Prosthetics and Orthotics International, 1983, 7, 17–24

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

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Abstract

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

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

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

Introduction

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

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

Material and methods

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

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Clinical Standard of Measurement and Classification of Amputation Stumps

ISPO 1982

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

Name and address of patient:

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

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

Date of amputation
....

Basic Parameters of Stumps

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

} Inspection

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

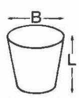
} Palpation

Side:
☐ Rt ☐ Lt

Mark level of amputation on figure:

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

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



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

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

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

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

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

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

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

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

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

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

12. *Date and signature:*

....

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

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

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

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

Results

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

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

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

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

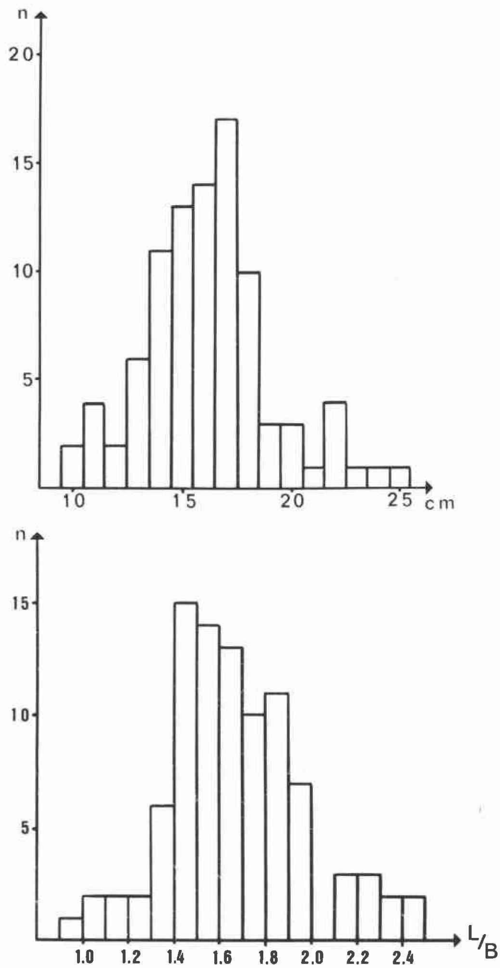


Fig. 2. Top, length of below-knee stumps. Bottom, proportional length of below-knee stumps.

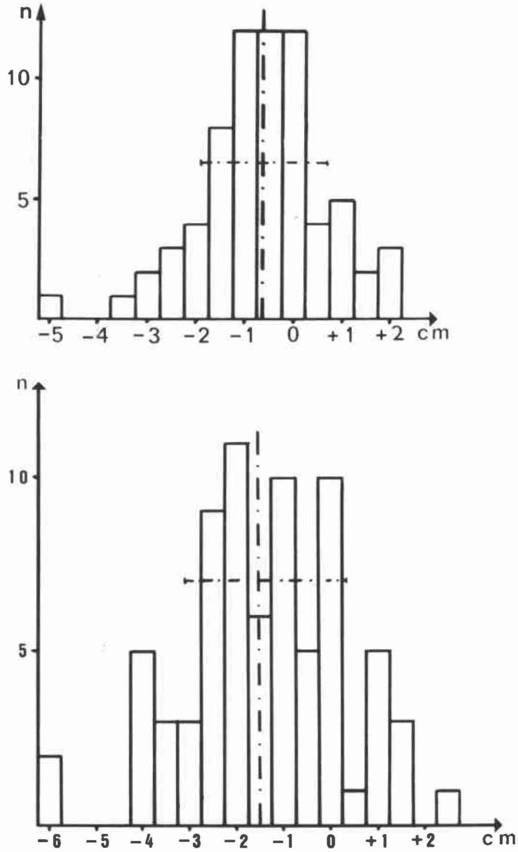


Fig. 3. Top, change of proximal circumference between 2 and 3 weeks in below-knee stumps. Bottom, change in proximal circumference between 2 and 12 weeks in below-knee stumps. Dotted cross indicates mean value and standard deviation.

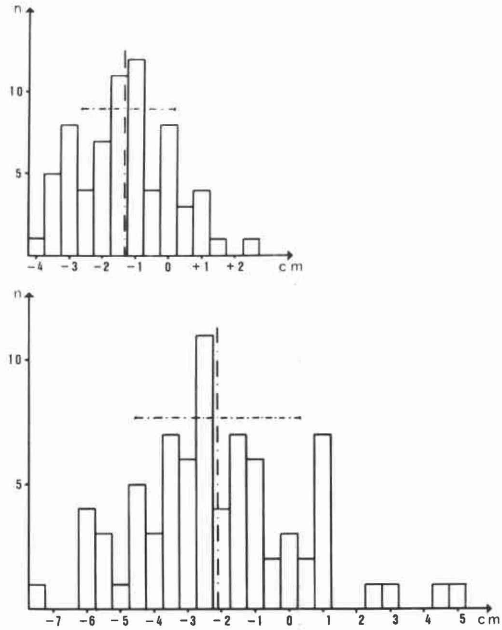


Fig. 4. Top, change in distal circumference between 2 and 3 weeks in below-knee stumps. Bottom, change in distal circumference between 2 and 12 weeks in below-knee stumps. Dotted cross indicates mean value and standard deviation.

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

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

In part two the result of using the ISPO classification form showed that some classifications are totally dependent upon level. Of the lower limb stumps created by joint

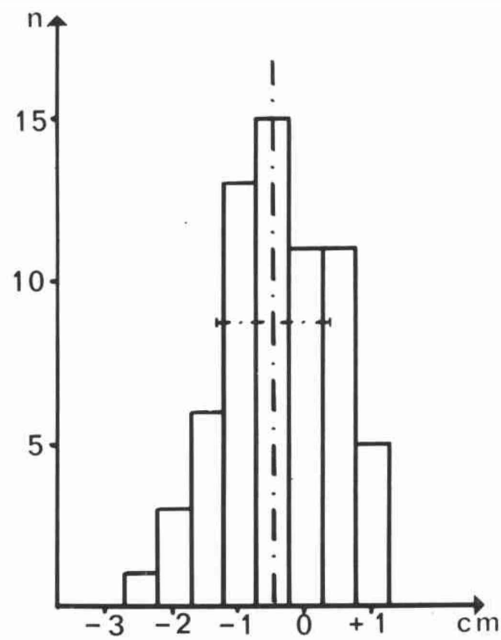


Fig. 5. Change in measured length of below-knee stumps between 2 and 12 weeks. Dotted cross indicates mean value and standard deviation.

disarticulation, for instance, all five were long and club-shaped with insignificant stump pain and phantom pain. Only the below-knee level, however, contained enough patients to make statistical analysis reasonable, 116 of all 135 measurements were below-knee, 12 in above-knee and the residual 7 in disarticulations at hip, knee and ankle levels. Eighty-two per cent of the patients had been amputated for arterial occlusive disease with or without diabetes.

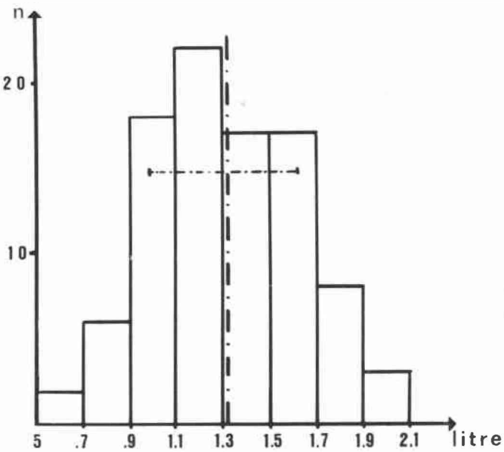


Fig. 6. Arbitrary volume of calculated cut cone representing below-knee stump volumes.

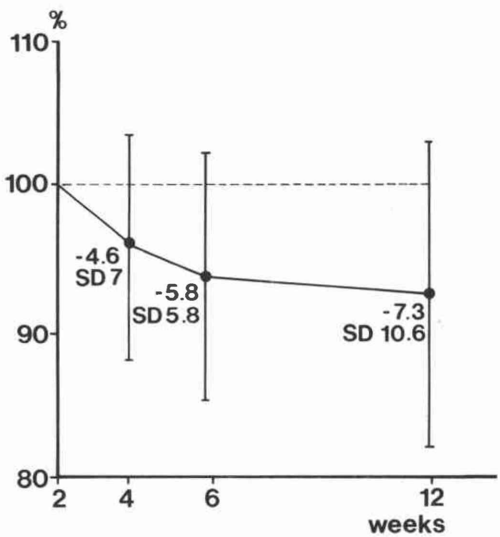


Fig. 7. Change in calculated below-knee stump volumes between 2 and 12 weeks. Mean values and standard deviations.

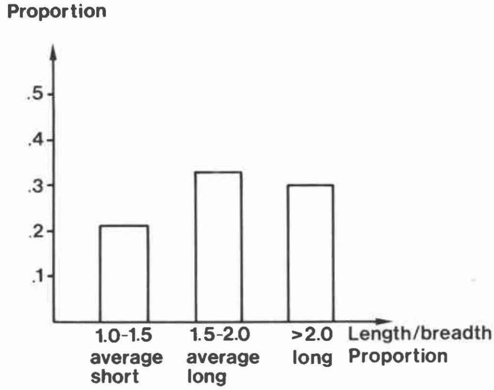


Fig. 8. Proportion of unhealed wounds of below-knee stumps in three groups of proportional length.

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

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

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

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

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

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

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

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

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

Discussion

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

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

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

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

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

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

Acknowledgements

The authors wish to thank Landstingets Inköpscentral and Malmöhus Läns Landsting for financial support.

REFERENCES

BAUMGARTNER, R., LANGLOTZ, M. (1980). Amputee stump radiology. *Prosthet. Orthot. Int.*, **4**, 97–100.

BURGESS, E. M., ROMANO, R. L., ZETTL, J. H., SCHROCK, R. B. (1971). Amputations of the leg for peripheral vascular insufficiency. *J. Bone Joint Surg.*, **53-A**, 874–889.

ERIKSSON, U. (1965). Circulation in traumatic amputation stumps: an angiographical and physiological investigation. *Acta Radiol. Suppl.*, **238**.

FISHMAN, S., BERGHOLTZ, S. G., DOLAN, C. M. E. (1971). Stump-socket models study. New York University Post-Graduate Medical School, Prosthetics and Orthotics, New York.

GOLBRANSON, S., KOSTA, C., WEBER, E., WIRTA, R. (1980). A preliminary study of volume changes in post-operative below-knee amputation stumps. In: *Abstracts of the ISPO 3rd World Congress*, Bologna, 58.

GOLDIE, I., EEG-OLOFSSON, T., RENSTRÖM, P., ELIASSON, T. (1976). A new leg-prosthesis socket. (letter) *Lancet*, **1**, 1224.

GREVSTEN, S., STÅLBERG, E. (1975). Electromyographic study of muscular activity in the amputation stump while walking with PTB and PTB-suction prosthesis. *Upsala Journal of Medical Science*, **80**, 103–112.

HANSSON, J. (1964). The leg amputee. *Acta Orthop. Scand. Suppl.*, 69.

HÜBNER, K. H., AHLEMANN, L. M., WEISE, K. (1981). Computer-tomographische Untersuchungen an Beinamputierten. *Z. Orthop.*, **119**, 336–339.

ISHERWOOD, P. A., ROBERTSON, J. C., ROSSI, A. (1975). Pressure measurements beneath below-knee amputation stump bandages: elastic bandaging, the Puddifoot dressing and a pneumatic bandaging technique compared. *Br. J. Surg.*, **62**, 982–986.

JAMES, U., ÖBERG, K. (1973). Prosthetic gait pattern in unilateral above-knee amputees. *Scand. J. Rehabili. Med.*, **5**, 35–50.

LEVY, S. W. (1980). Skin problems of the leg amputee. *Prosthet. Orthot. Int.*, **4**, 37–44.

MURDOCH, G. (1975). Research and development within surgical amputee management. *Acta Orthop. Scand.*, **46**, 526–547.

PERSSON, B. M. (1974). Sagittal incision for below-knee amputation in ischaemic gangrene. *J. Bone Joint Surg.*, **65B**, 110–114.

PERSSON, B. M., BRUNK, B. (1974). Rehabilitation of lower limb amputees in Sweden. In: *Proceedings of the World Conference for Physical Therapy, Montreal*, 376–381.

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

STAROS, A. (1963). Dynamic alignment of artificial legs with the adjustable coupling. *Artif. Limbs*, **7(1)**, 31–43.

WEISS, S. A., FISHMAN, S., KRAUSE, F. (1971). A psychological test battery for predicting success in prosthetic rehabilitation. New York University, New York Medical Center, New York.