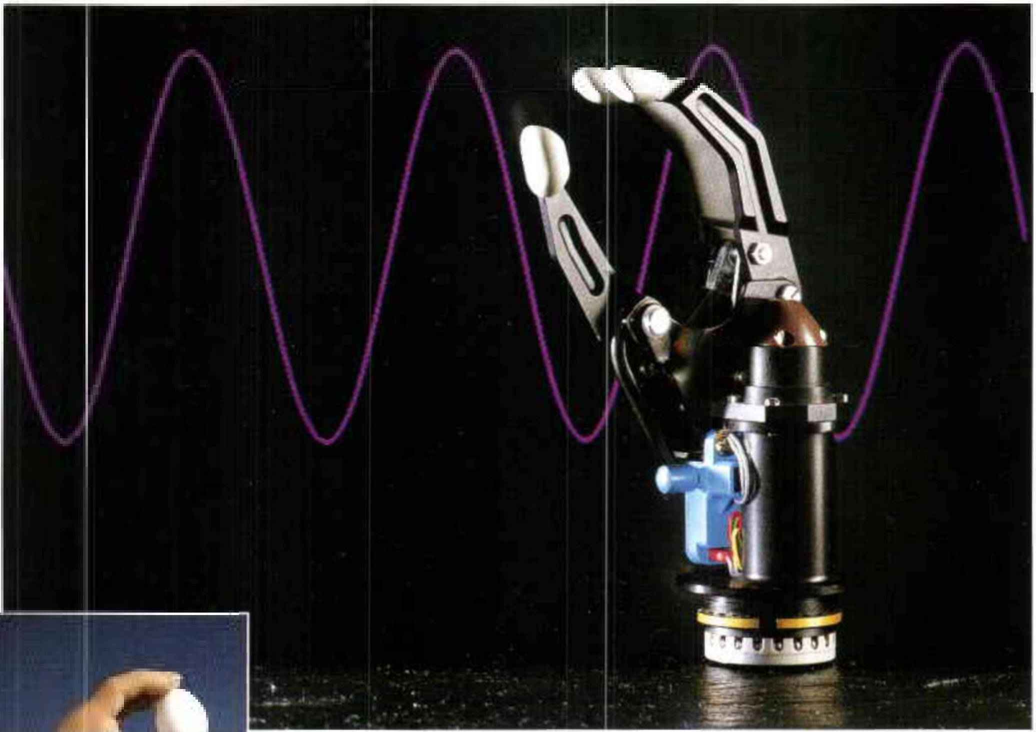

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ENDOLITE

The Journal of the International Society for Prostheics and Orthotics

December 1994, Vol. 18, No. 3

Contents

ISPO

Prosthetics and Orthotics International, 1994, 18, 139–141

Editorial

The basic idea behind the formation of ISPO was the establishment of an umbrella organisation which could encompass all those who provide treatment and service to amputees and other physically disabled patients. The focus throughout would be on the team approach. It became obvious at an early stage that great emphasis would be placed on education. Over the years through a series of seminars (Holte 1968, Montreux 1974, Moshi 1984, Toronto 1984, Jonkoping 1985, Glasgow 1987) ISPO identified its priorities in education, evolved a philosophy and laid down guidelines. As a consequence, when WHO established its own guidelines for training of personnel in developing countries in 1990, ISPO was in a good position to influence the outcome.

ISPO has also striven to establish the basis of patient care through consensus conferences, in Glasgow, Scotland 1990 on amputation surgery and in Durham, USA 1994 on cerebral palsy. These are to be followed by another consensus conference on appropriate prosthetic technology in Cambodia, in 1995.

ISPO has in the past arranged short-term courses on amputation surgery and related prosthetics in the industrialised world. Following the Glasgow consensus conference the Executive Board and the re-constituted Education Committee decided on an outreach programme for the developing world by organising one-week courses on Compound Fractures, Amputation Surgery and Related Prosthetics and Rehabilitation. A detailed description of the first programme in Tanzania, 1993, was published in Prosthetics and Orthotics International in August of that year. The intention in incorporating the handling of compound fractures, which does not normally fall within the field of ISPO's work, was that in the developing world such events often lead to amputation because of the soft tissue problems encountered after war injuries or other high energy trauma with excessive risk of infection. In offering these courses, ISPO felt it imperative to collaborate with other important bodies working in the developing world like the World Health Organisation (WHO), and non-governmental organisations such as World Orthopaedic Concern (WOC) and in particular the International Committee of the Red Cross (ICRC) which has extensive experience in providing services based on local conditions. These organisations have willingly participated and financially covered their own lecturers, whereas ISPO has picked up the costs of the additional faculty and all the local arrangements. To encourage reasonably large attendance, registration fees have been kept down to 100 USD. With the high air fare rates for the international faculties in particular this could only be done at a cost to ISPO. The lecturers have not received any fees, but their direct costs for transport and accommodation have been reimbursed together with a modest subsistence, based on Danish Civil Servants regulations. ISPO wishes to acknowledge the contribution from the lecturers, who all took part without compensation for loss of income and incurred excessive work-load accrued at their institutions or companies after their return to work. ISPO has many good and supportive friends in the industry, and our expenses for these courses have been considerably decreased through exhibition fees or direct payments for translation, social events and the like; and further, some have directly supported individuals to participate.

The lecturers are shown in the attached table which also displays the content of the programmes. The Society has used lecturers who have a high level of teaching experience and professionalism, have an international reputation, and have an experience or understanding of the needs in the developing world. Also, we have aimed to involve individuals who know the philosophies of ISPO and its collaborating bodies. It has been found useful to involve individuals from the area, appointed by the local organisers, in order to create a programme which is in accordance with the practice of the region.

In Thailand, the co-organisers were the Thai Orthopaedic Association (Chairman, S. Waikakul). There were 68 patients from Thailand, Cambodia, Japan, Malaysia, Singapore, and Vietnam. The special feature of this programme was the discussion about education in prosthetics and orthotics and about prosthetic supply conducted by T. Keokarn, Thailand; S. Sawamura, Japan; J. Gehrels, ICRC; Ha Ahn, Vietnam. It appears that in Thailand most personnel in prosthetics and orthotics are educated to "Category 3". The goal is "Category 2", which could be made possible by the Japanese support for a school in the region. The provision of CAD CAM prostheses in Vietnam was described by E. Burgess, USA. Further the community based rehabilitation programmes advocated by WHO (E. Pupulin) were discussed.

	Thailand	Slovenia	Panama
General subjects			
Education	J. Hughes, Scotland	N. A. Jacobs, Scotland	J. Hughes, Scotland
Transport Systems	E. Chulacharitta, Thailand		A. Saldana, Panama
Compound fractures			
War Injuries	S. Pipethkul, Thailand	D. A. Nagel, USA (WOC)	
Classification	R. Merryweather, England (WOC) M. Chantarasorn, Thailand	R. Hammer, Sweden	D. A. Nagel, USA (WOC)
General Principles	A. Tassanawipas, Thailand	D. A. Nagel, USA (WOC)	A. Saldana, Panama
External Fixation	S. Waikakul, Thailand R. Merryweather, England (WOC)	R. Hammer, Sweden	D. A. Nagel, USA (WOC) G. Pinilla, Panama
Fracture Bracing	M. Stills, USA	B. Persson, Sweden	M. Stills, USA
Bone & Joint Infections	R. Merryweather, England (WOC)	R. Hammer, Sweden	D. A. Nagel, USA (WOC)
Amputation surgery			
General Principles and Revision Surgery	A. Jain, Scotland S. Sawamura, Japan R. Merryweather, England (WOC)	A. Jain, Scotland G. Neff, Germany B. Persson, Sweden	F. Gottschalk, USA M. Pinzur, USA
Team Approach	S. Sawamura, Japan	A. Jain, Scotland	M. Stills, USA
Physical Medicine and Rehabilitation	S. Kukietnan, Thailand	R. Ham, England	G. Tejada, Panama G. Hostetter, USA
Patient Care Systems	E. Pupulin, Switzerland (WHO)	C. Marincek, Slovenia H. Burger, Slovenia E. Isakov, Israel L. Kullman, Hungary	J. Perry de Saravia, Colombia
Basic Biomechanics	J. Hughes, Scotland	N. A. Jacobs, Scotland	J. Hughes, Scotland
Materials	J. Gehrels, Switzerland (ICRC)	N. Govan, Scotland	G. Nury, Colombia (ICRC)
Local Fabrication			
Trans-femoral amputations			
Biomechanics	J. Hughes, Scotland	N. A. Jacobs, Scotland	J. Hughes, Scotland
Prosthetics	N. Govan, Scotland J. Gehrels, Switzerland (ICRC)	A. deBont, Ireland N. Govan, Scotland	M. Schuch, USA G. Nury, Colombia (ICRC)
Surgery	J. Steen Jensen, Denmark	A. Jain, Scotland	F. Gottschalk, USA
Physiotherapy		R. Ham, England	G. Hostetter, USA
Knee disarticulation			
Biomechanics	J. Hughes, Scotland	N. A. Jacobs, Scotland	N. A. Jacobs, Scotland
Prosthetics	N. Govan, Scotland J. Gehrels, Switzerland (ICRC)	A deBont, Ireland N. Govan, Scotland	M. Quigley, USA G. Nury, Colombia (ICRC)
Surgery	J. Steen Jensen, Denmark	G. Neff, Germany	M. Pinzur, USA
Physiotherapy		R. Ham, England	G. Hostetter, USA
Trans-tibial amputations			
Biomechanics	J. Hughes, Scotland	N. A. Jacobs, Scotland	J. Hughes, Scotland
Prosthetics	N. Govan, Scotland J. Gehrels, Switzerland (ICRC)	A deBont, Ireland N. Govan, Scotland	M. Schuch, USA
Surgery	S. Sawamura, Japan	B. Persson, Sweden	J. Steen Jensen, Denmark
Physiotherapy		R. Ham, England	G. Hostetter, USA
Ankle and foot amputations			
Biomechanics	J. Hughes, Scotland		N. A. Jacobs, Scotland
Prosthetics	J. Gehrels, Switzerland (ICRC)		M. Schuch, USA G. Nury, Colombia (ICRC)
Surgery	A. Jain, Scotland		M. Pinzur, USA F. Gottschalk, USA

The co-organisers in Slovenia were Professor Črt Marinček and his staff from the Rehabilitation Institute in Ljubljana. There were 73 participants from Slovenia, Albania, Armenia, Azarbaijan, Belgium, Bosnia/Herzegovinia, Czech Republic, Croatia, Finland, Georgia, Hungary, Iceland, Israel, Italy, Jordan, Kuwait, Lithuania, Malta, Russia, Tajikstan and Yugoslavia. Of particular relevance was a session on war injuries delivered by the WOC representative, Don Nagel, USA. A session was allocated to WHO, represented by H. Hermanova, WHO Europe, and B. Lagerkvist, WHO Croatia, which addressed issues related to standards for rehabilitation of the amputee. As a result the dialogue will continue between WHO, the WHO collaborating centres, ISPO and other agencies in order to develop European Guidelines for the rehabilitation of all persons with amputations in both the stable and emergency situations.

In Panama the co-organisers were ISPO Panama, represented by A. Saldana and R. de Saez. There were 117 participants from Panama, Colombia, Costa Rica, Curacao, Dominican Republic, El Salvador, Guatamala, Jamaica, and Trinidad and Tobago. Again, the special feature of the closing day was a long discussion on education systems in the Central American region. There is a great variation with regard to the prosthetic and orthotic services between the countries, ranging from 11 orthopaedic technologist (Category 2) in Panama to serve 2.5 million inhabitants, an equivalent situation in El Salvador, but only 15 un-educated workers to serve 30 million inhabitants in Colombia. A working group with one representative from each country present was formed with the purpose of analysing the situation following the close-down of the World Rehabilitation Fund school in the Dominican Republic, and formulating a proposal to each of the governments in the area with regard to the establishment of a regional school.

ISPO has now completed four courses in the developing world with great success. The message about the team approach has been well received, but there are obvious communication problems between the professionals in most countries and in particular between the surgeons and the other members of the team. All courses were well attended by surgeons, rehabilitation physicians, physiotherapists, and providers of prosthetic and orthotic services. The content of the teaching programmes has been based on approved principles and techniques, flavoured with high technology from the industrialised world, and appropriate technology based on sound and approved biomechanical principles but using locally available materials. The collaboration with ICRC in respect of appropriate technology, with WHO regarding patient care systems, and with WOC on trauma surgery has indeed been very successful and stimulating. ISPO may in the future arrange at least one course per year in the developing world with a now well tested formula. As the site for the next course has not yet been decided, proposals or invitations will be most welcome.

John Hughes
Norman A. Jacobs
J. Steen Jensen

Prosthetics and Orthotics International, 1994, 18, 142–149

Benchmark data for elderly, vascular trans-tibial amputees after rehabilitation

W. A. HUBBARD* and G. K. McELROY**

* *The Queen Elizabeth Centre, Ballarat, Victoria, Australia*
** *Ballarat University College, Ballarat, Victoria, Australia*

Abstract

Benchmark data for lower limb amputees is often limited to young subjects who have had their amputations as the result of trauma. The majority of trans-tibial amputees rehabilitated are, however, elderly vascular amputees who may have different gait characteristics than their younger counterparts. Without biomechanical analyses to provide such benchmark data for this group it is not possible to compare the effects of different rehabilitation programmes, gait training regimens, or prosthetic devices.

Twenty elderly vascular trans-tibial amputees rehabilitated at The Queen Elizabeth Centre, Ballarat, Australia and at least six months post-amputation were measured in respect of kinetic and kinematic parameters, and relationships between gait speed, consistency, and function were demonstrated. Further, an unexplained vertical ground reaction force pattern was demonstrated in faster, more functional amputees.

Introduction

While different rehabilitation programmes and types of prostheses exist for lower limb amputees, no benchmark biomechanical analyses are available for elderly trans-tibial vascular amputees against which the performance of patients leaving a rehabilitation programme can be measured.

Such profiles exist for fit people of all age groups, and in part for those with pathology (Cheung *et al.*, 1983; Olney *et al.*, 1979). Without detailed gait profiles for fit, elderly, vascular amputees there is no standard against which to assess the relative differences between the various rehabilitation approaches for this group.

This study, conducted at The Queen Elizabeth Centre, Ballarat (QECB), quantifies the gait performance of vascular trans-tibial amputees who have participated in a gait training regimen which is particularly designed to facilitate early discharge from in-patient treatment. The training regimen relies on the whole method of motor re-education, minimising the use of support rails, rather than the more traditional progressive part methods and early reliance on rails. The philosophy of early discharge is balanced against the necessity of ensuring a gait pattern which is economical of effort and promotes optimal functional mobility.

The relatively short in-patient stay at the QECB for new amputees, 17 days on average in 1991/92 (Carter, 1992) compared to much longer stays in other settings (Baker and Hewison, 1990), permits this group of clients to return home quickly after surgery and to expect a high level of gait quality.

It is envisaged that clinicians who advocate the use of different therapeutic regimens and prostheses will be able to assess the length of stay and gait performance of their clients in the light of the parameters investigated in this study.

Rehabilitation outcomes can be measured in several ways, dependent upon the perceived goals of care. Length of time spent in hospital provides an estimate of treatment cost, while functional measures provide information about the ability of individual clients to live independently once the rehabilitation process has been completed.

All correspondence to be addressed to Wendy A. Hubbard, Chief Physiotherapist, The Queen Elizabeth Centre, Ballarat, PO Box 199, Ballarat, Victoria, Australia 3350.

More detailed and objective measures are required, however, when considering the efficiency and effectiveness of particular treatment techniques offered by individual therapies, such as the gait re-education programmes offered by physiotherapists to trans-tibial amputees.

While some base-line measures of amputee gait through objective gait analysis have been reported, there is currently no basis for choosing a particular programme, and no ongoing evaluation of outcomes except in terms of length of hospital stay, which gives no indication of the quality of walking or function for those discharged.

Method

Twenty vascular trans-tibial amputees rehabilitated at the QECB at least 6 months previously were analysed using a Selspot Movement Monitoring System and AMTI force plate. All subjects walked without walking aids for the test, although three required a cane for outdoor ambulation.

All subjects wore their usual prosthesis, patellar-tendon-bearing prostheses made using titanium componentry and SACH feet. Prior to data collection all subjects were reviewed by a qualified prosthetist to ensure appropriate fit and alignment of the prosthesis worn.

Six light emitting diodes (LEDs) were placed on the subjects prior to sagittal plane data collection. Markers were placed at the tip of the acromion, the greater trochanter of the hip, the mid-point of the prosthesis at the patellar bar, the mid-line at the foot attachment to the shank, at the heel and at the point of what would be the fifth metatarsal head. The subsequent identification of the limb and body segments was used in the calculation of joint forces, moments and powers in the manner of Winter (1979), and the resulting data normalised by dividing by body weight.

Results and discussion

Parameters selected for further analysis were:

- preferred walking speed;
- functional scores;
- temporal and spatial parameters;
- kinetics, including:
  - vertical ground reaction force (GRF);
  - joint moments of force and power patterns;
  - hip and knee interaction

Preferred walking speed

The mean preferred walking speed of subjects tested was 0.8 m.s.$^{-1}$, with a standard deviation (SD) of 0.19 m.s.$^{-1}$ Skinner end Effeney (1985) reported a mean walking speed of 0.75 m.s.$^{-1}$, SD = 0.15 m.s.$^{-1}$, and, as these data are the compilation from the literature for vascular amputees, it is probably indicative of the typical performance of rehabilitated amputees.

Functional scores

To ensure that subjects were performing at a functional level which was similar to those with whom comparisons were being made, functional scores were ascertained for each subject.

The functional measure, reported by Day (1981), was designed specifically for the amputee population and takes into account the necessity for donning and doffing the prosthesis as well as its use in indoor and outdoor activity. The scores obtained on the Day scale display a reasonable spread over the population group (Fig. 1), and preferred walking speed was found to correlate highly with this functional ability measure ($r = 0.63$, $p = 0.0018$).

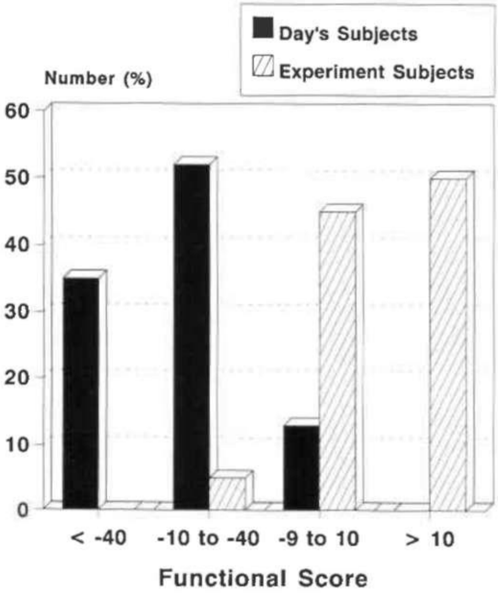

Fig. 1. Day scores for Day's subjects and all experimental subjects.

Temporal and spatial parameters

The group of vascular amputees described in the current study had a mean stride time of 1.3 s (*SD* = 0.14 s) and a mean stride length of 0.97 m. A statistically significant association was demonstrated between prosthetic stride time and speed ($r = -0.77$, $p = 0.0001$), and between prosthetic stride time and the Day functional score ($r = -0.65$, $p = 0.0025$).

These data support the argument presented by Dewar and Judge (1980) who contended that stride time may be used as a substitute measure for walking speed, even for those with pathological gait patterns. Cheung *et al.* (1983) verified this association when monitoring the performance of a group of amputees as they progressed through rehabilitation.

Symmetry

Of the elderly vascular amputees studied, 63% of subjects had a longer prosthetic than non-prosthetic step, and 37% had a longer duration prosthetic step than non-prosthetic. Symmetry calculations were made by division of the shorter step into the longer one, no matter which was the prosthetic step, providing a non-directional measure of symmetry. Using this method, step length symmetry and preferred walking speed were associated positively and significantly ($r = 0.56$, $p = 0.014$).

A significant association was also found between prosthetic step length and walking speed ($r = 0.65$, $p = 0.0026$) in the experimental group, and between prosthetic step length and step length symmetry ($r = 0.68$, $p = 0.0012$), indicating that those amputees taking longer prosthetic steps were tending to a more even spatial gait pattern, as well as walking faster.

Step timing symmetry, however, displayed no significant relationship to either step length symmetry ($r = 0.11$, $p = 0.64$) or walking speed ($r = -0.33$, $p = 0.17$), Indeed, the tenuous link between temporal symmetry and speed is negative, so that the lower the ratio (where 1 is the best symmetry score possible), the higher the walking speed.

These data support the contention of Winter and Sienko (1988) that pursuit of absolute gait symmetry may be unrealistic and unattainable for trans-tibial amputees, casting doubt on the wisdom of equating perfect symmetry with optimal amputee gait performance.

While it is possible to maintain spatial symmetry with the prosthesis, unless step timing is compromised, walking speed (and by inference, functional ability) will be reduced.

Kinetics

Vertical ground reaction forces (GRF)

Three basic patterns in the vertical GRF were identified (Fig. 2). These were the two peak pattern (seen in subject 20), typically recorded in the normal gait pattern (Andriacchi *et al.*, 1977), a three peak pattern not typically

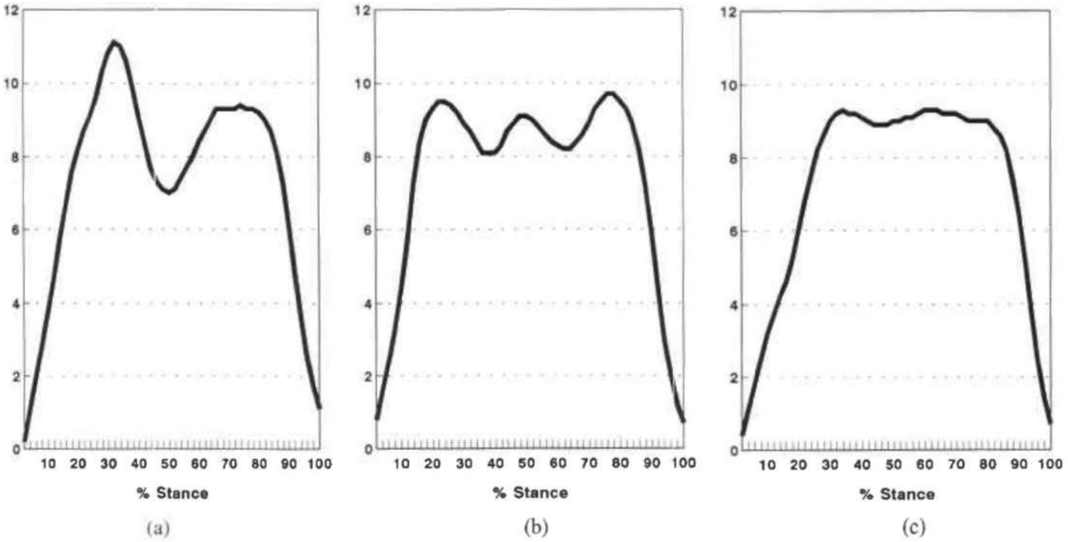

Fig. 2. Three sample patterns of vertical ground reaction force.
a) two peak pattern b) three peak pattern c) flattened pattern.

described (Subject 2), and a flattened pattern (Subject 5) where Z_1, Z_2, and Z_3, show little difference in magnitude.

Because the three vertical GRF pattern types are nominal data only, an association between the types and preferred walking speed was investigated using the contingency coefficient (Siegel, 1956). Analysis revealed a significant relationship ($C = 0.61$, $p = 0.027$) between the pattern type and the preferred walking speed for this group of vascular trans-tibial amputees, with those walking at fast speed most likely to have a three peak vertical ground reaction force pattern, and those walking slowly to have a flattened pattern.

This unexpected relationship may have been due to the nature of walking style adopted by faster walking amputees to maintain that speed. In normal walking the foot does not become a rigid lever for the plantarflexors until the toes have reached full extension, just prior to push off. For the amputee, however, once the SACH heel has compressed and decompressed, the rigid wooden keel provides leverage if a preliminary mid-stance push is needed.

Alternatively, the faster amputees may have compressed the SACH heel to such an extent that the wooden keel was struck prior to decompression, creating a vertical force which subsided once body weight was transferred to the front of the foot and decompression begun. No other authors have identified such a relationship, and more work needs to be done in this area to determine the relevance and implications of the association identified.

Seliktar and Mizrahi (1986), analysing the force patterns for 23 trans-tibial amputees, pointed out that even in normal gait the shoes worn have an effect which is complex and individual to both the shoe type and the heel itself. This variation in shoe type, which was not controlled in this study, may help to explain the larger inter-subject variability (CV = 0.17) observed here and also reported by Winter (1984) for normals. Intra-subject variation for this parameter was relatively low (mean CV = 0.08 $N.kg^{-1}$, SD = 0.03 $N.kg^{-1}$), again consistent with Winter's findings (1984).

The moment patterns at the ankle, hip, and knee for the subjects measured in this study had higher intra-subject mean variations (mean CV = 0.16 $Nm.kg^{-1}$, SD = 0.09 $Nm.kg^{-1}$, mean CV = 0.54 $Nm.kg^{-1}$, SD = 0.26 $Nm.kg^{-1}$, and mean CV = 0.36 $Nm.kg^{-1}$, SD = 0.17 $Nm.kg^{-1}$ respectively) than that of the vertical GRF. Addressing the same phenemenon in normal subjects, Winter (1984) surmised that the individual joint motor patterns provide a measure of the flexibility of the motor system to produce the same over-all response patterns.

Preferred walking speed was found to correlate negatively ($r = -0.46$, $p = 0.046$) with the relative time taken ($T_1\%$) to attain peak vertical GRF (Fig. 3). This implied that subjects who walked at the highest speed loaded their prosthetic limbs most quickly (as a proportion of their total stance period) as might be expected, and this provided the basis for selecting the best walking performance for each subject over their recorded trials. This "best performance" trial for each subject was then used for analysis of inter-subject performance, and for averaging, although all trials were used calculations of intra-subject variation.

Individual joint moments, and power patterns

Ankle

The mean ankle moment throughout the

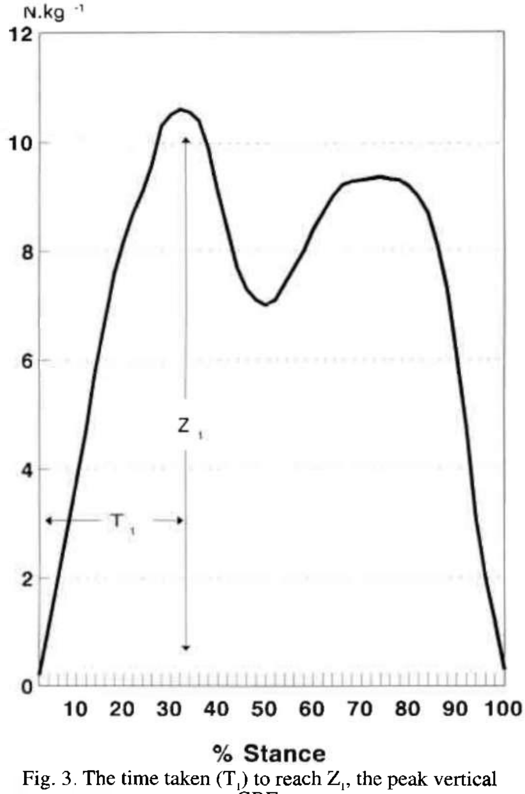

Fig. 3. The time taken (T_1) to reach Z_1, the peak vertical GRF.

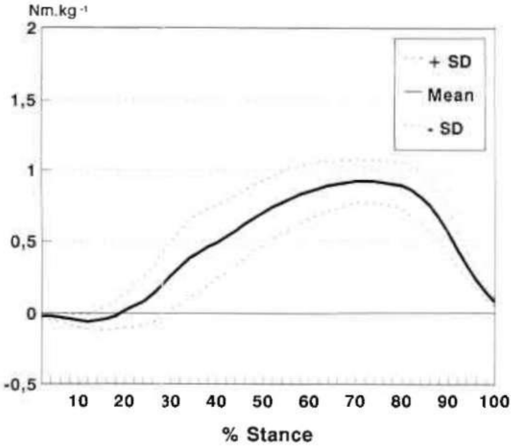

Fig. 4. Ankle moment pattern for the duration of stance phase (all subjects).

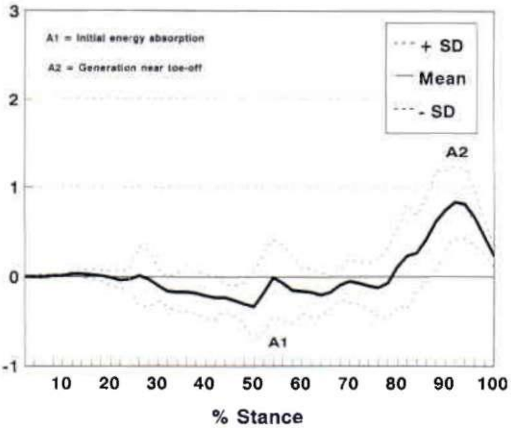

Fig. 6. Mean ankle power pattern for all subjects.

stance phase for the "best" trial of the available 19 experimental subjects appears in Figure 4.

The general pattern of ankle moments for trans-tibial amputees was consistent with that reported by Winter and Sienko (1988) who reported a preliminary dorsiflexor moment followed by a gradually increasing plantarflexor moment peaking in late stance (Fig. 5). In the group of older amputees in the current study, however, the initial moment continued as dorsiflexor for an average of 20% stance. Winter and Sienko (1988) described the duration of dorsiflexion as 18% of stride, where stance for their group was said to be 60% of the total stride. Thus for Winter and Sienko's group of 5 amputees the dorsiflexor moment lasted a mean of 30% of stance, slightly longer than for this experimental group, while for normals it is cited as lasting only 3% of stride (Winter and Sienko, 1988).

Winter hypothesised that the rigid ankle

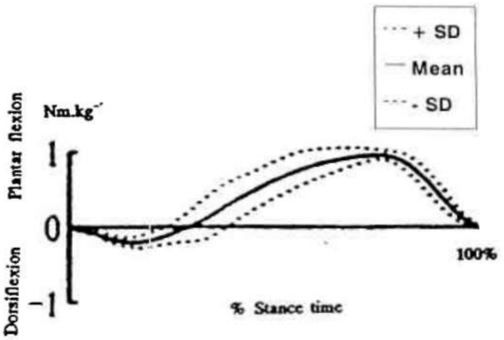

Fig. 5. Ankle moment patterns for five trans-tibial amputees (adapted from Winter and Sienko, 1988).

generates an "internal dorsiflexor moment" (Winter and Sienko, 1988) from heel strike to foot flat, compounded by a marked delay in the rotation of the amputee's shank forward over the prosthetic foot. This is consistent with the findings of Zernicke *et al.* (1985) who noted that the centre of pressure in the SACH foot remained at the posterior section of the foot for 43% of stance while for normals this is only so for 34% of stance.

The power patterns at the ankle for all subjects (Fig. 6) showed a typical pattern of energy absorption (A1) until late stance, when energy is then generated (A2).

These data, however, differ from those reported by Winter and Sienko (1988) for the latter part of the stance phase (Fig. 7). They reported initial energy absorption (A1) as the prosthetic foot deformed in dorsiflexion from heel-strike to mid-stance. This energy is not returned, according to Winter, with no comparable A2 power burst at terminal stance for trans-tibial amputees using SACH feet.

Data recorded for the 19 vascular amputees tested in this study showed an obvious A2 power burst of around one third of the normal magnitude (mean=1.1 $W.kg^{-1}$, SD=0.5 $W.kg^{-1}$). While this disparity may have been due to some notional difference in resilience of Australian SACH feet, or to the altered pattern of the amputees' gait trained at the QECB, it is more likely due to the difference in the definition of the foot segment for calculation of the ankle angle.

Since power is calculated as the product of angular velocity and joint moment, the ankle

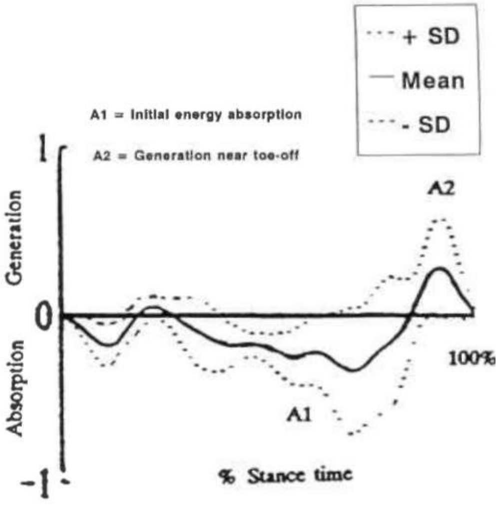

Fig. 7. Ankle power patterns for five trans-tibial amputees (adapted from Winter and Sienko, 1988).

powers recorded in the present study may be considered as a measure of the absorption and subsequent return of energy within the prosthetic foot.

Although Winter (1984) identified ankle power as the key to variation in a normal individual's walking speed, in the experimental group peak ankle power did not correlate significantly with preferred walking speed ($r = 0.37$, $p = 0.12$). Rather it was the peak hip power, occurring in the second half of the stance phase, which was found to be significantly related to speed ($r = 0.069$, $p = 0.0011$), indicating that once the mechanical rebound of the SACH foot has been exhausted

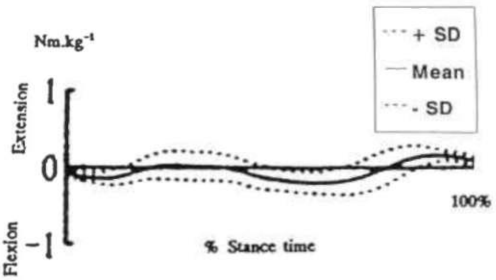

Fig. 9. Knee moment patterns for five trans-tibial amputees (adapted from Winter and Sienko, 1988).

as a source of propulsion, the vascular trans-tibial amputees in the present group utilised the musculature around the hip to optimise their functional walking ability.

Knee

Knee moments reported in this group (Fig. 8) are similar in pattern and magnitude to those reported for trans-tibial amputees by Winter and Sienko (1988) in Figure 9.

This pattern is similar to that reported by Winter and Sienko (1988) for five trans-tibial amputees (Fig. 11).

The average K3 fell within the normal limits for older subjects (Winter *et al.,* 1990), indicating that there remained a limiting action of the quadriceps on the shank in terminal stance. The level of variability in knee power was found to be significantly related to the preferred walking speed ($r = -0.68$, $p = 0.01$), indicating that consistency in power patterns at that joint is related to a better gait performance.

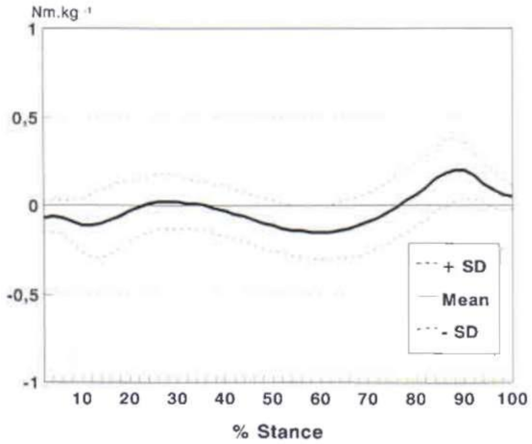

Fig. 8. Mean knee moment pattern for all subjects.

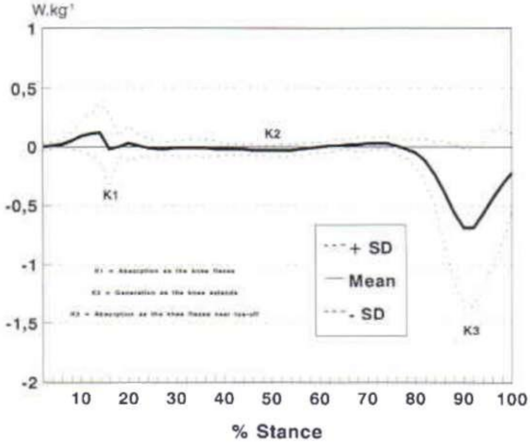

Fig. 10. Mean knee power pattern for all subjects.

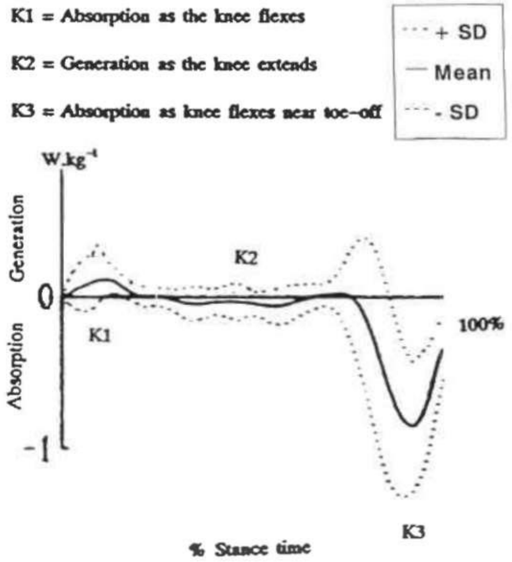

Fig. 11. Knee power patterns for five trans-tibial amputees (adapted from Winter and Sienko, 1988).

Hip

The general pattern of hip moments for trans-tibial subjects (Fig. 12) in the present study and those reported by Winter and Sienko (1988) in Figure 13 are similar in magnitude and direction. Extensor moments dominated the first half of the stance phase, followed by similar magnitude flexor moments.

Winter and Sienko (1988) reported that the mean variability of hip moments of force was greater in the population of trans-tibial amputees tested in that study than for normal subjects. In the present study, the degree of

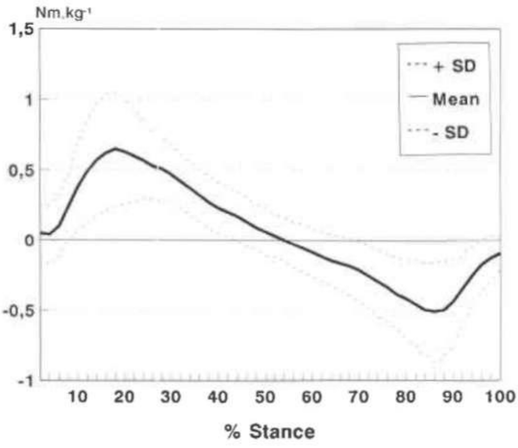

Fig. 12. Mean hip moment pattern for all subjects.

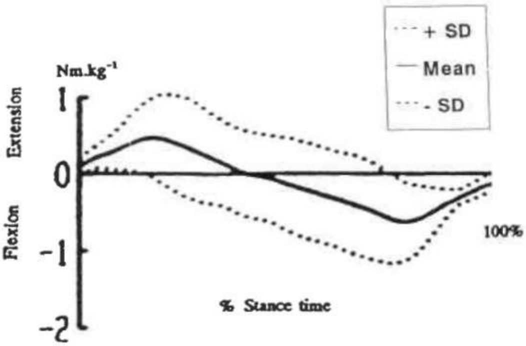

Fig. 13. Hip moment patterns for five trans-tibial amputees (adapted from Winter and Sienko, 1988).

variability in hip moments for amputees tested was found to correlate significantly with the preferred walking speed ($r = -0.72$, $p = 0.0052$), indicating that the higher the speed of walking performance recorded, the more consistent the hip response. This indicates that the trans-tibial amputees with the highest quality gait approached hip moment variability levels closer to the normal population.

This relationship between joint moment of force and preferred walking speed was not found for either the ankle moment variability ($r = 0.23$, $p = 0.44$), or the knee moment variability ($r = 0.028$, $p = 0.93$). Thus, in this population of trans-tibial amputees, the speed of walking is related to greater consistency only at the hip.

As previously stated the peak hip powers were found to be significantly associated with preferred walking speed. Like knee powers, more consistent hip power responses were found to be associated with higher preferred walking speeds ($r = -0.68$, $p = 0.01$), indicating that the well practised and experienced walkers used a consistent hip/knee power response on the prosthetic side to produce functional walking speeds.

Hip and knee interaction

Winter *et al.* (1990) described several ways of quantifying the interaction which can be demonstrated between the hip and knee during gait, particularly during the stance phase. For this group, covariance between the hip and knee moments for the "best" walk was calculated, where the linear association between them was identified.

For this calculation, the magnitude and

direction of the variation of the moments at each joint from their mean was tested. If both variables fall above or below their means at the same time, covariance will be positive, while if one variable is typically above its mean while the other is below, the covariance will be negative (STSC, 1989).

A negative covariance of moments at the hip and knee occurred in 69% of the current amputee group, the more negative the covariance recorded, the greater the preferred walking speed ($r = -0.47$, $p = 0.043$). A similar, though stronger, association was found between the Day functional measure score and the covariance of hip and knee moments ($r = -0.55$, $p = 0.016$), and the time (T_1) to reach peak vertical GRF ($r = 0.67$, $p = 0.0016$). The inference which may be drawn from these significant relationships is that the interplay between hip and knee demonstrated in normal elderly subjects (Winter *et al.,* 1990) also exists in trans-tibial amputees, and that the more complementary the interplay, the faster and more functional the amputee.

Conclusion

In conclusion, a general gait profile of elderly, vascular, trans-tibial amputees may be constructed. There was, within this group of 20 subjects, a marked variation in the traditionally consistent gait measures, with complex profiles of gait quality built around consistency in a few key parameters. While average walking speeds, functional measures, and other derived data were shown to match those reported in the literature, actual performance ranged from speeds of 0.4 $m.s^{-1}$ to 1.1 $m.s^{-1}$.

At the lower end of the scale were those vascular amputees with a low preferred walking speed and a low functional score. These subjects were slow to transfer weight to the prosthetic limb, strides were short and took longer than those of more active counterparts to perform. Step lengths were uneven, and knee and hip powers varied markedly from step to step. Peak hip powers were relatively low, probably because there were no consistent responses to the hip moments of force.

In contrast, more able amputees took long, quick strides. They quickly moved their weight onto the prosthesis and walked with evenly spaced, though unevenly timed steps. Hip moments of force were uniform for each step, providing a dependable base upon which to generate consistent hip powers, and knee power response was also steady from step to step. Relatively large magnitude peak hip powers on the prosthetic side produced the required walking speeds to carry out a more functional lifestyle.

It should now be possible to use these data to compare with that of rehabilitated amputees in other programmes with different philosophies, to ensure that they are chosen on merit, rather than on fashion.

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Standing balance in trans-tibial amputees following vascular disease or trauma: a comparative study with healthy subjects

Y. HERMODSSON*, C. EKDAHL**, B. M. PERSSON* and G. ROXENDAL**

* *Department of Orthopaedics, Helsingborg Hospital, Helsingborg, Sweden*
** *Department of Physical Therapy, Lund University, Lund, Sweden*

Abstract
Standing balance measured as sway and standing time both on one and two legs, was studied by use of a stable force platform (Kistler) in 36 patients aged 48-87 years with trans-tibial amputation and 27 healthy subjects matched for age. The aim of the study was to compare postural function in standing in two groups with unilateral trans-tibial amputations, separating vascular disease from trauma. Results revealed that the vascular group had a significantly increased sway in the lateral direction compared with the healthy group, when standing on both feet close together for 30 seconds, looking straight ahead or blindfolded (p values ranging from 0.003 to 0.02). In the sagittal direction the trauma amputees had a significantly decreased sway when looking straight ahead, compared to the vascular and healthy groups (p values = 0.03). No significant differences in the lateral or sagittal direction were seen among the three groups when comparing standing on one leg. There was a significant difference, however, in the standing time in the one-leg standing test of the vascular group when compared with the trauma and healthy groups (p values ranging from 0.0009 to 0.02). In contrast to the vascular group, all subjects in the trauma and healthy groups from 48 to 59 years could stand on the healthy leg for 30 seconds when looking straight ahead, and from 60 to 79 years they could stand for 5 seconds. None in the vascular or trauma group older than 80 years could stand on the healthy leg for 5 seconds. The standing balance of the vascular amputees was found to be inferior to that of the trauma amputees. In conclusion, vascular and trauma trans-tibial amputees should not be considered as an entity in test situations or rehabilitation programmes.

All correspondence to be addressed to Y. Hermodsson, RPT, Department of Orthopaedics, Helsingborg Hospital, S-251 87 Helsingborg, Sweden.

Introduction

In physiotherapy early rehabilitation of the leg amputee comprises exercises in one-leg standing. Not until the patient is fitted with a prosthesis is training in standing and walking on both feet possible (Moncur, 1969).

In Northern Europe, 85% of the amputations are performed because of vascular disease with or without diabetes mellitus, the rest are because of trauma, tumours or congenital deficiency (Murdoch, 1984). Many of the vascular amputees have concomitant diseases reducing their chances of regaining their balance while standing and of becoming a user of a prosthesis (Hansson, 1964; Levine, 1984). Smoking is a well-known factor affecting the course of vascular disease (Liedberg and Persson, 1983). The vascular amputee has a lower success rate in prosthetic fitting than other groups of amputees, and female vascular amputees have a higher failure rate than males in using the prosthesis (McKenzie, 1953). Due to the systemic disease, the vascular amputee is generally older than 50 years at the time of amputation in contrast to the trauma amputee who usually is younger, with men being predominant (Hansson, 1964).

Sway is a measurement of standing balance (Begbie, 1969; Brocklehurst *et al.*, 1982; Mathias *et al.*, 1986). Many reports have described sway as being related to age (Brocklehurst *et al.*, 1982; Dornan *et al.*, 1978; Ekdahl *et al.*, 1989; Ekdahl and Andersson, 1989; Fernie *et al.*, 1978; Overstall *et al.*, 1977; Sheldon, 1963) and sex (Ekdahl *et al.*, 1989; Ekdahl and Andersson, 1989, Juntunen *et al.*, 1987; Overstall *et al.*, 1977; Yoshida *et al.*, 1983) in healthy subjects. Vision influences sway (Jarnlo and Thorngren, 1991; Pykkö *et al.*, 1990) and this has by some authors been shown to be of particular importance when the somatosensory information is reduced as in leg-amputees (Dornan *et al.*, 1978; Fernie *et al.*, 1978; Guerts *et al.*, 1992; Holliday *et al.*, 1978) though this has not been found by others (Vittas *et al.*, 1986). In a recent investigation, male trans-tibial amputees with diabetes mellitus were found to sway more than healthy subjects, with eyes either open or closed when standing on both feet (Isakov *et al.*, 1992). Medication is likely to influence sway, but has not been proven to do so (Brocklehurst *et al.*, 1982; Overstall *et al.*, 1977).

Timed balance tests are related to age in the same way as sway (Bohannon *et al.*, 1984). In the literature various time limits such as 30 seconds (Bohannon *et al.*, 1984; Ekdahl *et al.*, 1989; Ekdahl and Andersson 1989) and 60 seconds (Brocklehurst *et al.*, 1982; Dornan *et al.*, 1978; Fernie *et al.*, 1978) have been used to test the ability to stand on both feet with eyes open or closed. Standing on one leg while looking straight ahead for 30 seconds was regarded as normal for healthy subjects up to the age of 54 by Ekdahl *et al.* (1989), while a time limit of 5 seconds for this test was considered to be adequate by Bohannon *et al.* (1984) for healthy subjects from 60 to 69 years.

Most studies concerning standing balance in leg-amputees have been carried out with regard to the level, irrespective of the cause of the amputation. Thus, there is a lack of knowledge as to whether the standing balance in vascular amputees differs from that of other amputees and little interest has been shown in the one-leg standing of the leg amputee. In this study the authors have focused on the standing balance during quiet stance in leg amputees, measured as sway and standing time both on one and two legs.

The aim of the study was to compare postural function in standing in two groups with unilateral trans-tibial amputations for either vascular disease or trauma and to compare the results of the two groups with the results from a group of healthy subjects.

Subjects and methods

Subjects

The criteria for inclusion in this study were: unilateral trans-tibial amputation for either vascular disease or trauma with an age of 48 years and above at the time of investigation; no major sight problems (with glasses if needed); ability to talk and write in Swedish and to be able to walk indoors with a prosthesis without using a walking aid.

A total of 36 patients fitted with a prosthesis at the Orthopaedic Workshop at the Helsingborg Hospital, Sweden, fulfilled the inclusion criteria and were asked to participate in the study. All the men in the vascular group and all the women in the vascular and trauma groups selected agreed to participate. Two men in the trauma group were unwilling to take part in the study and one man was excluded due to drug abuse.

Vascular amputee group. Included in the study were 18 subjects (6 women, 12 men; mean age = 68.8 years, SD = 12.0, range = 48-87 years). The mean age of the women was 71.8 years (SD = 15.0, range = 51-87), and of the men 64.7 years (SD = 10.6, range = 48–82). Mean time since the amputation was for the women 5.0 years (SD = 4.7, range = 2-14) and for the men 7.0 years (SD = 5.7, range = 0-18). Half of the women and one third of the men in the vascular group had diabetes mellitus. Concomitant diseases among the women were hypertension in 3 cases and among the men, gastric ulcer in 1 case and varicose ulcer of the healthy leg in another. In addition, 1 woman and 2 men had a big toe amputation on the healthy leg. Concerning pharmacological treatment, 5 of the 6 women and 6 of the 12 men were on antihypertensives and/or analgesics; 1 woman and 1 man were on antihypertensives, analgesics and sedatives; 1 man was on antacids and 4 were not on drugs at all. Three men considered their hearing to be bad, but this was not evident at the clinical investigation. Further characteristics of the vascular group are shown in Table 1.

Trauma amputee group. Included in the study were 18 subjects (3 women, 15 men; mean age = 63.9 years, SD = 10.0, range = 48-82 years). The mean age of the women was 57.0 years (SD = 7.8, range = 48-62), and of the men 65.3 years (SD = 10.0, range = 48-82). Mean time since the amputation and the first prosthesis was for

Table 1. Characteristics for the groups studied.

	Vascular		Trauma		Healthy	
Characteristics	Women n = 6 f	Men n = 12 f	Women n = 3 f	Men n = 15 f	Women n = 8 f	Men n = 19 f
Sight (normal/ slight impairment)	3/3	7/5	2/1	10/5	3/5	14/5
Hearing (normal/ slight impairment/bad)	3/3/0	7/2/3	3/0/0	8/5/2	6/2/0	8/11/0
Smoking habits (smokers/ ex-smokers/non-smokers)	1/1/4	5/4/3	1/0/2	3/7/5	0/1/7	3/6/10
Concomitant diseases (yes/no)	3/3	2/10	2/1	6/9	–	–
Medication (yes/no)	6/0	8/4	2/1	8/7	–	–
Side of amputation (right/left)	3/3	5/7	2/1	8/7	–	–
Stump pain (yes/no)	4/2	4/8	0/3	5/10	–	–
Phantom sensation (yes/no)	4/2	11/1	0/3	5/10	–	–
Phantom pain (yes/no)	4/2	10/2	2/1	8/7	–	–
Walking aid outdoors (yes/no)	5/1	5/7	1/2	6/9	–	–

the women 11.3 years (SD = 11.0, range = 4-24) and for the men 36.3 years (SD = 19.4, range = 5-62). Concomitant diseases among the women were thyroid enlargement in 1 case and hypertension in another. Among the men, 2 had asthma and 1 had both cardiac insufficiency and chronic bronchitis. Two men had had myocardial infarction and another had had a minor stroke more than one year previously but they were all back to normal again without any sequelae. Concerning pharmacological treatment, 1 woman and 6 men were on antihypertensives and/or analgesics; 1 man was on antihypertensives, analgesics and sedatives; 1 woman was on thyroid hormone medication and 1 man was on anti-asthmatic inhalation medication; 1 woman and 7 men were not on drugs at all. Two men considered their hearing to be bad, but this was not evident at the clinical investigation. Further characteristics of the trauma group are shown in Table 1.

Healthy reference group. The vascular and trauma amputee groups were matched for age with a group of 27 healthy persons (8 women, 19 men; mean age = 69.6 years, SD = 9.8, range = 48-86). The mean age of the women was 71.8 years (SD = 11.2, range = 52-86), and of the men 68.7 years (SD = 9.4, range = 48-82). The criteria for inclusion in this group were feeling healthy, taking no medicine and having experienced no problems with standing balance. All the subjects selected according to these criteria agreed to participate. Further characteristics of the healthy group are shown in Table 1.

Methods

Force platform. A stable force platform (Kistler) in the Vifor system was used for the data collection (Lanshammar, 1991). The standing balance was measured with 50 samples per second during 30 seconds, after which a summary of the measurement was displayed on the screen connected to the force platform. This summary contains a graphic illustration of the variations as standard deviations of the position of the centre of pressure on the platform. Parameters shown on the summary picture for the test battery: S(x), S(y) = the standard deviations of the sway amplitudes (mm) in the lateral and sagittal directions, respectively. During the test battery standing time (ms) was recorded simultaneously on the screen (Lanshammar, 1991).

Standing balance. The standing balance test was carried out according to the test battery of Ekdahl *et al.* (1989), earlier shown to be satisfactorily valid and reliable. Every test was performed three times for a period of 30 seconds, in order to obtain the best performance from each person and according to increasing degree of difficulty. The recording with the smallest sway amplitude from the three tests was chosen. Standing blindfolded on one leg was found to be too difficult in a pilot test and for that reason was excluded. During the following tests all persons had their ordinary walking shoes on.

Test I: Standing with feet close together, looking straight ahead and with arms hanging.

Test II: Standing blindfolded in the same position as in Test I.

Tests III and IV: Standing on one leg. For the leg-amputees: first the sound leg (Test III) and then the leg with the prosthesis (Test IV). For the healthy subjects: first the right (Test III) and then the left leg (Test IV). All looking straight ahead and with arms hanging. Compensatory movements of the arms and the lifted leg were accepted in Tests III and IV.

Questionnaires. Before the tests for postural function, the subjects were asked to fill in a questionnaire about sight (normal/slight impairment), hearing (normal/slight impairment/bad), smoking habits (yes/ex-smokers/non-smokers), concomitant disease (yes/no) and medication (yes/no). For the leg-amputees, additional questions were asked about time since the amputation (years), side of amputation (right/left), stump pain (yes/no), phantom sensation (yes/no), phantom pain (yes/no) and if they used any walking aids outdoors (yes/no).

Statistics. When overall significance testing was performed, that is, when all three groups were compared, the Kruskal-Wallis test was used (Siegel and Castellan, 1988). All pairwise comparisons were analysed using the Wilcoxon Rank Sum test and the within group comparisons were analysed with the Wilcoxon Signed Rank test (Siegel and Castellan, 1988). Analysis of covariance was used to investigate whether the year since amputation or phantom sensation had any influence on Tests I, II and III (Berenson *et al.*, 1983). The Chi-square test was used to analyse 2*2 tables (Pocock, 1983). The significance level was set to 5%, a two-sided test. The statistical software used in the analysis was SAS Version 6.08.

Results

There were no sex or age differences between the vascular, trauma and healthy groups. Thus, the results are presented for women and men together. A longer period of time since the amputation ($p = 0.0001$) and a lower frequency of phantom sensation ($p = 0.0001$) among the trauma amputees were the only characteristics showing significant differences between the vascular and trauma groups, but these were not found to affect the results of the test battery. There were no significant differences between the three groups concerning the characteristics in common.

Table 2. Sway and standing time. Means, standard deviations and frequency of success at performing the tests for the vascular, trauma and healthy groups.
Abbreviations: S(x), S(y) = standard deviations of the sway amplitudes (mm) in the lateral and the saggittal directions, respectively.
Test I = standing on both feet looking straight ahead;
Test II = standing on both feet blindfolded;
Test III = standing on the healthy leg for the amputee groups/the right leg for the healthy group;
Test IV = standing on the prosthetic leg for the amputee groups/the left leg for the healthy group

		Vascular + trauma (n = 36)			Vascular group (n = 18)			Trauma group (n = 18)			Healthy group (n = 27)		
Test		M	SD	n	M	SD	n	M	SD	n	M	SD	n
I	S(x)	5.7	1.6	36	6.1	1.6	18	5.3	1.6	18	4.7	1.4	27
	S(y)	5.2	2.0	36	6.0	2.3	18	4.4	1.5	18	5.2	1.2	27
	Standing time (s)	30.0	0.0	36	30.0	0.0	18	30.0	0.0	18	30.0	0.0	27
II	S(x)	7.2	2.3	30	7.8	1.5	13	6.8	2.8	17	6.0	2.3	27
	S(y)	6.8	2.6	30	6.8	2.6	13	6.8	2.7	17	6.7	2.3	27
	Standing time (s)	22.6	8.7	36	23.3	11.3	18	30.0	0.0	18	30.0	0.0	27
III	S(x)	9.8	6.1	16	9.4	2.5	5	10.0	8.2	11	9.4	4.8	19
	S(y)	10.1	6.1	16	11.2	2.8	5	9.6	7.2	11	9.7	3.9	19
	Standing time (s)	16.4	14.3	36	10.9	14.3	18	22.3	12.2	18	24.5	9.9	27
IV	S(x)	–	–	0	–	–	0	–	–	0	10.3	7.0	19
	S(y)	–	–	0	–	–	0	–	–	0	10.6	6.0	19
	Standing time (s)	1.5	3.6	36	1.0	4.0	18	2.0	3.2	18	24.4	9.8	27

Table 3. Standing time. Frequency with respect to standing time in seconds for the vascular, trauma and healthy groups during the tests for 30 seconds.

Test	Time (s)	Vascular (n = 18) f	Trauma (n = 18) f	Healthy (n = 27) f
I	30	18	18	27
II	30	13	17	27
	15-29	–	–	–
	5-14	3	–	–
	1-4	1	–	–
	0	1	1	–
III	30	5	11	19
	15-29	2	1	1
	5-14	–	2	5
	1-4	–	–	–
	0	11	4	2
IV	30	–	–	19
	15-29	1	–	3
	5-14	–	2	2
	1-4	1	4	1
	0	16	12	2

Standing balance on two legs

Sway. Means, standard deviations and frequency of success in performing the tests included in the test battery are presented in Table 2. There were significant differences between the three groups, concerning the sway amplitudes in the lateral ($p = 0.02$) and the sagittal ($p = 0.04$) directions when looking straight ahead, but only in the lateral direction when blindfolded ($p = 0.02$). In both test situations, all amputees together and the vascular group separately had a significantly increased sway in the lateral direction (p values ranging from 0.003 to 0.02) compared with the healthy group (Table 5). In the sagittal direction, the trauma amputees had a significantly decreased sway ($p = 0.03$) when looking straight ahead compared with the vascular and healthy groups.

Standing time. There were no dropouts in the two-leg standing test looking straight ahead for 30 seconds (Table 2) and there was no significant difference in standing time between the three groups. When blindfolded, the five dropouts in the vascular group were two women (85 and 88 years) and one man (83 years) who stood less than 15 seconds, one man (65 years) who stood less than 5 seconds and one woman (78 years) could not stand at all on both feet when blindfolded (Table 3). The only dropout in the trauma group was a man (82 years) who was unable to stand for a single second on both feet blindfolded. There was a significant difference between the three groups concerning the standing time when blindfolded ($p = 0.002$). All amputees together ($p = 0.04$) and the vascular group separately ($p = 0.004$) had a significantly shorter standing time compared to the healthy group (Table 5). The vascular amputees had a significantly shorter standing time than the trauma amputees ($p = 0.02$). No such difference was seen when comparing the trauma amputees with the healthy subjects.

Standing balance on one leg

Sway. No significant differences in the lateral or sagittal directions were seen between the three groups when comparing standing on one leg. Due to complete failure to stand on the prosthetic leg for 30 seconds in all patients, a comparison with the prosthetic leg could not be carried out.

Standing time. The minimum standing time on one leg for the subjects between the age of 40 and 59 was for the healthy subjects 30 seconds for the right as well as for the left leg,

Table 4. One-leg standing and age. Distribution of frequency according to age in decades for the standing time in seconds looking straight ahead on the healthy leg for the vascular and trauma groups (Test III) and for the right and left leg, respectively, for the healthy group (Tests III-IV).

	Vascular group (n = 18)		Trauma group (n = 18)		Healthy group (n = 27)			
	Healthy leg		Healthy leg		Right leg		Left leg	
Decades	0-4 s f	5-30s f	0-4s f	5-30s f	0-4s f	5-30s f	0-4s f	5-30s f
40-49	–	1	–	3	–	1	–	1
50-59	–	3	–	1	–	4	–	4
60-69	3	2	1	8	–	6	–	6
70-79	4	1	1	2	–	9	1	8
80-89	4	–	2	–	2	5	2	5

30 seconds for standing on the healthy leg for the trauma amputees and 20 seconds for the vascular amputees (Table 4). Of the subjects aged 60 to 69 years, all in the healthy group could stand for 5 seconds. In the trauma group only one woman failed and in the vascular group three men failed to stand on the healthy leg. Between the age of 70 and 79 years all the healthy subjects could stand for 5 seconds, except one woman who failed to stand on the left leg. In the trauma group one man failed to stand for 5 seconds, and in the vascular group only one man succeeded in standing on the healthy leg. When reaching the age of 80 to 89 years, all of the amputees failed to stand for 5 seconds. In the healthy group two women failed to stand on the right leg and one woman and one man failed to stand on the left leg. There was a significant difference between the three groups when standing on one leg ($p = 0.002$). Significantly shorter standing time was found when comparing all amputees together ($p = 0.02$) and the vascular group separately ($p = 0.0009$) with the healthy group as well as for the vascular amputees compared with the trauma amputees ($p = 0.02$) (Table 5). No such difference was seen when comparing the trauma amputees with the healthy subjects.

One man in the vascular group succeeded in standing on the prosthetic leg for 17 seconds and one woman in the trauma group succeeded in standing for 11 seconds. They were both 48 years. The one-leg standing on the prosthetic leg showed no significant difference between the vascular and trauma amputees.

Comparison of sway amplitudes when standing on both feet looking straight ahead and blindfolded

All the amputees, separately or together, and also the healthy subjects, increased their sway amplitudes in the lateral and the sagittal direction when blindfolded, compared to looking straight ahead in the two-leg standing test (p values ranging from 0.0002 to 0.05). None of the three groups had a significantly larger increase in the sway when blindfolded.

Discussion

The test battery of standing balance proved to discriminate between vascular and trauma amputees. The vascular amputees in this study represent the total population of the vascular amputees in the Helsingborg and Landskrona Health Care District in Southern Sweden who passed the inclusion criteria. The youngest in the vascular group was 48 years. In order to make a comparison with the trauma amputees in the same district, trauma amputees 48 years and older were included. The distribution of men and women among the amputee groups corresponds well to the proportion reported earlier in the literature (Hansson, 1964; Levine, 1984; McKenzie, 1953).

The results of this study show an increase in

Table 5. Within group differences (p values) for the variables of mean sway amplitude in the lateral and sagittal direction (x, y) and the standing time in Tests I-IV.

Test		Vascular + trauma /healthy	Vascular /healthy	Trauma /healthy	Vascular /trauma
		p	p	p	p
I	S(x)	0.01	0.0004	0.21	0.16
	S(y)	0.44	0.42	0.03	0.03
	Standing time	1.00	1.00	1.00	1.00
II	S(x)	0.02	0.003	0.30	0.13
	S(y)	0.93	0.88	0.79	0.83
	Standing time	0.04	0.004	1.00	0.02
III	S(x)	0.75	0.61	0.45	0.33
	S(y)	0.74	0.17	0.20	0.12
	Standing time	0.02	0.0009	0.59	0.02
IV	S(x)	a)	a)	a)	a)
	S(y)	a)	a)	a)	a)
	Standing time	0.0001	0.0001	0.0001	0.08

a) This test cannot be performed on empty groups.

the sway in trans-tibial amputees and healthy subjects when blindfolded compared to looking straight ahead in the two-leg standing test. All trans-tibial amputees showed an increase in the lateral sway in the two-leg standing test when looking straight ahead or blindfolded, compared to the healthy subjects. Trans-tibial amputees have earlier been found to sway more than healthy subjects when standing with eyes open or closed (Fernie *et al.*, 1978; Isakov *et al.*, 1992). Variations in foot position affect the measurements of standing balance (Kirby *et al.*, 1987) thus making comparisons with the result of these studies difficult (Fernie *et al.*, 1978; Isakov *et al.*, 1992). Vittas *et al.* (1986) found trans-tibial amputees for vascular disease and trauma, men and women between 16 and 59 years, to have a reduced sway in both directions, and men above 59 years to have a limited sway in the sagittal direction, compared to healthy subjects when standing for 60 seconds with their eyes closed. This is partly in agreement with the findings of the present study and further discussed below.

When comparing the vascular and the trauma amputees separately, when standing on both legs, the sway amplitude of the trauma amputees in the sagittal direction was decreased compared to the healthy subjects, when looking straight ahead, while the vascular amputees showed increased postural sway in the lateral direction in both test situations compared to the healthy subjects. An increased sway in the lateral direction compared to the sagittal direction in elderly persons, was reported by Jarnlo and Thorngren (1991) as a possible sign of decreasing balance capacity. The men above 59 years in the study of Vittas *et al.* (1986) were also found to have a limited sway in the sagittal direction. They thought the reduced sway to be caused by the relatively stiff ankle of the prosthesis and the fact that the healthy leg only needs slight muscle movements to maintain balance.

No significant differences in the lateral or sagittal directions were seen between the three groups when comparing the sway amplitudes while standing on one leg. But the decreased balance capacity of the vascular amputees, reflected as increased postural sway in the lateral direction when standing on both feet, compared to the healthy subjects as mentioned previously, is now shown in the significant difference in standing time when compared with the trauma and healthy groups. This is caused by the many dropouts in the vascular group of all ages.

Not being able to stand with feet together, eyes open or closed, for 30 seconds was considered abnormal for subjects younger than 79 years by Bohannon *et al.* (1984). As the dropouts in the vascular and trauma groups were on the whole older than 79, the authors are inclined to say that a standing time of 30 seconds did not discriminate the amputees from the healthy subjects. Ekdahl and Andersson (1989) also came to this conclusion when comparing subjects with rheumatoid arthritis with healthy subjects.

Standing on one leg for 30 seconds with subjects between the age of 48 and 59 years caused dropouts exclusively among the vascular amputees. The standing capacity of the trauma amputees was quite up to the standard of the healthy subjects in this age group. No comparison can be made with others regarding the amputees, as the one-leg standing test has not been reported for amputees previously. The results obtained from the healthy subjects were in accordance with the findings of Ekdahl *et al.* (1989).

As the healthy subjects in this study were standing with their shoes on and were allowed to move their arms when standing on one leg, the time limit of 5 seconds could be considered adequate for the healthy subjects from 70 to 79 years as well as for this test. Still, the trauma amputees kept pace with the healthy subjects while the vascular amputees had some failures. In theory, the authors think it could have been possible for the trauma amputees to have had a better standing balance on the healthy leg than the healthy controls, but this study did not show that.

Considering the loss of the calf muscles, standing on the prosthetic leg cannot be recommended as a test of standing balance in amputees. However, the authors found it interesting to investigate as it has not been reported on previously.

One man in the vascular group and one man in the trauma group were on sedatives. Both failed in the one-leg standing test. The trauma amputee was the only dropout of a total of three in the trauma group between 70 and 79 years, while the vascular amputee did not affect the result of the vascular group in this age range. The authors are inclined to say that in agreement with the findings of Brocklehurst *et al.* (1982) and Overstall *et al.* (1977) medication has not been proven to influence standing balance.

At the age of 80 and above, all the amputees failed to stand on the healthy leg for 5 seconds with even the healthy subjects starting to show dropouts. This is worth noting as the age group of 80 years and older at amputation for vascular disease in the south of Sweden has been found to be the only age group showing an increase (Eneroth and Persson, 1992).

In the literature there is some disagreement as to whether women (Overstall *et al.*, 1977; Yoshida *et al.*, 1983) or men (Ekdahl *et al.*, 1989; Ekdahl and Andersson 1989; Juntunen *et al.*, 1987) show greater postural sway. There are, however, methodological differences that could affect the results of these measurements. It would be interesting to see in an extended study, whether the poor success of prosthetic fitting in female vascular amputees in the present study could be explained by a lower balance performance, compared to male vascular amputees.

As the vascular amputees showed a decreased balance capacity measured as standing time compared with the healthy subjects and the trauma amputees in the one-leg standing test, it may be argued that this difference could be explained by the vascular disease. Further studies will concentrate on the effect of specific training in the one leg standing of the vascular amputee in connection with the amputation. In addition, the possibilities of the vascular amputee becoming a user of a prosthesis will be investigated.

To conclude, the standing balance of the vascular trans-tibial amputees was found to be inferior to that of the trauma trans-tibial amputees. Consequently, vascular and trauma trans-tibial amputees should not be considered as an entity in test situations or rehabilitation programmes.

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Four-bar linkage prosthetic knee mechanisms: kinematics, alignment and prescription criteria

C. W. RADCLIFFE

Mechanical Engineering Department, University of California, Berkeley, USA

Introduction

Four-bar linkage knee mechanisms for the trans-femoral amputee are widely available, but although they may offer functional advantages to certain amputees, they are fitted in a limited number of cases. It may be assumed that one reason for this is that persons responsible for prescription and fitting may not be familiar with the kinematic characteristics and possible advantages of such mechanisms and are reluctant to use a device which they do not understand completely.

This paper will describe the kinematics of several types of four-bar mechanisms, and discuss the differences and prescription criteria for three different classes of four-bar linkage mechanisms currently available for fitting to amputees. Before beginning the discussion of four-bar prosthetic knees, it will be helpful to review some fundamental concepts.

The load line

The line along which the equivalent single load force acts on a weight-bearing prosthesis seldom, if ever, acts along a line directed from the hip joint to the ankle. Neither does it, in general, act from a single point at the level of the socket brim to the centre of pressure on the sole of the foot. The location and direction of the load line can be measured by a force plate during walking and it is constantly changing its location and direction with respect to the geometric long axis of the prosthesis (or anatomical long axis for the non-amputated side).

All correspondence to be addressed to Professor C.W. Radcliffe, Hosmer Dorrance Corporation, 561 Division Street, Campbell CA 95008-6905, USA.

The direction of the load line as seen from the medial or lateral side for a trans-femoral amputee is directly related to the stability of the prosthetic knee. When the load line passes anterior to the knee joint axis the prosthetic knee is forced into full extension against the extension stop. In order for the knee to flex while bearing weight at push-off the load line must shift to a position where it passes posterior to the knee centre. The amputee can actually control the direction of the load line as seen in the mediolateral view by active use of the flexion-extension musculature about the hip joint of the stump. This leads to the concept of "voluntary control of knee stability" which is of particular interest in the design and use of certain four-bar or other polycentric knee mechanisms. The same concepts are also important to any trans-femoral amputee using a non-locked single axis knee. A trans-femoral amputee with a weak hip who is unable to exert the necessary muscle effort would obviously have greater difficulty in maintaining knee stability without dramatic changes in alignment stability or installing a brake type mechanism.

A lesson in basic engineering mechanics may help to explain how the muscle moments exerted by the amputee influence the direction of the load line. Consider the schematic diagrams of Figure 1. An outline of a trans-femoral prosthesis is shown in Figure 1(a) at heel contact, the most critical period of the stance phase for knee security. The upper reference point is arbitrarily selected at the hip joint which allows the analysis to proceed without considering the manner of socket fitting. In diagram (a) a prosthesis is shown at the instant that weight bearing begins. In this case the amputee is not exerting an extension

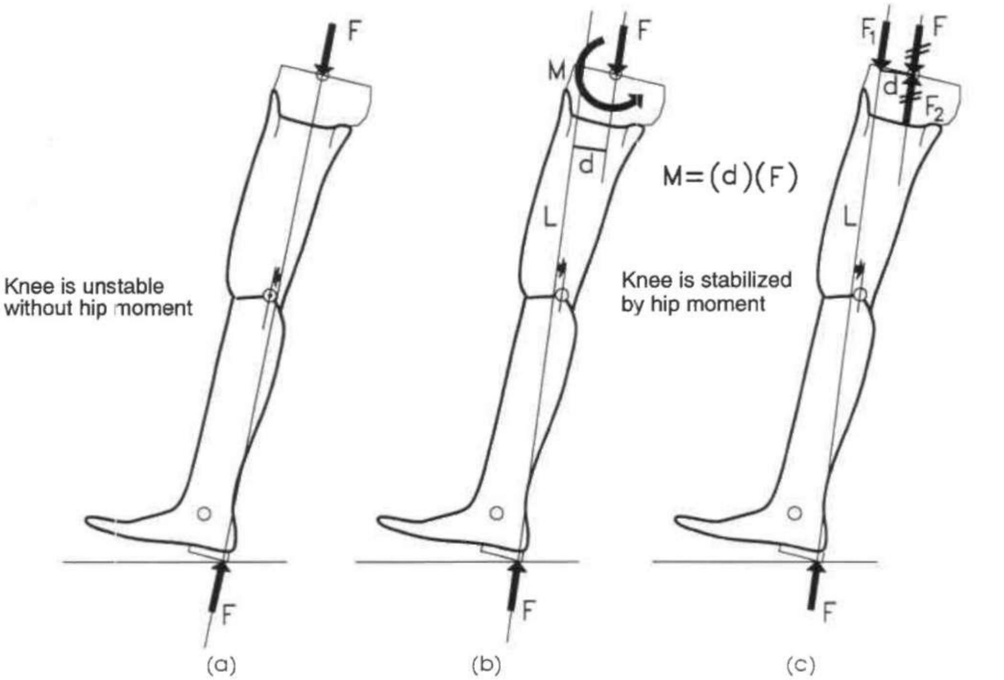

Fig. 1. A single force F_1 acting along the load line L is equivalent to force F and moment M acting about the hip of trans-femoral amputee.

moment about the hip and the load on the prosthesis would be a direct thrust from hip joint to heel contact point. In diagram (a) the "load line" passes behind the knee centre and the knee would buckle under load. What is the mechanism by which the knee is made secure so that it will not buckle?

Consider Figure 1(b). In this case the amputee is exerting an extension moment about the hip. This tends to drive the heel into the ground and the ground pushes back on the heel. Since Newton's law states "action = reaction", the result is a second component of force acting forward on the heel and the load line inclines in front of the knee centre giving a stable knee.

This phenomenon can also be explained by considering the combination of joint force and extension moment acting at the hip joint. Consider Figures 1(b) and (c). One may replace the hip extension moment M in (b) by a pair of equal and opposite forces of magnitude F separated a distance D which has the same extension moment as M, i.e., M = (D) x (F). This pair of forces F_1 and F_2 are now placed on diagram (c) in a position such that F_2 is in-line with the actual force F. The moment M has been replaced hypothetically by the forces F_1 and F_2 offset by the distance D and the forces F and F_2 cancel each other. The equivalent inclined load line from the heel would pass ahead of the hip joint by the distance D. F_1 and the heel force F act along the same load line.

This variable location of the load line during the dynamic events of the stance phase of a walking cycle make the definition of a "load line", which can be drawn or visualized on a lower limb prosthesis, dependent on knowing the complete set of forces and moments acting on the prosthesis at each phase of the walking cycle. In the standing at rest position, it also requires more data than is available to the prosthetist and many assumptions would have to be made. It is therefore best to leave the concept of an exact load line to laboratories with the instruments to measure it and use a "vertical reference line" to describe the geometry of a lower limb prosthesis relative to this line.

Bench alignment vertical reference lines

A vertical line, or plumb line, is the reference line used by prosthetists for the "bench alignment" of the prosthesis. This line is used to assemble the components of the prosthesis such that the prosthesis will provide stability in weight bearing during the first walking trials when fitted to the amputee. It is anticipated that small changes in the bench alignment settings will be made during the first walking trials, a procedure known as "dynamic alignment". With careful bench alignment, the changes during dynamic alignment should be small, and necessary only to fine tune the prosthesis for the needs of an individual amputee.

The German bench alignment system

In Germany, and some other European countries, a bench alignment system is often used which shows the prosthesis in a reference position corresponding to the highest position of the hip joint as the amputee rolls over the ball of the foot in the stance phase. This results in a vertical reference line which extends downward from the hip joint (sometimes assumed to pass through the centre of stump cross-sectional area at the brim level) to approximately the mid-length point of the foot. The bench alignment procedure involves specifying offsets to locate the knee joint centre and ankle joint centre posterior to this vertical reference line. This system was developed over 50 years ago and was considered necessary to account for the large number of knee and foot mechanisms used in Germany. Each knee-foot combination has a specific pair of offsets.

The reference position, with the foot assumed to be bearing weight on the ball of the foot, also requires the incorporation of a specific air space under the heel (the "safety factor") for each style of foot. The illustrations used show an exaggerated heel height similar to a cowboy boot. This is not the heel height for the shoe but the sum of the heel height plus the safety factor. The safety factor improves the stability of the knee at heel contact during walking since it is equivalent to plantar flexion of the foot during bench alignment.

The UC Berkeley bench alignment system

At the Biomechanics Laboratory, University of California at Berkeley, comparative studies in 1964 of the European bench alignment system with the then commonly used TKA line (Trochanter-Knee-Ankle vertical reference line as seen from the lateral side) concluded that the actual optimal alignment obtained was very similar, particularly for single-axis knee mechanisms. The major source of difference was the difficulty in locating the trochanter or upper reference point relative to the upper socket brim. Note that to locate the trochanter relative to the socket brim the amputee must be present and fitted into the socket. Rotation contracture of the femur relative to the pelvis or the presence of excessive soft tissues can cause significant error in location of the trochanter point on the socket.

A new system was adopted which did not depend upon the location of the trochanter but arbitrarily used the Bisector of the Medial Brim (BMB point) as the upper reference point on the medial socket brim. This point can be located accurately and easily on a typical quadrilateral shaped trans-femoral socket and does not require that the amputee be present. If the socket deviates from a quadrilateral shape, the centre-of-area at the brim level can be projected to the medial wall of the socket as a reasonable approximation.

As viewed posteriorly the upper reference point on the socket is the point of contact of the tuberosity of the ischium. This point can be estimated by palpation of the point of contact of the ischium relative to the socket brim. Fortunately this point need not be located as accurately as the BMB point and a good approximation is usually adequate for bench alignment. This point is used to estimate the outset of the foot relative to the socket. The outset of the foot can vary from a negative value for very active walkers with a long stump to a positive 5 cm (2 in) or more for very short stumps. A positive outset is required whenever the amputee is not capable of using the stump for lateral stability and must bring the load line as seen posteriorly to a position which passes close to the hip joint.

In the Berkeley system the alignment of the prosthesis is referred to lines drawn on the medial and posterior sides of the prosthesis. The vertical reference line is the centre line of the shank pylon tube and the medial side of the prosthesis is much more convenient for viewing an extension of the shank tube centre line from above or checking the alignment by use of a plumb bob in a vertical fabrication jig. The vertical reference line, in both posterior and medial views of the prosthesis, becomes the reference for offsets or angles for alignment of foot, knee, and socket during bench alignment. At Berkeley the use of endo-skeletal systems with aluminium tubing as the shank structure and the SACH (Solid Ankle Cushion Heel) foot without ankle joint was the preferred system dating back to the 1950s. It was convenient to use the centre of the shank pylon as the vertical reference line and refer the heel lever arm and forefoot lever arm for the foot, knee centre anterior-posterior location, the socket flexion and adduction, and the anterior-posterior location of the socket at the brim level to this line. The recent popularity of a variety of endo-skeletal systems and energy return feet without ankle joints clearly makes the use of the shank pylon centre line the system of choice for the vertical reference line.

Comparison of the German and Berkeley reference positions

As a demonstration that good bench alignment can be achieved using either the UC Berkeley system or the German system, the two systems are compared in Figure 2. This illustration is similar to one developed during the 1964 studies by the Danish prosthetist, Erik Lyquist, while he was a visiting research prosthetist at the UC Biomechanics Laboratory. Note that the same basic diagram is used in both cases. The only difference is the reference position. The Berkeley system is much easier to check in the vertical alignment jig or by use of a plumb bob with the completed prosthesis.

Bench alignment as viewed in the anterior-posterior direction

Many modern lower limb prosthesis systems incorporate built-in alignment devices which allow changes in the angle of the foot relative to the shank tube, angular changes between knee mechanism and shank tube at the proximal end of the tube and angular (and sometimes translational) adjustments between knee mechanism and the distal end of the socket.

Given such a plethora of adjustments, the prosthetist is often tempted to use them all. All can be useful in certain circumstances, but it must be recognised that in some cases too many adjustments can cause conflicting results and often do more harm than good. Figure 3 shows medial and posterior views of typical bench alignment settings using the UC Berkeley system for a single axis knee mechanism (without a

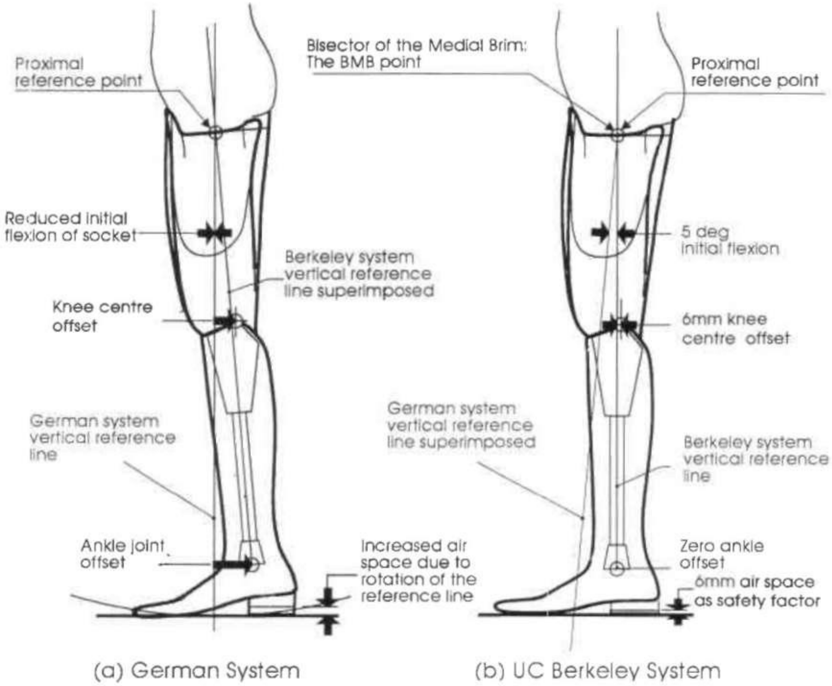

Fig. 2. Bench alignment – medial view comparison of German and UC Berkeley systems.

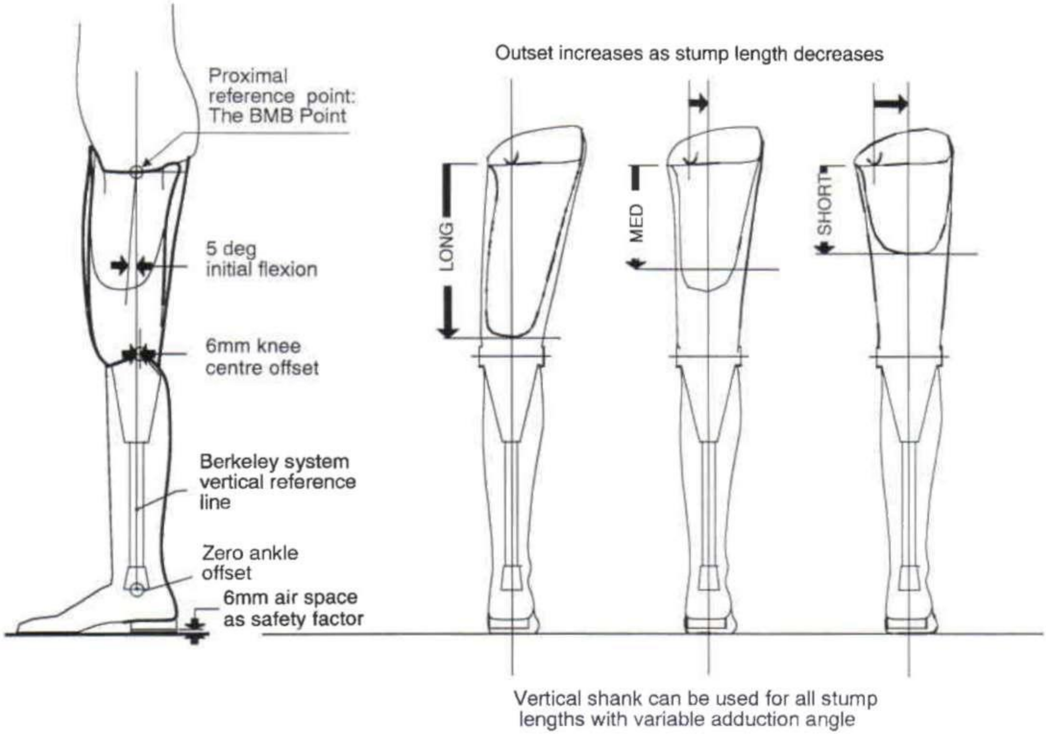

Fig. 3. Typical bench alignment for varying stump length UC Berkeley system.

brake or hydraulic stance control) and a SACH foot (with *soft* heel cushion) for amputees with short, medium, and long stumps. Only minor changes from these guidelines should be required if the amputee is fitted comfortably and has good control of the prosthesis through his or her stump-socket fitting.

Increasing knee-stability during dynamic alignment

The proper way to increase the "alignment stability" of the knee is to increase the posterior offset of the knee centre relative to the vertical reference line. In modular endo-skeletal systems this dimension is set by the manufacturer and built into the hardware. This makes it necessary to check the posterior offset for the knee mechanism being fitted. The vertical reference line dropped from the bisector of the medial brim (the BMB point) should pass a *minimum* of 6 mm (¼ in) ahead of a single-axis knee centre as viewed from the medial side. Remembering that the knee bolt is typically rotated externally about a vertical axis by approximately 5 degrees, the knee centre as viewed from the lateral side would be more than 6 mm (¼ in) posterior, perhaps as much as 12 mm (½ in).

During dynamic alignment the prosthetist can increase knee stability by increasing the posterior offset of the knee axis using the following two-step procedure:

1. Extend the socket a small amount in approximately one degree increments using the adjustable coupling between socket and knee.

   This will shift the upper reference point at the brim of the socket forward approximately 6 mm (¼ in) per degree of socket extension. After the adjustment the amputee must bring the upper reference point back to the standing position by a posterior rotation about the point of support on the foot which will result in a decrease in the air space (safety factor) previously set during bench alignment.

2. Plantar flex the foot a small amount using the adjustable coupling at the ankle.

The plantar flexion adjustment will restore the air space to the desired amount. The final result will be a posterior shift of the knee axis with minimal disturbance of the desired socket-foot relationship.

The amount of forward shift (S) of the BMB point per degree of socket extension (E) for a given BMB-knee dimension (D) can be computed easily using the following formula:

S = (D)(E)/57.3
For example to find S, given D = 380 mm (15 in), E = 1 degree
S = (380)(1)/57.3 = 6.6 mm (0.26 in) (per degree of extension)
where 57.3 is the factor for conversion of degrees to radians

Therefore, it is apparent that small changes in the socket angle can have a major effect on the posterior offset. The compensating angular change at the ankle would be somewhat smaller. Assuming a length (L = 760 mm (30 in)) from BMB to ankle, the angular change (A) at the ankle would be computed from the formula:

A = 57.3(S)/(L)
A = 57.3(6.6)/(760) = 0.50 degrees plantar flexion

To decrease the built-in offset, the socket is flexed a small amount and the ankle is dorsi-flexed.

Effect of foot adjustments on knee stability

It should be emphasized that a bit more plantar flexion will probably be welcomed by the amputee since it will give more stability at heel contact. To achieve the optimal settings there are several foot function adjustments that will have to be checked with the amputee:

1. If the amputee complains that heel pressure is not felt while standing, have the amputee move the foot rearward and stand on the ball of the foot. Explain to the amputee that this is necessary if dynamic knee stability at heel contact while walking is to be achieved efficiently. This may require patience, practice and retraining, but the result will be worth the time and effort. When an air space is incorporated into the bench alignment, the amputee should not contact the heel on the floor when standing at rest. Clearly this system is not recommended for bilateral trans-femoral amputees.
2. If the amputee complains of the leg being too long, first check the leg length by examining the height of the iliac crests and spinal curvature with equal weight distribution on both feet. If the prosthesis is too long, the shank tube may need shortening, the foot may have too much air space under the heel, or the ankle has been plantar flexed more than required for stability at heel contact.
3. If the amputee complains of lack of support on the ball of the foot during roll-over try increasing the amount of plantar flexion. This is particularly important with energy return feet which must store energy by deflection of the keel (forefoot) under load.

In walking, the foot should approach the floor in a slightly plantar flexed attitude, the centre of pressure should move quickly and smoothly forward from the heel to the ball of the foot, and the amputee should not have the sensation of either "walking over a hill" or "lack of support during roll-over".

The knee will be secure as soon as pressure is established on the ball of the foot. Most knee instability problems are due to 1) a dorsiflexed foot, 2) a stiff plantar flexion bumper, or 3) a firm heel cushion action. Any of these factors will prolong the time of weight bearing on the heel.

If a SACH foot is used the heel cushion must be softer than for a trans-tibial amputee. Use a *soft* grade and ensure the foot is fitted in the shoe to allow at least 9 mm (3/8 in) of heel compression. An energy return foot should be plantar flexed to account for the forefoot deflection at push-off. The anterior-posterior location of the foot relative to the shank centre line would also be important as related to the knee centre offset. But again, the foot position is usually determined by the mechanical design of the foot and the ankle connector.

In bench alignment the proper location of the upper reference point on the socket, along with the knee offset, should provide the necessary knee stability. Adjustments to knee stability should be done first at the foot and ankle.

A prosthetic foot of any type must provide three functions:

1. Shock absorption at heel contact
2. Smooth transition to a stable weight bearing mode on the ball of the foot

3. Smooth transition from stance to swing phase

An energy return foot may be important to athletic individuals but is not a necessary feature for many amputees.

The knee-stability diagram

One way to compare stability characteristics of either single-axis or four-bar linkage knee mechanisms is to visualize the contribution of the residual hip musculature on the amputated side to the stability of the knee during the stance phase of walking.

Figure 4 shows schematic diagrams of the equivalent forces and moments acting on the foot and about the hip joint of a typical trans-femoral amputee fitted with a single-axis knee mechanism. Two diagrams are shown corresponding to two phases of the walking cycle: (a) heel contact and (c) push off. These two diagrams are then superimposed as shown in (b). Note that these diagrams would apply to any method of socket fitting, assuming that the socket is comfortable and allows the amputee to exert muscle moments about the hip joint as seen from the side.

Note that the line of the floor reaction force does not pass through the centre of the hip joint at either heel contact or push off. At heel contact, the line of action of the force on the heel must pass ahead of the prosthetic knee centre in order for the knee to be stable during the heel contact – shock absorption phase. The amputee actually controls the orientation of the force line by actively exerting a small extension moment about the hip.

The same principles apply to the force system at push off. At push off the amputee should be able to initiate knee flexion for the transition into the swing phase without lifting the prosthesis from contact with the floor. This is accomplished by a flexion moment from the hip musculature which has the effect of shifting the force line originating at the ball of the foot to an orientation which passes behind the knee joint centre and would cause the knee to flex.

If the diagrams of Figures 4(a) and 4(c) are superimposed and it is assumed that the amputee is capable of exerting the required muscular moments about the hip joint, the stability diagram shown in Figure 4(b) is

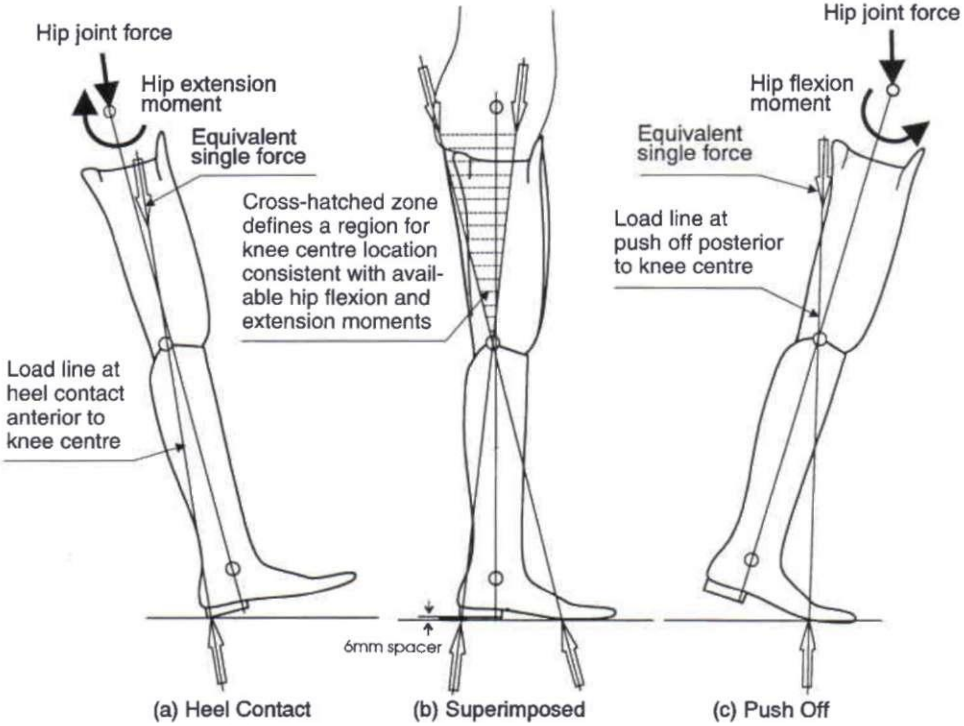

Fig. 4. Stability diagram – single axis prosthetic knee mechanism.

obtained. The cross-hatched area represents an area where the knee centre in full extension can be located and still maintain the two desired characteristics: 1) stability at heel contact and 2) ability to initiate knee flexion voluntarily just prior to push off. The actual required muscular effort on the part of the amputee will vary depending on the alignment of the knee joint within this V-shaped region.

The diagrams of Figure 4 have been drawn for a typical trans-femoral prosthesis with knee stability determined solely by alignment of the knee centre. No friction brake mechanism is assumed to be incorporated into the knee mechanism. Many active trans-femoral amputees have the ability to exert muscle moments about the hip joint much larger than the moments required in Figure 4. It should also be obvious that flexion and extension moments about the hip are absolutely essential. An amputee with a weak hip could not control a single-axis knee without a knee brake or lock.

The instant centre

The "instant centre", or more properly the "instantaneous centre of zero relative velocity", is a point where, for a very small change in the angle of knee flexion, the thigh section rotates about a point on an extension of the shank which appears to be temporarily fixed. For small angles of relative rotation one could imagine a temporary hinge connecting the shank and thigh sections at the instant centre. For larger angles of rotation the instant centre will change its location and a new temporary hinge must be imagined.

For a four-bar linkage knee, the instant centre (in any position of knee flexion) can always be located at the intersection of the centre lines of the anterior and posterior links which connect the socket section to the shank section of the prosthesis. As the knee flexion angle is increased the instant centre takes a series of positions which typically trace a path on an extension of the shank which progresses forward and downward toward the cosmetic or anatomical knee centre.

An elevated and posterior location of the instant centre will increase knee stability (see the Appendix). With a single axis knee, the location of the knee joint is also dictated by placing it at an approximate anatomical location with good cosmetic appearance while seated with the knee at 90 degrees of flexion. A properly designed four-bar linkage knee also allows the possibility of locating the instant centre in full extension in a position within the desired stable region of the stability diagram, yet which maintains acceptable cosmetic appearance at 90 degrees of flexion. Small differences in link lengths and pivot locations can result in major changes in the kinematic behaviour of four-bar linkages, as will be discussed in the following paragraphs.

The knee stability diagram is useful in comparing the characteristics of three different classes of four-bar linkage prosthetic knee mechanisms: 1) the four-bar mechanism with elevated instant centre, 2) the hyper-stabilized four-bar, and 3) the voluntary control four-bar. Each of these three classes of four-bar knee mechanisms has a place in the fitting of different groups of trans-femoral amputees.

The four-bar linkage with elevated instant centre

The four-bar prosthetic knee with elevated instant centre has been available for many years and has the general appearance shown in Figure 5. It typically has a long anterior link and a short posterior link. A four-bar linkage knee of this class offers considerable stability at heel contact and is of primary benefit to geriatric amputees or other amputees with limited ability to control stability through active and voluntary control using residual hip function on the amputated side. Devices of this type can be designed to give a variety of functional characteristics depending upon the arrangement and length of the link lengths, pivot locations, and extension stop adjustment.

The links of the hypothetical device shown in Figure 5 have been designed to give extreme stability at heel contact by having the instant centre for full extension of the knee located considerably posterior to the load line at heel contact as shown in Figure 2(a). The knee is forced into extension and is essentially kinematically locked in extension, No hip extension moment exerted by the amputee is required.

At push off the hip flexion moment exerted by the amputee, with help from the offset load on the ischial seat, is easily capable of shifting the load line behind the instant centre as required to initiate knee flexion. The elevated

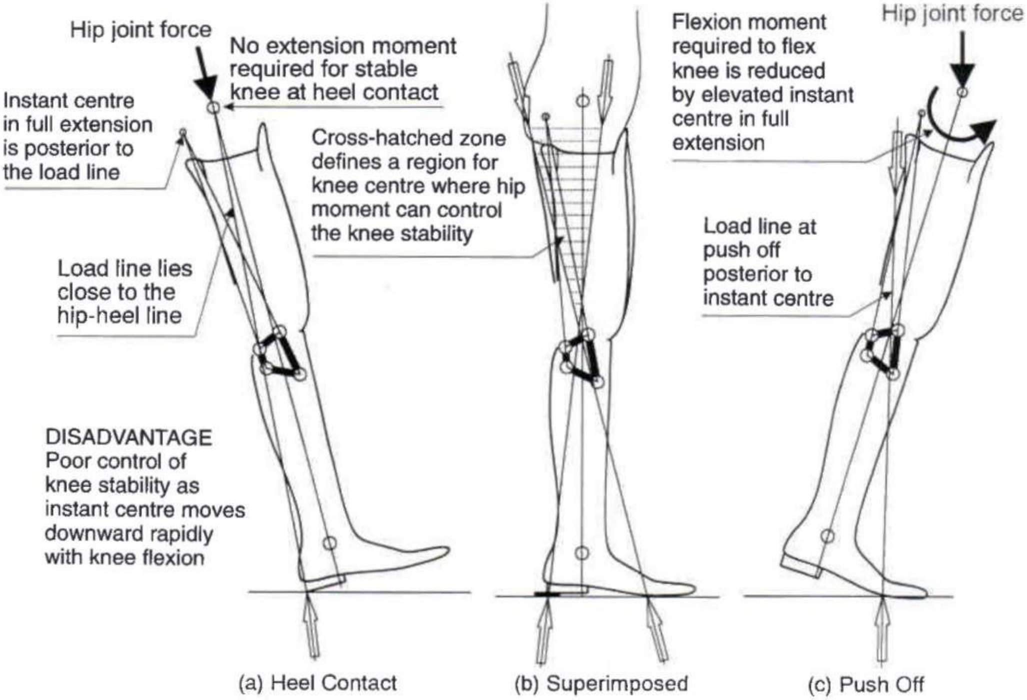

Fig. 5. Stability diagram – four-bar knee with elevated instant centre.

position of the instant centre has been shown to contribute to the ease by which the hip moment can maintain a stable weight bearing knee. Thus the elevated posterior location of the instant centre allows the possibility of initiating knee flexion with minimal effort by the amputee. At first glance this class of mechanism appears to have several advantages for the trans-femoral amputee.

However there are some limitations. All classes of four-bar linkage knees can be designed to provide a reasonable cosmetic appearance at 90 degrees of flexion. Note however, that to allow good cosmesis in sitting, an elevated instant centre must move downward very rapidly with knee flexion, This sudden shift of the instant centre does not allow the amputee to maintain control of the weight bearing knee if the knee flexes a few degrees as a result of some unforeseen event. However, a knee mechanism with an elevated and posterior instant centre in full extension will essentially be locked in extension at heel contact. At the end of the stance phase, the amputee typically initiates knee flexion by initiating swing-through from the hip after lifting the prosthesis from contact with the walking surface. This class of knee mechanism has a definite place in providing knee stability similar to a locked knee for geriatric amputees or other amputees with limited physical capability.

It should be noted that the position of the instant centre in full extension is very sensitive to small changes in the full extension angle. This feature can be used as a means of adjustment of the knee stability in full extension by small changes in the position of the knee extension stop. With proper adjustment the initial instant centre location can be moved to the desired offset from the vertical reference line and serve as simple means of adjusting knee stability at both heel contact and push off.

The hyper-stabilized four-bar knee mechanism

The physical arrangement of the hyper-stabilized four-bar knee mechanism will often be similar to the four-bar with elevated instant centre. In this case the kinematic behaviour can be dramatically different with only small changes in dimensions. Figure 6 shows the kinematics of a typical device of this class. Note again that the initial location of the instant centre, hence the stability at heel contact, can be

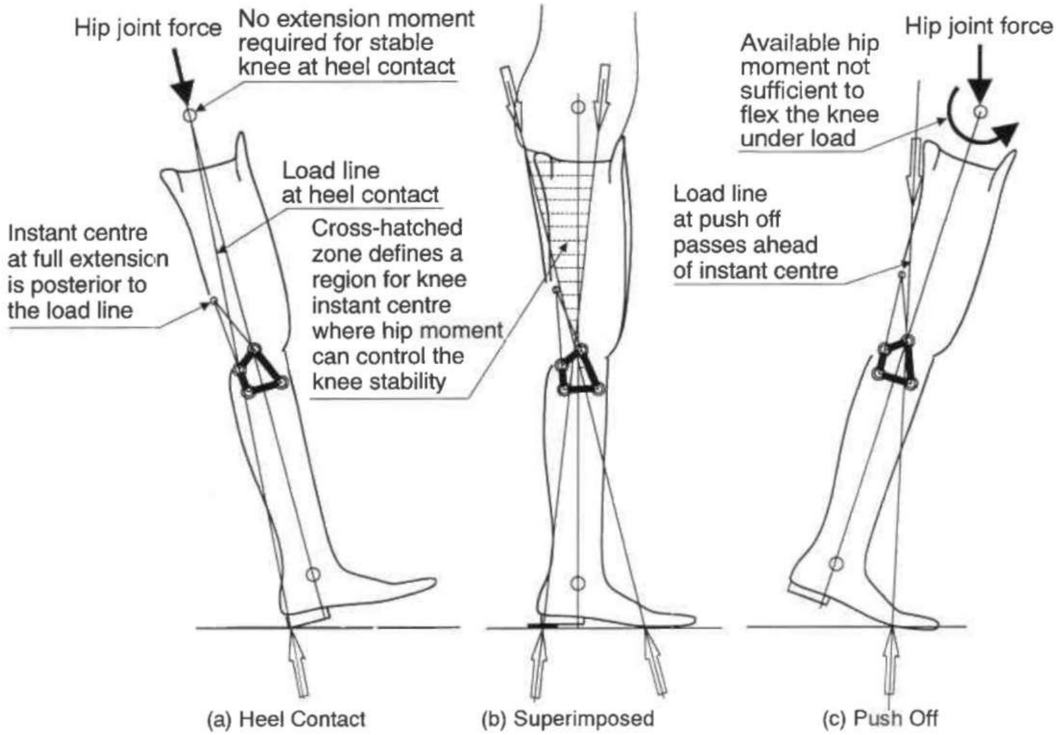

Fig. 6. Stability diagram – hyper-stabilized four-bar knee mechanism.

fixed easily by the designer at the intersection of the centre lines of the anterior and posterior links with the knee in full extension. The determination of actual link lengths and initial pivot locations which will allow for good cosmesis during knee flexion and at 90 degrees of flexion is a greater challenge.

The term "hyper-stabilized" refers to the very positive alignment stability built into devices of this type. As shown in Figure 6(a), the instant centre in full extension is located well behind the load line, which, with no hip extension moment required, lies close to the hip-heel line at heel contact. At push off, even with the maximum possible hip flexion moment exerted by the amputee, the instant centre is still behind the load line and it is not possible for the amputee to initiate knee flexion while the prosthesis is weight bearing. Again, this class of four-bar knee mechanism is of primary interest for geriatric or otherwise less active amputees who require the equivalent of a knee lock in the stance phase of walking.

It should be noted that an over-stabilized prosthetic knee with excessive alignment stability can lead to problems for the active amputee. There would be many situations where activities of daily living will be difficult if not impossible due to the inability to flex the knee in a controlled manner while weight bearing. These activities would include stair and ramp descent foot over foot, sitting from a standing position in cramped quarters such as a theatre seat, entering and exiting automobiles, etc.

The voluntary control four-bar mechanism

Figure 7 shows a four-bar linkage for which the instant centre lies within the stability zone at both heel contact and push off. In this case the initial elevation of the instant centre is not as high as for the linkage of Figure 5 and the downward path of the instant centre stays somewhat elevated and within the zone for the first few degrees of knee flexion. Figures 8 and 9 show the path of the instant centre for devices of this class. Each point on the path is labelled with the corresponding angle of flexion of the socket relative to the shank of the prosthesis.

The voluntary control four-bar knee is designed to give the amputee the ability not only to control knee stability at both heel

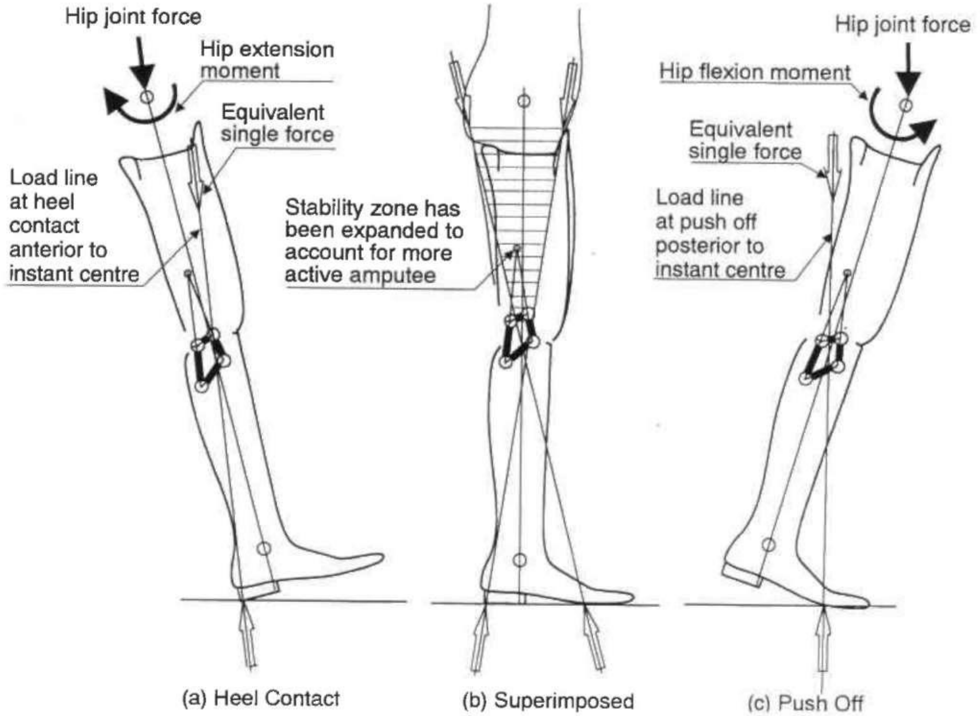

Fig. 7. Stability diagram – Hosmer voluntary control four-bar knee mechanism.

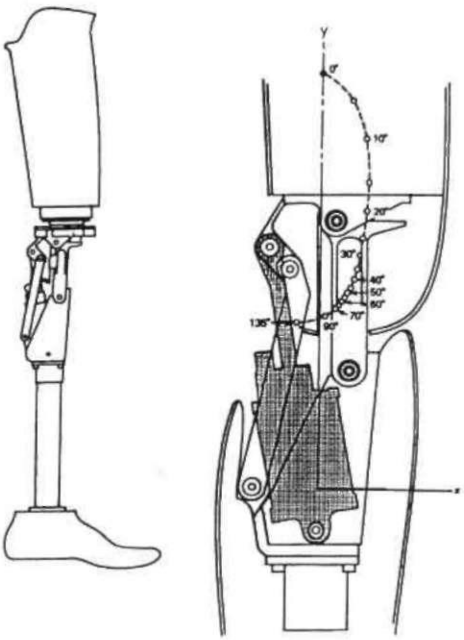

Fig. 8. Path of instant centre UCBL four-bar polycentric knee.

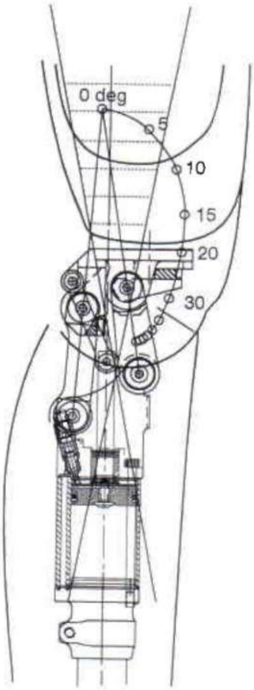

Fig. 9. Path of instant centre – VC[4] Hosmer voluntary control four-bar knee.

contact and push off, but to have complete control of knee stability over a limited range of knee flexion. The actual ability to control the motion and stability of a flexed knee depends upon the physical capabilities of the amputee. It is desirable for the amputee to be able to react to an event which might disturb the stability of the weight bearing knee, particularly at heel contact, to arrest the tendency toward uncontrolled flexion and voluntarily move the knee to a stable position in full extension. As the amputee gains experience in the use of a voluntary control four-bar prosthetic knee, these reactions become almost involuntary since this is the way a non-amputee senses and reacts to control knee stability.

Voluntary control of the stance phase stability is most important over the first 10 degrees of flexion from a position of full extension. Figure 8 illustrates the path of the instant centre for the University of California four-bar polycentric knee. This design has been extensively tested and the kinematics have been shown to offer many advantages to active patients with a desire to be aggressive walkers. The voluntary control is perceived by the patient as a "gliding motion" of the knee block forward and backward over the shank with controlled flexion and extension of the knee. This has been shown to offer benefits in controlling stability while the patient walks on rough ground, sloping surfaces, or stair descent. Other advantages include the ability to bear weight on a slightly flexed knee while taking short steps around a counter, dancing, playing golf, etc. Voluntary control may not be optimal for geriatric patients, although devices of this type have been fitted successfully to both active older patients and active patients with very short stumps.

The path of the instant centre for a voluntary-control four-bar knee mechanism does not begin at the extremely elevated and/or posterior position in full extension, as has been shown for the other two classes of four-bar mechanisms. The full extension location of the instant centre is approximately 100 mm (4 in) above and 6 mm (¼ in) posterior to the vertical reference line. This location allows the path of the instant centre to move smoothly forward and downward with increasing angles of knee flexion yet stay in an elevated position within the stability zone for as much as 10 degrees of flexion. The angles noted at points circled along the path of the instant centre indicate the corresponding angle of knee flexion.

The arrangement shown in Figure 9 is a new design of a four-bar prosthetic knee, with voluntary control characteristics very similar to the original University of California model, which has been developed by Hosmer-Dorrance in cooperation with the author. The new model is designed to provide equal or better kinematics in a package which is well suited to installation in current modular prostheses. The original pneumatic swing phase control cylinder and two-way valve have been retained with minor modifications to allow installation as part of the shank structure.

There are several functional advantages for the mechanisms of Figures 8 and 9 which may not be immediately apparent:

1. Ease of slope and stair descent. The experienced and active user can descend stairs using the "jack-knife" method without having to place the heel on the outer edge of the stair tread. The technique involves placing the foot in the normal position then flexing the knee under load and allowing the opposite foot to drop down to the next step. This can actually be done by locating the heel of the prosthetic foot rearward against the riser of the step, even with poor visability.
2. Approximately 130 degrees of knee flexion. This feature becomes very important in entering and exiting automobiles. The amputee can sit on the seat then reach down and lift the flexed prosthesis into place rather than place the extended prosthesis into place before sliding into the seat. The extra degrees of knee flexion can also be helpful in many kneeling activities.
3. Increased toe clearance during swing phase. Rotation about an elevated instant centre creates a posterior translation component for the motion of the shank-foot which as the knee flexes effectively raises the toe of the foot more than 25 mm (1 in) higher than would be seen with a single axis knee. It is virtually impossible to stub the toe of the prosthetic foot in level walking.

Alignment of the voluntary control four-bar knee

The voluntary control four-bar should be aligned in full extension with the soft tabs on the extension stop compressed to give contact on the firm portion.

Using the methods of the following paragraph will automatically locate the instant centre properly. This will give the average active patient excellent control of knee stability at heel contact. Figure 9 indicates that such a location will allow the instant centre to remain within the stable region over more than 5 degrees of flexion. The 90 degree rotation centre corresponding to the single-axis or anatomical centre is located at the same level and slightly behind the upper pivot on the anterior link.

Figure 10 shows the preferred method of bench alignment of the socket relative to the knee unit. A vertical reference line is shown drawn upward through the centre line of the shank pylon tubing ending at a point at the bisector of the medial brim (the BMB point) of a quadrilateral socket. The socket is shown flexed approximately 5 degrees. The universal socket adapter has been located on the four-bar mechanism to anticipate the necessary forward location of the distal portion of the socket. Regardless of the amount of flexion built into the socket, the BMB point must lie on or close to the vertical reference line extending upward through the shank centre line. A forward shift of the socket without a secondary plantar flexion adjustment at the ankle will not give a more stable knee. Some improvement in standing stability may be noted but at the expense of a decrease in stability at heel contact while walking. If the knee is unstable at heel contact the most likely cause is unsatisfactory foot function! The prosthetist must always remember that a forward shift of the socket is perceived by the amputee as a rearward shift of the foot!

The adduction of a socket for a long stump will automatically result in a narrow walking base as shown in Figure 3. The shorter stump will require a wider walking base. In general the axes of the mechanism should be parallel to the floor and perpendicular to the shank tube. The shank tube should be perpendicular to the floor in midstance as viewed anteroposteriorly. The heel stiffness and lever arm have the most

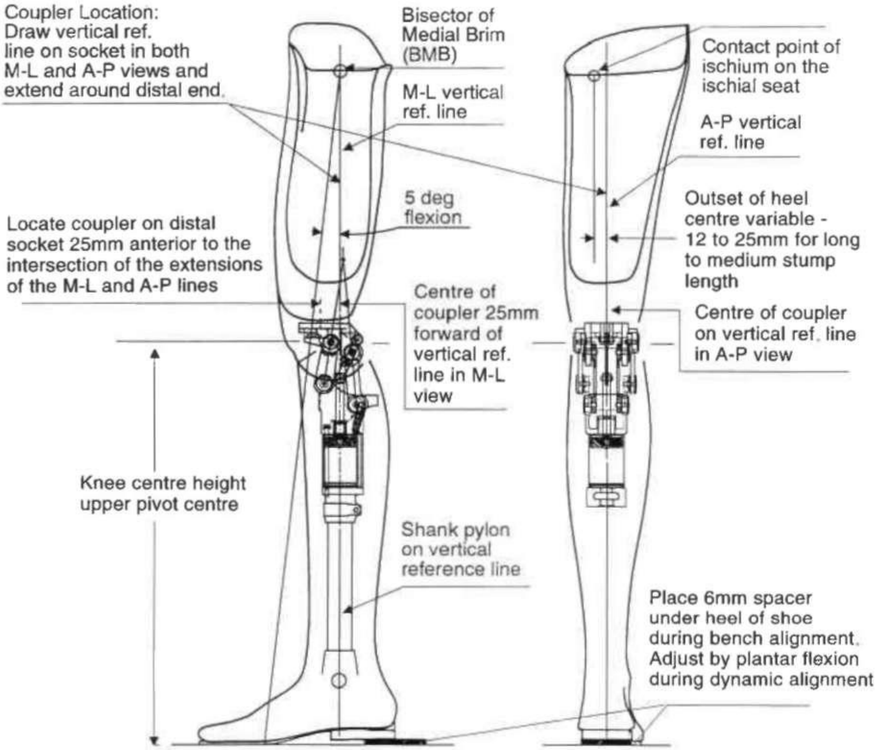

Fig. 10. Bench alignment of the Hosmer voluntary control four-bar knee.

obvious influence on knee stability at heel contact. The knee may feel unstable to the amputee during the period when all weight is supported on the point of the heel. The function of the foot should be to minimize this period and move the support point to the ball of the foot smoothly and rapidly. The heel cushion or plantar flexion stiffness should be as soft as possible without creating foot slap and/or difficulty in rolling over the ball of the foot.

Use of the SACH foot with a voluntary control knee

The SACH foot has been described by some as not being optimal for trans-femoral amputees. This would apply if the foot was fitted with too hard a heel cushion or without air space under the heel. Either error will extend the period of heel contact. It has been the author's experience that a properly selected and fitted SACH foot will provide excellent function when used with a voluntary control four-bar knee.

The heel cushion stiffness must be carefully selected. In general, a trans-femoral amputee must be fitted with a softer grade of heel cushion than a trans-tibial amputee of similar weight and activity level. Many SACH feet, or other similar solid-ankle feet, have been used successfully with trans-femoral amputees.

Some comments on walking training

The walking training of the amputee in the use of a voluntary control four-bar knee must begin with a careful explanation to the amputee of the concept of the instant centre and the principles of voluntary control. The stability of a voluntary control knee is not automatic and the amputee must be instructed carefully in how to participate in the control of knee stability by use of hip musculature. An active amputee with a properly aligned single-axis knee will, most probably, already be using the hip musculature and the initial sensation of the amputee will be that the voluntary control simply makes the control of knee stability a lot easier.

For those amputees who have relied on excessive alignment stability with a single axis or over-stabilized four-bar knee there will be a period of readjustment. The amputee cannot relax the hip at heel contact and rely on the alignment stability to provide knee security. The amputee must be instructed to extend the hip and press the stump backward in the socket just enough to maintain the knee in full extension against the stop at heel contact. If the stump is not pressed backward the knee will be unstable. The amount of hip moment required is small and the amputee will quickly learn to adopt this very natural method of knee stability control.

It is assumed that the initial training will be done during the dynamic alignment of the prosthesis. If the amputee experiences a feeling of lack of knee stability the foot function and alignment should be checked, then, if necessary, the socket should be extended in about one degree increments and the foot plantar flexed until the knee feels stable. Once the amputee feels secure the training in the use of hip musculature can continue.

Every effort should be made to move the amputee outside the parallel bars as soon as possible. One effective technique for walking training is as follows:

1. Have the trainer providing instruction walk alongside the amputee with the amputee's arm over the shoulder of the trainer to provide support in case the knee buckles.
2. The trainer should use both hands to control the flexion and extension of the socket as the amputee walks. Place one hand on the anterior surface of the socket and the second hand posteriorly. The trainer provides the stability control for the initial walking trials by gently extending and flexing the socket at the appropriate time.
3. As the amputee walks the trainer continues to demonstrate and describe the control action to the amputee. As the amputee becomes more familiar with the necessary hip moments the trainer can gradually reduce moments provided manually and the amputee will continue to walk unaided.

Appendix: The knee stability equation

Figure 11 shows the derivation of an equation, (Eq. 4), which gives the magnitude of the hip extension moment $\mathbf{M}_h$ which would be required to provide knee stability as a function of the axial load **P**, the magnitude of an existing brake moment $\mathbf{M}_k$, and the x-coordinate (forward offset) and y-coordinate (elevation) of the instant centre at heel contact. Note that a friction brake will typically provide a moment $\mathbf{M}_k$ which exceeds the value of **P** times x hence

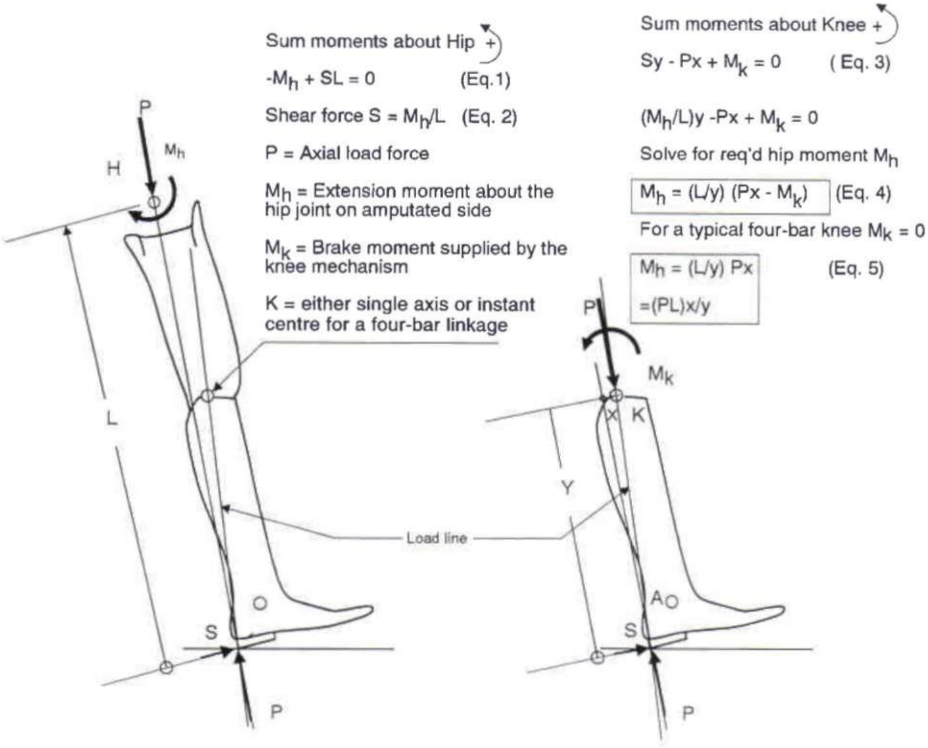

Fig. 11. Derivation of the knee stability equation $M_h = (L/y)(Px-M_k)$

the required hip moment $\mathbf{M}_h$ becomes zero.

A four-bar linkage typically does not incorporate a brake mechanism hence the simplified Equation 5 can be used to estimate the hip extension moment required as the position of the instant centre changes.

Both the x and y coordinates of the instant centre are important in the design of a voluntary control four-bar knee linkage. The required hip moment for voluntary control can be reduced in two ways:

1. Reduce the x-coordinate, i.e. locate the initial position of the instant centre closer to the heel-hip line. The x-coordinate of the instant centre should not increase rapidly as a function of knee flexion.
2. Increase the y-coordinate. To gain optimal benefit from the elevation of the instant centre the y-coordinate must not decrease too rapidly as a function of the knee flexion angle.

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A study of 200 cases of congenital limb deficiencies

S. K. JAIN

Artificial Limb Centre, Pune, India

Abstract

An analysis of 200 patients with congenital limb deficiency who attended the Artificial Limb Centre, Pune from January 1984 to April 1990 is presented. This group is representative of the congenital limb deficient population of the country. The commonest deficiencies were transverse phalangeal total/partial deficiency and transverse forearm partial deficiency (below elbow) in upper limbs, whereas transverse metatarsal total/partial deficiency and transverse leg partial deficiency (below knee) were commonest in lower limbs. Transverse forearm partial deficiency was more common in female, while transverse leg partial deficiency was more common in male children, 16 patients did not require any treatment, 6 needed only surgical correction. Some 30 patients needed surgery before prosthetic fitting, while 148 patients required only prostheses. Some 68% of patients achieved satisfactory to excellent results; 18% showed poor rehabilitation. No definitive cause for the deformities could be isolated; however, many parents believed that possible exposure to the eclipse during pregnancy was the cause of the deficiency. The eldest child was most affected.

Introduction

The Artificial Limb Centre in Pune, one of the biggest in the country and with its own kind of rehabilitation centre, attracts limb deficient patients from all parts of the country. Therefore the limb deficient children attending this Centre can easily be accepted as a representative sample of the total congenital limb deficient population of India.

All correspondence to be addressed to Colonel S K Jain, Artificial Limb Centre, Pune 411 040, India.

Material and methods

This study includes 200 consecutive patients with congenital limb deficiency, who came for treatment to the Artificial Limb Centre, Pune from January 1984 to April 1990.

Every patient was examined in detail and deficiencies recorded. Special care was taken to elicit history of maternal illness, consumption of drugs, exposure to radiation as well as hyperemesis, foetal trauma, vaccination, smoking and alcoholic habits of expectant mothers during pregnancy. Other factors such as the socio-economic status of the parents, family history, position of child in the family tree and history of any other sibling or close relative similarly affected, which could possibly throw light on the cause of the limb deficiency were also examined.

Patients requiring any surgical intervention before the prosthetic fitting were identified. Surgery was carried out wherever necessary and a prosthesis provided. The state of rehabilitation was assessed as excellent, good, satisfactory, or poor, based upon functional achievement with the help of a prosthesis. The group of patients which did not require any treatment surgical or prosthetic was also identified.

Observations and discussion

Incidence

The 200 congenital limb deficient patients who visited this Centre were from a total number of 5375 amputees making the incidence 37 per thousand amputees. In western literature the incidence is 30 per thousand (Vitali *et al.*, 1988).

Table 1. Associated causative factors

Causative factors (probable)	No of patients
Drugs	19
Previous abortions	8
Previous premature births	3
Previous Caesarean births	4
Injury to the abdomen during pregnancy	4
Radiation during pregnancy	4
Heredity	1
Exposure to eclipse	19
Total	62

Sex incidence

There were 130 (65%) male and 70 (35%) female patients (ratio 13:7), while the comparative sex incidence in various other studies (Lamber, 1971; Agarwal *et al.*, 1986) show this ratio to be 13:12.

Age at the time of reporting for treatment

It was seen that the number of males outnumbered females in all age groups except the 10-15 years age group, where the number of girls was more than the boys; maybe they and their parents became more conscious of the disability at this age.

Birth serial of the patients

The position of the child in the family lineage was recorded. It was seen that 82 (41%) of patients were the eldest in the family. Contribution of first 3 children was 84%.

Aetiological factors

An attempt was made to discover the exact cause which might have produced the disability. In only 62 patients was some sort of history noted which could probably be correlated with the limb deficiency, as shown in Table 1.

Most limb defects developed between the third and eight post-ovulatory week (Kenedy, 1967; Swanson, 1981) and only a few parents were aware of the pregnancy till late in the third month of gestation; fewer still could remember an intake of any drug or an illness suffered.

The noticeable finding was a history of previous abortions in 8 cases. This may indicate some kind of placental insufficiency which may have caused the previous abortions as well as the deficiency in the new born. Only 19 mothers could remember having taken drugs namely antiemetics, antibiotics, antispasmodics and antidepressants during the pregnancy. None of these drugs is specifically known to have been a cause of limb deficiencies (The pharmacological basis of therapeutics, 1985). However 168 mothers gave a history of taking haematenics and multivitamins during pregnancy.

An interesting finding was a history of exposure of expectant mother to the eclipse during pregnancy in 19 cases. Though no documentary evidence exists to correlate it with the deficiency in the literature, still many parents believe this to be the cause of limb deficiency in the new born.

Despite the various factors mentioned, no definite cause could be isolated except in one case where the new born and the mother both had deficient/weak thumbs in both hands. The cause was perhaps genetic. However in this case no one else in the family was affected.

Previous treatment

Only 18 patients had received some treatment; 15 had undergone some surgical treatment and only 8 patients had received prostheses. This indicates ignorance or the lack of facilities to deal with limb deficient children,

Deficiencies

It is not practically possible to classify or group all the deficiencies encountered. However the simple classification of deficiencies followed earlier by the author (Jain *et al.*, 1989) has not been used in this article. It has been changed to conform to the International Standard Organisation (ISO) Classification (Day, 1991) as shown in Figures 1 and 2 for upper limbs and lower limbs respectively. This classification is descriptive and can be used under most circumstances.

The deficiencies are classified into two basic categories.

1. *Transverse Deficiency*: This resembles an amputated limb where the limb has developed normally up to a particular level and beyond which no bony element is present. Transverse deficiencies are:

(a) Transverse upper limb deficiencies:
- (i) phalangeal total/partial deficiency;
- (ii) metacarpal total/partial deficiency;
- (iii) carpal total/partial deficiency;
- (iv) forearm total/partial deficiency;
- (v) upper arm total/partial deficiency;
- (vi) shoulder total/partial deficiency.

(b) Transverse lower limb deficiencies:
- (i) phalangeal total/partial deficiency;
- (ii) metatarsal total/partial deficiency;
- (iii) tarsal total/partial deficiency;
- (iv) leg total/partial deficiency;
- (v) thigh total/partial deficiency;
- (vi) pelvis total/partial deficiency.

2. *Longitudinal Deficiency*: All other cases where an element or elements within the long axis of the limb is/are reduced or absent, are grouped in longitudinal deficiency.

(a) Longitudinal upper limb deficiencies:
- (i) radius total carpus partial ray 1 total deficiency;
- (ii) radius total/partial deficiency;
- (iii) ulna total carpus partial rays 2, 3, 4, 5 total deficiency;
- (iv) ulna total/partial deficiency;
- (v) radius ulna total/partial deficiency;
- (vi) humerus total deficiency;
- (vii) humerus total radius ulna total/partial deficiency.

(b) Longitudinal lower limb deficiencies:
- (i) tibia total tarsus partial ray 1 total deficiency;
- (ii) tibia total/partial deficiency;
- (iii) fibula total tarsus partial rays 2, 3, 4, 5 total deficiency;
- (iv) fibula total/partial deficiency;
- (v) tibia fibula total/partial deficiency;
- (vi) femur total/partial deficiency;
- (vii) femur total tibia fibula total/partial deficiency.

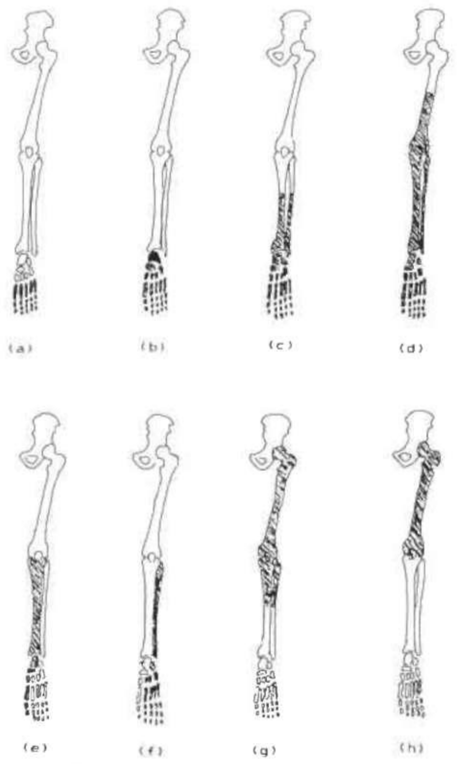

Fig. 1. Congenital upper limb deficiencies.
(a) Phalangeal total deficiency
(b) Carpal partial deficiency
(c) Fore arm partial deficiency
(d) Upper arm partial deficiency
(e) Radius total carpus partial ray 1 total deficiency
(f) Ulna total carpus partial rays 2, 3, 4, 5 total deficiency
(g) Radius total deficiency
(h) Ulna total deficiency

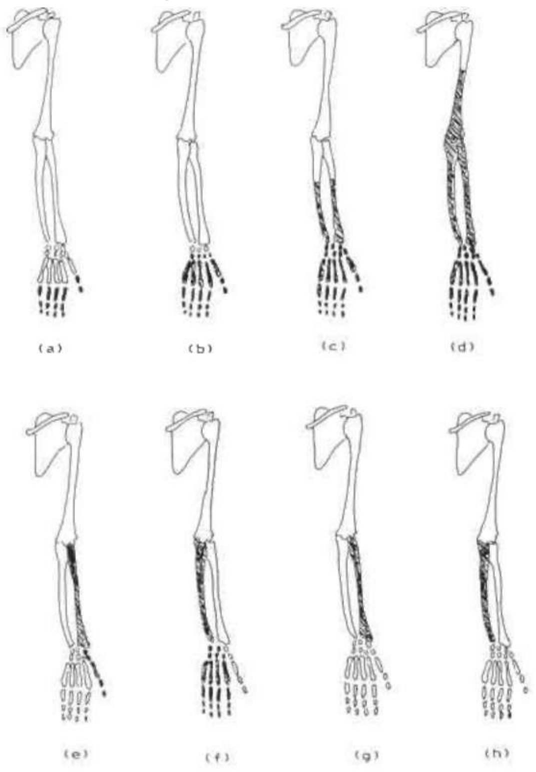

Fig. 2. Congenital lower limb deficiencies.
(a) Metatarsal total deficiency
(b) Tarsal total deficiency
(c) Leg partial deficiency
(d) Thigh partial deficiency
(e) Tibia total tarsus partial ray 1 total deficiency
(f) Fibula total tarsus partial rays 2, 3, 4, 5 total deficiency
(g) Femur total tibia fibula partial deficiency
(h) Femur total deficiency

Deficiency in upper limbs

Table 2 shows deficiencies observed in the upper limbs. It was interesting to note that the most common deficiency was transverse forearm partial deficiency (below elbow), found in 57 patients (2 bilateral cases). Some 34 (60%) were females and 23 (40%) were males. The left side was a little more affected than the right side. Transverse phalangeal deficiency was seen in 23 patients (14 single-sided and 9 bilateral), where 15 (65%) were males and 8 (35%) were females.

Table 2: Upper limb deficiencies

Deficiencies	Rt	Lt	Bil	No of patients	No of limbs
Transverse deficiency					
Phalangeal total/partial deficiency	7	7	9	23	32
Metacarpal total/partial deficiency	2	6	–	8	8
Carpal partial deficiency	7	5	–	12	12
Carpal total deficiency	2	4	–	6	6
Forearm partial deficiency	23	32	2	57	59
Forearm total deficiency	3	2	–	5	5
Upper arm total/partial deficiency	4	5	–	9	9
Shoulder total/partial deficiency	1	–	–	1	1
Longitudinal deficiency					
Radial total carpal partial ray 1 total deficiency	2	–	–	2	2
Radius total/partial deficiency	1	–	–	1	1
Ulnar total carpal partial rays 2, 3, 4, 5 total deficiency	–	2	3	5	8
Ulna total/partial deficiency	–	1	1	2	3
Radius ulna total/partial deficiency	–	–	–	–	–
Humerus total deficiency	–	–	–	–	–
Humerus total radius ulna total/partial deficiency	–	1	–	1	1
Total	52	65	15	132	147

Table 3: Lower limb deficiencies

Deficiencies	Rt	Lt	Bil	No of patients	No of limbs
Transverse Deficiency					
Phalangeal total/partial deficiency	2	–	–	2	2
Metatarsal total/partial deficiency	4	12	6	22	28
Tarsal partial deficiency	1	3	–	4	4
Tarsal total deficiency	2	2	5	9	14
Leg partial deficiency	10	11	–	21	21
Leg total deficiency	–	2	–	2	2
Thigh total/partial deficiency	4	–	–	4	4
Pelvis total/partial deficiency	–	–	–	–	–
Longitudinal deficiency					
Tibial total tarsal partial ray 1 total deficiency	3	–	–	3	3
Tibia total/partial deficiency	–	–	–	–	–
Fibular total tarsal partial rays 2, 3, 4, 5 total deficiency	2	6	2	10	12
Fibula total/partial deficiency	1	–	–	1	1
Tibia fibula total/partial deficiency	–	3	–	3	3
Femur total/partial deficiency	–	5	–	5	5
Femur total tibia fibula total/ partial deficiency	6	5	–	11	11
Shortening					
Tibiofibular	4	7	–	11	11
Femoral Tibiofibular	5	2	–	7	7
Total	44	58	13	115	128

Table 4: Distribution of deficiencies

Limbs involved	No of patients	Upper limb	Lower limb
One upper limb	84	84	–
One lower limb	59	–	59
Bilateral upper limbs	17	34	–
Bilateral lower limbs	20	–	40
One upper and one lower limbs	8	8	8
Three limbs	6	9	9
Four limbs	6	12	12
Total	200	147	128

Deficiency in lower limb

Table 3 shows the deficiencies in the lower limbs. The commonest deficiency was transverse metatarsal deficiency in 22 patients (6 bilateral). Another common deformity was transverse leg partial deficiency (below knee). It was found in 21 patients (no bilateral case) of which 13 (62%) were males and 8 (39%) were females.

Distribution of deficiencies

More than one limb was involved in 57 patients. Two limbs were involved in 45 patients (22.5%) three in 6 (3%) and all four in 6 patients (3%). In the study by Kay (1974) the percentage of two, three and four limbs was 15, 5 and 10 respectively. Details of the distribution of the deficiency are shown in Table 4. Involvement of the upper limb was more common than involvement of the lower limb in single limb deficiency, while bilateral deficiency was more common in lower limbs.

Associated defects

Some 21 patients were found to have various associated defects as shown in Table 5. Constriction ring was the commonest defect noticed, which could be the cause of the limb deficiency. Three children with talipes equinovarus deformity had deficiency in the upper limbs.

Table 5. Associated defects

Defects	No of patients
Constriction rings	8
Talipes equinovarus	3
Syndactyly	6
Spina bifida	1
Dislocation of hip	1
Craniostenosis	1
Absent pectoralis major and minor	1
Total	21

Management

Of the 200 patients in this study 16 patients did not require any treatment, 6 patients needed only surgical correction of deformity while 30 patients required surgical treatment such as amputation and the release of a constriction ring before a prosthesis was fitted. Surgery was performed only in the lower limbs. Some 148 patients required no other treatment except prosthetic fitting.

Prostheses were provided in 178 cases. The commonest upper limb prosthesis was trans-radial (57 cases) while in lower limbs it was trans-tibial (21 cases). Extension prostheses for shortening of the lower limb was given to 25 patients.

Rehabilitation status

The rehabilitation status was assessed not only in respect of function achieved but also in appearance which had a definitive role in improving self-confidence. The results are shown in Table 6.

Satisfactory to excellent results were achieved in 68% of cases, while in 18% of cases rehabilitation was poor, mainly representing patients with upper limb deficiency, since rehabilitation is difficult in upper limb deficiency as a rule. These results are similar to the study carried out by Jain *et al.* (1989).

Table 6. State of rehabilitation

	Limb involved				
State of rehabilitation	Upper	%	Lower	%	Overall
Excellent	8	5%	30	23%	14%
Good	36	24%	60	48%	36%
Satisfactory	44	30%	8	6%	18%
Poor	34	23%	15	12%	18%
Not known	13	9%	3	2%	5%
Not relevant	12	9%	12	9%	9%
Total	147		128		

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ERRATUM

The address for correspondence for the paper *A new modular six-bar linkage trans-femoral prosthesis for walking and squatting* by J. K. Chakraborty and K. M. Patil published in the last issue of Prosthetics and Orthotics International was incorrect. All correspondence concerning this article should be addressed to

Professor K. M. Patil
Department of Applied Mechanics
Indian Institute of Technology
Madras 600 036
INDIA

Prosthetics and Orthotics International, 1994, 18, 180-190

Technical note

A pilot study to test the influence of specific prosthetic features in preventing trans-tibial amputees from walking like able-bodied subjects

D. J. STEFANYSHYN*, J. R. ENGSBERG**, K. G. TEDFORD*** and J. A. HARDER***

**Human Performance Laboratory, University of Calgary, Alberta, Canada*
***St. Louis Children's Hospital, St. Louis, Missouri, USA*
****Alberta Children's Hospital, Calgary, Alberta, Canada*

Abstract
The purpose of this pilot investigation was to develop a method to test the influence of specific prosthetic features in preventing trans-tibial amputees from walking like able-bodied subjects. An able-bodied subject was fitted with a patellar-tendon-bearing orthosis incorporating several features of an amputee's prosthesis. Kinetic, kinematic and metabolic data were collected as features were systematically removed from the orthosis. While wearing the orthosis the gait of the able-bodied subject closely simulated trans-tibial amputee gait kinematically, kinetically and metabolically. Although it was obvious that the various prosthetic features influenced the kinetics and kinematics of gait, they were difficult to quantify with only a single subject. However, the two features which appeared to have the largest influence in preventing trans-tibial amputees from walking like able-bodied subjects were patellar tendon loading and a solid ankle.

Introduction
It has been well documented that trans-tibial amputees (TTAs) do not walk like able-bodied individuals (Breakey, 1976; Doane and Holt, 1983; Culham *et al.*, 1984; Lewallen *et al.*, 1986; Winter and Sienko, 1988; Smith, 1990). Engsberg *et al.* (1993) stated that TTAs will now walk like able-bodied (AB) subjects until a prosthesis is developed that functions like an intact leg and foot. If the design of such a device is to be undertaken it is critical to understand the relative contribution of each component of the prosthesis towards permitting or preventing TTAs from walking like ABs.

A patellar-tendon-bearing prosthesis with a Symes foot terminal device includes the following major components: a) a solid ankle allowing no dorsiflexion-plantarflexion or eversion-inversion, b) substantial loading on the patellar ligament and other soft tissue regions of the stump, c) passive flexion-extension at the metatarsal-phalangeal joints, d) slight knee flexion imposed by the socket and thus preventing full knee extension, and e) a cushioned heel to assist the foot in attaining a foot-flat position. The contribution of each of these components towards permitting or preventing TTAs from walking like ABs is presently unknown. For example, the lack of dorsiflexion-plantarflexion in the solid ankle of the foot must prevent normal walking. It would seem that the extent of this prevention should be quantifiable.

Two difficulties arise when considering the use of an amputee as a subject. The first is that adding and removing components of a prosthesis is impossible since the amputee requires the prosthesis to function. The second is that if components were removed, they could not be replaced with able-bodied functions, thus, it would be impossible to directly determine the influence of the component in preventing the TTA from walking like an AB. However, if an orthosis could be created for an AB that functions like a prosthesis, features of the prosthesis could be systematically varied to

All correspondence to be addressed to Jack R. Engsberg, Director, Motion Analysis Laboratory, St. Louis Children's Hospital, One Children's Place, St. Louis. Missouri 63110, USA.

help understand the numerical contribution of each component. The purpose of this investigation was to develop a method to test the influence of specific prosthetic features in preventing TTAs from walking like ABs.

Methods

An able-bodied individual fitted with an ankle-foot orthosis (AFO) that incorporated the main features found in an amputee's prosthesis was used as a subject. The features were systematically removed one at a time and replaced with actual able-bodied functions throughout the protocol. As a result each consecutive orthosis became increasingly more like an AB limb and less and less like an amputee's prosthesis. By using this protocol, the relative differences of the observed variables between the AFOs could be used to determine the influences of specific prosthetic features on gait.

Subject

The AB subject who volunteered for this study was a 24 year old, 165 cm tall male of 59.15 kg mass. It should be noted that throughout the document the legs of the AB subject are referred to as prosthetic and non-prosthetic. While this is not the exact subject's condition, it clearly describes the limitations that were imposed upon him.

Preliminary investigations

The first prototype AFO, constructed by a registered orthotist, had a Kingsley Symes (size 7) foot attached to its bottom, thus incorporating the cushioned heel and forefoot features of the prosthetic foot. With the foot attached, a lift of approximately 7 cm had to be fabricated in the shoe of the non-prosthetic leg to compensate for the height difference. Although preliminary tests showed that this lift height did not significantly affect the subject's kinetics, the kinematics of his gait were altered. Thus, it was necessary to reduce the lift height associated with the non-prosthetic leg. To decrease the lift height, the most obvious solution was to remove the Symes foot from the bottom of the AFO and incorporate the characteristics of the foot directly into the AFO.

Load-deformation tests were performed with an Instron materials testing machine on the Symes heel and forefoot to determine to what extent the parts of the foot were influenced by the forces associated with walking for the AB subject.

To test the deformation of the Symes heel, the Symes foot was placed in the testing machine at a number of different angles representing relevant angles found between the

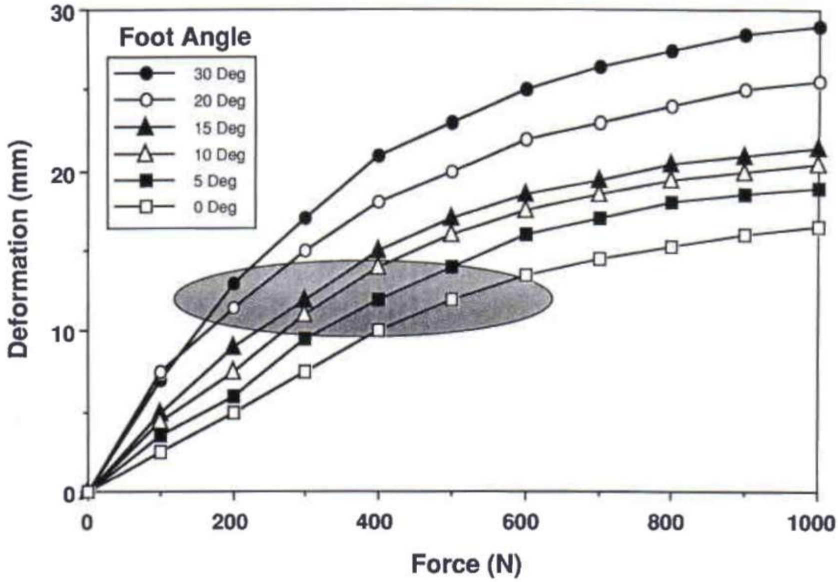

Fig. 1. Symes heel deformation curves at various foot angles. Shaded region indicates deformations for foot angles corresponding to forces produced by the AB subject.

sole of the foot and the floor while walking (0°-30°). At each of the different angles the heel was compressed from 0-1000 N (0-1.7 BW) and the deformation was recorded (Fig. 1). The vertical forces produced by the AB subject during walking that corresponded to these foot angles lie in the shaded region of the graph. The maximum deformation was about 15 mm which correlated to a change in foot angle of approximately 3°. Since the main purpose of the cushioned heel is to hasten the foot to a full ground contact position and since the change in foot angle was minimal, it was decided to eliminate the cushioned heel from the pilot study. This permitted a significant reduction in the lift height required for the shoe on the non-prosthetic leg.

The deformation of the Symes forefoot was tested at various distances from the heel by applying a normal load along a thin section (approximately 6 mm) of the plantar surface of the forefoot (Fig. 2). The forefoot was loaded until the limitations of the measurement methods were reached (i.e. until the deformation of the forefoot caused loads to no longer be applied perpendicular to the plantar surface of the foot resulting in slippage). The solid lines represent actual data collected while the dashed lines are linear extrapolations. By correlating the magnitude of the vertical ground reaction force produced by the subject while walking to the appropriate point of application, the approximate deformation of the forefoot was determined (shaded region of Figure 2). Since the deformation of the forefoot was substantial (maximum of approximately 40 mm) it was decided that passive forefoot flexion-extension was an important feature of the Symes foot and should remain a part of the investigation.

As a result of the preliminary deformation tests the orthotist fabricated a new AFO for the protocol without an actual prosthetic foot. The new AFO had the following features: a) a solid ankle, b) patellar tendon loading, c) passive flexion-extension of the forefoot, and d) slight knee flexion, however, it did not include a cushioned heel. The forefoot deformation was incorporated directly into the base of the AFO by thinning the plastic and placing the toe-break at a location similar to that of the Symes foot.

A final preliminary measure was to ensure the subject was non-weight bearing at the heel (i.e. the load was being supported by the patellar tendon and other tissues). A Tekscan pressure insole was placed underneath the sole of the subject's foot and several standing and walking trials were collected. In all trials the

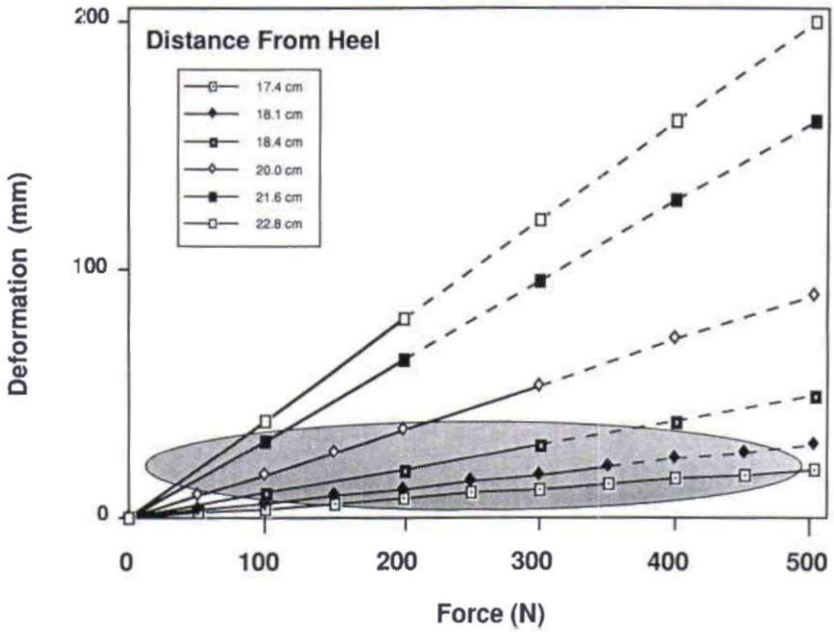

Fig. 2. Symes forefoot deformation curves at various distances from the heel. Shaded region indicates deformations for distances from the heel corresponding to forces produced by the AB subject.

pressure at the heel was below the threshold of the Tekscan insole (40 kPa) thus ensuring that the weight of the subject was being supported by the patellar tendon and other weight bearing regions.

Protocol

The study began with the collection of kinematic and kinetic data on the AB subject while walking normally without any AFO. The subject was then fitted with the first ankle-foot orthosis (AFO1) incorporating: a) a solid ankle, b) patellar-tendon-bearing, c) passive flexion-extension of the forefoot at the metatarsal-phalangeal joints, and d) slight knee flexion (approximately 10°). Kinetic and kinematic data were collected immediately after the subject was fitted with AFO1 (i.e. AFO1-I). The subject then underwent a two week period where he wore AFO1 for 2-3 hours a day and walked in AFO1 a minimum of 30 minutes/day. During this period a gait training programme with a registered physiotherapist who regularly trained trans-tibial amputees was undertaken. At the end of the two week wearing period, the subject again had kinematic and kinetic data collected (i.e. AFO1-F). Oxygen uptake data while walking normally and walking with AFO1 were also collected. The initial and final data collection sessions (i.e. AFO1-I and AFO1-F) were designed to evaluate any adaptation that occurred over the wearing period.

AFO1 was then modified by removing knee flexion resulting in 0° flexion in the orthosis. This second ankle-foot orthosis (AFO2) now had the features of: a) a solid ankle, b) patellar-tendon-bearing, and c) passive flexion-extension of the forefoot. Again kinematic and kinetic data were collected upon the initial fitting of AFO2 (i.e. AFO2-I). Having completed the physiotherapy treatment the subject underwent a one week wearing period of 2-3 hours a day ensuring that he walked in AFO2 a minimum of 30 minutes per day. Final fit kinetic and kinematic data were collected after the one week wearing period (i.e. AFO2-F).

Next AFO2 was modified by removing the passive flexion-extension of the forefoot allowing the subject to actively flex and extend his forefoot. The remaining features of the third ankle-foot orthosis (AFO3) were a) a solid ankle, and b) patellar-tendon-bearing. As with the protocol for AFO2, initial fit data were collected at the first fitting and final fit data were collected after a one week wearing period for AFO3.

The final modification was accomplished by removing the patellar-tendon-bearing feature from AFO3 and allowing the subject to bear weight on his foot. Hence, the fourth ankle-foot orthosis (AFO4) retained only a solid ankle preventing any dorsiflexion-plantarflexion or eversion-inversion of the ankle joint. Again initial fit data for AFO4 were collected and final fit data were collected one week later after wearing.

One week after final data collection with AFO4, normal kinetic and kinematic data (without an AFO) were again collected. The data from this second normal session were averaged with data from the first normal session to provide a composite of normal data.

By using this protocol, the relative differences between the AFOs could be used to determine the influences of specific prosthetic features on gait. For example, the difference between the normal data and the data for AFO4 would be attributed solely to the solid ankle and the difference between the data collected for AFO4 and AFO3 would be due to patellar tendon loading. Table 1 summarises the different features incorporated in each AFO.

Kinetics

The methods used to collect and evaluate kinetic data were similar to those previously reported by Engsberg *et al.* (1993). Briefly, vertical, anteroposterior, and mediolateral force data were collected using two adjacent force

Table 1. The various prosthetic features incorporated in each ankle-foot orthosis

Ankle-Foot Orthosis (AFO)	Features
AFO1	solid ankle patellar-tendon-bearing passive flexion-extension of the forefoot slight knee flexion
AFO2	solid ankle patellar-tendon-bearing passive flexion-extension of the forefoot
AFO3	solid ankle patellar-tendon-bearing
AFO4	solid ankle

platforms sampling at 1000 Hz. Data from six trials were collected for each condition in which three trials were collected with the prosthetic (left) leg landing first and three trials were collected with the non-prosthetic (right) leg landing first. The freely chosen walking speed determined from preliminary data collection sessions (1.6 m/s ± 10%) was enforced for each trial.

Force data were normalised by dividing by body weight and the total time spent of both plates was normalised to a value of 1. Average force-time curves of the six trials for each condition were determined. From the force-time curves, discrete variables were obtained for use in comparison. The discrete variables used in this investigation included first local vertical (ZMax1), second local vertical (ZMax2), anterior and posterior maxima (RMax and PMax, respectively).

Kinematics

Kinematic data were collected simultaneously with the kinetic data using a four camera video system sampling at 200 Hz. Three reflective spheres of 1 cm diameter were placed on the foot, shank, thigh and trunk to permit 3-dimensional analysis.

The coordinate systems used to determine angular orientations of the body segments were the same as those used by Engsberg *et al.* (1992). Consistent placement of the markers allowed relative comparisons between conditions, however, absolute angles had little or no meaning as joint centres were not determined for this pilot study.

Three trials were analysed for each condition and average angular position-time curves of the trials were determined. From the angular position-time curves, discrete variables were obtained for use in comparison. The discrete variables included sagittal plane touchdown angles of the trunk and thigh for both the prosthetic and non-prosthetic limbs (Engsberg *et al.*, 1992).

Metabolic

The methods used to collect metabolic data were similar to those used by Herbert *et al.* (in press). Briefly a Quinton Instruments Model 24-72 Treadmill System (Quinton Instruments, 2121 Terry Avenue, Seattle, Washington 98121) and Horizon Metabolic Measurement Cart System (SensorMedics Corporation, 1630 South State College Boulevard, Anaheim, California 92806) were used to measure oxygen uptake in millilitres/minute (VO_2). Heart rate in beats/minute (HR) was continuously monitored using a Polar Sport Tester PE 3000 (Polar U.S.A. Incorporated, 470 West Avenue,

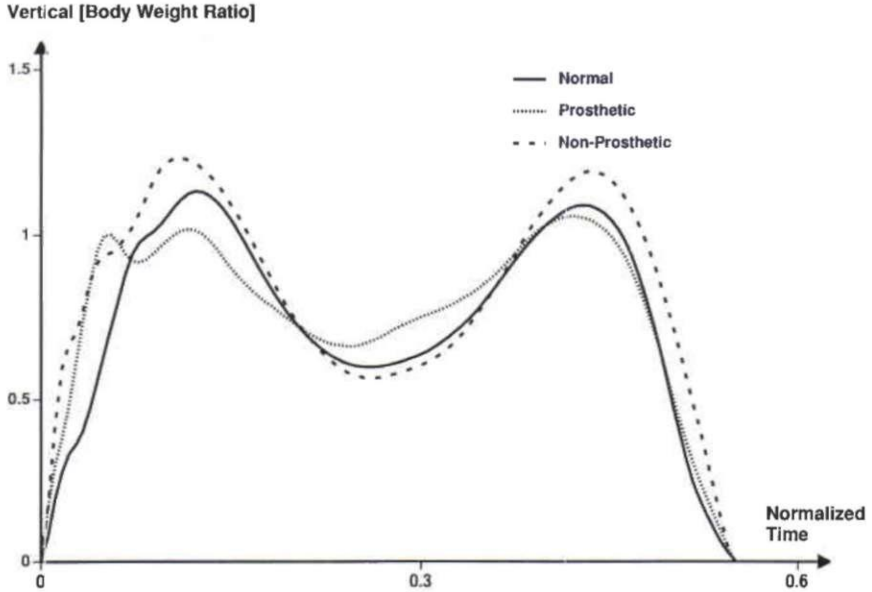

Fig. 3. Average vertical force-time curve for the subject walking normally and for the prosthetic and non-prosthetic legs while wearing AFO1.

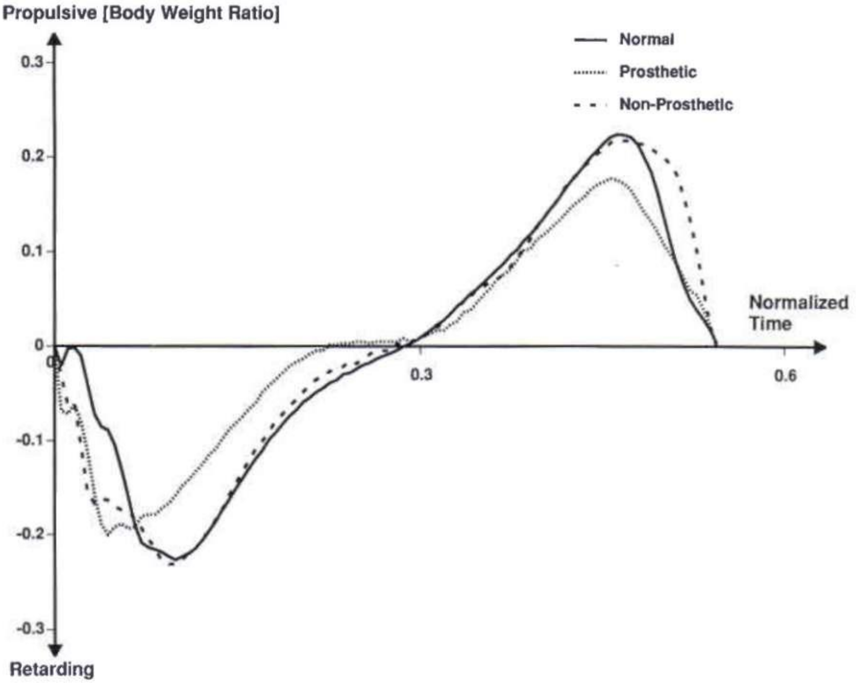

Fig. 4. Average anteroposterior force-time curve for the subject walking normally and for the prosthetic and non-prosthetic legs while wearing AFO1.

Stanford, Connecticut 109602) secured around the chest.

The subject was fitted with a noseclip and a headgear apparatus securing the mouthpiece to the expired gas hose. The subject then walked on the treadmill for 2 minutes at each of four speeds (freely chosen walking speed (1.6 m/s), 20% above freely chosen walking speed, 20% below freely chosen walking speed and a fixed speed of 1.2 m/s) in a randomly assigned order. Heart rate was recorded every 30 seconds throughout the test while oxygen consumption (ml/(kg·min)) was taken at 2 minute intervals. Oxygen consumption relative to distance (ml kg-m)) (SVO_2) was then calculated.

Results

The data presented will be from the final fittings of each AFO only (i.e. AFO1-F to AFO4-F). A comparison of data collected from the initial fitting to data collected from the final fitting is beyond the scope of this paper.

Figures 3 and 4 show final fit average force-time curves for the subject. Figure 3 shows the vertical force-time curves for the AB subject walking normally and for the non-prosthetic and prosthetic leg of the subject while wearing AFO1 (AFO1-F). Similarly, Figure 4 shows the anteroposterior (retarding-propulsive) force-time curves.

Figures 5, 6, 7 and 8 are results of discrete vertical and anteroposterior variables for both the prosthetic and non-prosthetic legs. Each figure compares the value of the discrete variable while walking normally to the value while walking with each AFO. Included in the comparisons and indicated by an asterisk are data collected by Engsberg *et al.* (1993) on AB and TTA children. For this study, AFO1 corresponds to the TTA case and normal correlates to the AB case. Figures 9 and 10 display final fit results of sagittal plane touchdown angles of the trunk and thigh, respectively, for both the prosthetic and non-prosthetic limbs (AFO1-F to AFO4-F).

Figure 11 compares SVO_2 during normal walking to SVO_2 during walking while wearing AFO1 for various walking speeds. For each walking speed, the oxygen uptake while wearing AFO1 was higher than while walking normally. When all speeds were combined, there was an average increase of 16% SVO_2 while walking with AFO1.

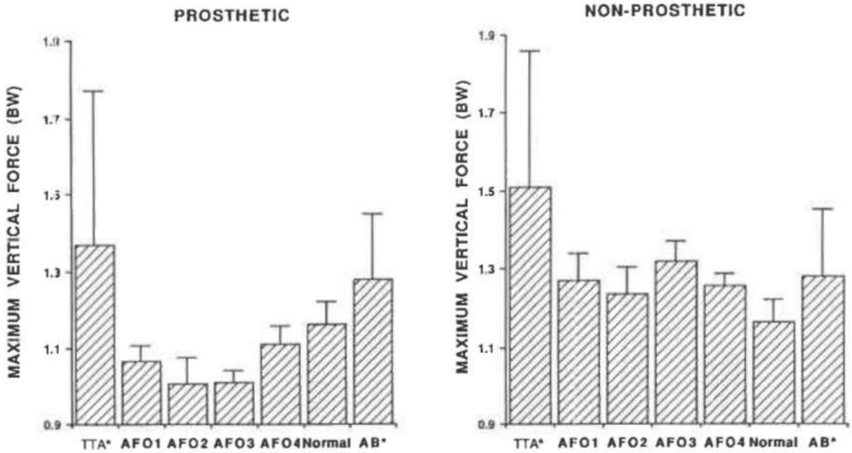

Fig. 5. Prosthetic and non-prosthetic comparisons of the first local maximum (ZMax1) of the vertical force-time curve for walking with the different AFOs and walking normally. *Indicates data included in the comparison for TTA and AB children from Engsberg *et al.* (1993).

Discussion

The purpose of this investigation was to develop a method to test the influence of specific prosthetic features in preventing TTAs from walking like ABs.

Since the investigation was designed only to develop a method and only a single subject was involved, no statistical treatment was performed on the data to determine significant differences between variables. A limitation of the study was that although the methods used to collect kinematic data allowed comparisons amongst conditions within this study (i.e. surface marker locations were consistent for all AFOs), the data from this investigation could not be quantitatively compared with data from previous investigations in the literature. Another limitation was that data were collected only while walking on level ground. Running and/or walking on uneven ground should be included in future investigations as the influence of the various prosthetic features could possibly change.

The three key elements of this investigation were to determine if: 1) AFOs could be fabricated that would incorporate the features of

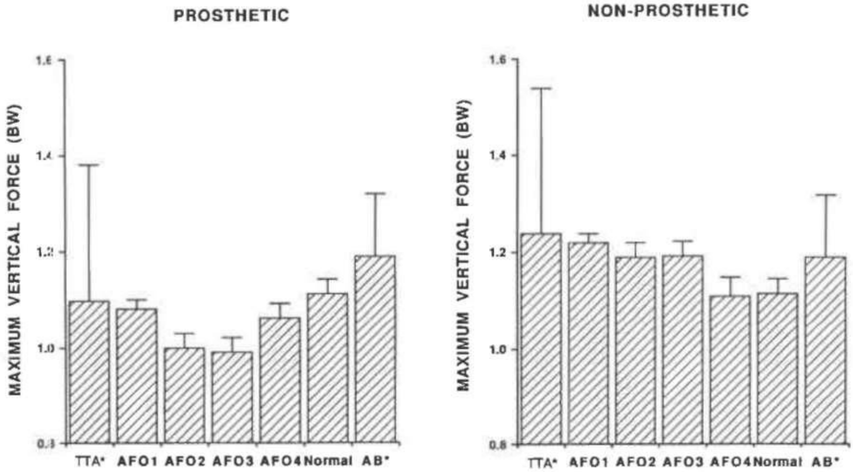

Fig. 6. Prosthetic and non-prosthetic comparisons of the second local maximum (ZMax2) of the vertical force-time curve for walking with the different AFOs and walking normally. *Indicates data included in the comparison for TTA and AB children from Engsberg *et al.* (1993).

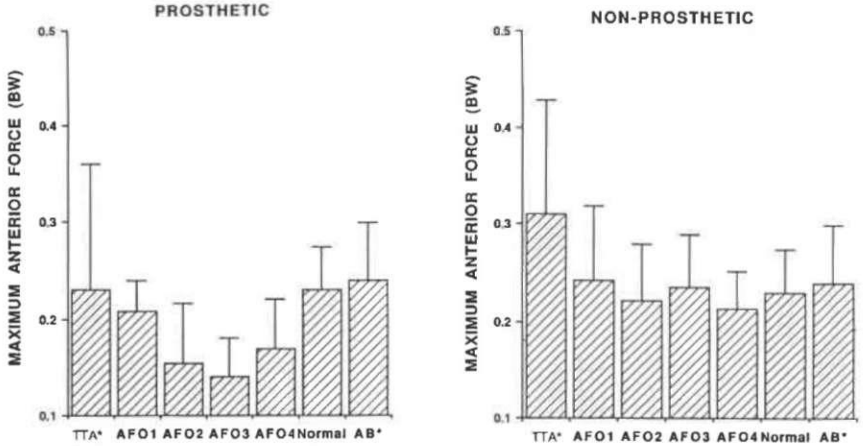

Fig. 7. Prosthetic and non-prosthetic comparisons of the maximum anterior force (RMax) for walking with the different AFOs and walking normally. *Indicates data included in the comparison for TTA and AB children from Engsberg *et al.* (1993).

a Symes foot prosthesis; 2) an AB subject wearing the AFOs would behave similar to a TTA and, 3) detectable differences in gait existed between AFOs with different features.

Regarding the first key element, it was possible to fabricate a single AFO with the following prosthetic features: a) a solid ankle, b) patellar tendon weight bearing, c) passive flexion-extension at the metatarsal phalangeal joints and d) slight knee flexion. It was also possible to systematically modify the AFO to examine the various features. This was an important factor since the cost associated with fabricating many AFOs for a large group of subjects would be quite high.

Information regarding the second key element is obtained by comparing data from the literature collected on TTA and AB subjects to data collected in this study. The average vertical and anteroposterior curves. (Figs. 3 and 4) were similar to those published by Engsberg *et al.* (1993). In both studies the average vertical ground reaction force maxima for the prosthetic leg were lower than normal while the maximum forces for the non-prosthetic leg were higher than normal. Similarly, in both studies, the maximum anteroposterior forces for the prosthetic leg were lower than normal while the

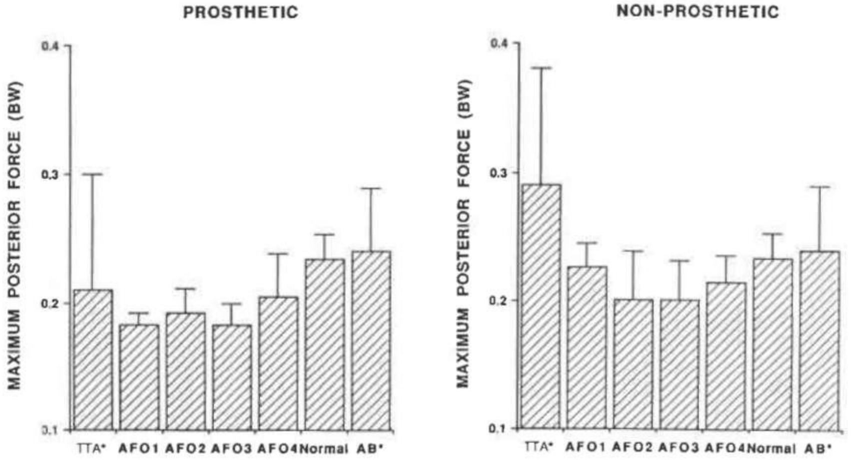

Fig. 8. Prosthetic and non-prosthetic comparisons of the maximum posterior force (PMax) for walking with the different AFOs and walking normally. *Indicates data included in the comparison for TTA and AB children from Engsberg *et al.* (1993).

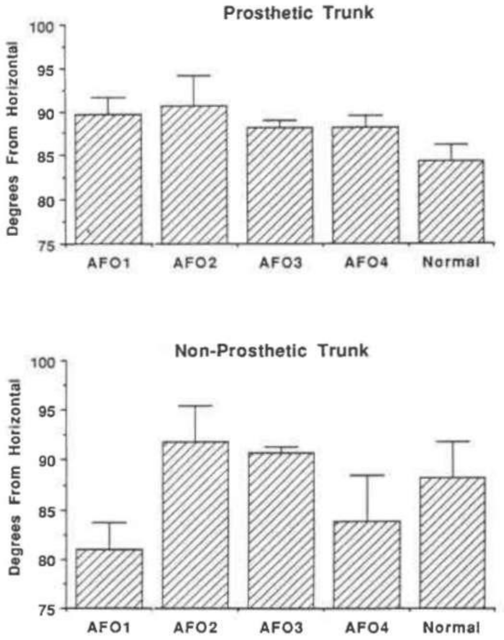

Fig. 9. Prosthetic and non-prosthetic comparisons of the sagittal touchdown angle of the trunk for walking with the different AFOs and walking normally.

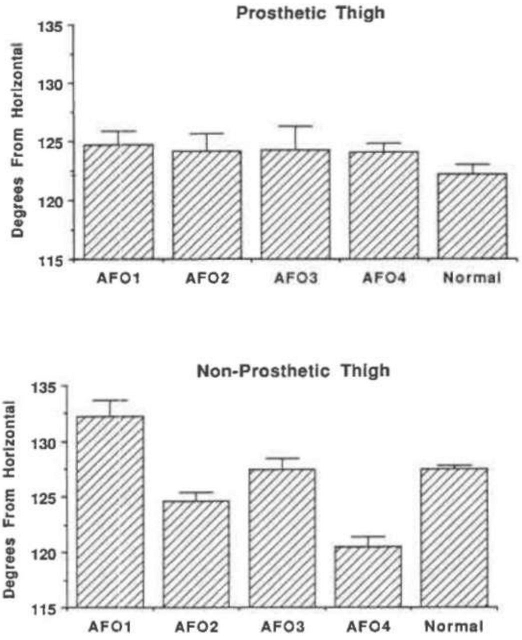

Fig. 10. Prosthetic and non-prosthetic comparisons of the sagittal touchdown angle of the thigh for walking with the different AFOs and walking normally.

forces for the non-prosthetic leg were slightly higher or equal to normal.

Sagittal plane knee angle data collected by Culham *et al.* (1984) on 10 TTA adults and by Engsberg *et al.* (1992) on 3 TTA children found touchdown knee angles to be larger in the non-prosthetic limb than the prosthetic limb. Engsberg *et al.* (1992) also found that AB children had smaller knee angles at touchdown in the sagittal plane than TTA children. The subject in this study had a knee touchdown angle at 10° when walking normally, 14° for the prosthetic limb and 15° for the non-prosthetic limb. As previously mentioned, the quantities cannot be compared directly to those of other studies, however, the trends appear to be similar to those found in actual TTAs.

Engsberg *et al.* (1992) found the trunk segment for TTA children had a greater amount of forward flexion on touchdown than that of AB children. This was the case for both non-prosthetic and prosthetic support. While wearing AFO1 in this study, the subject's trunk also had more forward flexion during non-prosthetic support but less forward flexion during prosthetic support (Fig. 9). Engsberg *et al.* (1992) also found that the thighs of the TTA children were oriented more horizontally than that of the AB children at touchdown. A similar trend was apparent in this study (Fig. 10) where the subject's thigh was oriented more horizontally at touchdown for both legs when walking with AFO1 than when walking normally.

When TTA adults walk at the same speed as AB adults, their energy expenditure is approximately 9% greater (Gonzalez *et al.*, 1974; Ganguli *et al.*, 1974). The metabolic data shown in Figure 11 corresponded to this data as well as data collected by Herbert *et al.* (in press) on TTA and AB children. Herbert *et al.* found SVO_2 to be significantly higher at all speeds of walking for TTA children. When averaging all speeds together, the subject consumed 16% more oxygen when walking with AFO1 than when walking normally.

It appears from the kinetic, kinematic and metabolic data in the literature that the gait of the AB subject while wearing AFO1 closely resembled TTA gait. Similarities existed in oxygen consumption, vertical and antero-posterior ground reaction forces, and sagittal knee and thigh angles. Only slight differences were found in the sagittal trunk angles, however, these differences were not substantial and overall it appeared that TTA gait was successfully simulated with an AB subject wearing an orthosis with various prosthetic features.

Regarding the third key element of this investigation, actual influences of the prosthetic features were difficult to quantify with measurements on only a single subject. However, some trends were apparent. The largest influence of the various prosthetic features on the kinematics of gait appeared to be in the non-prosthetic limbs. The sagittal touchdown angles for the prosthetic trunk and thigh did not appear to change dramatically (less than 5° in all cases). However, the sagittal touchdown angles for the non-prosthetic trunk and thigh seemed to be influenced to a much larger degree although no obvious pattern developed.

In comparing discrete kinetic variables (Figs. 5, 6, 7, and 8) it was assumed that the prosthetic and non-prosthetic limbs should have values equal or at least very similar to normal if a TTA is to walk like an AB. Thus, the hypothesis was that any prosthetic feature which caused the variable to move toward normal was a positive feature and any feature which caused the variable to move away from normal was a negative feature.

The first and second local vertical maxima, the anterior maximum and to a certain extent the posterior maximum followed a similar trend for the prosthetic limb. The removal of slight knee flexion (AFO2) created a negative effect, the removal of passive forefoot flexion-extension (AFO3) appeared to have little or no effect, the removal or patellar-tendon-bearing (AFO4) had a positive effect and since the values for AFO4 were less than normal in all cases, the removal of the solid ankle would have a positive effect. In each of these comparisons the values associated with the AFO1 and normal situations corresponded reasonably well with respective values for TTA and AB children (Engsberg *et al,* 1993).

A key qualitative result when considering the influence of the various prosthetic features was the subjective rating of importance of the prosthetic features in preventing the subject from walking normally. He rated the relative importance of the features in preventing TTAs from walking like ABs as follows (from most (1) to least (4) important): 1) patellar-tendon-bearing, 2) solid ankle, 3) passive flexion-extension of the forefoot, 4) slight knee flexion. The subject felt the ability to bear weight on the foot was the single most important feature in allowing him to walk more like an AB. Another feature which had a large influence was the solid ankle and the subject felt this feature was of great importance when walking on uneven

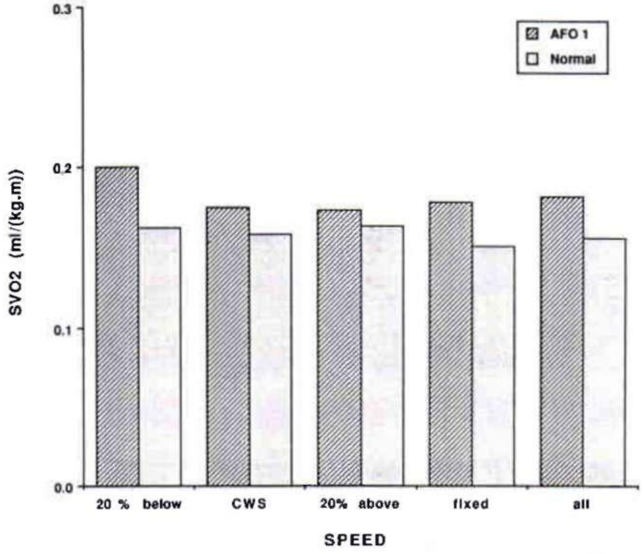

Fig. 11. Oxygen consumption, relative to speed, results for subject walking normally and while wearing AFO1. CWS is the chosen walking speed, 20% below is 20% below CWS, 20% above is 20% above CWS, fixed speed is 1.2 m/s, and all represents a summation of all speeds.

ground. The removal of both knee flexion and passive flexion-extension of the forefoot had small influences on gait according to the subject.

From the kinetic data and the supporting subjective rating it appeared that the patellar-tendon-bearing and the solid ankle had the largest negative influence. The flexion-extension of the forefoot did not appear to have influenced gait during walking. Also, it appeared the slight knee flexion was a positive feature incorporated in the prosthesis to compensate somewhat for the solid ankle and patellar-tendon-bearing. These results are important since current research is directed solely at developing better feet to improve function of the TTA. This data indicates that the loading of the stump may be at least as important. Research directed at alternative loading scenarios may be necessary if TTAs are to walk more like ABs.

In future studies it will be important to include a large number of subjects to see if similar trends appear and to be able to quantify the influences of the various prosthetic features. It will also be important to include other activities in the protocol to determine the influence of the prosthetic features during activities other than level walking (i.e. walking on uneven ground and running.)

Acknowledgments

The authors would like to thank Mark Schneider for fabrication of the various ankle-foot orthoses and the Hospital for Sick Children Foundation for the financial support (#XG91-078).

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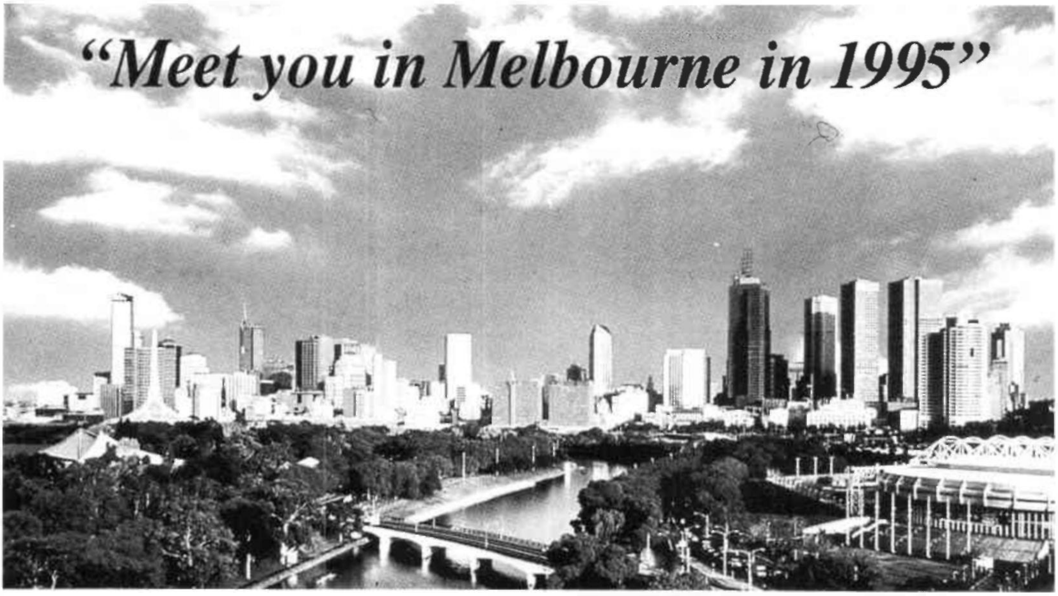

VIII World Congress
2 – 7 April, 1995, Melbourne, Australia

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ICMS
84 Queenbridge Street
South Melbourne
Victoria 3205
Australia
Telephone +613 682 0244
Fax +613 682 0288

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8TH WORLD CONGRESS
ISPO
MELBOURNE, AUSTRALIA
INTERNATIONAL SOCIETY FOR PROSTHETICS AND ORTHOTICS

Message from the President

ISPO's World Congress is the largest international scientific event which covers all aspects of prosthetics, orthotics and rehabilitation engineering. This Congress occurs every three years and brings together all the disciplines involved in the rehabilitation of the physically challenged – orthotists, prosthetists, physicians, surgeons, therapists, nurses, engineers, educators – all those who work each day to restore or provide function to individuals with neuromuscular skeletal disorders.

This 8th World Congress, our Silver Jubilee, will bring experts from around the world to Melbourne, Australia. This is the first time the ISPO World Congress will take place in the Southern Hemisphere. It is the opportunity to hear the latest in scientific information and technical advances. The organisers have chosen the theme of "East meets West-ISPO in the Western Pacific meeting the rest of the world". It is also an opportunity for all of us to explore the world "Down Under".

The 8th World Congress scientific programme will be of interest to the entire rehabilitation team. The scientific programme includes the popular instructional course lecture series early each morning followed by symposia presentations. Symposia presenters are all invited and include experts from each of the disciplines involved in prosthetics, orthotics and rehabilitation engineering delivery. After lunch the Australian organisers have introduced sessions called "Expert Viewpoint". Again, these are given by invited experts presenting their viewpoints on selected topics, followed by response of an invited discussant. This discussant may concur with what has been presented or may have a different viewpoint. This programme is designed to stimulate thought and discussion. You can be sure the organisers have selected some topics where controversy exists.

The free paper section of the programme provides the opportunity to bring the newest information to participants. Researchers and clinicians from around the world have submitted abstracts of their work, and we will all have the opportunity to see the future direction in which our profession is heading. The commercial exhibit will give us the big picture. We will be able to see the components, manufacturing materials, and equipment, and treatment devices used in all aspects of rehabilitation.

Poster presentations and videos provide another format of education. We will be able to fill every moment while at the Congress with information and knowledge that we can use when we return home.

The Congress will not be all work We will all have an opportunity to experience the Australian hospitality and culture. I encourage all of you to take the opportunity to visit and experience the natural beauty of this part of the world. Melbourne itself is a beautiful city with something to offer each of us

The programme is organised, events are scheduled, and all plans have been made The Australian Organising Committee has participated in all the past World Congresses, and they are well aware of what is expected. All we need to do is register and go to Melbourne. You will take home the experience of a lifetime.

Melvin L. Stills

Message from the Secretary General

The ISPO World Congresses had their genesis at the ISPO International Symposium in Australia in August 1972, which was held so successfully.

In 1995 the first ISPO Triennial World Congress in the Southern Hemisphere is being held in Melbourne, Australia.

A very special effort has been made to present a stimulating and challenging Scientific programme. Additionally delegates can experience our unique culture during and after the Congress.

It is a great honour that His Excellency, the Honourable Richard McGarvie, Q.C., Governor of Victoria is giving his official support to this 8th ISPO World Congress.

The theme of the Congress is "East meets West – ISPO in the Western Pacific meeting the rest of the world".

There is a high and diversified standard of rehabilitative care in Australia. The ISPO Congress is adopting a multi-cultural approach to ensure that the needs of particular groups are met in the best possible way. The opportunity will be available to study the wide and diverse network of services which are available to people in the area.

For many, attendance at our Congress will be the first opportunity of visiting our country "down-under" and I strongly recommend that you take advantage of this occasion to extend your stay to visit other parts of Australia. The choice is endless from the beautiful beaches and spectacular coral of the Barrier Reef to the sunburnt centre of Central Australia and Ayers Rock; the unique fauna and flora throughout the continent to the spectacular rainforests of the tropics; the national parks and mountains in the southern parts of Australia.

Please come and join us on this historic occasion of the Silver Jubilee of ISPO.

Valma Angliss

Scientific Programme

The scientific programme has been designed to place special emphasis on a discussion to place special emphasis on a discussion and investigation of current problems and the relevant research across the entire field of ISPO, as we approach the 21st century. Each day has been allocated a special theme relevant to the issues of our profession and within that theme, topics will be addressed segmented into different categories.

Expert Viewpoint

These presentations provide an opportunity for experts to present an overview of a state-of-the-art topic drawing on personal experience, ideas and research in summarising significant changes over the past three to five years. The presenter's paper will be followed by a response, either endorsing the views of the presenter or challenging the statements by providing alternate viewpoints. Interaction and discussion from the floor will be encouraged throughout the latter part of the session.

The provisional programme of Expert Viewpoint sessions includes:

- Changing attitude to amputation surgery

- Knee orthoses
- CAD CAM update
- Prosthetic and orthotic education in the developing world
- Management of limb fractures
- Assessement of foot disorders
- Lower limb prosthetic socket technology
- Prosthetic and orthotic education in the industrial world
- Early management of the lower limb amputee
- Adolescent scoliosis
- Upper limb prosthetics
- Low back pain.

Symposia

Symposia are multidisciplinary sessions or panel sessions on reasonably specialised topics, equivalent to free paper sessions except that they have been pre-planned. The selected speakers will present different aspects of a topic or different approaches to the topic. These sessions will feature current trends and recent developments, presented by prominent speakers chosen according to their international reputation.

The provisional programme of Symposia topics includes:

- Interdisciplinary prosthetic care in a community based rehabilitation setting
- Intelligent prosthetic knees/electro-mechanical prostheses
- Footwear and management of foot deformities
- Late effects of post-poliomyelitis
- The elderly amputee
- Ischial containment sockets
- Prosthetic and orthotic services in the Western Pacific and South East Asia
- Mobility for the adult paraplegic
- Management of the diabetic foot ulcer
- CAD CAM in clinical practice
- The technical approach for prosthetic provision in developing countries
- FES and hybrid orthotic systems
- Pain in the amputee
- Energy storing feet
- Consumer focus
- Management of spasticity to improve function in the adult
- Cultural attitudes to limb losses and prostheses
- Assistive technology for severe disabilities
- Prosthetic and orthotic education in developing countries
- Management of spasticity to improve function in children
- Amputee athletes
- Clinical gait analysis
- Surveys of upper limb amputees.

Instructional Courses

The objective of the instructional courses is to provide practical education in a specific topic by covering information on methods that instructors have found to be clinically effective. The courses are designed to cover the technical aspects of accepted practice in a workshop environment.

The topics were chosen mostly with a clinical emphasis and give a wider coverage of non-prosthetic areas. The aim is to cover in a ninety minute period all the facets of each topic. Another aim is to attract and bring together all appropriate disciplines for the topic in the one integrated session.

The overall approach is to encourage full week attendance by offering several parallel series, each consisting of related topics dealt with sequentially. On each day there is also a range of topics to allow a choice for each discipline. The weekly programme will allow each discipline a topic throughout the week for a variety of disabilities.

Instructional courses will be scheduled daily for 90 minutes duration. As the cost of attendance is not included in the registration fee please study the topics offered and indicate the choice of courses you wish to attend by filling in the appropriate box on the application form. The cost of attendance is $AUD 50 per session which must be remitted in addition to the registration fee.

The provisional programme of instructional courses includes:

Sunday, April 2, 10.30-12.00

- Amputation in vascular disease (S1/90)
- Spinal cord injury – a team approach to patient management (S2/90)
- Fracture cast bracing (S3/90)
- Management of the limb deficient child (S4/90)
- Management of cerebrovascular accident patients (S5/90)

Monday, April 3, 08.00-09.30

- Syme and partial foot amputation: surgery, prosthetics, orthotics and rehabilitation (M1/90)
- Management of degenerative disease of the spine (M2/90)
- Amputations in trauma and cancer (M3/90)
- Upper limb orthotics (M4/90)
- Anaplastology/optimising cosmesis (M5/90)

Tuesday, April 4, 08.00-09.30

- Trans-tibial amputation: Part 1 – surgery (T1/90)
- Scoliosis and kyphosis: surgical, conservative and orthotic management (T2/90).
- Functional independence for amputees (T3/90)
- Assessment and management of the insensitive foot (T4/90)
- Management of burn patients (T5/90)

Wednesday, April 5, 08.00-09.30

- Trans-tibial amputation: Part 2 – prosthetics and rehabilitation (W1/90)
- Seating: design and assessment of the patient (W2/90)
- Management of foot disorders (W3/90)
- Upper-limb amputation: Part 1 – surgery (W4/90)
- Management of the unstable knee (W5/90)

Thursday, April 6, 08.00-09.30

- Knee disarticulation and trans-femoral amputation: Part 1 – surgery (TH1/90)
- Wheelchair design and prescription (TH2/90)
- Footwear and orthotics (TH3/90)
- Upper limb amputation: Part 2 – prosthetics and rehabilitation (TH4/90)
- Orthotics for arthritis (TH5/90)

Friday, April 7, 0800-09.30

- Knee disarticulations and trans-femoral amputation: Part 2 – prosthetics and rehabilitation (F1/90)

- Prosthetics and orthotics for sports applications (F2/90)
- Computer information systems for prosthetics (F3/90)
- Principles and practice of myoelectric technology (F4/90)
- The ICRC system of component manufacture (F5/90)

Free Papers

Authors of accepted papers will present the results of their research, clinical and technological experience, to benefit those who are interested and engaged in the same field of activity. This will provide the opportunity for discussion and interchange of information.

An invitation for application for scientific presentations has already been circulated in a separate brochure. Authors worldwide are invited to submit abstracts to be included in the Free Paper Sessions or the Poster or Video presentations and deadline for receipt of abstracts for any of the session categories is September 1, 1994. Please contact the Congress Secretariat if you require further information.

Poster Sessions

Poster presentations will be exhibited daily during the lunch break.

Video Sessions

Several sessions will be held during the Congress for video presentations.

Manufacturers' Sponsored Workshops

Three workshops will be held from Monday through to Friday concurrently with the instructional courses.

The format of the Workshops will allow Manufacturers to instruct a wide range of health practitioners about their

- Products
- Prescription principles
- Applications
- Special techniques/alignments.

An additional fee of $AUD 25 is applicable for each workshop attended. Please select your choice by completing the appropriate box on the application form and remit payment in addition to the registration fee.

The programme of Manufacturers Workshops includes:

Monday, April 3, 08.00-09.30

FLEXFOOT INC.: Optimising clinical results with the flexfoot (MW1).

BLATCHFORD: The criteria with functionality of high activity (MW2).

M + IND, SEATTLE MEDICAL SYSTEMS GROUP: Maximising efficiency in a cost conscious environment. Effective use of CAD/CAM and appropriate limb systems (MW3).

Tuesday, April 4, 08.00-09.30

BOSTON BRACE INTERNATIONAL INC.: Treatment of ACL deficient knee using a Boston knee brace (MW4).

OTTO BOCK: Time saving tips in orthotic manufacture (MW5).

USMC: The new USMC series of energy storing lower extremity prosthetic components (MW6).

Wednesday, April 5, 08.00-09.30

FILLAUER INC.: New application for carbon composites – PolyCar-C for thermobonding to plastic and metal (MW7).

OTTO BOCK: A biomechanical approach to prosthetic knee selection (MW8).

COMFORT & FIT AUSTRALIA: Pedonthic management of the diabetic foot (MW9).

Thursday, April 6, 08.00-09.30

BLATCHFORD: The benefits of a Microprocessor controlled lower limb system (MW10).

OTTO BOCK: Myoelectric prosthesis: basic troubleshooting (MW11).

USMC: Technical update of USMC lower extremity modular prosthetic systems (MW12).

Friday, April 7, 08.00-09.30

FILLAUER INC.: Silicone suction socket (38) update – upper and lower extremities (MW13).

BLATCHFORD: The prescription criteria of knee componentry (MW14).

HOSMER: Lower extremity endoskeletal systems (MW15).

Knud Jansen Lecture

Knud Jansen, M.D. was the founder of the International Society for Prosthetics and Orthotics (ISPO), and was its President from 1970-1977. He was an esteemed Orthopaedic surgeon in Denmark, having been Chairman of the Danish Orthopaedic Association and the Danish Society of Orthopaedic Surgery.

He was also Secretary General of the Scandinavian Orthopaedic Association and for many years served as editor of one of the most prestigious international journals, Acta Orthopaedica Scandinavica. Knud Jansen was a staunch supporter of the concept of the clinic team and his influence has carried that important concept to prosthetics and orthotics care worldwide. Jansen was a champion of technical orthopaedics and rehabilitation. His vision created ISPO and his influence still guides the organisation.

The lecture in Knud Jansen's name was established by ISPO as a memorial to its founder. The lecture is presented by a distinguished member of the society at each Triennial World Congress.

The Knud Jansen lecture for 1995 will be delivered by Sepp Heim and will be presented immediately after the Opening Ceremony in the John Batman Theatre on Sunday, April 2.

Awards

The Brian Blatchford Prize

The Brian Blatchford Prize has been established by the Blatchford family to honour the memory of Brian Blatchford. It is awarded every three years at the World Congress of the International Society for Prosthetics and Orthotics.

The prize of £2,500 will be awarded to an individual who has an outstanding record of innovative achievement in the field of prosthetics and/or orthotics. The achievement should be related to prosthetic and/or orthotic hardware, or scientifically based new techniques which result in better prostheses or orthoses. The

President, in seeking to identify the recipient of the award, will also consider nominations or applications from National Member Societies or individuals. Such nominations or applications should contain a justification together with a curriculum vitae of the candidate and should reach the President of ISPO by November 1, 1994, at the following address:

M. L. Stills
Orthopaedic Surgery Department
UT Southwestern Medical Center
5323 Harry Hines Boulevard
Dallas, Texas 75235-8883, USA.

The prizewinner shall make a presentation based on his work at the World Triennial Assembly on Thursday April 6 and the paper shall be duly published in Prosthetics and Orthotics International.

The President and Executive Board of the International Society for Prosthetics and Orthotics and the Blatchford family reserve the right to withhold the prize should no suitable candidate be identified.

The Forchheimer Prize

The Forchheimer Prize has been established by the Forchheimer family to honour the memory of Sylvia and Alfred Forchheimer. It is awarded every three years at the World Congress and will be presented at the World Triennial Assembly.

The prize will be awarded 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 the International Society for Prosthetics and Orthotics and the Forchheimer family reserve the right to withhold the prize should no suitable paper be published.

Exhibition

The commercial and scientific exhibitions will be held in the You-Yangs Exhibition Hall at the world Congress Centre.

As this is the first time the Congress will be held in the Southern Hemisphere the event will draw delegates from the Asian/Pacific region and provide exhibitors with a valuable platform for sales opportunities and for opening up new markets. Additionally, the Congress expects to attract a worldwide audience of prosthetists, orthotists, therapists, physicians, surgeons, engineers, nurses, rehabilitation specialists, and others.

The Exhibition will be officially opened on Sunday April 2, immediately following the Congress opening and Knud Jansen Lecture and delegates will be given ample time to view the exhibits throughout the Congress week.

Companies are invited to contact the Congress Secretariat for further information on participation.

Registration Information

Please complete the registration form and return with payment to the Congress Secretariat. Each delegate must complete a separate form. Clear photocopies or facsimiles are acceptable, however, in the case of the latter you are requested to mail the original copy noting that a facsimile has previously been forwarded.

Congress Secretariat

All registration forms and enquiries should be made to:

ISPO Congress
ICMS
84 Queenbridge Street
South Melbourne
Victoria 3205
Australia
Telephone +613 682 0244
Fax +613 682 0288

Entitlements

Delegates are entitled to:

- Attend the Opening Ceremony and all Scientific Sessions;
- Attend the Welcome Reception;
- Attend the Farewell Lunch;
- Lunches daily (excluding Wednesday);
- Morning/afternoon teas;
- Congress satchel;
- Receive a copy of the Proceedings.

Accompanying persons are entitled to:

- Attend the opening ceremony;
- Attend the Welcome Reception;
- Meet the Partners Coffee;
- Half day tour;
- Attend the Farewell Lunch.

Please note fees do not include admission to the Instructional Courses or Manufacturers' Workshops, the Congress Dinner, Technical tours, Orientation and optional sightseeing tours or accommodation costs. Please remit additional payment for these with your registration fee.

Payment of fees

Payment of fees must accompany all registration forms. Fees can be paid either by:

- Credit card (Visa, Mastercard, Bankcard only)
- Bank draft in Australian dollars;
- Australian registrants only – personal cheque.

If you have any difficulty with remittance of payment by any of the above caused by your country's foreign exchange regulations, please contact the Secretariat for advice before forwarding any other form of payment.

Your registration will be ackowledged in writing confirming your requirements according to your Registration Form. Attendance at the Congress will be confirmed only on receipt of payment.

Registration fees

Payment received prior to December 31, 1994.

Delegates:	
Members	$AUD650.00
Non-members	$AUD775.00
Accompanying Persons:	$AUD200.00
Students:	$AUD200.00
Day Registrants:	$AUD200.00

AN ADDITIONAL FEE OF $AUD100.00 WILL APPLY TO ALL DELEGATE AND STUDENT REGISTRATION FEES RECEIVED AFTER

DECEMBER 31, 1994.

In order to qualify for membership fee, please advise ISPO membership number on the registration form.

Cancellations and Refunds

Cancellations must be notified in writing to the Congress Secretariat. Cancellations received prior to February 15, 1995 will receive a 75% refund of registration fees paid. After this date no refunds will be applicable. Refunds of accommodation deposits are subject to individual hotel policies on application.

Attendance Verification

Certificates of attendance at the Congress will be available on request.

Letters of Invitation

The Organising Committee will be pleased to send letters of invitation to prospective delegates making such a request. It is understood that such an invitation is intended to help potential attendees to raise travel funds or to obtain a visa. It is not a commitment on the part of ISPO to provide any financial support.

Liability

In the event of industrial disruption, the Congress organisers accept no responsibility for loss of monies incurred by delegates.

Keyword Programme Section

Please indicate up to six keywords of topics or your particular field of interest on the registration form as coded below:

A01 Cerebral palsy
B01 Cerebral vascular accident (CVA)
C01 Diabetes
D01 Education and training
E01 Foot disorders
F01 Fracture bracing
G01 Independent living
H01 Leprosy
I01 Measurement technology
J01 Muscular skeletal disabled
K01 Orthopaedic footwear
L01 Orthotics-lower limb
M01 Orthotics-upper limb
N01 Paraplegia and quadraplegia
001 Performance appraisal of programmes
P01 Poliomyelitis
Q01 Public health and epidemiology
R01 Recreation, leisure, music, sport
S01 Scoliosis
U01 Sockets-prosthetic
V01 Symes and partial foot amputee
W01 Technology
X01 Trans-femoral (above-knee) amputee
Y01 Trans-tibial (below-knee) amputee
Z01 Upper limb amputee

Social Programme

Welcome Invitation

Your first opportunity to officially experience the fun and friendly spirit of your Australian hosts, whilst catching up with old acquaintances and meeting some new ones. The reception will be held in the Atrium of the World Congress Centre and we hope to tantalise the taste buds with our unique Australian fare and entertain you with the folk lore of our more recent beginnings. There could even be the opportunity for some toe tapping with our bush friends.

Date: Sunday, April 2, 18.00-21.00.
Dress: Casual
Fee: Included in delegate and accompanying person registration fee.

Melbourne Dine-out

Epicurean delights abound in Melbourne, the culinary capital of Australia. The variety of Melbourne's restaurants is a gourmet's delight as there are over 3,000 of them representing 70 national cuisines. We recommend that you sample an appetising cross-section of these restaurants during your stay and we have dedicated this night for you to start your gastronomique experience. Our restaurant advisory service will be on site on Sunday, April 2 to assist with recommendations and bookings according to your budget.

Date: Monday, April 3
Fee: Pay direct to restaurant of your choice
Bookings: On site at the World Congress Centre.

Congress Dinner

Our Congress Centre transforms to a backdrop for the Congress Dinner, where the theme of Australia's multicultural background will be reflected. Dinner will combine the best of Australia's fresh produce presented in the many tastes of our ethnic population. The entertainment for the night will also reflect the same theme as a pot-pourri of talent will entice you to join them in a night of great fun and enjoyment.

Date: Tuesday, April 4, 19.30-23.00
Fee: $AUD85.00
Bookings: Registration Form
Dress: Lounge Suit.

Performance by the Australian Opera

A limited number of seats have been booked for the Australian Opera's performance of Gilbert & Sullivan's Patience. Starring Anthony Warlow, well known to Australian audiences for his superb lead role in the local production of Phantom of the Opera and also included in the cast acknowledged Gilbert & Sullivan specialists Dennis Olsen and Heather Begg. The performance will be staged at the Victorian Arts Centre, a renowned complex well worth the visit. Deadline for bookings is January 15, 1995.

Date: Thursday, April 6, 1995
Fee: $65.00
Bookings: Registration Form.

Farewell Lunch

Join us to throw a "Prawn on the Barbie" at our farewell barbeque. The opportunity to finally farewell your international colleagues.

Date: Friday, April 7, 12.00-14.30
Fee: Included in delegate and accompanying person registration fee
Dress: Casual.

Accompanying Persons Programme

The Organising Committee welcomes delegates' partners to join us in Melbourne in 1995. A special programme has been designed to allow you the time to explore our city and surrounds independently but also includes the choice of some special tours which are not readily available to the public.

Inclusive Tours – Monday
(Accompanying persons)

Please select one of the three tours listed below and indicate your choice on the registration form. Although the cost of the tour is included in the accompanying person registration fee, a booking will not be held if the form is not completed.

• KOORI WALKABOUT: The Kooris – the mighty Kulin – indigenous people of the Western Plains in South Eastern Australia. We visit their Traditional hunting grounds in the You Yang ranges where countless thousands of Koori women have met for 40,000 years. As we sit together overlooking the plains where the women gathered food, Janine, our guide, will help you explore their culture – as it was, and as it is today. This is a rare opportunity for you to discover this timeless and nearly extinct people. Numbers are limited, so book early.
Includes: Coach, guide, admission fees and morning tea
Duration: 10.00-14.00 hours

• SHOP TILL YOU DROP: We all love to shop. Discover the many secrets of Melbourne shopping as we visit some unique wholesale outlets. Melbourne is definitely the home of fashion and style. You won't be able to resist the bargains. All outlets visited manufacture quality Australian-made products. Morning tea is included by Gemtec – one of Australia's leading opal merchants.
Timing: 10.00-13.00 hours
Includes: Coach, guide and morning tea.

• THE AUSTRALIAN BALLET CENTRE: A look behind the scenes of this world renowned ballet school and centre. The interior has many unique facilities, in particular, the eight superb rehearsal studios and the Production Department where the costume and millinery are designed, created and manufactured for all the Australian Ballet's performances. View dance archive exhibitions and rehearsal activities in the dance studios.
Includes: Transfer, guide, admission fee and morning tea
Duration: 10.00-12.30 hours.

Orientation Tour – Sunday

This tour will orientate you with your host city – Melbourne. The inhabitants of Melbourne love her elegant layout, her Victorian grandeur and architecture, her wide tree-lined streets. Let us introduce you to the hustle and bustle of this thriving metropolis. At the termination of the tour we visit Gemtec, one of Australia's leading Opal Merchants, who will give you a brief introduction and educational film on where opals are mined, cut and polished into the finished product.
Cost: $30.00 per person
Includes: Guides, 5 star coach equipped with toilet
Timing: 09.30-11.30 hours
Minimum: 25 passengers

Meet the Partners – Morning Coffee

An informal morning coffee at the Congress Centre to meet up with the accompanying persons and your Melbourne hosts – a great opportunity to chat to our local tour experts on shopping, touring or just general information on what Melbourne has to offer before departing on a tour.
Monday, April 3, 09.00-10.00.

Sightseeing Tours

The Programme Committee has purposely left Wednesday afternoon free of any scientific sessions to allow time for delegates to join their partners to participate in a choice of either a technical or sightseeing tour.

The sightseeing tours are subject to minimum numbers.

Please indicate your choice of tour on the registration form and remit payment with your registration fee.

The tours desk will also book individual tours to many of Melbourne's unique attractions including the Victorian Arts Centre complex housing our performing arts theatres and Sovereign Hill where the early gold digging era is reproduced.

• **Penguins on Parade**

Travel to Phillip Island in Westernport Bay to view these special species of the animal world.

Perhaps the most amazing and delightful tour of all, the Penguin Parade is unique among animal displays. Completely uninfluenced by man, the penguin extravaganza takes place at dusk as these charming 'fairy' penguins waddle through the twilight up the beach, over the sand dunes to their burrows. We also come face-to-snout with some koalas and kangaroos.
Cost: $64.00 per person
Includes: 5 star coach equipped with toilet.
Admission fees: Summerland Beach Fauna Reserve
Timing: 13.00-22.00 hours
Optional add-on: Hot lobster dinner: $55.00 per person.

• **Victorian Wineries**

The elixir of life is certainly produced and bottled – so Victorians believe – in the foothills of the Yarra Valley. This picturesque valley is home to some delightful wine producing vintners. Domaine Chandon, built by the world French champagne house Moet Chandon, will be delighted to show us the intrigues of champagne production with a little sampling – of course. St. Hubert's, de Bortoli and Yarra Ridge are smaller producers who each have very distinct wines. We will wend our way through the valley sampling wine with some of these producers. Cheers!!
Cost: $99.00 per person
Includes: 5 star coach equipped with toilet
Wine tastings: Domaine Chandon; de Bortoli; St. Huberts; or Yarra Ridge.

Lunch at The Grand Hotel in Yarra Glen.
1 glass of house wine with lunch.
Timing: 12.15-18.00 hours.

- **Australian Animals**

If you want to see Australian animals in their natural bush environment, then our visit to Healesville Sanctuary will enthral you. This wonderful sanctuary recreates each animal's natural habitat. You'll smell the eucalypt forest and hear the many sounds of the Australian bush as you peak at koalas, kangaroos, platypus, emu, echidna – just to name a few. To complete this experience enjoy a traditional "Aussie BBQ".

Cost: $99.00 per person.
Includes: 5 star coach equipped with toilet
Admission fee
BBQ dinner with beer, red and white wine
Timing: 12.30-20.30 hours

Technical Tours

Please indicate your choice on the registration form

TOUR 1: (Code TT01)

Centre Of Integrated Equipment Services

This centre incorporates many areas. We will be confining our visit to three of them, the Independent Living Centre, the Microcomputer Applications Centre and the Equipment Library. Experienced staff are available for asssessment and advice with regard to the specialised equipment on display. Arrangements can be made to hire equipment for trials prior to expensive purchases being made.

Tour Time: 13.30-15.30
Cost: $30.00

TOUR 2: (Code TT02)

The Alfred Group Of Hospitals

The Alfred Group of Hospitals is a large tertiary referral centre providing a wide range of services. This tour will include the Road Trauma Unit, a specifically equipped and staffed centre to care for road trauma patients. This centre is supported by the facilities of the Alfred Hospital, which has a complete range of specialist services and investigational facilities. The centre can be rapidly accessed by both ambulance helicopter and surface transport. The Hyberbaric Unit will also be open for delegates to visit. Hyberbaric medicine involves the use of barometric pressure greater than that at sea level for the treatment of diseases.

The tour will then visit the Caulfield campus to view the Amputee Unit; a purpose adapted and fully equipped unit which houses all staff with clinical, theraputic, technical and manufacturing facilities and the Monash Rehabilitation Technology Research Unit consisting of an inter-disciplinary team with medical, theraputic, and engineering expertise, which work toward the enhancement of quality of life of the musculo-skeletal disabled patient.

Tour Time: Alfred Hospital (Acute): 13.30-15.00
Caulfield Campus (Rehabilitation): 15.00-17.00
Cost: $30.00

TOUR 3: (Code TT03)

Austin Hospital

The Austin hospital is a teaching hospital with both acute and rehabilitation campuses. Delegates will be concentrating on the rehabilitation area of this hospital. Client Groups catered for by this hospital include, Amputees, Spinal Cord Injuries, Orthopaedics, Neurology, and Acquired Brain Injuries. Tours of the following areas will be available: Spinal Cord Injuries Unit, Prosthetic and Orthotic Department, Physiotherapy Department, Occupational Therapy Department, Amputee Unit, and the Gait Clinic.

Staff will avail themselves for brief introductions to all areas or for more detailed visits, depending on the interest from delegates.

Tour Times: Spinal Cord Injuries Unit, Prosthetic & Orthotic Department Gait Clinic: 13.30-15.15
Physiotherapy, Occupational Therapy, Amputee Clinic: 15.15-17.00
Cost: $30.00

TOUR 4 (Code TT04)

Demonstration of Amputee Athletes

In the recent past it had been considered appropriate to discourage physical activity among amputees. Now modern prosthetic technology allows many a level of function almost equal to their pre-amputation potential. The demonstration will show how individuals with amputations can realise their full physical abilities.

A group of amputee athletes (including many who have represented Australia) will perform a range of sporting activities.

Standard componentry will be demonstrated in addition to more advanced componentry and equipment specifically designed and manufactured to accommodate particular sporting needs.

Athletes will be available to discuss features of their sporting prosthesis and how that prosthesis differs from the prosthesis they wear on a daily basis.

Cost: $30.00.

General Information

Venue

The World Congress Centre, Melbourne is a new, modern Convention Centre conveniently located in the heart of the city, within walking distance of city hotels and is well serviced by public transport. It is incorporated in a modern complex which also includes the hotel, Centra Melbourne on the Yarra, the World Trade Centre and a Casino. This complex contains facilities for banking, postal and secretarial services, photocopying and facsimile transmission. A number of restaurants, lunch and coffee bars are situated in the area. Hairdressers, pharmacy, medical centre and newsagents are also available.

World Congress Centre
Corner of Flinders and Spencer Streets
MELBOURNE VIC 3000
Phone (61) (03) 629 4100
Fax: (61) (03) 614 6565

Registration and Information Desk

The registration desk will be located at the World Congress Centre. We advise you to collect your documents as soon as possible after your arrival. The registration desk will be open during the following hours:

Saturday, April 1 – 12.00-17.00

Sunday, April 2 to Thursday April 6 – 07.30-17.00
Friday, April 7 – 07.30-12.30

Passport and Visa

Travellers require a passport and visa for entry into Australia and applications may take some time to process. The airline or travel agent will advise you regarding the procedures for lodgement of the visa application. It is essential to purchase a return ticket.

Quarantine

Australia is free from many plant and animal diseases prevalent in other countries. Very strict quarantine rules apply to the importation of animals and plants which cannot be brought into the country without prior application. Animal and plant products are also restricted.

Travel

For international passengers, we suggest that you allow at least a day in which to adjust to the time difference and relax after the flight. Travellers across the Pacific are reminded that they will lose a day by crossing the International Date Line. This will be reversed on the return journey.

Arriving in Melbourne

It is recommended that international delegates select flights which operate direct to Melbourne to avoid possible transfers from international to domestic terminals in other Australian airports.

Foreign exchange facilities are available at the international terminal. Transfers to the city from the domestic and international terminals are easily accessed. A taxi will cost approximately $AUD25.00. Alternatively, airport buses will take you to the Central Business District and, during weekdays only, to most major city hotels for around $AUD9.00 per person.

Time Difference

Australian Eastern Time is GMT + 10 hours.

Climate

April is mid-autumn in Melbourne and you can expect the weather to be pleasantly mild. The average maximum temperature is around 22 degrees C (72 degrees F). However, evening temperatures could be as low as 12 degrees C (54 degrees F).

Official Airline

Quantas Airways Ltd has been appointed the official international carrier. Under this arrangement, Quantas offices in all parts of the world will be pleased to discuss with you and your travel needs and itineraries, and will explain airfare structures for the most economical travel to Australia.

When making enquiries please quote reference number JB58VU.

Associated Meetings

Pre-Congress Tour: New Zealand

The 7 day tour incorporates a one-day scientific meeting in Wellington and visits to artificial limb centres throughout New Zealand.

The tour will commence in Auckland and will visit both the North and South Islands before departing to Melbourne from Christchurch.

Please indicate your expression of interest on the registration form and further detailed information will be forwarded.

Accommodation

Melbourne is well-supplied with hotels of all standards and styles. A wide selection of excellent hotels and apartments has been reserved for the Congress with a range of room rates.

A special Congress rate has been secured and can be obtained only by booking your accommodation via the Registration Form prior to 15th February, 1995. Any bookings received after this date cannot be guaranteed at the Congress rate. Accommodation will be allocated in order of receipt of bookings and payment. Early registration is advised.

The Secretariat will do everything possible to place you according to your preference within our room allotments and you will be notified of your hotel's name in a letter of confirmation.

Pre-registration

Many international flights arrive in Melbourne in the very early morning and as check-in time at most hotels is 2.00 pm, it is possible that your room will not be ready for occupancy on your arrival. Hotels try to accommodate their guests' needs. However, if you feel it necessary, you can ensure immediate availability by paying an extra day's tariff and booking the room for the night before you are due to arrive. If you take this precaution, please advise the Secretariat in a covering note so that the hotel management understands the room is "pre-registered".

Late Arrivals

Please indicate on your Registration Form if you will arrive at your hotel after 6.00 pm; failure to do so may mean that your room will be released.

Deposit

The deposit for your chosen hotel as listed on the Registration Form must accompany your reservation. Please include this payment with your registration fees. The deposit will be forfeited if the room is not occupied on the advised date of arrival.

Batman's Hill Hotel

$AUD 110.00

Accommodation comprises stylishly appointed rooms offering a wide range of facilities ensuring your every comfort. A five minute walk to the World Congress Centre.

66-70 Spencer Street,
MELBOURNE VIC 3000.
Phone: (61) (03) 614 6344
Fax: (61) (03) 614 1189

Centra Melbourne on the Yarra (Congress Hotel)

$AUD 160.00

Situated on the Yarra River close to Central Business District and Southgate. Attached to the World Congress Centre and equipped with full business facilities. Accommodation room facilities include air-conditioning, mini-bar, refrigerator, tea and coffee-making facilities,

AM/FM radio, direct IDD/STD, iron and ironing board, remote colour TV, hairdryer, heated outdoor swimming pool, gymnasium, currency exchange.
Corner Flinders & Spencer Streets,
MELBOURNE VIC 3000,
Phone: (61) (03) 629 5111
Fax: (61) (03) 629 5624

Hotel Enterprise
Single $AUD 69.00 Double $AUD 79.00
Comfortable, affordable accommodation in the city. Country hotel atmosphere in older style property. 300 metres to World Congress Centre and trams at the door. Each room has private facilities air-conditioning, tea and coffee making facilities and TV.
44-54 Spencer Street,
MELBOURNE VIC 3000,
Phone (61) (03) 629 6991
Fax: (61) (03) 614 7963

Le Meridien at Rialto
$AUD 195.00
In the heart of Melbourne's commercial district, with the World Congress Centre within 5 minutes walking distance. Each room features, IDD/STD phones, mini bar, toaster, hairdryer, tea and coffee making facilities, 24 hour room service.
495 Collins Street,
MELBOURNE VIC 3000,
Phone: (61) (03) 620 9111
Fax: (61) (03) 614 1219

Novotel Melbourne on Colins
$AUD 144.00
Most centrally located hotel in the city. Each room features electronic cardlocking, individually controlled air conditioning, remote control TV with complimentary in-house movies. There are STD/IDD phones, mini-bar, tea and coffee making facilities, daily newspapers, hairdryer and 24 hour room service.
270 Collins Street,
MELBOURNE VIC 3000,
Phone: (61) (03) 650 5800
Fax: (61) (03) 650 7100

Riverside Apartments
1 bedroom $AUD 140.00
2 bedrooms $AUD 176.00
Serviced apartment accommodation situated on the top four floors of a new 18 storey building featuring panoramic views of the Yarra River, Port Phillip Bay and the city skyline. Choice of one or two bedrooms. Lounge/dining room, bathrooms with full size bath, hairdryer, washing machine and clothes dryer. Fully equipped gourmet kitchen includes microwave and dishwasher. ISD/STD indial exchange phone system, iron/board, liquor and pantry service and individually controlled air conditioning.
474 Flinders Street,
MELBOURNE VIC 3000,
Phone: (61) (03) 283 7633
Fax: (61) (03) 629 7582

Savoy Park Plaza
$AUD 150.00
The hotel features two restaurants, and bar, gymnasium and close proximity to the Congress Centre. Rooms feature IDD/STD telephones, mini bar, tea and coffee making facilities.
630 Little Collins Street,
MELBOURNE VIC 3000,
Phone: (61) (03) 622 8888
Fax: (61) (03) 622 8877

Sheraton Towers Southgate
$AUD 235.00
Melbourne's newest hotel. Rooms feature individually controlled air-conditioning and heating, remote control TV, in-house movies, AM/FM radio, IDD/STD phone access, mini-bar, tea and coffee making facilities, hairdryer, butler service and full buffet breakfast. Non-smoking rooms are available and there is a health club for guests' use. A 10 minute walk to the World Congress Centre.
One Brown Street,
SOUTH MELBOURNE VIC 3205
Phone: (61) (03) 696 3100
Fax: (61) (03) 690 5880

The Sebel of Melbourne
$AUD 250.00
The Sebel is an all suite hotel located a 5 minute walk to the World Congress Centre. Each room has IDD/STD phone, insuite ironing facilities, invidually controlled air-conditioning and windows that open.
321 Flinders Lane,
MELBOURNE VIC 3000
Phone: (61) (03) 629 4088
Fax: (61) (03) 629 4066

The Victoria Hotel
Single $AUD 52.00
Double $AUD 64.00
In the heart of Melbourne's best shopping, theatres and restaurants, this "Old World" hotel caters to the budget-conscious. Rooms feature colour TV, direct dial telephones, refrigerator, tea and coffee making facilities.
215 Little Collins Street
MELBOURNE VIC 3000
Phone: (61) (03) 653 0441
Fax: (61) (03) 650 9678

Welcome Hotel
$AUD 100.00
The Welcome Hotel features air conditioning, colour TV, in-house movies, radio, mini bar, tea and coffee making facilities, toaster and direct dial ISD/STD telephone. The hotel is located in the centre of Melbourne and is close to public transport.
265-281 Little Bourke Street,
MELBOURNE VIC 3000
Phone: (61) (03) 639 0555
Fax: (61) (03) 639 1179

8TH WORLD CONGRESS OF THE INTERNATIONAL SOCIETY FOR PROSTHETICS AND ORTHOTICS

MELBOURNE APRIL 2-7, 1995

REGISTRATION FORM

REGISTRATION *PLEASE TYPE OR PRINT IN BLOCK LETTERS*

Family Name ______ Title (Prof. Dr. Mr. Mrs. Ms.) ______

Given Name ______ Department ______

Organisation ______

Address (Number/Street) ______

Town/Suburb ______ State/Province ______

Country ______ Post/Zip Code ______

Telephone Number (   ) ______ Facsimile Number (   ) ______

Accompanying person's name if participating in Congress programme:

Given Name ______ Family Name ______

**Please indicate if already faxed to secretariat*

KEYWORD PROGRAMME SELECTION **INDICATE YOUR KEYWORD SELECTION BELOW:**

REGISTRATION FEES

Delegate Fees		No. of Tickets	Total Cost AUD
Member	$AUD650.00		
Non-Member	$AUD775.00		
Accompanying Persons:	$AUD200.00		
Students	$AUD200.00		
Late Fee (after 31 December 1994)	$AUD100.00		

ISPO Membership No. ______

REGISTRATION FEE SUB TOTAL AUD: ______

INSTRUCTIONAL COURSES **COST: $AUD50.00 PER COURSE PER DAY**

PLEASE INDICATE THE CODE OF THE INSTRUCTIONAL COURSE YOU WISH TO ATTEND EACH DAY.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday

INSTRUCTIONAL COURSE FEE SUB TOTAL AUD: ______

MANUFACTURERS WORKSHOPS **COST: $AUD25.00 PER COURSE PER DAY**

PLEASE INDICATE THE CODE OF THE MANUFACTURERS WORKSHOPS YOU WISH TO ATTEND EACH DAY.

Monday	Tuesday	Wednesday	Thursday	Friday

MANUFACTURERS WORKSHOP FEE SUB TOTAL AUD: ______

TECHNICAL TOURS **COST: $AUD30.00 PER PERSON**

Please indicate (✔) which tour you wish to attend on Wednesday April 5.

TT01		TT02		TT03		TT04	

TECHNICAL TOURS FEE SUB TOTAL AUD: ______

ACCOMMODATION

I/We will require (tick which required)

Single ☐ Double ☐ Twin Share ☐

Suite ☐ Apartment ☐

**(Note suites and apartments apply to certain hotels only)*
Please indicate (✔) selected hotel in the approppriate box.

Date in [/ /95] Date out [/ /95]

Estimated time of arrival (if known) [ ]

HOTEL		Deposit required per room AUD	
☐ Batman's Hill Hotel		$110.00	
☐ Centra Melbourne on the Yarra		$160.00	
☐ Hotel Enterprise	Single	$69.00	
	Double/Twin	$79.00	
☐ Hotel Swanston		$120.00	
☐ Le Meridien at Rialto		$195.00	
☐ Novotel Melbourne on Collins		$144.00	
☐ Riverside Apartments:	One Bedroom	$140.00	
	Two Bedroom	$176.00	
☐ Savoy Park Plaza		$150.00	
☐ Sheraton Towers/Southgate		$235.00	
☐ The Sebel of Melbourne		$250.00	
☐ The Victoria Hotel:	Single	$52.00	
	Double	$64.00	
☐ Welcome Hotel		$100.00	

If sharing please give full name of person sharing room:

No accommodation booking will be accepted unless accompanied by the mandatory deposit per room.

ACCOMMODATION DEPOSIT SUB TOTAL AUD [ ]

SOCIAL FUNCTIONS & TOURS

Please indicate number of tickets required.
Tickets will not be issued unless requested, even when events are included in the registration fee

	No. of tickets	Cost per person	Total cost AUD
Sunday 02 April			
Orientation Tour		$30.00	
Welcome Reception		Inclusive in delegate & accompanying person fee	
Monday 03 April			
Meet the Partners - Morning Tea		Inclusive in accompanying person fee only	
Select one of the following three tours:			
Koori Walkabout		Inclusive in accompanying person fee only	
Shop till you Drop			
The Australian Ballet			
Tuesday 04 April			
Congress Dinner		$85.00	
Wednesday 05 April			
Sightseeing Tours:			
● Penguins on Parade		$64.00	
● Victorian Wineries		$99.00	
● Australian Animals		$99.00	
Thursday 06 April			
Gilbert & Sullivans 'Patience'		$65.00	
Friday 07 April			
Farewell Lunch		Inclusive in delegate & accompanying person fee	

Pre-Conference Tour - New Zealand *I wish to receive additional information of the pre-conference tour.* ☐

SOCIAL FUNCTIONS & TOURS SUB TOTAL AUD [ ]

PAYMENT SUMMARY

Registration Fees [ ]

Instructional Courses [ ]

Manufacturers Workshops [ ]

Technical Tours [ ]

Accommodation Deposit [ ]

Social Functions/Tours [ ]

GRAND TOTAL AUD [ ]

All payments must be made in AUSTRALIAN DOLLARS only.
Payment in any other currency will NOT be accepted.
Overseas delegates please note that personal cheques will not be accepted and will be returned to sender.
If you have any difficulty with remittance of payment caused by your country's foreign exchange regulations, please contact the Secretariat for advice before forwarding any other than the acceptable form of payment.
Please make cheques/bank drafts payable to:
8th ISPO WORLD CONGRESS or please charge my credit card:

Please indicate which card: Mastercard ☐ Visacard ☐ Bankcard ☐ *(Australian delegates only)*

Signature of cardholder: [ ]

Card Number: [ ] [ ] [ ] [ ]

Name of cardholder: [ ] **Expiry Date:** [/]

OFFICE USE ONLY

Cheque/Draft No ______ **Drawer** ______

Bank ______ **Branch** ______

Prosthetics and Orthotics International, 1994, 18, 203–205

Calendar of Events

National Centre for Training and Education in Prosthetics and Orthotics
Short Term Courses 1994-95

Courses for Physicians, Surgeons and Therapists

NC505 Lower Limb Prosthetics; 23-27 January 1995
NC510 Wheelchairs and Seating; 7-9 February, 1995
NC511 Clinical Gait Analysis; 3-5 May, 1995
NC506 Fracture Bracing; 9-12 May, 1995

Courses for Prosthetists

NC226 Advanced Trans-Femoral Prosthetics; 30 January-3 February, 1995
NC212 Hip Disarticulation Prosthetics; 27 February-3 March, 1995
NC221 Trans-Tibial Suction Socket; 6-10 March, 1995

Courses for Orthotists and Therapists

NC225 Direct Application Upper Limb Orthotics; 16–18 January, 1995
NC217 Ankle-Foot Orthoses for the Management of the Cerebral Palsied Child; 26–28 April, 1995

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' Rd., Glasgow G4 0LS, Scotland. Tel: 0141-552 4400 ext. 3298.

15-18 February, 1995
First Regional Meeting of IEEE Engineering in Medicine and Biology Society, New Delhi, India.
Information: Prof. Sujoy K. Guha, Centre for Biomedical Engineering, Indian Institute of Technology, New Delhi 110016, India.

16-18 February, 1995
11th International Seating Symposium, Pittsburgh, USA.
Information: Elaine Trefler, University of Pittsburgh Medical Centre, Dept. of Conference Management, Nese-Barkan Building, Suite 511, Pittsburgh, PA 15213, USA.

16-21 February, 1995
American Academy of Orthopaedic Surgeons Annual Meeting, Orlando, USA.
Information: AAOS, 222 S. Prospect Ave., Park Ridge, IL 60068, USA.

17-18 February, 1995
ISPO (UK) Annual Scientific Meeting, Hull, England.
Information: Mr. D. Simpson, ISPO Hull '95, NCTEPO, University of Strathclyde, 131 St. James' Rd., Glasgow G4 0LS, Scotland.

2-5 March, 1995
International Congress and Instructional Course on Advances in Biomechanics and Surgical Techniques of the Elbow, German Society of Orthopedics and Traumatology and the European Society of Biomechanics, Cologne, Germany.
Information: Dr. C. Jantea, Orthopaedic Dept., Heinrich Heine University, PO Box 260 214, D-400 95, Dusseldorf, Germany.

18-19 March, 1995
11th Annual Conference of the Association of Prosthetists and Orthotists, Telford, England.
Information: Mr. W. Dykes, APO Conference Co-ordinator, NCTEPO, University of Strathclyde, Curran Building, 131 St. James' Rd., Glasgow G4 0LS, Scotland.

21-25 March, 1995
American Academy of Orthotists and Prosthetists Annual Meeting, New Orleans, USA.
Information: Annette Suriani, 1650 King St. Suite 500, Alexandria, VA 22314, USA.

27-31 March, 1995
12th World Congress of the International Federation of Physical Medicine and Rehabilitation, Sydney, Australia.
Information: IFPMR Congress Secretariat, DC Conferences, PO Box 629, Willoughby NSW 2068, Australia.

30-31 March, 1995
New Horizons in Cerebral Palsy: A Multidisciplinary Approach.
Information: New Horizons in Cerebral Palsy, PO Box 235, Balwyn North, Victoria 3104, Australia. Phone (613) 859 6899, Fax (613) 859 2211.

2-7 April, 1995
8th World Congress of the International Society for Prosthetics and Orthotics, Melbourne, Australia.
Information: Congress Secretariat, 8th World Congress of the International Society for Prosthetics and Orthotics, PO Box 29, Parkville 3052, Victoria, Australia.

7-9 April, 1995
32nd Annual Rocky Mountain Bioengineering Symposium, Colorado, USA.
Information: Dr. M. F. Nichols, Nicholos Technologies Inc., 3208 LeMone Industrial Blvd., Columbia, MO 65201, USA.

9-11 April, 1995
68th Annual Meeting of the Japanese Orthopaedic Association, Yokohama City, Japan.
Information: Dr T. Kurokawa, President, Dept. of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, 113, Japan.

26-28 April, 1995
1st Arab and Jordanian Conference on Physical Medicine and Rehabilitation, Amman, Jordan.
Information: Dr. Khalil Abadi, 1st Arab and Jordanian Conference, Jordan Medical Association, PO Box 915, Amman, Jordan.

30 April-2 May, 1995
9th Instructional Course of the International Society for the Study of the Lumbar Spine, Riyadh, Saudi Arabia.
Information: International Society for the Study of the Lumbar Spine, Sunnybrook Medical Centre, 2075 Bayview Ave., Room a309, Toronto M4N 3M5, Canada.

12-16 May, 1995
1st Mediterranean Congress on Physical Medicine and Rehabilitation, Israel.
Information: Ortra Ltd., PO Box 50432, Tel Aviv 61500, Israel.

28 May-1 June, 1995
5th European Congress on Research in Rehabilitation, Helsinki, Finland.
Information: Prof. Simon Millar, Division of Clinical Neuroscience, The Medical School, The University, Newcastle upon Tyne, NE2 4HH, England.

Summer, 1995
Medicon '95: 7th Mediterranean Meeting on Medical and Biological Engineering, Israel.
Information: Prof. S. Siderman, c/o Prof. W. Welkowitz, Dept. of Electrical Engineering, PO Box 909, Piscataway, NJ 08854, USA.

9-14 June, 1995
RESNA International Conference, Vancouver, Canada.
Information: RESNA, Tel 703-524-6686, USA.

18-22 June, 1995
22nd Annual Meeting of the International Society for the Study of the Lumbar Spine, Helsinki, Finland.
Information: Dr. B. Rydevik, International Society for the Study of the Lumbar Spine, Sunnybrook Medical Centre, 2075 Bayview Ave., Room a 309, Toronto M4N 3M5, Canada.

2-3 July, 1995
5th International Conference of the European Orthopaedic Research Society, Munich, Germany.
Information: Dr. H. P. Scharf, Orthopadische Klinik/RKU, Oberer Eselsberg 45, D-89081 ULM, Germany.

16-19 July, 1995
7th International Conference on Mobility and Transport for Elderly and Disabled People, Reading, England.
Information: 7th Int. Conf. Secretariat, Disability Unit, Dept. of Transport, Room S10/21, 2 Marsham Street, London SW1P 3EB, England.

5-8 September, 1995
2nd Leeds European Rehabilitation Conference: Neurological Rehabilitation, Leeds, England.
Information: Dr. A. Cutts, Rheumatology and Rehabilitation Research Unit, The University of Leeds, 36 Clarendon Road, Leeds, LS2 9NZ, England.

8-10 September, 1995
4th Scientific Meeting of the Scandinavian Medical Society of Paraplegia, Oslo, Norway.
Information: Congress Secretariat, 4th Scientific Meeting of SMSOP, c/o Sunnaas Hospital, N-1450 Nesoddtangen, Norway.

11-19 September, 1995
10th Asia Pacific Regional Conference of Rehabilitation International, Jakarta, Bali.
Information: Secretary, 10th ASPARERI, H Hang, Jebat 11-2 Blok FIV, Kebayoran Baru, Jakarta 12120, Indonesia.

19-23 September, 1995
American Orthotic amd Prosthetic Annual National Assembly, San Antonio, USA.
Information: Annette Suriani, 1650 King St. Suite 500, Alexandria, VA 22314, USA.

Prosthetics and Orthotics International
Index to Volume 18, 1994

Author Index

Prosthetics and Orthotics International, 1994, 18, 208-210

Subject Index