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for Prostheties and Orthotics

Prosthetics and Orthotics International

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Editorial

Many of you will only recently have received a copy of the Society's Constitution. No doubt it will have received more or less attention depending on the volume of correspondence already in your "In Tray". Of course, this document contains much information which is solely concerned with the organization and operation of our Society—the classes of membership with their obligations and privileges, the committee structures, the officers and their duties, the national organizations—information which for the most part is simply available for guidance and reference.

The Preamble along with Article 1, however, running as it does to a single page, identifies the whole reason for the existence of the Society. The Preamble states that the Society is formed, "In order to promote high quality orthotic and prosthetic care of all people with neuromuscular and skeletal disabilities." Article 1 goes on to identify the way the Society hopes to achieve that universal goal, outlining in seven simple paragraphs a plan for international coordination, guidance and action.

Detailed examination of Article 1 reveals that the Society is active in most of the seven areas of activity. Continuing and useful dialogues are being developed with other agencies in this field; scientific exchange is being effected through international and national conferences and not least through this Journal; the Society already has a record of achievement in the international coordination of research as exemplified by the programme of "Amputee Performance Measurement"; our efforts in education have resulted in two international meetings this year, with one planned for next year leading to ever improving standards; our's is the strongest input to the International Standards Organization's development of standards in this field. There is no reason for complacency. Much remains to be done but our efforts and effectiveness are on the increase.

Perhaps our greatest success has been in the development, as defined in our Constitution, of our National Member Societies. To take a typical example, the United Kingdom had no interdisciplinary forum for the professionals in this field before the establishment of the UK National Member Society. Now a thriving society of some 240 members fulfils that role. There is an annual Scientific Meeting held in different parts of the Kingdom, regular regional meetings in three different areas: Glasgow, Newcastle and London, a Newsletter, prizes for various activities such as papers presented at meetings, fellowships offered by the British Limbless Ex-servicemen's Association and commercial companies for attendance at international meetings and, perhaps most important of all, continuing contact with one's peers.

Of course, the only credit the International Society can take for this is in identifying the professionals, putting them in contact and encouraging them to work. And work they do! All of these activities require hard, dedicated, continuing work by officers and members of the National Member Society involved.

One of the side-effects associated with national success however, is that the national activity becomes foremost in our minds and we lose sight of our international aspirations. The most immediate benefit to us as members may be these very national activities but we do believe that we have joined an international society which will not only bring benefit to our patients and ourselves but will widen the availability of these benefits to all.

The remainder of the Constitution is concerned with the modus operandi of our International Society and it clearly provides a functional model. Our Society is indeed working at both national and international level. The Executive Board is concerned, however, that our international collaboration, either as individual members or as national societies must be further fostered. Communication, involvement, activity at all levels must be improved if we are to achieve the goals which we have set ourselves. We would welcome the ideas and comments of the membership at large.

John Hughes
President Elect

Prosthetics and Orthotics International, 1984, 8, 124–129

Biomechanical significance of the correct length of lower limb prostheses: a clinical and radiological study.

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Abstract
The length of the lower limb prosthesis was compared with the length of the contralateral lower extremity in 113 Finnish war-disabled amputees by a radiological weight bearing method developed by the author. Considering a shortening of 10 mm for above-knee prostheses and of 5 mm for below-knee prostheses as tolerance limits, the length of the prosthesis was acceptable only in 17 cases (15% of the total group). In 79 cases (70%) the prosthesis was up to 47 mm too short and in 17 cases (15%) up to 40 mm too long. Chronic pain symptoms of low back, hip and knee correlated significantly with the lateral asymmetry caused by incorrect length of the prosthesis. Independently of the side of amputation, the unilateral sciatica and chronic hip pain occurred mainly on the long leg side. Physical activity of the lower limb amputees seemed to correlate with the suitability of the length of the prosthesis, and was unrelated to the length of the amputation stump.

Introduction

Being a weight bearing substitute for a lost part of the lower extremity, the prosthetic limb should be of correct length to fulfil its biomechanical task. To avoid lateral imbalance in standing, walking, and running, the length of both exo and endoprosthesis ought to be adjusted to the length of the contralateral lower extremity.

In spite of the technical development in prosthetics, assessment of the length of the prosthesis still takes place with conventional clinical methods e.g. by direct tape measurement or indirectly by estimating the heights of the iliac crests or other bony prominences in the upright position. Devices have been developed e.g. by Hirschberg and Robertson (1972) for determining the level of pelvis.

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Clinical methods for measuring leg length inequality, however, contrary to general belief, have proved to be inaccurate and even misleading with observer error of ±10 mm or even more (Nichols and Bailey, 1955; Clarke, 1972; Morscher, 1977) as compared with the results of significantly more accurate radiographic measurements. The errors in clinical measurements are partly due to difficulties in locating the exact bony points for measurement through layers of soft tissues, and partly because of the prevalence of iliac asymmetries (Ingelmark and Lindström, 1963). The amputee's subjective opinion about the correct length of the prosthetic limb may also be misleading, particularly if the previous prosthesis has been of incorrect length. A rather common belief has been that walking with a short prosthesis should be easier than with one of equal length to the contralateral lower extremity.

On the other hand, a pelvic tilt caused by leg length inequality of even less than 10 mm is nearly invariably compensated with a functional scoliosis and associated with a varus position of the hip joint on the long leg side (Krakovits, 1967; Gofton and Trueman, 1971; Clarke, 1972). These mechanisms evidently have a predisposing role in the aetiology of chronic low back and hip pain symptoms and in the development of degenerative hip disease (Gofton and Trueman, 1971; Clarke, 1972; Heufelder, 1979; Friberg, 1983). The criteria for the optimal length of lower limb prostheses generally differ for below-knee and above-knee prostheses. A shortening up to 2 cm (Krämer et al, 1979) of above-knee prosthesis is generally allowed for ground clearance in the swing phase of walking. However, a shortening of not more than 1 cm, and for suction socket prostheses with minimal piston action only 6 mm or even less, has been suggested by Duthie and Bentley (1983). Recommendations to make a below-knee prosthesis full length and to avoid prostheses longer than the contralateral lower extremity are probably in accordance with the current general opinion.

The aim of this study was to find out how the above mentioned criteria for the length of lower limb prostheses are in fact satisfied, and to study the correlation of correct and incorrect prosthesis length with the incidence and severity of chronic low back, hip and knee pain symptoms in lower limb amputees.

Material and methods

This study comprises a series of 113 Finnish war-disabled lower limb amputees of whom 84 subjects had a below-knee prosthesis and 29 an above-knee prosthesis. The amputation was unilateral in all cases but one who had undergone an above-knee amputation and a contralateral below-knee amputation. In four cases a total hip replacement had been performed, the endoprosthesis being on the amputated side in one case and on the non-amputated side in three cases. The primary amputations were made during the wars 1939–40 and 1941–44, 39 to 45 years before this study.

To record the complaints associated with the amputation and the prosthesis, the patients were interviewed with a questionnaire and by personal inquiry. Special attention was drawn to symptoms of low back, hip and knee joints and to their laterality.

The clinical and radiological examinations were performed in 1983–84 at the Central Military Hospital, Helsinki, at the Tampere Radiological Center, Tampere, and at the Military Hospital 3, Kouvola. The majority of the amputees came to examination from the Kaskisaari Rehabilitation Center of the Fraternity Association of War Invalids.

Radiological assessment of the length of prostheses

The length discrepancy between the lower limb prosthesis and the contralateral lower extremity was measured with a weight-bearing radiographic method developed by the author (Friberg, 1983). In this method, the patient stands in front of a chest X-ray stand with straight knees and the weight equally distributed between both legs. A 15 cm broad block between the heels keeps the loading axes of the legs parallel and the positioning of the patient reproducible. A gonad shield supplied with an O-shaped plastic tube partly filled with mercury is strapped to the patient (Figs. 1 and 2). To avoid swaying the patient is advised to lean

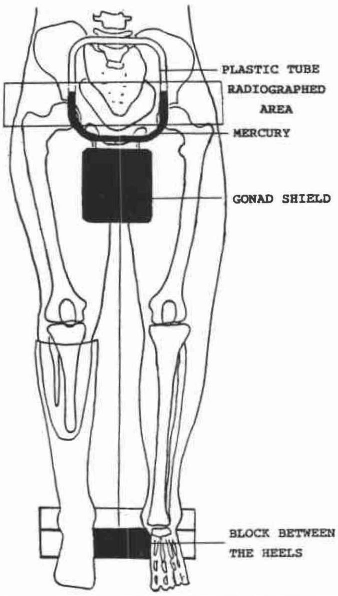

Fig. 1. Equipment and positioning of the amputee for measurement of the length of the prosthetic limb as compared with the length of the contralateral lower extremity (=the heights of the femoral heads).

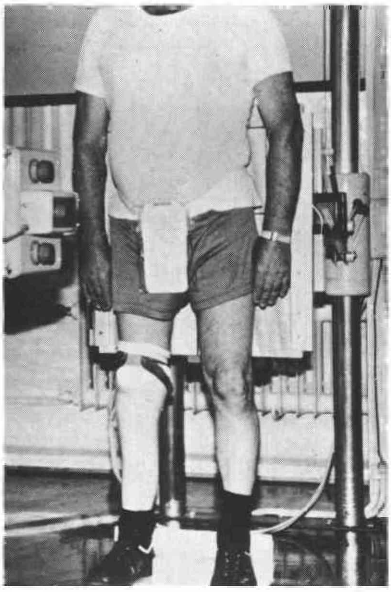

Fig. 2. Weight bearing radiographic measurement of the discrepancy between the length of lower limb prosthesis and contralateral lower extremity.

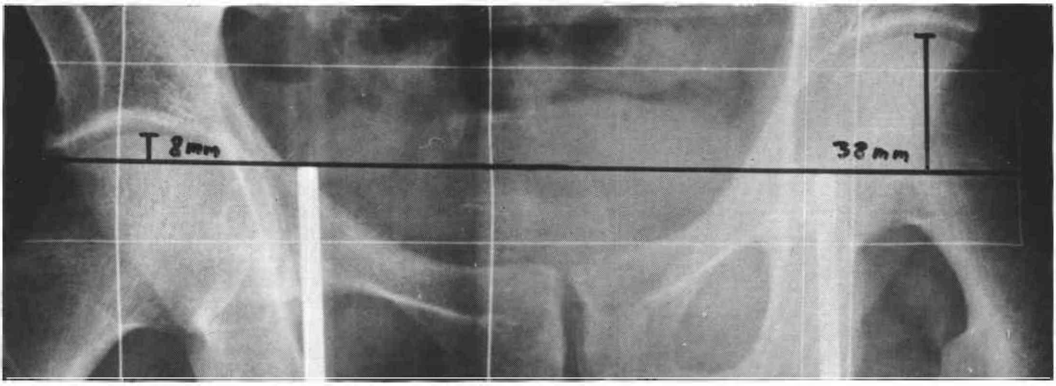

Fig. 3. A radiograph taken for measurement of the length of lower limb prosthesis. In this case there is 30 mm shortening of the prosthetic limb (right).

gently against the cassette holder with both buttocks. The central X-ray beam is focused on the pubic symphysis, and an A-P radiograph of both hip joints is taken. A horizontal reference line is drawn on the radiograph through the tops of the roentgen positive mercury pillars, from which the distances of the highest articular points of both femoral heads are measured (Fig. 3). The difference of the heights of femoral heads indicates the inequality of the weight-bearing lower extremities.

As the distance of the X-ray tube is constant and long enough, the magnification error is insignificant and can be ignored. The main source of error, unequal extension of the knees, is easily avoided by proper positioning of the patient.

Clinical examination

Special attention was paid to the pelvic tilt, lumbar scoliosis and other static body asymmetries in erect posture, which, if necessary, were radiologically documented. A block of equal thickness to the leg length inequality measured, was then placed under the foot of the shorter limb to reveal the subjective, clinical and radiological response of the body to the equalization of the pelvis. If the response was positive, i.e. the patient experienced the lift as comfortable and balancing, and the scoliotic curve straightened, the patients were advised to try a fixed lift under the shoe of the short leg before making a decision to have a permanent change in the length of the prosthesis.

Results

The mean age of the patients was 65.1 years (range 54 to 80 years), the mean length 173.5 cm (range 158 to 189 cm) and the mean body mass 80.9 kg (range 51 to 102 kg). The mean length of the above-knee stumps was 19.8 cm (range 8 to 30 cm) and of below-knee stumps 22.4 cm (range 12 to 28 cm).

Length of the prostheses

Though a majority (78.8%) of the amputees were of the belief that their prostheses were of equal length with the contralateral lower extremity, the length discrepancies were extremely prevalent and significant, ranging from a shortening of 47 mm to a lengthening of 40 mm (Table 1). Of the total group, the length discrepancy was more than 10 mm in 66.4% and more than 20 mm in 33.6% of the cases (Table 2). For comparison, in a group of 359 symptom-free Finnish Army conscripts aged 17 to 24 years (Friberg, 1983), leg length inequality of less than 10 mm occurred in 84.5% of the cases, and more than 20 mm in one case only.

In below-knee prostheses, the length was appropriate (length discrepancy less than 5 mm) in only 10 (11.9%) out of 84 patients, and in

Table 1. Subjective opinion of amputees about the length of the prosthesis and the ranges of measured length discrepancies.
("+" signs lengthening and "−" shortening of prosthetic limb)

Prosthesis felt	N	%	Ranges of measured length discrepancy
Equal	89	78.8	−47 mm to+37 mm
Shorter	17	15.0	−37 mm to+15 mm
Longer	7	6.2	−23 mm to+40 mm
Total	113	100.0	−47 mm to+40 mm

Table 2. Leg length inequality (difference of the height of femoral heads) in bipedal standing of 113 amputees with lower limb prostheses.

Leg length inequality mm	N	%
0–9	38	33.6
10–19	37	32.7
20–29	23	20.4
30 or more	15	13.3
‹10 mm	38	33.6
›10 mm	75	66.4
›20 mm	38	33.6
›30 mm	15	13.3

above-knee prostheses (discrepancy less than 10 mm) in only 7 (24%) out of 29 cases. In 17 cases (15%) out of the total the prosthesis was on average 14.4 mm longer than the contralateral lower extremity (Table 3).

Accuracy of radiological measurements

In a previous study with non-amputees, the mean error between two or more subsequent measurements was 0.6 mm (range 0 to 2 mm) Friberg, 1983). In the present study, a re-examination was made in 10 cases and in a further 10 cases after correction of the incorrect length of the prosthesis or by insertion of a lift equivalent to the leg length inequality under the foot of the short leg. the mean error between these measurements was 1.2 mm (range 0 to 4 mm).

Low back pain

Chronic low back pain symptoms were prevalent in the present series of lower limb amputees. Only 6 patients (5.3% of the total series) were completely free from low back pain. In altogether 25 patients, however, the low back symptoms were occasional and fairly mild. In these patients the mean leg length discrepancy was 6.1 mm. The mean discrepancy in 32 amputees with frequent or constant and severe low back pain was 21.7 mm. The difference between the mean leg length discrepancies in these two groups was statistically highly significant ($p<0.001$, $t=4.65$). A chronic unilateral sciatica was present in 23 cases, the radicular pain radiating into the longer lower extremity in 14 (60.8%); of the cases, independently of the side of the amputation, the mean discrepancy of leg length was 19.9 mm. Sciatica occurred on the short leg side in 9 cases, the mean leg length inequality being 12.6 mm.

Hip pain

Of the total material, 30 amputees were without any significant hip pain symptoms. In these patients, the mean length discrepancy of lower extremities was 8.8 mm. In 36 patients the hip pain symptoms were bilateral and the mean leg length discrepancy 14.8 mm. In 47 cases, the chronic hip pain symptoms were unilateral, the mean leg length discrepancy being 16.3 mm. The unilateral hip pain symptoms occurred on the side of the longer lower extremity in 61.7% of the cases, independently of the side of amputation (Table 4).

Knee pain

Significant knee joint pain was absent in 21 of the amputees. The mean leg length inequality in these patients was 7.6 mm. Only two above-knee amputated subjects were free from knee pain.

Bilateral knee pain symptoms in below-knee subjects occurred in 33.3% of the cases, the mean leg length inequality being 15.6 mm. In patients with unilateral knee symptoms the leg

Table 3. Suitability of the length in lower limb prostheses

Prosthesis	Total N	Fit N	Too short N	Too short × mm	Too long N	Too long × mm
Below-knee	84	10	60	15.9	14	15.4
Above-knee	29	7	19	28.9	3	10
Total	113	17	79	19.0	17	14.4
Per cent	100	15	70		15	

Table 4. The location of unilateral hip pain symptoms and leg length inequalities (mean errors of the prosthesis length).

Pain symptoms in the hip of	Total N	Total %	Longer limb N	Longer limb $\bar{x}$	Shorter limb N	Shorter limb $\bar{x}$
Amputated limb	15	31.9	4	10.0 mm	11	18.9 mm
Non-amputated limb	32	68.1	25	18.1 mm	7	16.4 mm
Total	47	100	29	61.7%	18	38.3%

length inequality was 12.8 mm. The complaint occurred on the amputated side in 25% of the cases and on the non-amputated side in 75% of the cases.

Sporting activity of the amputees

Physical activities like jogging, skiing or gymnastics were carried out daily by 43 below-knee amputees. The mean leg length inequality in these amputees was 9.7 mm. In 25 below-knee subjects without daily physical activity, the mean leg length inequality was 18.5 mm. The difference between these means proved to be statistically significant ($p<0.01$, $t=2.95$). The mean length of the stumps in these two groups showed no difference, being 18.9 cm and 18.5 cm. Similarly, in 12 physically active above-knee amputees, the leg length discrepancy was 17.3 mm, and in 12 inactive above-knee amputees it was 22.6 mm, the difference, however, being statistically not significant ($p<0.1$). No difference between the mean lengths of the stumps was found.

Discussion

Contrary to subjective beliefs, most lower limb amputees in the present series were found to use a prosthesis of incorrect length. Also in non-amputated material, subjects with a leg length inequality of up to 20 mm were mostly unaware of the asymmetry (Friberg, 1983). In spite of the advanced age of the amputees, experimental equalization of the pelivc tilt with a shoe lift was generally experienced as comfortable and balancing. On examination, a significant straightening of the lumbar scoliosis could mostly be observed and documented radiologically. In an ongoing study, the long-term effects of correcting the length of the prosthesis are being followed-up. Until now, correction of the length of the prosthesis has mostly been favourable with an alleviation of low back and hip pain symptoms and a significant improvement in walking pattern, particularly after shortening of a prosthesis which was too long.

The assessment of the severity of low back, hip, and knee pain symptoms is difficult, but the present results clearly suggest that the amputees with symmetrical length of the prosthesis have significantly less pain symptoms than those with marked lateral asymmetry. Accordingly, the amputees using a prosthesis of acceptable length seemed to be physically more active than those with a prosthesis of incorrect length.

Likewise in non-amputees, the unilateral symptoms such as sciatica or hip pain (Gofton and Trueman, 1971; Clarke, 1972; Friberg, 1983) occurred in lower limb amputees mostly on the long leg side, regardless of the side of the amputation. This suggests that, not only the amputation but the incorrect length of the prosthesis is a significant factor in causing discomfort, torsion and unequal distribution of load in the knee and hip joints and in the lumbar spine.

Pelvic tilt caused by unequal length of the lower extremities results in a compensatory functional scoliosis which is mostly concave to the long leg side (Ingelmark and Lindström, 1963; Heufelder, 1979), and in a varus position of the hip joint on the same side (Gofton and Trueman, 1971; Clarke, 1972; Friberg, 1983). (Figs. 4, 5). Lateral bending of lumbar motion segments compress the disc on the concave side, causing a protrusion toward the concavity. In connection with lumbar lordosis, this makes the posterolateral part of the disc bulge toward the spinal nerve root on the long leg side which may be a cause for radicular symptoms (Friberg, 1983).

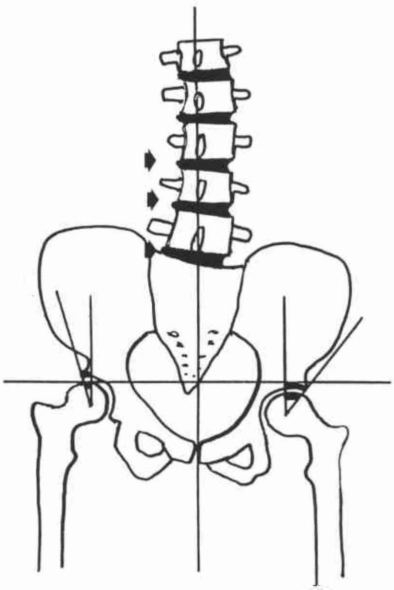

Fig. 4. The biomechanical effects of a leg length inequality—pelvic tilt to the short leg side—varus position of the long leg hip (note Wiberg's angle)—functional scoliosis toward the short leg—protrusion of discs to the concavity.

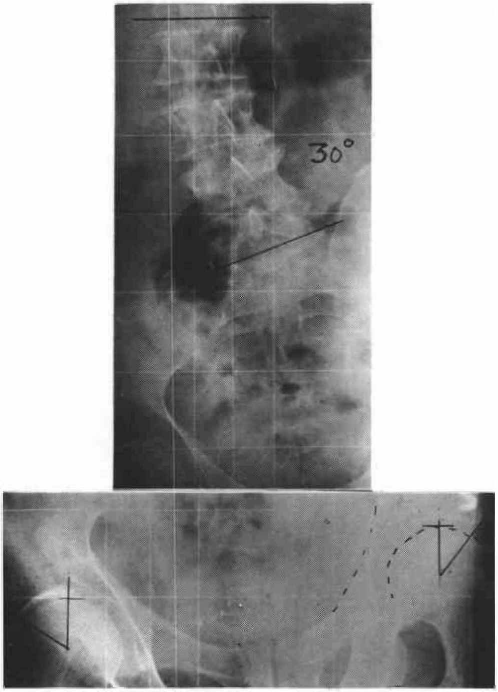

Fig. 5. A case, with an above-knee prosthesis on the right side which was 40 mm too short, suffering from constant low back and left hip pain since amputation in 1944. Note: diminution of weight-bearing articular surface of the longer lower limb as illustrated by Wiberg's angle, and the functional scoliosis with wedge-shaped intervertebral spaces and axial rotation of the vertebrae (radiographs taken in a standing posture). The response to the correction of the prosthesis length was excellent.

The varus position of the long leg hip as illustrated by Wiberg's angle (Krakovits, 1967; Morscher, 1977) results in a diminution of weight-bearing articular area of the joint, thus speeding the degenerating breakdown in the hip. Concurrent occurrence of symptoms from lumbar spine and hip, the hip-spine syndrome (Offierski and Macnab, 1983), was common among lower limb amputees, evidently because of the high prevalence of lateral asymmetries due to incorrect length of the prostheses.

In the light of present results, conventional assessment of the length of lower limb prostheses with clinical methods seems to be inaccurate and unreliable. The range of errors in the length of the lower limb prostheses was as high as 87 mm (47 mm too short to 40 mm too long). The weight-bearing radiographic method for measurement of leg length inequality offers an accurate, reliable and simple tool to adjust the correct length for lower limb prostheses. The costs of radiography are minimal when compared with the expense of manufacturing a prosthetic limb. Paricularly in adjusting the first prosthesis for a recently amputated patient, the assessment of the correct length of the prosthesis appears imperative to allow the subject to adapt from the beginning to symmetry of the lower extremities, to train him to walk without a limp, and to avoid malpositions and development of degenerative changes in hip, knee and lumbar spine.

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Spatial parameters of gait related to the position of the foot on the ground

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Abstract

A number of parameters related to the position of the foot on the ground during normal level walking were analysed for a group of young and a group of old subjects, divided in two sub-groups each, according to sex.

The analysis has shown asymmetries between the left and the right side of a number of subjects, differences between sexes and differences between age groups. Changes in the parameters of gait for the old subjects served the task of providing a larger base of support and a smaller loading of the hip musculature.

Introduction

Recent work on the biomechanics of human gait has been directed mostly to dynamic and energetic aspects, while kinematic studies appear more and more rarely in literature. Following the work of the California group (Eberhart, 1947) kinematic data was provided by Levens et al (1948), Ryker (1952), Murray et al (1964, 1966, 1969, 1970), Lamoreux (1970, 1971) and more recently by Dainis (1980), Hershler and Milner (1980), Bajd and Kralj (1980), Durie and Farley (1980), Cappozzo (1981), Mena et al (1981). A small part of this work is devoted to the kinematics of the foot.

Aspects of the position of the foot on the ground during walking attracted interest many years ago. Dougan (1924) measured the angle of gait, that is the angle of the long axis of the shoe and the line of progression, for young males. The angle of gait was also studied by Morton (1932) and by Barnett (1956). The most comprehensive data on the position of the foot on the ground was provided by Murray et al (1964, 1966, 1970), who reported a series of studies of a large number of spatial and temporal parameters of free and fast speed walking for normal men and women of different ages.

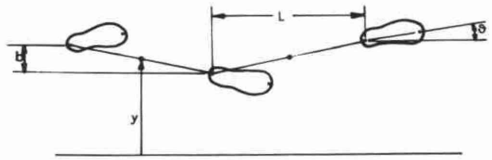

Fig. 1. The parameters analysed in the present study.

This study aims at the analysis and interpretation of a number of spatial parameters related to the position of the foot on the ground during level normal walking of young and old subjects of both sexes. These parameters, defined as shown in Fig. 1, are the following:

1. Foot angle, θ
2. Step length, L
3. Stride width, b.
4. Mid-line, y.

Apart from reporting our results on parameters that have been studied before by other investigators, this work examines the variability of these parameters from step to step of the same subject during a certain trial. It also provides comparisons between left and right side of each subject. Furthermore, values for step length and stride width are expressed not only in absolute terms but also in percent of the subject's stature (Defined as "relative" quantities by Grieve, 1968).

Method

Two groups, one of young subjects and another of old ones were tested. The group of young subjects consisted of 35 (25 male and 10 female) students, aged 17 to 24 years (Mean= 19 years, SD=2.1 yrs). The group of old subjects consisted of 24 (14 male and 10 female) boarders at a home for the aged. Their ages ranged

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between 65 and 90 years (Mean=78 yrs, SD=6.9 yrs). Cases described as pathological were not considered.

After a few trials of familiarization with the walking area, each subject was asked to walk freely at his/her natural speed along a corridor, part of which was covered by paper laid over carbon paper. The points of contact of the toes and the heel were clearly marked on the paper by small pins set at the corresponding points on the long axis of the shoe. The first and last steps of each subject on the paper walkpath were not taken into account; a tendency to make the last step shorter was evident in many cases.

The number of footprints on each side that were analysed was six for each young subject and seven for each old subject. The sample size of each of the parameters studied is shown in the corresponding table.

Mean values of a certain parameter were considered different when their difference was statistically significant ($p<0.10$, t-statistic).

Results

1. Foot angle, θ

The foot angle showed a considerable scatter not only from subject to subject, but also from step to step of the same subject. The mean foot angles of each subject ranged between −2.6 degrees and +17.4 degrees for the young and between −3.0 and +24.8 degrees for the old group.

In 16 out of 35 cases of young subjects the mean foot angle on the left was different from that on the right ($p<0.05$). The same was true in 17 out of 24 cases of old subjects.

The mean foot angles and their standard deviations for the different subgroups are shown in Table 1.

Within the same subgroup the mean foot angle on the left was in all cases smaller than that on the right. This difference, though, was statistically significant ($p<0.1$) only in the case of young males.

Table 2. Mean step length and its standard deviation (SD), in cm and in percent of the subject's stature.

Age	Young		Old	
Sex	Male	Female	Male	Female
Sample size	300	120	196	140
$\bar{L}\pm1SD$ (cm)	74.5±3.97	71.1±4.72	54.3±8.92	46.7±5.53
$(\overline{L/H})\pm1SD$ percent	42.1±2.22	42.9±3.35	33.8±6.06	30.9±3.61

The mean foot angles of old subjects were in all cases significantly larger than the corresponding angles of young subjects ($p<0.01$).

2. Step length, L

The mean value of the step length and its standard deviation was determined for the left and for the right side of each subject. In 7 out of 35 cases of young subjects the mean step length on the left was significantly different from that on the right ($p<0.05$). This was also so in 6 out of 24 old subjects. Some of the subjects took a longer left step, others a longer right one.

When comparing the mean step lengths on the left and on the right of each sub-group—and not of each individual subject—no statistically significant difference occurred. Both left and right steps were therefore pooled together for each sub-group and the mean step length was computed. The mean step length for each sub-group is shown in Table 2, together with its standard deviation.

Table 2 shows that step lengths were longer for males than for females and for young than for old subjects ($p<0.001$).

Table 2 also shows the step length in percent of the subject's stature, H. In this case the difference betwen young males and females disappears. The common mean step length and its standard deviation become 42.2±2.50 percent of the subject's stature. The mean value for old males remains significantly larger than the corresponding value for old females

Table 1. Mean values and standard deviations (SD) of the foot angles.

Age	Young				Old			
Sex	Male		Female		Male		Female	
Side	left	right	left	right	left	right	left	right
Sample size	150	150	60	60	98	98	70	70
$\theta\pm1SD$ degrees	5.4±4.46	8.0±3.83	5.0±3.36	6.4±2.73	9.3±5.01	10.9±7.89	8.7±8.08	10.0±8.29

(p<0.001). Values for the old subjects are clearly smaller than the corresponding values for young subjects (p<0.001).

3. Stride width, b.

The mean value and the standard deviation of the stride width b, were determined for each subject. Negative values of b were observed in some steps, but the mean value of b for each subject was in all cases positive. The mean value of b for each sub-group was determined and is given in Table 3, together with its standard deviation.

Table 3. Mean stride width b and its standard deviation, in cm and in percent of the subject's stature.

Age	Young		Old	
Sex	Male	Female	Male	Female
Sample size	300	120	196	140
$\bar{b}\pm 1SD$ (cm)	6.5±3.81	5.2±4.66	6.8±4.81	8.8±3.52
$\overline{(b/H)}\pm 1SD$ percent	3.6±2.15	3.1±2.82	4.2±2.96	5.3±2.85

The value of the stride width b was also expressed in percent of the subject's stature. The mean value of this parameter for each sub-group is given in Table 3. Mean values for young males (3.6 percent) and females (3.1 percent) were not significantly different. On the contrary, the mean value for old females (5.5 percent) was larger than the mean value for old males (4.2 percent) at a very high level of significance (p<0.001).

Old subjects showed a significantly larger stride width than young subjects of the same sex (p<0.05). This difference was particularly stressed for females (p<0.001).

4. Mid-line, y.

The mid-line was defined as the line joining the mid-points of each step (Fig. 1). The distance y of each of these points from an axis parallel to the walkpath was determined. Then the standard deviation S_y of these distances was computed for each subject. This parameter is an index of the mean path lateral deviation of the subject. Mean values of the mid-line deviation S_y for each sub-group are shown in Table 4.

The mid-line deviation was also computed in percent of the subject's stature. Mean values of this new parameter for each sub-group are also shown in Table 4.

Table 4. Mid-line deviation in cm and in percent of the subject's stature.

Age	Young		Old	
Sex	Male	Female	Male	Female
Sample size	25	10	14	10
$\bar{S}_y\pm 1SD$ (cm)	2.2±1.33	3.1±1.44	2.2±0.68	2.8±1.07
$\overline{(S_y/H)}\pm 1SD$ percent	1.3±1.23	1.9±.94	1.4±0.45	1.9±0.71

Comparisons of the mean values of the mid-line deviation, both in cm and in percent of the subject's stature for the four sub-groups of subjects, revealed no statistically significant differences.

5. The variability of gait parameters

The standard deviation of each of the parameters presented in Tables 1, 2, 3, and 4 of this study relates to the variability of this parameter within a sample where an equal number of steps of each subject were pooled together. Although the standard deviation computed from such a pooled sample provides information about the range where any particular measurement of the corresponding gait parameter is expected to lie—with any degree of confidence—it does not describe the variability of the specific parameter from step to step of the same subject, neither does it describe the variability from subject to subject of the corresponding mean values.

The variability of gait parameters from step to step of the same subject and also from subject to subject is a piece of information necessary to the correct design of human gait experiments. It is also useful in understanding and quantifying the characteristics of normal gait.

The variability of a certain parameter is measured by its SD.

Table 5 presents

a) The mean ± 1SD of the variability from step to step of the same subject of each of the gait parameters studied in this work.

b) The variability from subject to subject of the corresponding mean values for the above parameters.

c) The variability of the above parameters within a sample, where an equal number of sequential steps of each subject were pooled together.

Table 5. Variability of gait parameters. The variability is measured by the SD. Relative quantities are expressed in percent of the subject's stature. Six steps on either side of each young subject (25 males and 10 females) and six steps on either side of each old subject (14 males and 10 females) were analysed.

		Young				Old			
		Male		Female		Male		Female	
		l	r	l	r	l	r	l	r
Foot angle θ (degrees)	From step to step of the same subject	1.68±0.751	1.77±0.688	3.51±2.115	2.95±1.632	2.94±0.964	3.08±1.432	2.86±1.192	3.03±0.524
	Mean, from subject to subject	4.45	3.79	3.14	2.52	5.06	8.11	7.81	8.05
	From step to step of all subjects	4.46	3.83	3.36	2.73	5.01	7.89	8.08	8.29
Relative step length (percent)	From step to step of the same subject	1.18±0.348		2.03±1.001		1.96±0.572		1.65±0.410	
	Mean, from subject to subject	2.17		3.16		6.04		3.54	
	From step to step of all subjects	2.22		3.35		6.06		3.61	
Relative stride width (percent)	From step to step of the same subject	1.39±0.562		2.56±0.976		1.79±0.735		1.89±0.358	
	Mean, from subject to subject	1.64		1.17		2.40		2.48	
	From step to step of all subjects	2.15		2.82		2.96		2.85	
Relative mid path lateral deviation (percent)	From subject to subject	1.23		0.94		0.45		0.71	

Discussion

Analysis of the foot angle and step length revealed statistically significant asymmetries between the left and the right side of a number of subjects considered normal. It is thought that these asymmetries have an important contribution in forming the characteristic gait of a subject. Whether these asymmetries correspond to skeletal, muscular or other asymmetries cannot be inferred from this study. This will require a larger number of parameters to be analysed and also a larger number of subjects to be tested.

Among the parameters analysed, the step length showed the least relative variability between steps of the same subject, or between subjects of the same sub-group. It seems therefore likely that this parameter may constitute a useful differentiator between normal and pathological gait.

The SD is inversely related to the sample size which would be required to define a mean value not differing from the true mean by a certain amount. For example, when it is required that a 95 percent confidence interval on the mean step length of any one normal young man will be ± 2 percent of his stature, then a sample size of n=4 steps is needed. When it is required that the same interval will be ± 1 percent of the subject's stature, then a sample size of n=16 steps is needed. The number of steps or of subjects required for any particular gait analysis depends on the variability of the parameter of interest.

The variability of sequential steps of the same subject was considerably higher for old than for young subjects. This fact is in agreement with Spielberg's (1940) theory that the motor pattern of walking goes through several stages of disintegration. At the third stage the uniformity of sequential steps is increasingly disturbed. It is interesting to note though, that such decrease of uniformity is not observed for the rest of the gait parameters analysed in this study.

Step length was relatively smaller for old than for young subjects. This feature that has been described by Spielberg (1940), has also been reported in an extensive study by Drillis (1961), and later by Murray et al (1969). It is attributed to the fact that smaller step lengths result in smaller moments about the joints of the lower limb and therefore smaller effort is required to be exercised by the weakened musculature of old subjects.

Mean values for the foot angle are reasonably close to those reported by Dougan (1924), by Morton (1932) and by Murray et al (1964, 1966, 1969, 1970).

Comparisons of foot angle, θ, and stride width, b, between young and old subjects showed a significant increase in the case of the latter. Foot angle and stride width, taken together, define the overall width of the supporting base for the walking subject. Old people who suffer more instability, due to weaker hip abductors and poorer physical condition, require a larger base of support during their gait. This is achieved by increasing both the foot angle and the stride width. The increase in stride width is particularly stressed in the case of old women. This may be due to the fact that the female pelvis is relatively wider than the male one. Murray et al (1964) observe a significant increase in the mean foot angle with age, but their analysis reveals no increase of stride width with age. They, therefore, conclude that wider base of support is achieved in old age by out-toeing and not by both out-toeing and greater stride width, as this study reveals.

It was felt likely that instability of the elderly might result in greater side-ways sway (mean path lateral deviation), than that shown by young subjects. This hypothesis was not justified by the analysis of the mid-line deviation, indicating that instability is adequately counter-balanced by the increase in the size of the supporting base. It should, nevertheless, be pointed out, that data on the mid-line deviation might be biased, as the subjects were more or less "guided" to walk along a straight line by the paper walkpath itself. To reach final conclusions about this parameter a much wider paper walkpath will be required.

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The effect of oxygen inhalation and intravenous Naftidrofuryl on the transcutaneous partial oxygen pressure in ischaemic lower limbs

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Abstract

The effect of oxygen inhalation at atmospheric pressure and Naftidrofuryl infusion (N) on the $TCpO_2$ is shown.

At the central control site—5 cm below the midclavicular line—oxygen inhalation produced a significant increase in $TCpO_2$, whereas there was no change after Naftidrofuryl infusion. At the 10 cm below-knee site, there were significant rises after oxygen inhalation alone, Naftidrofuryl alone and both combined. The study was conducted on 20 patients (23 legs).

It is suggested that this study can form the basis for a regimen to improve the viability of ischaemic limbs showing borderline $TCpO_2$ readings, and increase the chances of a successful below-knee amputation.

Introduction

The value of transcutaneous partial oxygen pressure ($TCpO_2$) recording in assessing skin viability has been the subject of recent publications (Achauer et al, 1980; Dowd et al, 1983). In a previous communication we have shown average $TCpO_2$ in a group of young healthy volunteers, elderly healthy volunteers, and a group of patients with lower limb ischaemia in varying degrees of severity (Mustapha et al, 1983).

Our findings relate closely to other researchers' results. A $TCpO_2$ recording of 40 mm Hg or over indicates adequate perfusion of the skin, and a recording below 30 mm Hg is clear indication of inadequate perfusion (Holstein et al, 1979).

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In the management of the ischaemic lower limb and especially in situations where the $TCpO_2$ recording shows values in the borderline range of 30–40 mm Hg it is desirable to enhance the viability of the limb in general and the skin in particular, either to avoid surgery (especially amputation) or to improve the chances of success of a distal (i.e. below-knee) amputation.

This is a study of the effect of oxygen inhalation and the effect of a drug Naftidrofuryl (Praxilene LIPHA) that has been shown to enhance oxidative metabolism at cellular level (Meynaud et al, 1973).

Patients, materials and method

In this and the previous studies (Mustapha et al, 1983; Jain 1982), the TCM1 (Radiometer, Copenhagen) $TCpO_2$ monitor is used.

Two site readings are recorded: a control site 5 cm below the midclavicular point (either side as convenient) and a site 10 cm below the knee anteriorly. This latter site marks the critical perfusion level especially in relation to the anterior incision line of the commonly performed below-knee amputation technique.

Oxygen inhalation is administered as a 24% mixture in air (2 litre flow per minute) through a face mask or nasal spectacle. A higher flow rate was found unnecessary as it produced only marginally higher $TCpO_2$ recordings. Naftidrofuryl (N) is given in a dose of 400 mg six hourly mixed in 5% Dextrose in water and administered in a continuous infusion.

Oxygen inhalation was initially given to two groups of healthy volunteers: six young volunteers aged 17–25 years (average 19.5 years), and six elderly volunteers aged 54–64 years (average 59 years) with no signs of

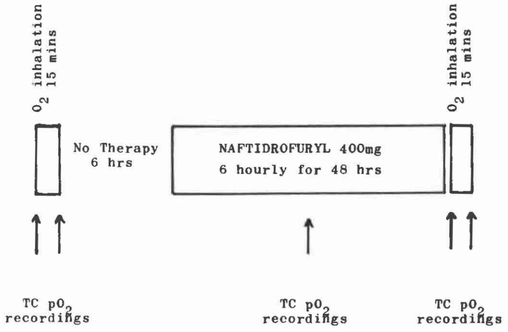

Fig. 1. $TCpO_2$ recordings in relation to therapy.

peripheral vascular insufficiency or central cardiopulmonary deficit.

The study was then extended to dysvascular patients, and in addition to the oxygen inhalation, the effects of Naftidrofuryl were noted according to the following regimen (Fig. 1):

A baseline $TCpO_2$ recording over the two sites is followed by oxygen inhalation for 15 minutes. The $TCpO_2$ is recorded again.

A period of six hours follows when no therapy is given, and then Naftidrofuryl 400 mg six hourly is administered for 48 hours. Soon after the end of the infusion, oxygen is administered for another period of 15 minutes. The $TCpO_2$ is recorded immediately before and immediately after this second oxygen inhalation.

This regimen was settled upon as the most convenient for the medical nursing staff workload as well as the clinical condition under study. It is, however, recognised that greater accuracy of assessment can be obtained if more frequent readings are taken, or the period of therapy and monitoring is extended.

Results

The group of young healthy volunteers (Table 1 and Fig. 2) showed an average $TCpO_2$ level of 80 mm Hg (S.D. 9.0) at the control site before oxygen inhalation, rising to 119 mm Hg (S.D. 14.1) after the 15 minutes of 24% oxygen mixture inhalation. This represents an average increase of 48% (S.D. 16.9) ($p<0.001$). At 10 cm below the knee anteriorly, the corresponding figures were 92 mm Hg (S.D. 8.5); 129 mm Hg (S.D. 11.5) and 41% (S.D. 19.5) ($p<0.001$).

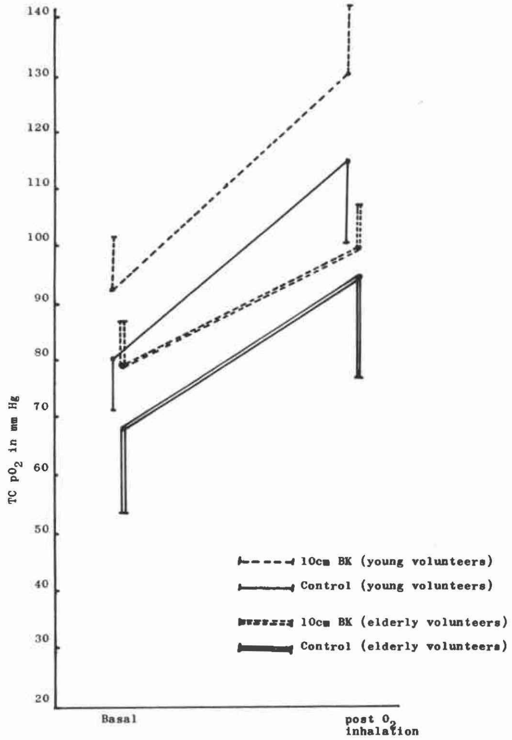

Fig. 2. Effect of oxygen inhalation on healthy volunteers.

Comparable results of $TCpO_2$ level in the healthy elderly group of volunteers (Table 2 and Fig. 2) were 68 mm Hg (S.D. 14.4); 94 mm Hg (S.D. 17.4); and 39.5% (S.D. 10.5) for the control site ($p<0.001$) and 79 mm Hg (S.D. 7.6); 99 mm Hg (S.D. 7.6) and 27% rise (S.D. 11.4) for the below-knee site ($p<0.001$).

Table 1. $TCpO_2$ changes in response to 0_2 inhalation in 6 young volunteers. Age range 17–25 years.

		Control site $TCpO_2$ mm Hg				10 cm B/K			
	Age	Before O_2	After O_2	% rise	Sign. diff. from pre O_2	Before O_2	After O_2	% rise	Sign. diff. from pre O_2
Average	19.5	80	119	48	$p<0.001$	92	129	41	$p<0.001$
S.D.	2.9	9.0	14.1	16.9		8.5	11.5	19.5	

Table 2. $TCpO_2$ changes in response to O_2 inhalation in 6 elderly volunteers. Age range 54–64 years.

		Control site $TCpO_2$ mm Hg				10 cm B/K $TCpO_2$ mm Hg			
Age		Before O_2	After O_2	% rise	Sign. diff. from pre O_2	Before O_2	After O_2	% rise	Sign. diff. from pre O_2
Average	59	68	94	39.5	$p<0.001$	79	99	27	$p<0.001$
S.D.	3.7	14.4	17.4	10.5		7.6	7.6	11.4	

Table 3. $TCpO_2$ changes in response to O_2 inhalation and Naftidrofuryl (Praxilene)

	$TCpO_2$ Control site (n=20)	Sign. diff. from Basal	pO_2 10 cm B/K (n=23)	Sign. diff. from Basal	Index $\frac{10\text{ cm B/K}}{\text{Control}}$	Sign. diff. from Basal
Basal	62.39±15.50	—	42.05±14.83	—	0.68±0.22	—
Post-Praxilene value	60.80±14.74	NS	51.74±17.26	$p<0.001$	0.86±0.26	$p<0.001$
Post-oxygen inhalation	87.71±18.33	$p<0.001$	56.77±18.49	$p<0.001$	0.64±0.15	NS
Post-Prax. and oxygen inhalation	86.38±16.76	$p<0.001$	64.13±19.80	$p<0.001$	0.73±0.20	NS

In the group of dysvascular patients studied, 20 patients, 23 legs (Table 3 and Fig. 3) recordings over the control site showed a significant rise following oxygen inhalation from an average of 62.39 mm Hg (S.D. 15.50) to an average of 87.71 (S.D. 18.33) ($p<0.001$). However there was no significant difference in $TCpO_2$ after Praxilene infusion, rather the value reduced from 62.39 mm Hg (S.D. 15.50) to 60.80 mm Hg (S.D. 14.74).

Following Praxilene *and* oxygen inhalation, the $TCpO_2$ recorded was still higher than the baseline average, but not significantly different from the recordings following oxygen inhalation alone.

On the 10 cm below-knee site, however, there was a significant rise following oxygen inhalation alone, Praxilene alone and Praxilene plus oxygen, the figures being: 42.04 mm Hg (S.D. 14.83) baseline, and 56.77 (S.D. 18.49) following oxygen inhalation ($p<0.001$), 51.74 mm Hg (S.D. 17.26) following Praxilene ($p<0.001$), and 64.13 (S.D. 19.80) following Praxilene and oxygen inhalation ($p<0.001$).

Discussion

Oxygen inhalation raises the $TCpO_2$ throughout the body in a direct and up to a certain extent, proportionate manner, as long as there is a circulation to carry it.

The addition of Praxilene however, had no effect on the control site in the dysvascular group

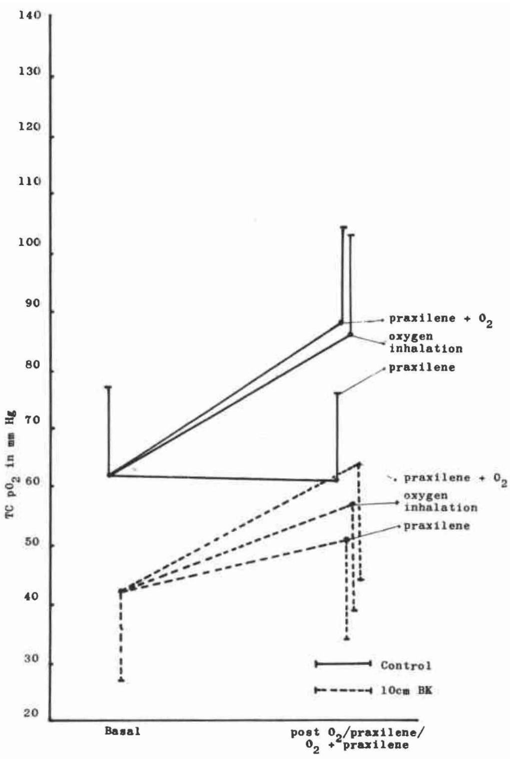

Fig. 3. $TCpO_2$ recordings in dysvascular patients showing the effect of O_2 inhalation and/or Praxilene.

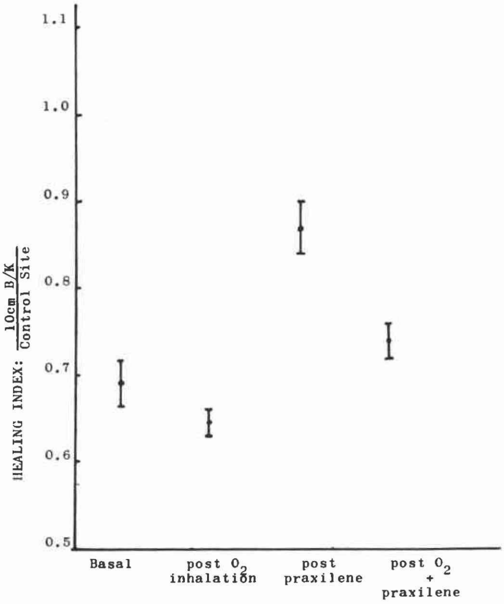

Fig. 4. $TCpO_2$ shown as an index $\frac{\text{10 cm B/K}}{\text{Control site}}$: The effect of O_2 inhalation alone, Praxilene alone and both combined.

but did contribute significantly to the $TCpO_2$ in the ischaemic part of the lower limb. This is in keeping with a previous observation that Praxilene effects ischaemic parts selectively (Gaylarde et al, 1980; Elert et al, 1976).

This fact is reflected again in the significant difference Praxilene produces in the $\frac{\text{10 cm B/K}}{\text{Control}}$ $TCpO_2$ index (Fig. 4). This idea (Healing index) (Jain, 1982) may not at this stage offer a reliable indication as to the severity of ischaemia, but its significance is under consideration and longer studies are required to establish its usefulness or otherwise.

No complications have been noted in this study from the use of oxygen inhalation or the above mentioned dosage regimen of Praxilene.

Conclusion

This study is an extension to the previous studies (Jain, 1982; Dowd et al, 1983; Mustapha et al, 1983;) in which the value of $TCpO_2$ was shown to be a reliable indicator of the state of perfusion in the tissues at large and the ischaemic lower limb in particular. Further studies are needed to establish whether such a regimen can assist the clinician in dealing with borderline ischaemic conditions before or immediately following an amputation. The regimen described is presented only as a guide and varying clinical conditions will inevitably call for a flexible application. A further comparative study is contemplated to establish the regimen more firmly.

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"Zero-position" functional shoulder orthosis

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Abstract

The "zero-position" of the shoulder joint described by Saha (1961) is recognized as a mechanical position between scapula and humerus, and the "scapular plane" is widely accepted as a mechanical plane at the shoulder joint. On the basis of biomechanical concepts of the "zero-position" and the "scapular plane", the authors designed the "zero-position" functional shoulder orthosis. This orthosis has been successfully fitted to more than 75 patients for the postoperative management of rotator cuff injuries, and to 3 patients for the treatment of scapular neck fractures. It is introduced here, together with biomechanical considerations, structure, functional and clinical results.

Introduction

A plaster cast has commonly been used for immobilization in the so-called optimal position of the shoulder joint after operation for rotator cuff injuries. However, it sometimes causes contracture of the shoulder joint and muscle imbalance around the shoulder girdle because, in such cast immobilization, patients cannot exercise their shoulder postoperatively. From this point of view, the authors initially used a "zero-position" plaster cast in the postoperative management of rotator cuff injuries (Ozaki and Nobuhara, 1978). On the other hand, however, some difficulties were found after the removal of the plaster cast in that almost all the patients complained of pain and could not continue with their exercises. This resulted in prolongation of the healing period. It was thought that if a functional shoulder orthosis were adopted it would enable adjustments to be made to the elevation angle from the "zero-position" step by step, thus producing less pain. This is the reason for the design of this functional shoulder orthosis.

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Biomechanical considerations

The shoulder joint consists of the small and shallow scapular glenoid fossa, the large humeral head, and abundant muscles. These structures give the shoulder joint the widest range of motion and the most varied movements of any joint in the human body. Therefore the shoulder mechanism has been an enigma to the anatomist. Codman (1934), and others demonstrated that whether the arm is elevated to the vertical in the saggital, the coronal, or in any other plane, the end result is always the same, and when the arm is elevated to the vertical in the coronal plane, it undergoes an appreciable degree of lateral rotation during the process. According to Johnston (1937), when the arm is raised to the vertical, no matter how many planes it may move through in the process, at the end of the movement the humerus must lie in the "plane of the scapula". He stated that the "plane of the scapula" is not easy to define, but may be regarded as a plane drawn at right angles to the glenoid cavity through its greatest vertical diameter. On the other hand, Codman (1934) pointed out a very natural position for the human arm when the body is recumbent. In this position, the axis of the humerus is in line with the axis of the spine of the scapula, and the head and neck of the humerus is in the same plane. He called this point a subordinate pivotal position in which the deltoid, the supraspinatus and the infraspinatus are relaxed. It is the most favourable position to encourage physical repair of lesions in and about the tuberosity. However, he never actually used this position for treatment. Saha (1961) has designated this point as the "zero-position", because muscular rotatory forces acting upon the humerus at this position are almost zero. He stated that this position of stability can be seen in fast-moving quadrupeds. According to Saha's observations, the "zero-position" is at about 155° of elevation from the anatomical position, with the axis of the humerus about 45° anterior to the coronal plane. He used this position in the reduction of fractures of the humerus and dislocations of the shoulder. However, this position had never been used for the postoperative treatment of rotator cuff injuries. In order to define the "plane of the scapula", Ozaki (1980) performed cineradiographic and radiographic studies on normal and disordered shoulders. He demonstrated that the "scapular plane" should be inclined forward at an angle of 30° to 45° to the frontal plane (Fig. 1), and that in the "zero-position", the humerus must be elevated to 150° in the "scapular plane" with individual variations (Fig. 2). On the basis of these biomechanical concepts, the functional shoulder orthosis, introduced in this paper, was designed.

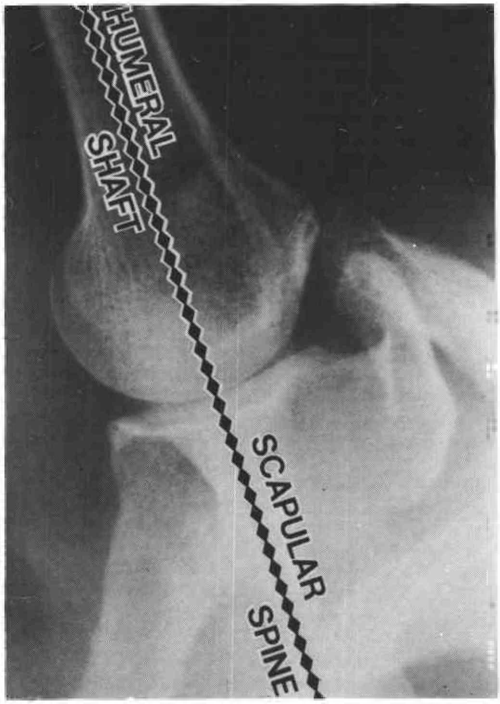

Fig. 2. Radiograph showing the normal shoulder joint in the "zero-position". The "zero-position" is at about 150° of elevation in the "scapular plane", and the axis of the humerus is in line with the axis of the scapular spine.

The design of the orthosis

The "zero-position" functional shoulder orthosis is shown in Figure 3. It consists of a pelvic girdle, an upright bar, a transverse cross bar, and an arm. The pelvic girdle is made of 4mm Subortholen plastic sheet.

The length of the upright bar can be changed since the distance from axilla to iliac crest varies according to the angles of elevation of the arm, and can be rotated in the horizontal plane and fixed in any position using two mechanical joints. The distance from axilla to elbow joint and from palm to forearm can be changed as required. Furthermore, the angle of rotation of the humeral axis and the forearm can be changed easily with the two mechanical joints.

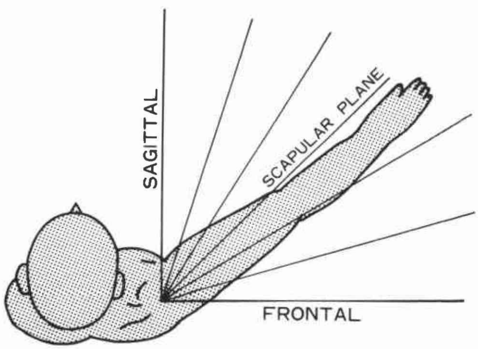

Fig. 1. The "scapular plane".

Clinical applications

Postoperative management of rotator cuff injuries

Immediately after the successful repair of a rotator cuff injury, the "zero-position" of the shoulder should be maintained by skin traction while the patient rests in bed (Fig. 4). After three days, a functional shoulder orthosis, which has been made to order preoperatively, is applied to maintain the "zero-position" in the scapular plane. At the beginning of the third postoperative week, the upper limb in the orthosis is extended at 100° abduction in the "scapular plane" and the patient is allowed to start gradual active-assisted abduction exercises of the arm. From the fourth to the sixth week, when the patient is able to perform active elevation in the range of 60° to 150°, the abduction angle of the orthosis can be decreased

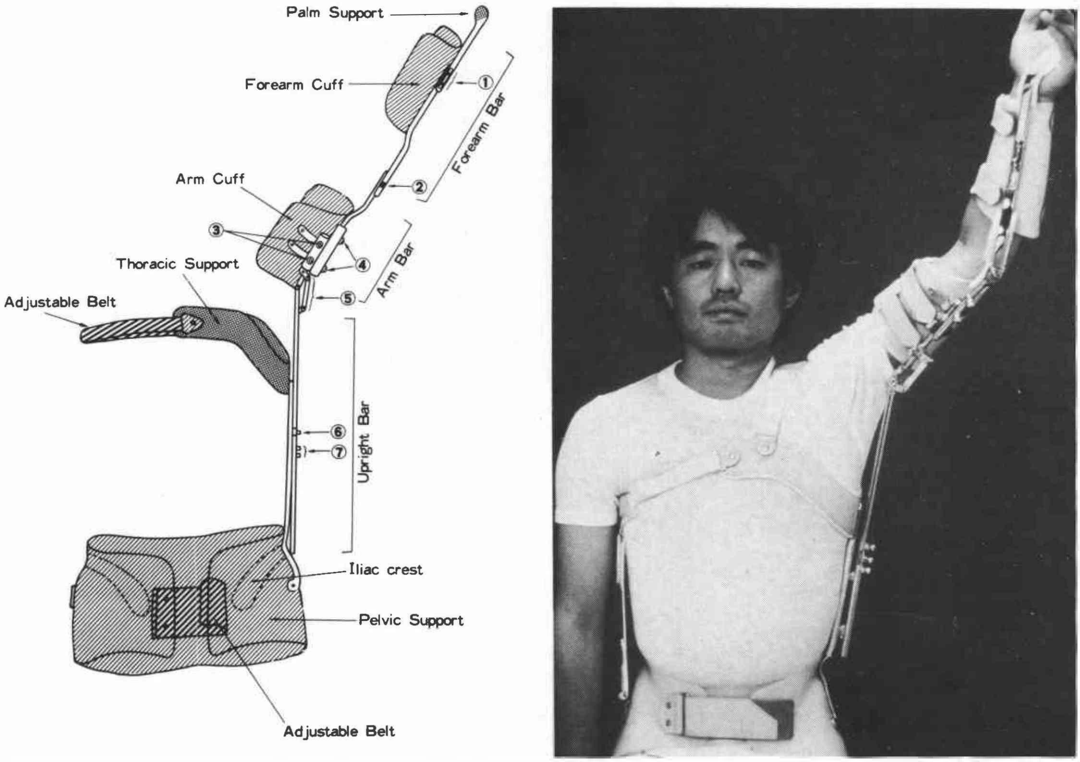

Fig. 3. "Zero-position" functional shoulder orthosis.

gradually to 30°. Mass movement exercise involving circular motion is indicated. Two to three months after surgery, the orthosis is removed. At this point the patient is able to use a full range of elevation, and after three to six months, the patient will have made maximum recovery.

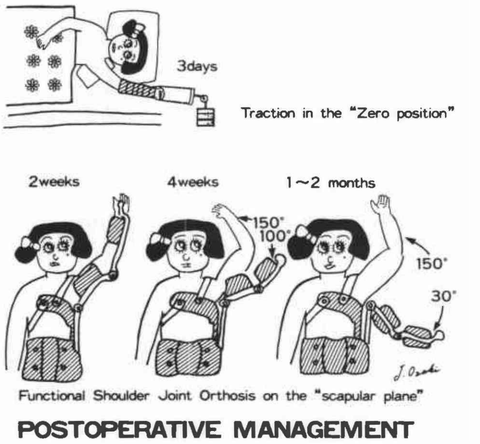

Fig. 4. Postoperative management of rotator cuff injuries using a "zero-position" functional shoulder orthosis.

For the postoperative management of rotator cuff injuries, this orthosis has been fitted to more than 75 patients. As a result of being able gradually to decrease the elevation angle from the "zero-position", pain was reduced compared to that suffered by patients of the plaster cast group in the "zero-position". Early healing and excellent results occurred in almost all cases.

Fractures of the scapular neck

Almost all cases of scapular fracture tend to be neglected because of their complications such as haemothorax, pneumothorax, and other associated multiple fractures. Moreover, immobilization of the fracture of the scapular neck has been done with a sling or a Velpeau bandage, but this cannot reduce the displaced fracture successfully, and sometimes causes contracture of the shoulder joint. Therefore, on the basis of the scapular mooring muscle network, the authors have been using the "zero-position" in the reduction of scapular neck

Fig. 5. Top, anteroposterior view shows a fracture of the scapular neck in a 50 year old man. Note the marked angulation of the scapular neck. Bottom, the reduction after 10 weeks in "zero-position" traction and fixation by a functional shoulder orthosis. The result was excellent.

fractures to prevent the consequent shoulder contracture and mooring muscular imbalance.

After the injury, traction in the "zero-position" should be maintained whenever severe complications exist. After relief from the complications, a functional shoulder orthosis is applied to maintain the "zero-position" in the "scapular plane". From four to six weeks after injury, the elevation angle of the upper limb in the orthosis in the "scapular plane" can be decreased gradually from the "zero-position", and the patient is allowed to start active abduction exercise of the arm. Six to ten weeks after injury, the orthosis is removed, and circular motion exercise is indicated. Three patients have been fitted with this orthosis for the treatment of scapular neck fractures, and their clinical results were excellent. Radiographs of a representative case are presented in Figure 5.

Conclusion

The "zero-position" functional shoulder orthosis has been successfully applied for the postoperative management of rotator cuff injuries and for the treatment of scapular neck fractures. Clinical trials of this orthosis can also be extended to the postoperative management of other shoulder conditions. In the cases of recurrent shoulder dislocation, post-traumatic shoulder dislocation, and inferior and multidirectional instability of the shoulder, this orthosis should not be used to immobilize at the "zero-position". In these cases glenohumeral dislocation may frequently be encountered due to their original glenohumeral instability as in Bankart, or Hill-Sacks lesions, and glenoid dysplasia.

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Cold injury amputees—a psychosocial problem?

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Abstract

The rehabilitation of 8 cold injury lower limb amputees is described, 7 of whom were alcoholic and had significant personality disorders. Delayed wound healing was the only common physical problem but the psychosocial difficulties were substantial and were the principal determinant of outcome following rehabilitation.

Introduction

Most of the literature on cold injury describes the immediate management and indications for different surgical procedures, little attention being paid to the problems associated with the rehabilitation of amputees resulting from this type of injury. We report here our experience of the management of 8 patients who have undergone amputation of part or parts of their lower limbs as a result of cold injury in the last 5 years. The popular image of the cold injury amputee is of the intrepid explorer or climber caught in a blizzard. Such cases undoubtedly occur but our experience has been that this condition is associated with less positive psychological attributes. The outcome of rehabilitation of these patients is determined by psychological factors rather than the physical disability.

Clinical features

Presentation

Seven of the eight patients (Table 1) were frostbitten in Scotland and 1 in Northern Sweden; 3 had hypothermia on admission to hospital. Four patients had been "sleeping rough" (3 of them sustaining cold injury in winter and 1 in summer) while the other 3 Scottish patients were living in their own unheated homes during the winter. The immediate management of all the patients was conservative and involved appropriate resuscitative measures including rapid warming. Surgical intervention took place between 48 hours and 3 months after cold injury.

Physical factors in rehabilitation

These are summarized in Table 2. The level of amputation of the lower limbs varied and the mobility achieved by the patients after limb fitting was in keeping with that expected of the patients in view of their ages, associated physical impairments and the level of amputation. Only one patient became wheelchair-bound and he was an older bilateral above-knee amputee. Delayed wound healing was common (50%), as might be expected from the conservative nature of the surgery performed, but affected the duration of stay in hospital in only one patient. The patient whose fingers were also affected had some difficulty in performing activities of daily living and required a number of aids.

Psychological factors

Seven patients were alcoholic (Table 3), the duration of their dependency varying from 2 to over 20 years. Patient 3 emphasized the wide ranging nature of the personality factors which may manifest themselves as alcohol dependency. As part of an apparently successful alcohol treatment programme, some time prior to the episode of cold injury, he had found a job

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Table 1 — Features at initial presentation

Patient	Sex	Age	Location	Circumstances	Inebriated	Systemically cold	Other diseases
1	M	33	Open country N. Sweden	Suicidal intent	no	yes	nil
2	M	68	Living rough	Alcoholic self neglect	no	yes	Hepatomegaly
3	M	39	Lying on floor of own home	Alcoholic self neglect	yes	no	nil
4	F	59	Own home	Depressed	no	no	nil
5	M	63	Living rough	Self neglect	yes	yes	deaf
6	M	66	Own home	Self neglect	no	no	Peripheral neuropathy
7	F	60	Sleeping rough	Alcoholic suicidal intent	no	no	Hepatomegaly
8	M	53	Own home	Alcoholic self neglect	yes	no	nil

as quality control tester for a pharmaceutical firm which makes heroin. It was not long before he was testing the quality of the heroin by consuming it as well as by testing it chemically! In 2 patients the episode of cold injury was clearly a suicide attempt and in 4 patients depression played a prominent role. Two patients required treatment for delirium tremens and 4 had anti-depressant therapy.

Seven patients had personality disorders. One of them (6) had such a severe schizoid personality that he required long-term psychiatric care. Patient 1 also had a gross personality disorder. He had a poor family history—his parents were divorced, his mother was schizophrenic, his uncle shot himself, his sister took a fatal overdose and his aunt, to whom he was sent for safe-keeping was subsequently found to be an alcoholic. He suffered from recurrent depressive illnesses and had taken 2 overdoses prior to the episode of cold injury. He had been discharged from the Royal Navy on psychiatric grounds but later found work in the City. After a disagreement

Table 2 — Physical factors in rehabilitation

Patient	Sex	Age	Level of amputation		Delayed wound healing	Fingers involved	Mobility	Activities of daily living
			right	left				
1	M	33	BK	BK	No	Temporary neuropraxia	Walked well with prosthesis	Independent
2	M	68	Toes	BK	Yes	No	Walked well with prosthesis	Independent
3	M	39	BK	—	Yes	No	Walked well with prosthesis	Independent
4	F	59	Syme's	Chopart	Yes	No	Walked well with prosthesis	Independent
5	M	63	AK	AK	No	Subtotal amputation of all fingers	Learned to walk but effectively wheelchair-bound	Partially dependent
6	M	66	Mid tarsal	Mid tarsal	No	No	Able to walk	Dependent
7	F	60	Mid tarsal	Mid tarsal	No	No	Walked about normally	Independent
8	M	53	Trans-metatarsal	Trans-metatarsal	Yes	No	Walked about normally	Independent

Table 3 — Psychological aspects of care

Patient	Sex	Age	Personality disorder	Alcohol addiction	Depression/ suicidal intent	Ward behavioural problems	Psychiatric after-care
1	M	33	+++	–	+	serious	OP Psych. care
2	M	68	+	+	+	nil	—
3	M	39	+	+	–	minor intermittent	Alcoholism Unit
4	F	59	+	+	+	minor intermittent	Alcoholism Unit
5	M	63	+	+	–	moderate frequent	—
6	M	66	+++	+	–	serious	L/T Psych. IP care
7	F	60	–	+	+	nil	Alcoholism Unit
8	M	53	++	+	–	minor intermittent	—

with one of the partners of the stockbroking firm for which he worked, he absconded to the Canary Islands with £23,000 of the firm's money. A bout of depression prevented him from enjoying this and in a state of great remorse, he travelled to Sweden where he took the train as far north as he could go and then set out on foot in the snow to try to commit suicide. He was, however, found and taken back to the local hospital where surgery was performed.

Behavioural problems were the main difficulty encountered during in-patient management.

Social problems

All patients had social difficulties (Table 4). None of the patients had close relationships and all were living isolated existences; 3 were of no fixed abode. Two patients (2 and 4) had developed serious drinking problems after being widowed.

Resettlement and after care

One patient required long-term psychiatric care. The other 7 were resettled within the community but 4 of them needed continuing psychiatric help after discharge. In spite of this 3 have resumed drinking although not as heavily as before. On the positive side, 2 patients (1 and 5) resumed contact with their families as a result of their illnesses and all 3 patients who were of no fixed abode at the time of their admission were successfully re-established in satisfactory accommodation within the community. It took some time, however, to arrange this.

Discussion

Patients free of psychological or social problems may suffer cold injury and subsequent amputation but we feel that our experience is typical of the patients presenting with this uncommon cause of amputation in Britain today. These amputees formed 2% of amputees going through our unit, a figure in agreement with that quoted by Bevan (1972). Most of the amputees seen by the rehabilitation services in Edinburgh have, on average, 2 other significant

Table 4 — Social aspects of rehabilitation

				Social Situation			
Patient	Sex	Age	Marital Status	Before	Duration of stay in hospital	After	Employment
1	M	33	S	Own flat	Intermittent over 1 year	Parent's home	yes
2	M	68	W	No fixed abode	8 months	Community Home	retired
3	M	39	S	Own flat	8 months	Own flat	no
4	F	59	W	Upstairs flat	3½ months	Ground floor flat	no
5	M	63	D	No fixed abode	2½ years	Sheltered accommodation	no
6	M	66	S	Own house	2½ months	Psychiatric hospital	retired
7	F	60	M	Own house	2 months	Own house	no
8	M	53	S	Own house	6 months	Supported accommodation	no

physical problems (Middleton and Stephen, 1981) but serious psychiatric problems are uncommon and the social problems are those of any elderly population. The cold injury amputees formed a distinctive group. From a physical point of view, they were relatively fit and were younger than average. Four of the 8 patients did have delayed wound healing but this influenced the duration of the patient's hospital stay in only one case. Their average duration of stay in hospital was 8 months (compared to 3 months for elderly atherosclerotic or diabetic amputees in our unit). The principal reason for this prolonged admission was their social resettlement which was determined, by and large, by their previous lifestyle and personality problems.

The high incidence of alcohol problems and personality disorders in cold injury amputees has been noted previously but there are variations in incidence between different series depending, as might be expected, on geographical factors. Miller and Chasmar (1980) reviewing 110 patients from Saskatoon collected over a ten year period, found alcohol consumption as a contributing factor in 39 patients and motor vehicle accident or breakdown in 33 others. Kyosola (1974) on the other hand, reporting 110 consecutive patients treated over a 2 year period in Helsinki, Finland, noted that "most" of them had suffered cold injury under alcoholic intoxication, being "skidrow" type alcoholics. Even Barat, et al (1978) with their extensive experience of 837 cases which occurred in a 2 week period of military manoeuvres in Kashmir in 1971, found that the relevant aetiological factors included not only accidents and disasters but "personal lapses". These and other papers have simply noted the existence of alcohol and personality problems and their relevance to the patients' acute management; our experience emphasizes their considerable importance in the patients' rehabilitation and resettlement.

It is apparent to all who treat these patients that their management requires an awareness of the psychological and social dimensions as well as of the physical problems. In this need for comprehensive management (i.e. rehabilitation), they do share common ground with our other amputees, although for different reasons.

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Biomechanical evaluation of SACH and uniaxial feet

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Abstract

A review of prosthetic prescription practice reveals that in the United Kingdom about 85% of below and above-knee amputees are fitted with uniaxial feet, whereas in the United States about 80% are fitted with SACH feet. An evaluation method was developed to assess the performance of these two different types of feet. This included a subjective assessment procedure and a biomechanical evaluation of the function of the two feet and their effects on whole body gait kinematics and lower limb kinetics.

Data were acquired by three Bolex H16 cine cameras and two Kistler force plates. This set-up allowed three-dimensional analysis on the prosthetic and contralateral sides of the subject. Investigations were undertaken in which an experimental prosthesis permitted the interchange of the ankle/foot while keeping the rest of the components the same. Altogether, six below knee and five above knee amputees were tested. No clear trend for preference for either type of foot was evident from the subjective survey; in general the patients showed a preference for the foot that they were accustomed to. Kinematic and kinetic analysis showed some differences in the function between the two prosthetic feet. It is the purpose of this paper to discuss these differences and their significance.

Introduction

Many prosthetic feet and ankle mechanisms have been designed to date, some incorporating ingenious mechanisms capable of imitating functions and movements of the normal foot and ankle complex (Wagner and Catranis, 1954). However, the complexity of most of these designs, their excessive maintenance requirements and unacceptably high mass have prevented their wide use. The two most common prosthetic feet used nowadays are the uniaxial (single-axis) type and the solid ankle cushion heel (SACH) foot.

The uniaxial foot in its present form originated in 1861, when J. E. Hanger (U.S.A.) replaced the cords in the "American Leg" by rubber bumpers about the ankle joint (American Academy of Orthopaedic Surgeons 1960). Since then, the device has undergone many modifications. However, its basic principle of operation still remains the same. There is an articulating ankle joint with a horizontal shaft located in plain bushes or ball bearings. Two bumpers (one in front and the other at the rear of the axis) provide the restraining and restoring moments about the ankle joint for plantar and dorsiflexion movements, simulating the normal foot and ankle flexion function during level walking.

The SACH foot was developed at the University of California, Berkeley, in the early 1950's. (Radcliffe and Foort, 1961). It consists of a wedge of cushioning material built into the heel and an internal keel, shaped at the ball of the foot to provide a smooth rolling action. The heel wedge cushions the impact at heel strike and compresses to give the effect, albeit limited, of plantar flexion. The foot has no articulating ankle joint thus eliminating the need for maintenance of moving mechanical parts.

Prescription criteria for prosthetic feet have been derived from experience gained by the clinician and prosthetist. Over the years several studies have been conducted to supply statisical data on prescription patterns of prosthetic components, notably: Litt and Nattress (1961), Davies et al (1970) and Fishman et al (1975), in the United States. In the United Kingdom, the Department of Health and Social Security (DHSS) has published annual statistics for England, Wales and Northern Ireland since 1957.

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Table 1. Prescription patterns for prosthetic feet.

	U.S.A. (Fishman et al. 1975)		U.K. (D.H.S.S., 1976)	
Ankle/foot components	B/K	A/K	B/K	A/K
Uniaxial	15%	23%	89%	79%
SACH	81%	74%	1%	2%
Others	4%	3%	10%	19%

A review of the above studies reveals that the most common prosthetic foot prescribed in North America for above and below-knee amputees during the 1970s was the SACH foot. On the contrary, in the United Kingdom the most common prosthetic foot prescribed was the uniaxial foot (Table 1) while the SACH foot was rarely prescribed. Recent statistics, however, indicate a slight increase in its usage (DHSS, 1980).

Review of published work

In 1955, New York University was contracted by the Veterans Administration to determine the performance of the SACH foot against that of the single axis (with toe-break type) wooden foot. (Fishman et al, 1955). Three below-knee and three above-knee "active" unilateral amputees participated in the programme. A high level of acceptance of the SACH foot was indicated in the clinical analysis. The engineering evaluation using force plate data showed that the above-knee amputees had a smoother transition from heel to toe with the SACH foot. This effect was not detected in the below-knee amputees. Following on in the 1960s, clinical experience in North America indicated a high preference for the SACH foot. (Gordon and Ardizzone, 1960; Wilson, 1962).

In the United Kingdom, there was no report of studies carried out to indicate the high preference for the uniaxial foot, although it had been suggested by experienced prosthetists that better knee stability could be achieved with the uniaxial foot during early stance.

Recently a study by Doane and Holt (1983) on the comparison of the SACH and single-axis foot in the gait of eight unilateral below-knee amputees was carried out. They found no significant difference in most of the kinematic data of the lower extremity and the temporal parameters during gait. The only significant difference was in the ankle angle at the beginning of the foot flat period where the single-axis foot displayed a plantar flexion angle 6.5° greater than that of the SACH foot. They concluded that the interchanging of the two prosthetic feet in a prosthesis does not affect the gait pattern of the amputees.

Subjects and materials

Surveys of amputation levels show that over 80% of the population are either below-knee or above-knee (Table 2). This is true for the United States as well as the United Kingdom. These two groups of amputees are the main users of prosthetic feet and were therefore considered in this evaluation programme. Altogether six below-knee and five above-knee male unilateral amputees were selected to participate in the trials. The average age of the below-knee and above-knee amputees was 53 (standard deviation SD=9) and 48 (SD=11) respectively.

To quantify the activity level of each amputee, the assessment method proposed by Day (1981) was used. The average score for the below-knee amputees was 33, while that for the above-knee amputees was 37. These values represented an active group of amputees.

In order to minimize the variables which might influence the results, it was necessary to provide each amputee with an experimental prosthesis, which was sufficiently adaptable to accommodate either the SACH or uniaxial foot. The Otto Bock modular system was found to be suitable for this purpose. All the below-knee amputees were fitted with a standard PTB with suprapatellar cuff suspension prosthesis, while all the above-knee amputees were fitted with a quadrilateral (total contact) suction socket and a single-axis knee mechanism prosthesis. Each prosthesis was provided with an additional shank tube to accommodate the height

Table 2. Distribution by level of amputation.

	U.S.A.		U.K.	
Amputation level	Glattly, 1964	Kay & Newman, 1975	D.H.S.S., 1976	D.H.S.S., 1980
Upper extremity	14.5%	8.3%	5.4%	4.3%
Above-knee Below-knee	44.1 36.8 80.9%	32.6 53.8 86.4%	52.7 31.4 84.1%	51.7 35.7 87.4%
Other lower extremity	4.6%	5.3%	10.5%	8.3%

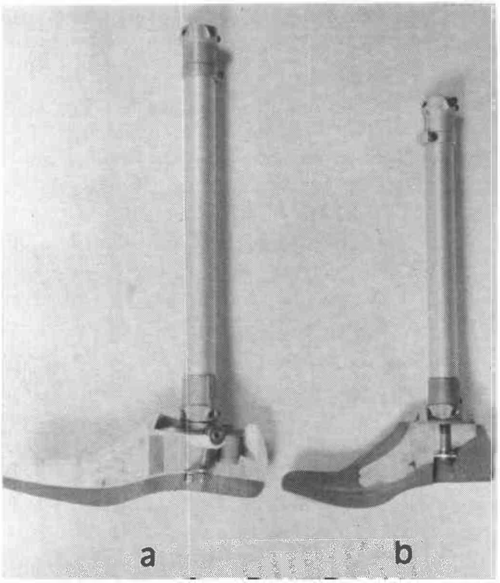


Fig. 1. Prosthetic feet evaluated (a) Uniaxial foot (b) SACH foot.

discrepancy between the SACH and uniaxial feet. Figure 1 shows the Otto Bock SACH and uniaxial feet used in this study.

Gait measuring system

The laboratory consisted of a walkpath approximately 20 metres long. Two Kistler force plates and three Paillard Bolex H-16 cine cameras were arranged as shown in Figure 2. This arrangement allowed three-dimensional analysis of both sides of the human body.

Each camera was driven by a synchronous motor at mains frequency (i.e. 50 Hz) through a gear ratio of 8: 1. The internal gear ratio of the camera is 1: 8, therefore a shutter frequency of 50 cycles/s was achieved. The sampling rate for the force plate signals was also set at 50 Hz. A PDP/12 mini computer was used to store data from both force plates. The three cine cameras and two force plates were synchronized during the walking trials by a single external event.

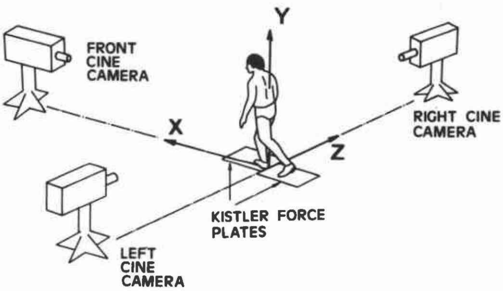
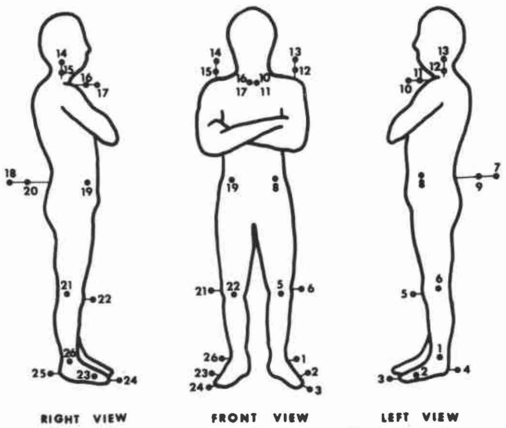


Fig. 2. Gait measuring system.

Methodology

Dynamic alignment of the experimental prosthesis (either with SACH or uniaxial foot) was performed by an experienced prosthetist prior to the walking trials. This involved rotating and tilting of the various prosthetic components, and selecting the most suitable density of heel wedge for the SACH foot or the plantar rubber bumper for the uniaxial foot. When the "optimum" alignment was achieved, the amputee was allowed to become accustomed to the prosthesis. Meanwhile, the prosthetist recorded a final assessment of the amputee's gait on a given form.

Lightweight, spherical (10 mm diameter) body markers were positioned and taped on to the anatomical landmarks (Fig. 3). The



Marker Numbers and Their Locations		
Right	Definition	Left
14	Acromion Process 1	13
15	Acromion Process 2	12
16	Sternum 2	11
17	Sternum 1	10
18	Pelvic Tail 1	7
19	Anterior Superior Illiac Spine	8
20	Pelvic Tail 2	9
21	Fibula Head	6
22	Tibial Tuberosity	5
25	Mid - Heel / Calcaneus	4
24	2nd Toetip	3
23	5th Metarsar Base	2
26	Lateral Malleolus	1

Fig. 3. Locations of body markers.

amputee was then instructed to walk along the walkpath towards the front camera. Five successful runs were recorded; successful meaning when contact was made with the two force plates, with the left foot on one and the right foot on the other. The amputee and the prosthetist were then asked to comment on the performance of the prosthetic foot, in respect of: function, cosmesis, comfort and effects of the foot on other components in the prosthesis.

The procedure was repeated after interchanging the prosthetic foot and shank tube. After the walking trials, the amputee and the prosthetist were asked to comment on the overall performance of each foot.

The alignment of the prosthesis was measured and the mass and mass moment of inertia were determined. Both prosthetic feet were also subjected to static tests on a tensile testing machine, according to the Veteran's Administration standard (Veterans Administration Prosthetics Center, 1973).

Data reduction

The cine films were processed and the positions of markers digitized for transfer to an ICL 1904S mainframe computer for analysis. The force plate data were sorted on the PDP/12 and subsequently also transferred to the ICL 1904S.

A suite of programs, written in Fortran, was used in the analysis of both the cine and force plate data. Initial data processing included calibration, parallax correction and digital filtering of raw displacement data. Further processing gave the three-dimensional kinematic data of the whole body as well as the forces and moments at the hip, knee and ankle of the prosthetic and contralateral limbs.

Results and discussion

The plantar rubber bumper supplied with the Otto Bock modular uniaxial foot (moulded-type) was too soft for most of the amputees. Consequently, plantar rubber bumpers of four different stiffnesses had to be specially moulded in the Bioengineering Unit. These allowed the selection of bumpers that were most acceptable to the amputees and prosthetists.

The proposed guide for the selection of the heel stiffness of the SACH foot by Radcliffe and Foort (1961) was found to be inadeqùate. For example, the medium grade SACH foot was preferred even by amputees whose body weight exceeded that recommended. Furthermore the guide does not make provision for amputees who require a soft grade SACH foot. A revised guide should be established in which the basis of selection of heel stiffness should not only include the level of amputation and body weight but also the level of activity of the amputee. There is no existing guide for the selection of rubber bumper stiffness for the uniaxial foot.

The Veterans Administration standard appears to be valid for the SACH feet only (Veterans Administration Prosthetics Center, 1973). It was observed that for a particular amputee, the heel stiffness preferred for the uniaxial foot was always more stiff than that of the preferred SACH foot according to the load versus deformation curve (Fig. 4). This is due to the different load bearing characteristic of the SACH and uniaxial foot. It is suggested that a standard be compiled for the articulating ankle joint type of prosthetic foot, in which the ankle moment versus angluar displacement is used as a means of classification.

The subjective assessment showed that of the six below-knee amputees tested, three preferred the uniaxial foot, two preferred the SACH foot and one had no specific preference. Of the five above-knee amputees, three preferred the uniaxial foot while the remaining two preferred the SACH foot. No clear trend of preference for

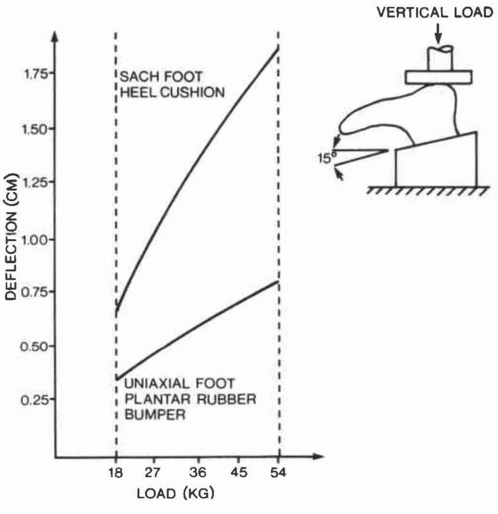


Fig. 4. Static plantar flexion testing. From VA Standards and Specifications for Prosthetic Foot/ Ankle Assemblies (1973).

Table 3. Subjective assessment of amputee's preference.

Amputation level	Amputee	Amputee's own prosthesis	Overall preference
Below-knee amputees	BR002	SACH	SACH
	BR003	SACH	SACH
	BL004	Uniaxial (wooden)	Uniaxial (moulded)
	BR005	SACH	Uniaxial (moulded)
	BR007	Uniaxial (wooden)	No preference
	BL012	Uniaxial (moulded)	Uniaxial (moulded)
Above-knee amputees	AR001	SACH	SACH
	AL006	Uniaxial (moulded)	Uniaxial (moulded)
	AR010	Uniaxial (wooden)	Uniaxial (moulded)
	AR011	Uniaxial (wooden)	Uniaxial (moulded)
	AL013	SACH	SACH

either type of foot was evident. In general the amputees showed a preference for the foot to which they were accustomed (Table 3).

When the prosthetic foot and shank tube were interchanged it was necessary to re-align the prosthesis. The difference in alignment was due to the height discrepancy of approximately 1.5 cm and the antero-posterior difference in attachment point of the foot bolt relative to the heel of the foot of approximately 1.5 cm. Furthermore, the heel stiffness of the prosthetic foot also influences the alignment of the prosthesis. Therefore in this evaluation, alignment of the prosthesis had to be considered as an integral part of the fitting of the respective foot. The alignment of the prosthesis, whether with the SACH or uniaxial foot, was found to be within the "optimum" alignment range established with the SACH foot in an on-going project in the Bioengineering Unit. No differences in gait were observed by the prosthetist resulting from the difference in alignment of the prosthesis with SACH and uniaxial foot.

Table 4 shows the averaged temporal parameters of the below-knee amputees. A two sample, two-tailed t-test at 5% level was used to determine whether the means were significantly different. The averaged preferred speed of walking was found to be the same whether the SACH or uniaxial foot was used. The stance phase of the sound limb is longer than that of the prosthetic side and consequently the swing of the sound limb is shorter than that of the prosthetic side. This is consistent with the findings reported by Molen et al (1973) and Breakey (1976). The percentage of the walking cycle occupied by stance phase however, for both the sound and prosthetic sides was shorter than that reported. This could be due to the faster speed of walking. The difference in prosthetic stance phase for the SACH and uniaxial foot was found to be insignificant.

The most significant difference was found in the temporal components of the prosthetic stance phase (Table 4). The uniaxial foot demonstrated similar characteristics to the normal foot. This is because the compression of the rear bumper controls the foot plantar flexion about the hinge joint, in a similar manner to the pre-tibial muscles in the normal subject. With the SACH foot, the period of heel-strike to foot-flat took twice as long as that of the normal foot; the rigid ankle prevents pivoting about the ankle axis. Consequently, foot flat position has to occur by compression of the heel cushion and forward movement of the knee joint. These

Table 4. Temporal parameters of below-knee amputees. Percentage of stance phase.

Temporal components of stance phase	Normal subjects	Below-knee amputees			
		Contralateral side		Prosthetic side	
		SACH foot	Uniaxial foot	SACH foot	Uniaxial foot
Heel-strike to foot-flat	17.9%	19.6%	21.1%	44.5%	22.4%
Foot-flat to heel-rise	55.2%	53.6%	50.0%	15.9%	44.0%
Heel-rise to toe-off	26.9%	26.8%	28.9%	39.6%	33.6%

	Normal	SACH foot	Uniaxial foot
Speed of walking (m/s)	1,465 (±0.085)	1,354 (±0.139)	1,360 (±0.095)

Table 5. Temporal parameters of above-knee amputees. Percentage of stance phase.

Temporal components of stance phase	Normal subjects	Above-knee amputees: Contralateral side SACH foot	Above-knee amputees: Contralateral side Uniaxial foot	Above-knee amputees: Prosthetic side SACH foot	Above-knee amputees: Prosthetic side Uniaxial foot
Heel-strike to foot-flat	17.9%	18.8%	18.1%	33.7%	20.4%
Foot-flat to heel-rise	55.2%	51.6%	53.5%	15.6%	36.5%
Heel-rise to toe-off	26.9%	29.6%	28.4%	50.7%	43.1%

	Normal	SACH foot	Uniaxial foot
Speed of walking (m/s)	1,465 (±0.085)	1,043 (±0.062)	1,043 (±0.062)

patterns were also evident in the above-knee amputees (Table 5).

The average speed of walking for the above-knee amputees was the same whether the SACH or uniaxial foot was used. This value is slightly higher than that reported by Murray et al (1980). No other significant differences in the temporal parameters were evident between the SACH and uniaxial foot.

In order to assess the smoothness and aesthetic quality of gait, the trajectories of the joint centres of the lower limb and shoulders were examined. It was thought that the hip and shoulder trajectories might provide useful evaluation criteria. However, comparison of the trajectories obtained with SACH and uniaxial feet showed no significant differences. This was true for both the below-knee and the above-knee amputees.

The ankle angle was found to be significantly different between the SACH and uniaxial foot during early stance phase i.e. the plantar flexion angle of the foot. Doane and Holt (1983) also reported this difference in below-knee amputees. The below and above-knee amputees showed an average difference of 7.5° and 5° respectively. The uniaxial foot in this respect functions in a manner closer to the normal foot than does the SACH foot. Those amputees who preferred the uniaxial foot expressed a liking for this plantar flexion action. One below-knee amputee commented that the uniaxial foot was "much more lively and natural". The average knee flexion angle was also found to be slightly greater during the stance phase for the uniaxial foot. However the difference was insignificant.

The ground reaction forces for below-knee amputees did not show any significant difference in magnitude or pattern when comparison was made between SACH and uniaxial feet, although, as expected, differences between the prosthetic and sound limbs were evident. From the force vector diagrams, shown in Figure 5 (top), the uniaxial foot displayed a slightly more rapid forward change in its point of force application during the mid-stance period than the SACH foot. This occurred during the transitional phase, when the plantar flexion bumper was relieved and initial loading of the dorsiflexion stop took place. The active below-knee amputees were able to use their intact knee to control this event to minimize any abrupt change in load action that might otherwise have occurred. Thus, the forces and moments at the hip, knee and ankle of the prosthetic and contralateral limbs showed no significant difference, whether the prosthesis incorporated the SACH or the uniaxial foot.

The vertical ground reaction force on the prosthetic side for the above-knee amputee showed differences in its loading pattern between the SACH and uniaxial foot. Figure 5, (bottom) shows the typical force vector diagrams. The SACH foot has a two peak loading pattern although the span of forces applied over the second peak is extended. This reflects the rocker-shaped design of the wooden keel in the SACH foot and also the inability of the prosthetic knee to control this event, whereby the amputee rolls over the ball of the foot with the prosthetic knee locked. The smooth "roll-over" can be characterized by the fairly constant forward change in the point of force application.

The uniaxial foot displayed a three-peak loading pattern. The second peak is the result of the rapid forward change of the point of force application during the transitional phase already mentioned above. The prosthetic limb is unable to control this phase well; this causes a rapid increase in the upward acceleration of the body.

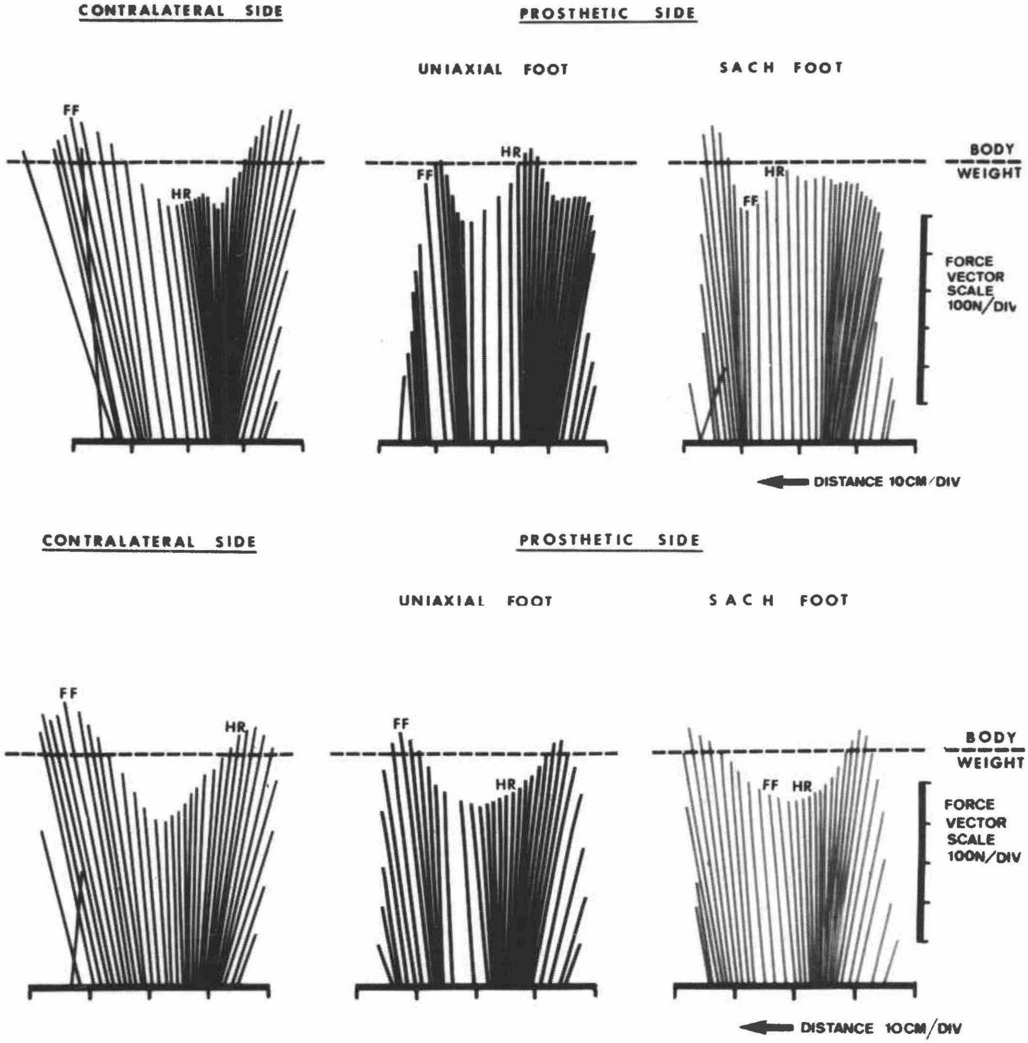


Fig. 5. Top, typical force vector diagrams of below-knee amputee. Bottom, typical force vector diagrams of above-knee amputee.

The third peak represents the initiation of toe-off. The design of the distal section of the uniaxial foot could also have influenced the smoothness of the "roll-over".

These differences in the ground to foot loading pattern and smoothness of "roll-over" obtained between the two designs of feet for above knee amputees were also reported by Fishman et al (1955). Apparently, however, these differences were compensated for by the amputees so that the moments at the hip, knee and ankle showed no significant difference.

Conclusions

Subjective assessment presented no clear trend of preference for either type of prosthetic foot. In general, the amputees showed a preference for the foot to which they were accustomed.

The kinematic analysis showed that considering foot action alone, the uniaxial foot resembles more closely the normal foot in providing plantar flexion in early stance. On the other hand, examination of the ground force actions showed that the SACH foot gives a smoother transition from heel-strike to toe-off. These differences nevertheless did not produce any significant differences in the whole body kinetics.

It can be concluded that with proper selection of heel stiffness and alignment of the prosthesis, both types of prosthetic feet can be made to function so that similar whole body kinetic patterns can be obtained. In this respect, if costs and maintenance requirements are included as factors in prosthetic foot selection, then the SACH foot would be the first choice for the unilateral active below and above-knee amputees.

Amputees, who are "inactive" (i.e. geriatric or enfeebled), might benefit from having early foot flat to provide better support and stability. In this case, the uniaxial foot might be a better choice.

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A 24 year survey of amputees in Hong Kong

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Abstract

A 24–year retrospective study of amputees was conducted at the Prosthetic and Orthotic Unit of the Kowloon Rehabilitation Centre, the first and largest rehabilitation centre in Hong Kong. A review was made of 1821 patients and a rising trend of amputee population was demonstrated probably related to the population growth. The ratio of lower limb to upper limb amputees was 1.83 to 1. The mean age of the amputees was 39 years. The commonest cause of upper limb amputation was trauma (89%) and of lower limb amputation was infection (35%). Vascular diseases were not as common in Chinese as in Caucasian communities. These patterns of amputee population indicate the demand for prosthetic service and provide guide-lines for future development.

Introduction

The total care of an amputee should start before the amputation. There have been extensive studies on the rehabilitation of amputees. The medico-social aspect of the care should be based on accurate epidemiological data of the community, which will provide guide-lines for the planning and implementation of the prosthetic service. Hughes (1983) has emphatically indicated the urgent requirement for a survey of the needs of the prosthetic service in Hong Kong. This survey has been conducted with the intention of serving future planning in the local prosthetic service.

Material and method

A retrospective study was carried out of all the records of the Prosthetic and Orthotic Unit at the Kowloon Rehabilitation Centre. The period of this study was 24 years, from January 1, 1960 to October 30, 1983. Each amputee was counted once at his/her first registration at the centre. The following data were collected and analysed:

Total number of amputees, age, sex, cause of amputation, site and type of amputation. Five periods (one of 4 years and four of 5 years) were considered in the statistical analysis.

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Table 1. Number of amputees attending the KRC Prosthetic Centre in different periods.

Periods	Number	Percentage	Percentage rise
60–63	261	14·33	
64–68	284	15·60	9
69–73	343	18·84	21
74–78	554	30·42	62
79–83	379	20·81	−32
Total	1,821	100.00	

Results

(1) *Number of amputees* (Table 1)

There had been a steady increase in the total number of amputees over the first 18 years. The growth rate had been moderate (<20%) at the start until the "74–78" period when a remarkable 62% increase was recorded. Thereafter there was a sharp decline of 32% in the last 5 years.

(2) *Age*

The mean age of amputees was 39·05, but the distribution ranged from less than 1 year to 89 years of age. Female amputees had a higher mean age (44·74) than males (37·03).

An interesting feature of the mean age distribution (Table 2) was that there was a definite rising trend from 31·79 in the "60–63"

Table 2. Mean age in each period.

	Period					
	60–63	64–68	69–73	74–78	79–83	60–83
Whole group	31·79	36·46	38·16	40·54	44·02	39·05
Male	33·90	35·52	36·13	38·80	39·49	37·03
Female	31·75	39·03	44·03	43·82	53·20	44·74

Table 3. Distribution of age groups.

Age group	60–63	64–68	69–73	74–78	79–83	Total
<20	40	55	72	118	53	338 (19·5%)
21–40	110	106	105	164	116	601 (34·7%)
41–60	70	86	116	148	88	508 (29·3%)
>60	7	23	38	116	101	285 (16·5%)
Total	236	270	331	546	358	1,732

period to 44·02 in the "79–83" period. This trend was more remarkable among the female amputees who had a mean age of 53·20 in the "79–83" period, compared with only 31·75 in the "60–63" period.

When the ages were broken down into 4 specific groups (Table 3), it was evident that the largest number of amputees fell within the 21–40 age group (34·7%) while those between 41–60 formed the second majority group (29·3%). The distribution did, however, change over the period of the survey.

(3) *Sex*

Among the 1821 amputees, there was a strong male preponderance: 1363 male (74·9%), compared with 452 females (24·8%). The overall male to female ratio was 3:1 (ranging from 2·30:1 to 3·83:1 in different periods).

When the specific age groups were analysed with respect to sex distribution, there were several interesting features (Table 4). Among the younger amputees of 21–40, the male to female ratio was almost doubled to 6:1 compared to the overall pattern. On the other hand, there appeared to be a steady increase in the number of female amputees over the age of 61, so much so that among the oldest amputees of "79–83" period, there were more females than males.

Table 4. Male to female ratio in each age group

Age group	Period				
	60–63	64–68	69–73	74–78	79–83
<20	2·27	2·06	4·54	2·81	2·53
21–40	5.88	7·15	7·08	4·66	6·73
41–60	3·38	2·19	3·64	3·00	3·19
>60	6·00	1·30	1·24	1·64	0·68

(4) *Site and type of amputation*

There were 1,178 (65%) lower limb amputees and 641 (35%) upper limb amputees, the ratio being 1·83:1.

The types of amputation are shown in Table 5, the commonest being below-knee amputation (37%), followed by above-knee (16%), below-elbow (15%) and hand amputation (13%).

Table 5. Level of amputation.

	Number	Percentage
Upper limb		
Shoulder disarticulation	15	0·85
Above-elbow	70	3·98
Below-elbow	269	15·30
Through-wrist	32	1·82
Hand	234	13·30
Lower limb		
Hip disarticulation	44	2·50
Above-knee	284	16·30
Through-knee	95	5·40
Below-knee	648	36·90
Syme	28	1·60
Foot	36	2·10
Others	3	0·20

The age distribution of 543 of the upper limb amputees was analysed (Table 6) and 248 patients (45·7%) were found to fall within the 21–40 age group. The commonest varieties were hand amputations and below-elbow amputations.

Table 6. Age distribution of upper limb amputees.

	S/D	A/E	B/E	T/W	Hand	Total
<20	4	11	47	8	78	148 (27·3%)
21–40	7	27	101	13	100	248 (45·7%)
41–60	3	17	58	9	43	130 (23·9%)
>60	0	2	11	1	3	17 (3·1%)
Total	14	56	217	31	224	543

The age distribution of 923 lower limb amputees was analysed (Table 7) and a different picture was revealed. The commonest age group was 41–60 (32·1%), followed by >60 (28·5%) and then 21–40 (24·6%). Below-knee amputation was the commonest variety among the lower

Table 7. Age distribution of lower limb amputees.

	H/D	A/K	T/K	B/K	SY	Foot	Total
<20	17	36	11	63 (50%)	2	8	137 (14·8%)
21–40	13	64	20	109 (48%)	10	11	227 (24·6%)
41–60	7	73	27	182 (61%)	4	3	296 (32·1%)
>60	3	48	22	181 (69%)	5	4	263 (28·5%)
Total	40	221	80	535	21	26	923

Table 8. Side of involvement.

	Upper limb	Lower limb	Total
Left	239	554	793
Right	306	549	855
Bilateral	21	42	63
Total	566	1,145	1,711

limb amputee, the incidence ranged from 48% in the 21–40 age group to 69% in the ›60 age group.

Among the lower limb amputees, there were about equal numbers of left and right involvements. In the upper limb group, however, the right sided variety exceeded slightly that of left side but the difference was statistically insignificant (Table 8).

Altogether 63 bilateral amputees were registered, 3% of the total population in this study. There was an overwhelming male preponderance (81%) within this group of patients, 67% of whom were lower limb and 32% upper limb amputees. Only 1 patient had one upper and one lower limb amputated simultaneously. The common age groups of the bilateral amputees were "21-40" (35%) and "41–60" (22%).

(5) *Causes of amputation* (Table 9)

Trauma was the commonest cause of amputation (42·4%) for the combined upper limb and lower limb groups. The next common varieties were infection (26·4%), and vascular disease and diabetes mellitus 22·8%. In these 2 latter types, there was an overwhelming predilection for the lower limbs (›95%) while trauma was the leading cause of upper limb amputation (89%). Amputation due to vascular disease and diabetes have been increasing steadily over the last 15 years. In the same period there has been a significant increase in the number of older amputees.

Table 9. Cause of amputation.

Cause	Type		Total (%)
	Upper limb	Lower limb	
Congenital	9 (5%)	12 (2%)	21 (2·83)
Traumatic	169 (89%)	145 (26%)	314 (42·4)
Infective	4 (2%)	191 (35%)	195 (26·4)
Neoplastic	6 (3%)	35 (6%)	41 (5·54)
Vascular and diabetic	1 (1%)	168 (31%)	169 (22·8)
Total	189	551	740 (100)

Note: % of ( ) is to the column.

When the causes of amputation were tabulated against the 4 different age groups, specific correlations were obvious (Table 10), 78% of congenital amputees were found among the ‹20 age group; 41% (131) of traumatic amputees were found among the 21–40 age group; 47% (89) of infective amputees were found among the 41–60 age group; 34% (14) of neoplasms in the 21–40 age group; and 60% (104) of vascular and diabetic causes in the over 60 age group.

Table 10. Causes of amputation by age group.

Cause	Age group				Total
	<20	21–40	41–60	>60	
Congenital	18	4	1	0	23
Traumatic	82	131	81	26	320
Infective	16	47	89	37	189
Neoplastic	12	14	8	7	41
Vascular and diabetic	3	18	51	104	176
Total	131	214	230	174	749

Discussion

The Prosthetic and Orthotic Unit in the Kowloon Rehabilitation Centre, Hong Kong, was the first established and the largest of the local limb fitting centres. This 24 year survey demonstrated the need for the development of prosthetic facilities. The steady rise in numbers of amputees in the successive periods identified was explained by the equivalent population growth (Hong Kong Census and Statistical Department 1976). A sharp increase in the "74–78" period was probably related to rapid growth and industralization (Hong Kong Commission for Labour Department, 1976). The subsequent decline in the next period "78–83" was related to the diversion of a significant proportion of the amputee population to a new regional prosthetic and orthotic centre which was developed as part of the regionalization programme in the medical services in Hong Kong.

It is envisaged that there will be significant differences between the population structures in different regions. The present study should therefore be extended to other regional prosthetic and orthotic centres in order to get a panoramic view of the real need for prosthetic services. It is only through comprehensive surveys that reliable statistics may be obtained and hence prospective planning on the provision of facilities and man-power be made meaningful.

The overall ratio of lower limb to upper limb amputees is 1·83 : 1. Among the upper limb amputees, trauma is the single commonest cause (89%) (Table 9). A medico-social study of occupational hand injuries in Hong Kong (Leung and Chan, 1981) indicated that the majority of these injuries were related to occupational hazards. It is therefore not surprising to find in this study that the majority of upper limb amputees are relatively young, 73% of them have ages of below 40, representing the major working force in industry (Table 6). The same reasons might explain the male and right-handed predominance (Table 8).

Among the lower limb amputees, there is a spread of pathological causes and age groups. Infection is the commonest group (35%), followed by vascular disease and diabetes mellitus (31%) and trauma (26%). There is also a relatively even distribution in age groups, 32% for those in the 41–60 group, 28% for the ›60 and 25% for those in the 21–40 group (Table 7). In the early 60's, leprosy was not uncommon in Hong Kong. This might account for a relatively high incidence of infection as a cause of amputation among the lower limb amputees. The problem of diabetes and peripheral vascular disease among the Chinese population seems to be less overwhelming than in most Caucasian communities, which commonly report a 60–70% incidence of vascular disease among lower limb amputees. In the same reports, a greater proportion of lower limb amputees are above 60 years of age (50% to 60%) Kerstein et al, 1975). In the last 5 years in Hong Kong, there has been an observable increase in the number of elderly lower limb amputees, particularly among the females (Table 2). If this pattern continues in the next decade or so, the pattern of amputation among the local Chinese population may resemble more closely that of the Western communities.

Whether this is due to changing life styles of the local population or other reasons may be revealed by further studies. Whatever the cause, the demand for prosthetic service is expected to follow closely the rising incidence of amputation.

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Prosthetics and Orthotics International, 1984, 8, 159–164

Foot loading in amputee stance

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Abstract

A survey has been carried out to establish information on foot loading in amputee stance. The parameters measured are percentage body weight and the positions of the centres of pressure under each foot.

The data was collected in a clinical environment by the use of a Double Video Forceplate (DVF), a tool developed at the Bioengineering Centre. The objective of the survey is to provide background information for the use of the DVF in static alignment of lower-limb prostheses.

Results are presented from a number of patients attending the Roehampton Walking Training School, and for a small group of patients attending the Bioengineering Centre for delivery of an experimental below-knee prosthesis. Scattergrams and averaged results provide normative data which can assist in interpretation of DVF displays during individual alignment.

Introduction

The pattern of foot loading under a lower limb prosthesis will in most cases reflect features of the alignment of the limb components. Based on this premise, a clinical tool has been designed to aid static alignment by rapid collection and display of foot loading parameters during stance at the time of fitting of a prosthesis (Smith et al, 1983; Smith and Lord, in press). A background of comparative data is required to interpret the significance of individual loading patterns seen in clinical assessments, and it is to provide such information that this study was initiated.

In symmetrical rest stance of a normal subject, the loads on each foot are dictated by anatomy, posture and balance. The loading under the feet of a lower-limb amputee is determined also by constraints imposed by amputation and fitting of a prosthesis. There has been to date little study of foot loading of the amputee in stance and its dependence on prosthetic considerations.

Ground loading can be expressed in terms of the foot-to-floor reaction force occurring at the support surface. For the whole body, the origin of the reaction force at the support surface is commonly defined as the Centre of Foot Pressure (CFP). The CFP corresponds to the projection of the body's Centre of Gravity onto the support surface averaged over a period of several seconds standing. The location of the CFP with respect to the foot positioning has been the subject of limited study. Carlsoo (1972) describes the location of the CFP by reference to a vertical line passing through the body's centre of gravity, stating that this "line of gravity passes 2–5 cm ahead of the movement axis of the talo-crural joint, which itself passes through the lower tip of the lateral malleolus". Hellebrandt et al, (1938) found the average location of the line of gravity to fall 50.8 mm in front of the ankle joint, but noted a wide range in this parameter.

In prosthetics, the location of the centre of pressure for an individual foot is of relevance, indicating the line of the limb loading at the foot. This line may be strongly influenced by the alignment of the prosthetic limb components. No studies have been identified that quantify the location of the centre of pressure for each foot individually (referred to hereafter as the ICFP). If it is reasonable to assume that a normal subject can stand symmetrically on request, the position of the ICFP under the left foot will be a mirror image of that for the right foot; then it can be deduced that the anteroposterior location of both ICFPs are the same as that of the CFP. However for amputees or other subjects with disabilities of the spine or lower limbs, the stance cannot be assumed to be symmetrical.

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There have been many studies of the small movements of the CFP occurring in the support plane during postural sway (Thomas and Whitney, 1959, De Wit, 1972) which have been analysed as indicators of disturbed postural balance (Njiokiktjien et al, 1978). It is widely reported that for normal adult subjects standing still for periods of less than a few minutes, sway movements of the CFP are confined within a few tens of millimetres of the mean position. The majority of the power is in the bandwidth of 0.1 to 10Hz, and therefore a mean location of the CFP can be described by averaging over ten seconds or more.

In the amputee population, it is anticipated that a greater variation in the anteroposterior location of the ICFP will be seen, dependent on the type of limb, level of amputation, hip complications, residual anatomy and muscle function. It might be anticipated, for example, that the meean location of the ICFP under a prosthesis with a patellar-tendon-bearing socket will be anterior to that expected in the normal subject, reflecting the anterior placement of the load at the knee. Conversely, the ICFP may be abnormally posterior under the prosthetic limb on an ischially-seated above-knee amputee. The ICFP on a remaining natural limb may be shifted in a compensatory response. However these variations should correspond to physical factors within a consistent framework of alignment and prosthetic fitting.

For amputees the magnitude of the limb load on the amputated side may not reach 50%. It is predictable that the natural limb should be favoured in the majority of cases where there are no severe complications of the remaining natural limb. However, failure to place a reasonable load through the prosthetic limb may reflect an undue lack of confidence, a short prosthetic limb, pain (stump, knee or hip) or some alignment factor. Data on magnitude of load may establish criteria for satisfactory weightbearing on the prosthesis.

In this study, the locations of the CFP, ICFPs and magnitude of load were recorded. The range and variability of loading parameters for the lower limb amputee are investigated, with an attempt to seek consistent trends.

Methods

Technique

A research prototype of a DVF (Double Video Forceplate) was used to assess groups of amputee patients and non-amputee subjects. The DVF consists of a pedestal with a separate forceplate for each foot, an output display for monitoring, a printer and a controlling microprocessor (Fig. 1). An additional facility of this device permits the projection of the reaction force line against the limb in the lateral view, although this was not explored in this study. Each patient was asked to stand in his customary footwear on the pedestal, which places the feet in a known orientation by reference to medial and rear guides (Fig. 2). The guides place the subject's feet with heel midpoints approximately

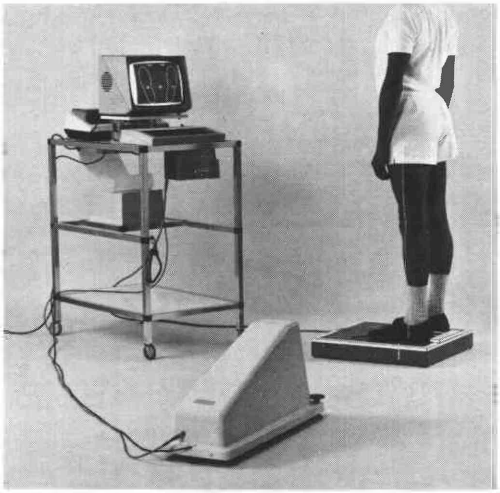

Fig. 1. The DVF equipment. A facility to project a laser line against the lateral aspect of the limb (shown in the foregound) was not used in this study.

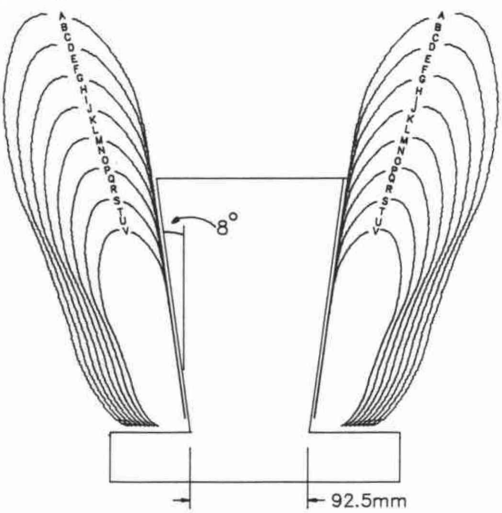

Fig. 2. Foot placement markings on the DVF pedestal.

150 mm apart and with 30° included angle between their midlines (bisectors of the angle between the medial and lateral tangents to the shoe outline). The foot outline corresponding most closely to the patient's shoe was selected by its letter code, and this size of outline is used subsequently for display and printout.

The patient was asked to stand as evenly as possible for 15 seconds, after which a printout of the time-averaged loading was produced (Fig. 3). During the recording period, the patient could not see the screen display of loading. Care was taken to ensure that the patient remained facing squarely forward without visual distractions.

The DVF is a live interactive device and on occasions the patients were asked to transfer load fore and aft or from the inside to outside border of the foot with reference to the screen display. This enabled the range of motion of the ICFPs to be observed. The ICFP positions can be determined from the DVF printouts to an accuracy of ±7, mm, and the weight distribution determined to within 1% for adult subjects.

Patients

Two groups of patients have been studied. One group comprised all A/K and B/K patients attending the Walking Training School at the Roehampton Limb Fitting Centre during a fixed period, who did not have prosthetic or medical complications. Data was collected by a physiotherapist collaborating on this project. The age range of the patients is not available.

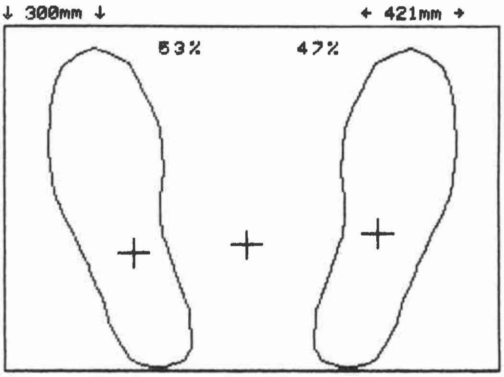

Fig. 3. A typical printout from the DVF, showing the loading pattern averaged over 15 seconds. Crosses indicate ICFPs and CFP, and the figures indicate the percentage weightbearing on the left and right foot respectively. The dimensions within arrows indicate the dimensions of the box drawn around the foot outlines. The DVF screen display is similar to the printout, but gives instantanous results.

The second group consisted of patients attending the Bioengineering Centre for fitting of an experimental vacuum formed thermoplastic socket PTB limb (Davies and Russell, 1979). These limbs were all similar, and fitted by the same prosthetist. The data was recorded at final fitting prior to delivery, either by the prosthetist or researcher. The age range of the patients was 20–78: mean age 47.

Non-amputee comparison

A group of non-amputee asymptomatic subjects was also studied. This data was collected in the same location, by the same researcher following the same procedure as with the second group of amputees. (Age range 16–72: mean age 42).

Analysis

From the DVF printouts, the position of the ICFP under each foot was measured in terms of its percentage length and width in the anteroposterior and mediolateral directions respectively (Fig. 4). A statistical investigation of CFP and ICFP positions indicated that representation of the range of distribution of the group averages by a standard deviation would not be meaningful because of the apparent non-Gaussian nature of the distribution and small sample sizes. Therefore the results for sample groups are presented visually in the

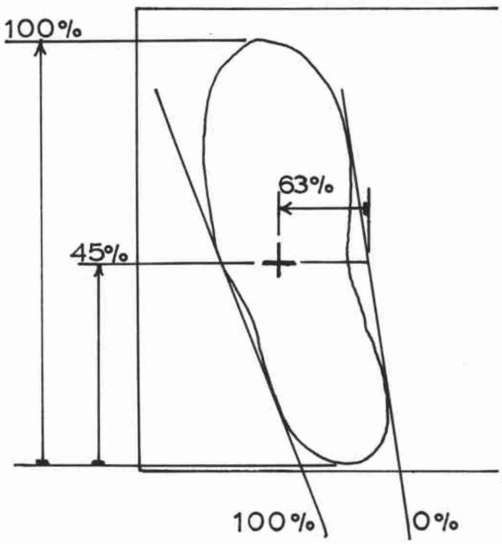

Fig. 4. Conversion of ICFP position to percentage length and width points. Construction for the right foot is a mirror image of that shown for the left foot.

unprocessed form of scattergrams. Each scattergram comprises the overlaid printouts for the individuals in the group, normalized for foot size. The numerical data represents group averages of mean ICFP positions and magnitude of limb load.

Results

Reproducibility of results from any one individual on repeated testing is obviously an issue to consider. In previous tests, 14 healthy young men were recorded on the DVF sequentially in shoes, barefoot, barefoot and in shoes (Smith and Lord, in press). The difference in position of the ICFPs between the first and last shod test was less than 20 mm in the anteroposterior direction in all cases. This represents approximately 7% of the average male shoe length. Preliminary tests repeated during a session with a few volunteer amputees indicated that a similar reproducibility of anteroposterior ICFP location could be expected. The other measures were similarly repeatable to better than 7%.

Scattergrams of the normal population are shown in Figure 5. On average, the weight bearing is close to the expected 50% on each limb. ICFPs lie in the range of 32% to 51% of shoe length in the anteroposterior direction and 34% to 63% of shoe width in the mediolateral direction. In contrast, the loading of the above-knee amputees (Fig. 6, top) is approximately 40% of body weight on the prosthesis, and the range of locations of the ICFPs under the prosthetic foot are from 23% to 71% anteroposteriorly, and 37% to 58% mediolaterally. Results of below-knee amputees from the second group of patients are also presented (Fig. 6, bottom), showing a similar pattern of decreased loading and increased scatter of ICFP locations under the prosthetic foot.

The locations of the ICFPs averaged by group are shown in Table 1, further grouped by

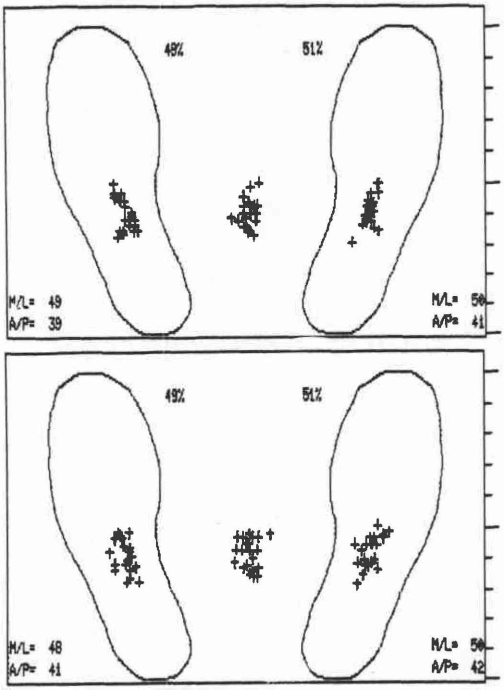

Fig. 5. Scattergrams of 42 non-amputee subjects, split randomly into two groups for clarity. For scattergrams the individual data is first normalized as shown in Figure 4, and then superimposed on a standard size footprint. The figures in the lower left and right hand corners are the average percentage positions of the left and right foot ICFPs.

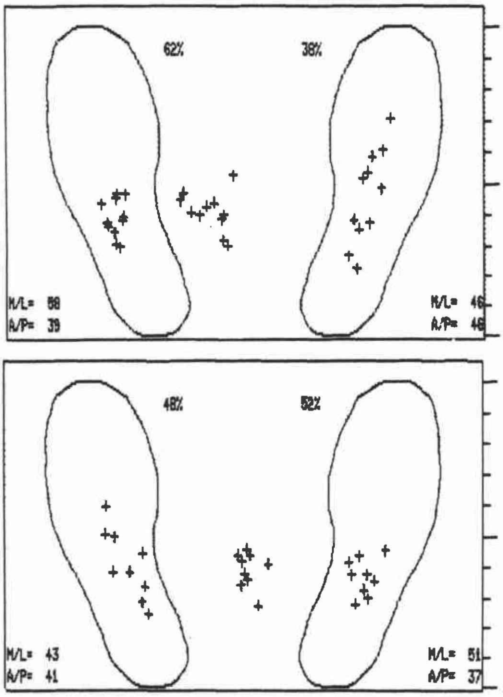

Fig. 6. Top, scattergram from 11 right above-knee amputees, wearing a variety of different limbs. Bottom, scattergram from 9 left below-knee amputees, wearing PTB prostheses with polypropylene sockets.

Table 1. Group averages of ICFP positions, expressed as a percentage of foot length and width. For amputees, the figures are given for left amputees, with those for right amputees in brackets. For the non- amputees the figures are averages for right and left natural limbs.

		Walking Training School A/K	Walking Training School B/K	Bioeng. Centre B/K	Non-amp. group
		n=12 (11)	10 (14)	9 (6)	42
Anteroposterior ICFP position (% from rear)	Prosthesis	36% (46%)	48% (45%)	41% (42%)	
	Natural limb	44% (39%)	37% (36%)	37% (33%)	41%
Mediolateral ICFP position (% from medial)	Prosthesis	46% (46%)	39% (42%)	43% (39%)	
	Natural limb	52% (58%)	54% (51%)	51% (51%)	49%

amputation level and side where relevant. Overall the measures vary considerably between the groups and for left and right amputees. Two points worthy of note are the anterior placement of the ICFP on the prosthetic side compared to the remaining natural limb for all B/K patients; and the medial location of the ICFP under all the prostheses with a lateral shift out on the natural side, compared to the non-amputee group.

Discussion

The study revealed some trends in the loading patterns of amputees although the results show a great deal of variability. The latter could be a reflection of the variability of the physiological condition of the patients, and the range of different prostheses worn by the various patients. However, it may reflect the fact that static alignment is not well standardized.

A constraint imposed by the DVF is the placement of the feet in standardized locations. The orientation shown in Figure 2 was tested for suitability for amputee use at the Walking Training School at the Roehampton Limb Fitting Centre. The stance was sometimes not the one that the amputee would normally assume in the rest position but was reported to be comfortable, except for bilateral amputees who needed a wider base of stance. Standardization of foot position has the advantage of removing one of the variables affecting standing balance, and aids comparisons between repeated measures on the same patient or between the individual and normative data.

The screen display and printouts refer to a standard foot outline, which is only matched in length to the patient's footwear. The position of the foot within the shoe is not estimated in any way, and variability in the toe space in different styles of shoes undoubtedly leads to ambiguity in the relation of the foot anatomy to the shoe outline. This is especially true in the case of high-heeled shoes, but these were not too common in the amputee population.

Repeated measures on a sample of both amputee and normal subjects have shown that reasonable repeatability of results can be expected provided that posture was controlled. Important points were voluntary maintenance of a constant pelvic orientation and head forward position.

Inspection of the individual results did not show any obvious correlations between the positions of the ICFPs and the type of limb worn. For example, above-knee patients with ischial seating sockets produced both the most anterior and posterior of the ICFP locations. It was suspected, but could not be proved within this study, that the anteriorly placed ICFPs were to be found on patients who made little use of the ischial seating. Further study on larger groups of patients is needed to correlate ICFP positions with such factors of socket fit, alignment, stump flexion etc.

It was found useful to express the location of the ICFP in terms of the percentage of foot length and width, in order to facilitate comparisons of patients with different foot sizes. As a result of the system adopted (Fig. 4) and the foot placement in toe-out, a saggital movement of the ICFP would lead to changes in both the percentage of foot length and width. Voluntary gross forward sway was typically accompanied by a reduction in percentage foot width position of the ICFP i.e. the ICFP moved medially.

Conclusion

Normative data on foot loading has been collected from amputees and normal subjects, and this has allowed differences between the two groups to be established. The chief findings are that amputees favour their natural limb with approximately 60% of bodyweight, and that the load is placed medially on the prosthesis with a compensatory lateral shift on the natural foot. Of particular significance is the large scatter in the anteroposterior location of ICFPs for amputees, which did not correlate clearly with the type of prosthesis and socket. It is possible that this variability was due in part to variations in the alignment of the limbs.

Whether static alignment expressed in terms of these foot loading parameters is of clinical significance is a question beyond the scope of this normative study, and remains to be established.

Acknowledgement

The Physiotherapy staff of the Roehampton Walking Training School, under the supervision of C. Van De Venn, collected patient data and participated in discussions of protocol and interpretation of the results. This collaboration is financially supported by a DHSS contract awarded to Queen Mary's Hospital.

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Prosthetics and Orthotics International, 1984, 8, 165

Technical note

Orthosis for barefoot walking

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National Institute of Prosthetic and Orthotic Training, Orissa, India

Introduction

Most lower limb orthoses cannot be used without footwear. Occasionally, barefoot walking by patients fitted with orthoses may be necessary due to economic circumstances, to satisfy the dictates of religion, or for other reasons, such as the discomfort of conventional footwear in hot and humid climates.

Invariably a boot or shoe is the foundation for an orthosis, with a stirrup riveted directly to the sole of the shoe under the anterior section of the heel. If the shoe with the stirrup is detached from the orthosis, the biomechanical function of the brace ankle joint is lost and relative movement between the brace and body takes place. Hence if a patient fitted with a lower limb orthosis desires to walk barefooted, certain modifications are necessary in the ankle-foot section of the orthosis.

In the system described below the sole of the foot on the orthotic side is bare under the heel and forefoot with a support only under the arch. This ensures a level pelvis in barefoot standing.

The orthosis

Instead of a shoe, a moulded arch support covering the longitudinal and transverse arches of the foot of the patient is substituted as a foundation. This support can be fabricated out of polyproplyene or epoxy/polyester resin fibreglass laminate. The vertical pieces of a split stirrup are incorporated in this arch support and the free ends of the stirrup are connected to the ankle joint of the orthosis. The stirrup is selected to match the ankle joint for the biomechanical function required. It is aligned to coincide with the anatomical ankle joint and obliquely set to the apex of the longitudinal arch on the medial side. The lateral stirrup piece is set parallel to the medial piece and both pieces are fixed on the arch support by riveting. The arch support is attached to the foot by D rings and Velcro fasteners.

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The orthosis with the arch support system can be used with or without footwear (Fig. 1, left) or this system can be detached and replaced by a shoe and stirrup system as an interchangeable plan (Fig. 1, centre).

For patients with drop foot, a monobar ankle-foot-orthosis with an arch support substitute system can be used (Fig. 1, right).

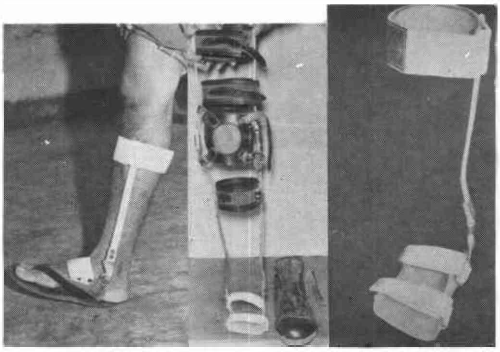

Fig. 1 Left, arch support system. Centre, arch support may be detached and replaced by shoe and stirrup system. Right, monobar AFO with arch support for drop foot.

Results

Paraplegics fitted with modified orthosis gave the following feedback on the advantages of the device.

(a) It is light and comfortable when compared to the shoe stirrup system.

(b) The device is easy to put on and take off (Donning and taking off shoes is more cumbersome).

(c) It is easier to walk because of the weight reduction.

Book Review

Cash's Textbook of Orthopaedics and Rheumatology for Physiotherapists.
Patricia A. Downie, editor.
Faber and Faber Limited, 3 Queen Square, London WC1N 3AU.
638p. £7.95.

Two of the most respected comprehensive textbooks for physiotherapists were *Cash's Textbook of Medical Conditions for Physiotherapists*, published in 1951 and *Cash's Textbook of Physiotherapy in Some Surgical Conditions*, published in 1955. This new book brings together in revised form the orthopaedic, fracture and rheumatology sections of the original volumes and consists of twenty eight chapters contributed by nineteen authors. Brian T. O'Connor, Robert Jones Professor of Orthopaedics at the Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, provides a brief introduction.

Of particular interest is the discussion of the mechanics of lower limb orthoses by engineer John Stallard. Orthopaedic surgeon, Gordon Rose, reviews gait biomechanics, but includes neither normal angles in the kinematic section nor the phasic action of specific muscles in the kinetics discussion. P. B. Butler, a physiotherapist, recommends video recordings to aid observational gait analysis. In his footwear chapter, Mr. Rose shows representative intrinsic and extrinsic modifications. He and therapist J. A. Bentley review functional anatomy basic to foot pathology and prescribe for juvenile and adult flat foot.

Orthopaedic surgeon, G. A. Evans and therapist V. Draycott advise the Pavlik hip harness and the Scottish Rite Perthes' brace. Therapist P. M. Wood recommends that therapists supply temporary collars and corsets. Corsets receive brief mention by Miss Wood and rheumatologist A. G. Mowat in their survey of degenerative spinal arthritis and intervertebral disc disease and by therapist E. Goss in the chapter on spinal surgery. Orthopaedic surgeon, J. P. O'Brien and Mrs. Draycott outline scoliosis management with the Milwaukee brace, including exercises within it. Following surgery to correct kyphosis, they advocate a well-fitting, but undefined, brace. Postoperative spondylolisthesis care involves a plaster jacket.

Plaster splintage to prevent arthritic deformities and corrective serial splints is noted by rheumatologist D. J. Ward and therapist M. E. Tidswell. They prescribe orthoses, especially for haemophilia and following hand surgery, but discourage supports for ankylosing spondylitis and omit shoe modifications for gout. Although warning that the arthritic balance rest with exercise, they neglect orthoses, except a shoe raise, cane and the telescopic knee support. Of various procedures described by orthopaedic surgeon G. T. Benke, the Girdlestone arthroplasty requires either a weight-relieving orthosis or a shoe raise. Physiotherapy following joint replacement, discussed by Miss Bentley, lacks orthoses, except slings and appliances after silastic metacarpophalangeal implant.

E. R. S. Ross, an orthopaedic surgeon, provides an especially pertinent overview of fracture management, including thermoplastic functional bracing. Mr. Ross and therapist C. E. Apperley chart common fractures, showing usual age of occurrence, how injury occurs, when movement is begun, complications and results. Therapist J. A. Fowler claims that splinting benefits severe injuries, bursitis and tenosynovitis. Concluding the text, therapist S. H. McLaren outlines advanced rehabilitation following trauma and describes "maxercises" (maximum physical and mental exercise combined with an element of fun). End features are a brief random bibliography, a list of organizations and an index.

While directed at physiotherapists, others in rehabilitation will find *Cash's Textbook* useful, even though orthoses receive scant emphasis. However, the generously illustrated, encyclopaedic coverage of skeletal and articular disorders makes this a volume to be recommended.

Joan E. Edelstein,
Senior Research Scientist.
New York University,
Post-Graduate Medical School.

Prosthetics and Orthotics International, 1984, 8, 167–172

Calendar of events

National Centre for Training and Education in Prosthetics and Orthotics
Short-Term Courses and Seminars 1984

Seminars

NC709 Amputation Surgery and Prosthetics—for Vascular Surgeons; 1 February, 1985.
NC706 Wheelchairs; 18–19 March, 1985.
NC707 Clothing for the Disabled (In conjunction with SCD) Dates: To be announced.
NC708 Footwear for the Disabled (In conjunction with SCD); 11 February, 1985.
NC710 Incontinence; 3 May, 1985.

Courses for Physicians, Surgeons and Therapists

NC505 Lower Limb Prosthetics; 14–18 January, 1985.
NC502 Upper Limb Prosthetics and Orthotics; 21–25 January, 1985.
NC507 Amputation Surgery and Pre- and Post-Operative Care for Physicians and Surgeons; 11–12 February, 1985.
NC509 Spinal Orthotics; 4–5 March, 1985.
NC501 Functional Electrical Stimulation (Peroneal Brace); 11–14 March, 1985.
NC506 Fracture Bracing; 1–4 April, 1985.

Course for Prosthetists

NC205 Above-Knee Prosthetics; 18 February—1 March, 1985.

Course for Orthotists

NC207 Spinal Orthotics, 28 January–8 February, 1985.

Course for Orthotics Technicians

NC604 7 January—5 April, 1985.
Module 1 Footwear; 7–25 January, 1985.
Module 2 Conventional Metal/Leather Orthoses; 28 January—1 March, 1985.
Module 3 Plastic Orthoses; 4 March—5 April, 1985.

Further information may be obtained by contacting Prof. J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, Curran Building, 131 St. James' Road, Glasgow G4 0LS, Scotland. Tel: 041–552 4400 ext. 3298.

North Western University Medical School
Short Term Courses
Courses for Physicians, Surgeons and Therapists

602–D, 603–D Lower and Upper-Limb Prosthetics; 4–8 March, 1985.
702–B, 703–B Spinal, Lower and Upper-Limb Orthotics; 22–26 April, 1985.

Courses for Physicians and Surgeons

603–C Lower and Upper Limb Prosthetics; 10–14 December, 1984.
603–E Lower and Upper-Limb Prosthetics; 8–12 April, 1985.
613–A Lower and Upper-Limb Prosthetics for the Adult and Juvenile Amputee.

Courses for Therapists

622–A Lower-Limb Prosthetics; 14–18 January, 1985.
652 Upper-Limb Prosthetics and Orthotics; 11–15 February, 1985.
622–B Lower-Limb Prosthetics; 29 April–3 May, 1985.

Courses for Prosthetists

651–A The Scandinavian Flexible Socket; 29–30 May, 1985.
612–A "The Wu Technique" for Pre-Prosthetic Management of the Below-Knee Amputee, 29 May–1 June, 1985.

Course for Rehabilitation Personnel

640–B Orientation in Prosthetics and Orthotics; 18–20 March.

Course for Pedorthists and Orthodists

801–A Pedorthic Management of the Foot; 3–7 June, 1985.

Applications for admission and requests for further information should be addressed to Charles M. Fryer, Director Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

New York University Medical School

Short Term Courses

Courses for Physicians and Surgeons

741–B Lower-Limb Prosthetics; 4–8 March, 1985.
741–C Lower-Limb Prosthetics; 6–10 May, 1985.
744–A Upper-Limb Prosthetics and Orthotics; 3–7 June, 1985.
751–B Lower-Limb and Spinal Orthotics; 18–22 March, 1985.
751–C Lower-Limb and Spinal Orthotics; 20–24 May, 1985.
759–B Prosthetics and Orthotics Update; 1–2 April, 1985.
754–B Foot Orthotics; 18–19 April, 1985.

Courses for Therapists

742–B Lower-Limb Prosthetics; 25 February–1 March, 1985.
742–C Lower-Limb Prosthetics; 29 April–3 May, 1985.
745–A Upper-Limb Prosthetics and Orthotics; 3–7 June, 1985.
752–C Lower-Limb and Spinal Orthotics; 20–24 May, 1985.
759–A Prosthetics and Orthotics Update; 13–14 December, 1984.
759–B Prosthetics and Orthotics Update; 1–2 April, 1985.
754–A Foot Orthotics; 10–11 December, 1984.
754–B Foot Orthotics; 18–19 April, 1985.

Courses for Prosthetists and Orthotists

759–B Prosthetics and Orthotics Update; 1–2 April, 1985.
7431 B The ISNY Flexible Socket System; 10–11 January, 1985.
743 1C The ISNY Flexible Socket System; 13–14 June, 1985.

Requests for further information should be addressed to Professor Sidney Fishman, Prosthetics and Orthotics, New York University Post-Graduate Medical School, 317 East 34th Street, New York, N.Y. 10016.

1985
"REHA-Aids for the Handicapped, 3rd International Fair and Forum", Düsseldorf, postponed from 1984.
Information: NOWEA, Düsseldorfer Messegesellschaft mbH. Postfach 320203 Stockumer Kirchstrabe 61 4000 Düsseldorf 30, Germany.

24–29 January, 1985
American Academy of Orthopaedic Surgeons Annual Meeting, Las Vegas, NV.
Information: AAOS, 444 N. Michigan Avenue, Chicago, IL 60611, USA.

30 January–3 February, 1985
Academy Annual Meeting and Scientific Seminar, San Francisco, California.
Information: The American Orthotic and Prosthetic Association, 717 Pendleton St., Alexandria.

21–23 February, 1985
Common Operative Problems in Children's Orthopaedics, Santa Monica, CA.
Information: AAOS, 444 N. Michigan Avenue, Chicago, IL 60611.

March, 1985
Sports—Special Olympics International, Utah.
Information: Special Olympics, Inc., 1701 K. Street, N.W., Washington, 20005, U.S.A.

28–29 March, 1985
International Society for Prosthetics and Orthotics, United Kingdom, Scientific Meeting, University of Warwick.
Information: Mr. R. L. Nelham, Secretary ISPO, Scientific Sub-Committee, Rehabilitation Engineering Unit, Chailey Heritage Hospital, Lewes, Sussex BN8 4EF.

15–19 April, 1985
AOTA's Annual Conference Atlanta, Georgia.
Information: The American Occupational Therapy Association, Inc., 1383 Piccard Drive, Rockville, Maryland 20850.

17–19 April, 1985
British Orthopaedic Association: Spring Meeting, Llandudno, Wales.
Information: Honorary Secretary, 35–43 Lincoln's Inn Fields, London WC2A 3PN.

18–20 April, 1985
AOPA Region IV Annual Meeting, Wilmington, North Carolina.
Information: Academy National Headquarters, AAOP, 717 Pendleton Street, Alexandria, VA 22314.

2–4 May, 1985
AOPA Region V Annual Meeting, Cleveland, Ohio.
Information: Academy National Headquarters, AAOP, 717 Pendleton Street, Alexandria, VA 22314.

8–11 May, 1985
3rd International Exhibition for Technical Aids for Rehabilitation with Workshop-Seminars "Rehabilitation stage '85", Germany.
Information: Borgmann GmbH, Hohe Strasse 39, D–4600 Dortmund 1, Fed. Rep. of Germany.

10–12 May, 1985
Rehabilitation Gazette's third international post-polio conference.
Information: Gini Laurie, Gazette International Networking Institute, 4502 Maryland Avenue, St. Louis, Missouri 63108.

15–18 May, 1985
Paediatric Orthopaedic Society Annual meeting, San Antonio, TX.
Information: 7950 Floyd Curl Drive, San Antonio, TX 78229,

19–25 May, 1985
XVI International Congress of Rheumatology, Sydney, Australia.
Information: The Secretariat, XVI International Congress of Rheumatology, GPO Box 2609, Sydney, NSW, Australia 2001.

4–8 June, 1985
Trade Fair and Congress—Orthopädie & Reha-Technik' 85 International.
Information: COC Kangressorganisation GmbH, Kongress-Zentrale, Wilhelm Syborg, Büro Rhein-Main, Postfach 696, Berliner Strasse 175, D–6050 Offenbach.

7–9 June, 1985
AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting.
Information: Academy National Headquarters, AAOP, 717 Pendleton Street, Alexandria, VA 22314.

9–13 June, 1985
American Orthopaedic Association, San Diego, CA.
Information: AOA, 444 N. Michigan Avenue, Chicago, IL 60611.

15–20 June, 1985
X International Congress of Biomechanics, Umea, Sweden.
Information: Professor Roland Örtengren, Division of Industrial Ergonomics, Linköping University, S–581 83 Linköping, Sweden.

24–28 June, 1985
RESNA '85, 8th Annual Conference on Rehabilitation Technology, Tennessee.
Information: RESNA, Suite 402, 4405 East West Highway, Bethesda, Maryland 20814 U.S.A.

30 June–5 July, 1985
International Symposium on Youth and Disability, Israel.
Information: The Secretariat, Youth and Disability Symposium, P. O. Box 394, Tel. Aviv 61003, Israel.

1–5 July, 1985
International Conference and Advanced Course on Amputation Surgery and Lower Limb Prosthetics, Dundee.
Information: Secretariat Dundee '85, Tayside Rehabilitation Engineering Service, Dundee Limb Fitting Centre, 133 Queen Street, Broughty Ferry, Dundee DD5 1AG, Scotland.

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

August, 1985
Health Care Expo '85
Information: Steven K. Herlitz, Inc., 404 Park Avenue South, New York, New York 10016.

11–16 August, 1985
XIV International Conference on Medical and Biological Engineering and VII International Conference on Medical Physics, Helsinki.
Information: Mr. Hannu Seitsonen, XIV ICMBE/VII I CMP. Secretary General, P.O. Box 105, 00251 Helsinki, Finland.

September or October, 1985
5th World Congress of the International Rehabilitation Medicine Association, Sydney, Australia.
Information: Prof. G. G. Burniston, Australian Association of Physical Rehabilitation Medicine, Prince Henry Hospital, Little Bay, 2036 Australia.

September, 1985
Scoliosis Research Society, San Diego, CA.
Information: SRS 444 N. Michigan Avenue, Chicago, IL 60611.

11–13 September, 1985
Fifth Annual Advanced Course in Lower Extremity Prosthetics, New York.
Information: Lawrence W. Friedman, M.D. Chairman, Dept. of Physical Medicine and Rehabilitation, Nassau County Medical Center, 2201 Hempstead Turnpike, East Meadow, New York.

16–18 September, 1985
8th International Congress of the Mediterranean and Middle Eastern Orthopaedic Surgery and Traumatology Society, France.
Information: Prof. J. G. Pous, C. H. U. Saint Charles, F–34059 Montpellier Cedex (France).

18–20 September, 1985
British Orthopaedic Association: Autumn Meeting, Leeds/Harrogate.
Information: Honorary Secretary, 35–43 Lincoln's Inn Fields, London WC2A 3PN.

2–6 October, 1985
Limb salvage in musculoskeletal oncology Orlando, Florida, U.S.A.
Information: W. F. Enneking, M. D., Box J–246, University of Florida, Health Centre, Gainesville, Florida 32610, U.S.A.

8–10 October, 1985
Melecon '85. Mediterranean Electrotechnical Conference, Madrid.
Information: Prof. A. Luque, Melecon '85, Instituto de Energia Solar, E.T.S.I. Telecomunicación, UPM, Ciudad Universitaria, Madrid–3, Spain.

15–21 October, 1985
AOPA International Assembly, Miami Beach, Florida.
Information: AOPA National Assembly, 717 Pendleton Street, Alexandria, Virginia 22314 U.S.A.

24–29 November, 1985
The 8th Congress Western Pacific Orthopaedic Association, Bangkok.
Information: Organizing Committee, G.P.O. Box 2708, Bangkok 10500, Thailand.

1986
Rehabilitation International 8th Asia and Pacific Regional Conference, New Delhi, India.
Information: Rehabilitation Coordination-India, P.O. Box 1496, Bombay, 400 001 India.

25 February, 1986
American Academy of Orthopaedic Surgeons Annual Meeting New Orleans, L.A.
Information: AAOS, 444 N. Michigan Avenue, Chicago, IL 60611, USA.

23–26 June, 1986
American Orthopaedic Association Annual Meeting Hot Springs, Va.
Information: AAOS, 444 N. Michigan Avenue, Chicago, IL 60611, USA.

29 June–5 July, 1986
ISPO 5th World Congress, Copenhagen.
Information: ISPO Secretariat, Borgervaengt 5,2100 Copenhagen Ø Denmark.

September, 1986
Scoliosis Research Society Annual Meeting, Bermuda, West Indies.
Information: SRS, 444 N. Michigan Avenue, Chicago, IL 60611, USA.

1988
16th World Congress of Rehabilitation International, Tokyo.
Information: Secretary General, 16th World Congress of Rehabilitation International, The Japanese Society for Rehabilitation of the Disabled, 13–15, 3–chome Higashi, Ikebukuro, Toshima-ku, Tokyo 170, Japan.

Prosthetics and Orthotics International, 1984, 8, 173–175

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Subject Index

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Bonar Hall, University of Dundee
1st–5th July, 1985

PROGRAMME

Sunday, 30th June, 1985
14.00–20.00 REGISTRATION IN WEST PARK HALL OF RESIDENCE

Monday 1st July, 1985
8.30 REGISTRATION IN BONAR HALL

10.00 Introduction	J. J. REID, Chief Medical Officer, Scottish Home & Health Department.
Epidemiology of amputation, causal conditions, levels and limiting factors	B. EBSKOV, Charlottenlund, Denmark.
Level assessment	V. SPENCE, Dundee, U.K.
Pre-operative and post-operative care, stump environment	I. M. TROUP, Dundee, U.K.
Principles of prosthetic fitting including biomechanics, socket alignment, components	C. H. PRITHAM, Louisville, Kentucky, U.S.A.
The Below-Knee Amputation	
Surgery, including levels, alternative techniques, growth period	E. M. BURGESS, Seattle, Washington, U.S.A.
Biomechanics, socket design, suspension and variants	J. HUGHES, Glasgow U.K. J. S. TAYLOR, Glasgow U.K.
Ankle/foot devices	D. N. CONDIE, Dundee, U.K.
Prescription principles including "early" and temporary prostheses	J. C. ANGEL, Stanmore, U.K.
Physiotherapy and the amputee including walking training	M. E. CONDIE, Glasgow, U.K.

WELCOME RECEPTION

Tuesday, 2nd July, 1985

Syme's Amputation	
9.00 Surgery with variants including growth period	S. SAWAMURA, Kobe, Japan.
Biomechanics, socket design, feet	C. H. PRITHAM.
The Partial Foot Amputations	
Surgery and level considerations	R. BAUMGARTNER, Zurich, Switzerland.
Biomechanics, prosthetic and orthotic solutions	D. N. CONDIE M. L. STILLS, Dallas, Texas, U.S.A.
Prosthetic Technology	
Shape, measurement and replication	J. FOORT, Vancouver, Canada.
Materials and manufacturing processes	R. M. DAVIES, London, U.K.
Alignment and gait optimization	M. SALEH, Sheffield, U.K.
Prosthetic technology; the patient, industry and government	B. KLASSON, Stockholm, Sweden.
Cosmesis	R. M. KENEDI, Glasgow, U.K.
Role of the consumer in prosthetics	P. H. DIXON, Chadwell Heath, U.K.
Cultural considerations	S. HEIM, Moshi, Tanzania.
Standards in Prosthetics	
Physical testing	J. J. SHORTER, Basingstoke, U.K.
Terminology and classification	D. N. CONDIE
Reporting the surgical experience	M. WALL, Uppsala, Sweden.
Role of government in prosthetic supply	G. ROBERTSON, Edinburgh, U.K.
Evaluation	A. B. WILSON, Jr., Charlottesville, Virginia, U.S.A.

Education

Education and training in prosthetics	S. FISHMAN, New York, U.S.A.
Education and training in developing countries	S. HEIM.

CIVIC RECEPTION

Wednesday, 3rd July, 1985

Congenital Limb Deficiency

9.00 Classification	H. J. B. DAY, Manchester, U.K.
Role of surgery; the leg	L. M. KRUGER, Springfield, Massachusetts, U.S.A.
The Van Ess procedure	R. GILLESPIE, Toronto, Canada.
Role of surgery, the arm	D. W. LAMB, Edinburgh, U.K.
Prosthetics in congenital limb deficiency	D. S. CHILDRESS, Chicago, Illinois, U.S.A.
Total management	E. MARQUARDT, Heidelberg, F.R.G.

AVIEMORE SAFARI

Thursday, 4th July, 1985

The Above-Knee Amputation

9.00 Surgery	G. NEFF, Tubingen, F.R.G.
Biomechanics	N. A. JACOBS, Glasgow, U.K.
Socket design	H. PFAU, Berlin
Flexible socket	O. KRISTINSSON, Reykjavik, Iceland.
Components	K. OBERG, Jonkoping, Sweden
Prescription criteria, fitting, check-out procedures and walking training	R. G. REDHEAD, London, U.K.

The Through-Knee Amputation

Surgery, including transcondylar and supracondylar procedures	J. STEEN JENSEN, Copenhagen, Denmark.
Biomechanics, socket design, alignment requirements	P. BOTTA, Biel-Bienne, Switzerland.
The Knee Unit Dilemma	E. LYQUIST, Copenhagen, Denmark.

Biological Mechanisms as Potential Sources of Feedback, Control and their possible Applications — D. S. CHILDRESS

CONFERENCE DINNER

Friday, 5th July, 1985

The Hindquarter Amputation and Hip Disarticulation

9.00 Tumour pathology, chemotherapy, radiotherapy and surgical options	D. L. HAMBLEN, Glasgow, U.K.
Factors in the planning of wide excision of tumours	R. S. SNEATH, Birmingham, U.K.
An experience with Interferon	U. NILSONNE, Stockholm, Sweden.
Biomechanical considerations following excision of malignant tumours in hip and pelvis	J. P. PAUL, Glasgow, U.K.
Design of prosthetic implants	J. T. SCALES, Stanmore, U.K.
Biomechanics, socket design, available components and external prosthetic design	A. W. McQUIRK, London, U.K.
Gait training	M. E. CONDIE
Experiences in prosthetic fitting following hip disarticulation, hemipelvectomy and hemicorporectomy	H. SCHMIDL, Bologna, Italy.

The Dundee Experience 1965–1985 — G. MURDOCH, Dundee, Scotland.

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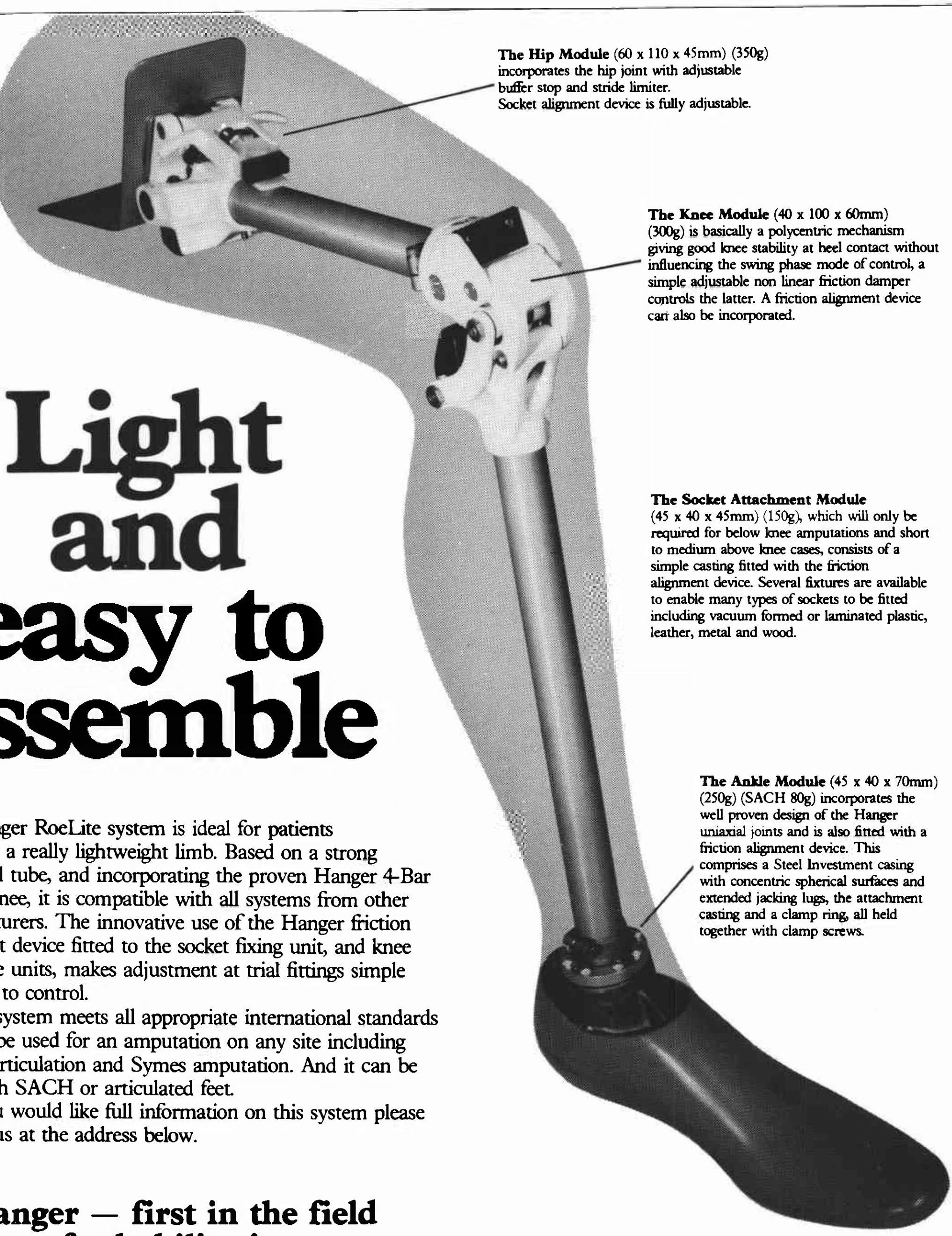
Further enquiries to Dr. I. M. Troup, Secretary General, Dundee '85, Limb Fitting Centre, 133 Queen Street, Broughty Ferry, Dundee DD5 1AG.



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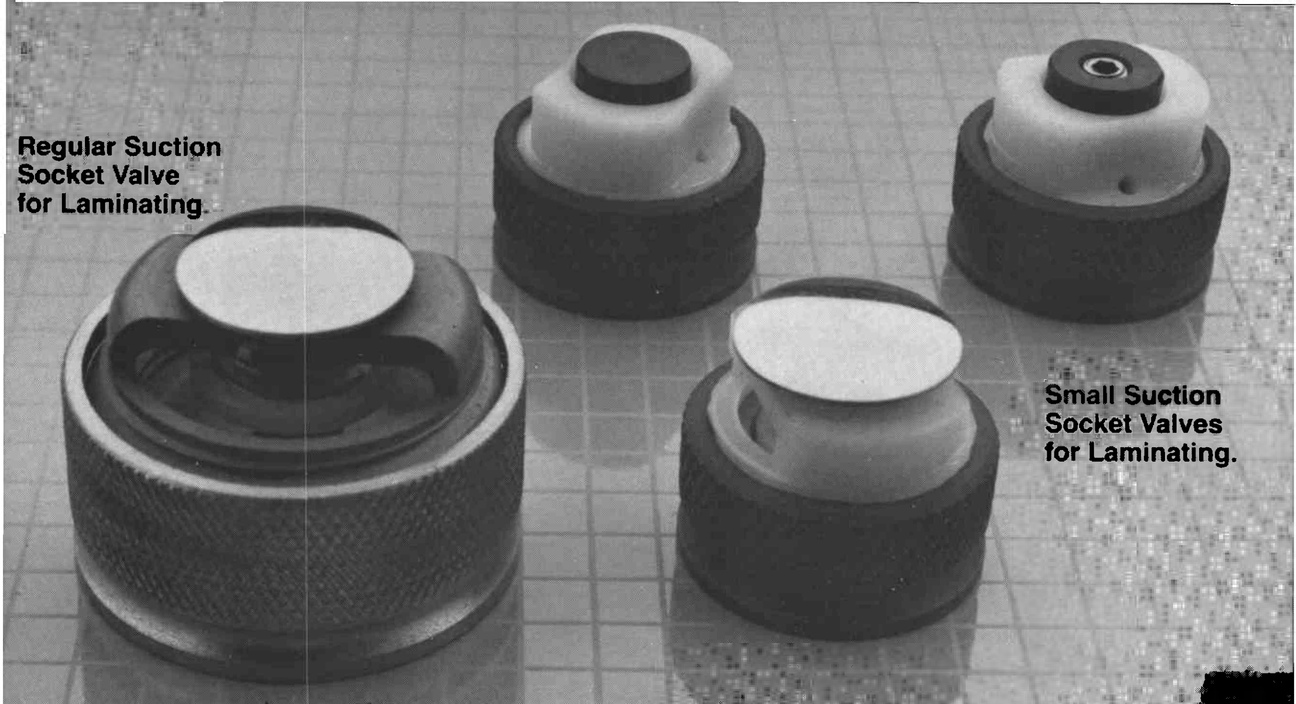

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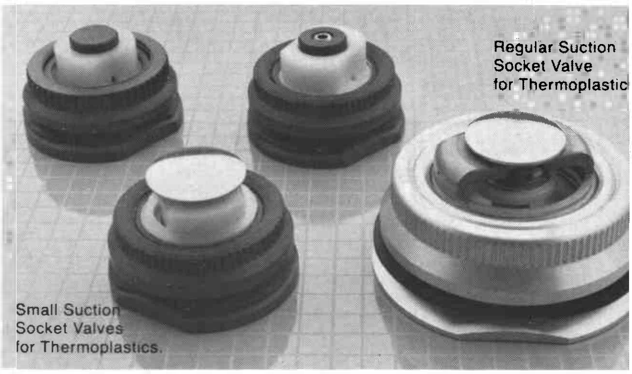

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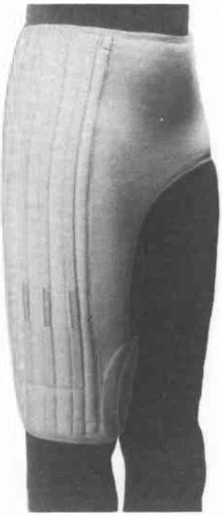

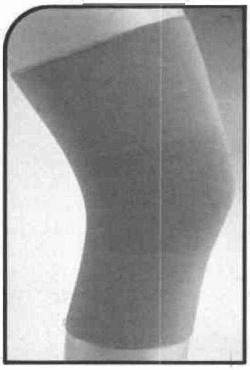

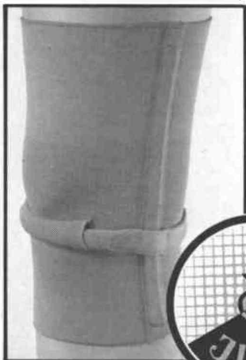

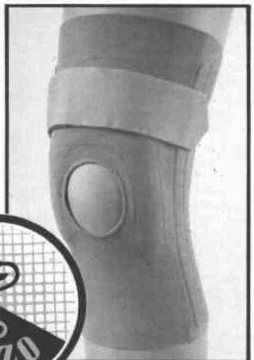

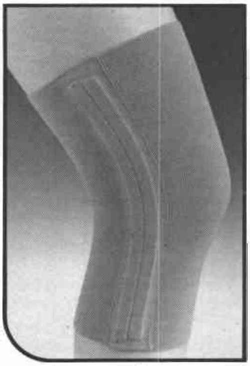

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Information for Contributors

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References

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Reference to an article in a journal

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

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

Reference to a contribution in a book

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

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

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