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**WORLD HEALTH ORGANIZATION
TECHNICAL REPORT SERIES**

No. 100

AMPUTEES AND PROSTHESES

Report of a Conference on Prosthetics

Copenhagen, 23-28 August 1954

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WORLD HEALTH ORGANIZATION

PALAIS DES NATIONS

GENEVA

NOVEMBER 1955

CONFERENCE ON PROSTHETICS

Copenhagen, 23-28 August 1954

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PRINTED IN SWITZERLAND

AMPUTEES AND PROSTHESES

Report of a Conference on Prosthetics

Copenhagen, 23-28 August 1954

A conference on prosthetics, convened by the Director-General of the World Health Organization,¹ met from 23 to 28 August 1954 at the WHO Tuberculosis Research Office, Copenhagen. The United Nations, the International Society for the Welfare of Cripples, and the World Veterans Federation also participated. The representative of the Director-General of the World Health Organization, Dr T. S. Sze, opened the Conference and welcomed the participants. Dr Henry H. Kessler was elected Chairman, Sir Harry Platt Vice-Chairman, and Dr G. Harlem Rapporteur. The provisional agenda was adopted.

INTRODUCTION

The problem of the amputee has been recognized as one of world-wide import involving social, economic, industrial, and psychological problems which affect many more people than those actually suffering amputation. All nations are involved—some more than others—and all seek information, guidance, and advice. It is necessary that the methods which have been or could be evolved for the prevention of amputation and the reduction of disability resulting therefrom through proper rehabilitation should be known.

The terms of reference of the Conference were to consider the problem of the amputee with special reference to prosthetic appliances.

1. INCIDENCE, CAUSATION, AND PREVENTION OF AMPUTATION

Incidence and statistics

In general, it was felt that statistics in this respect are inadequate. The need for obtaining statistics is twofold: first, to enable those intending to organize a limb service to have knowledge of the extent of the problem

¹ Provision for a conference on prosthetic appliances was made in the proposed programme and budget for 1954 (see *Off. Rec. Wld Hlth Org.* 1952, 44, 81), approved by the Sixth World Health Assembly (Resolution WHA6.26, *Off. Rec. Wld Hlth Org.* 1953, 48, 26).

which they have to face, though lack of such statistics need not prevent the provision of a limb service being commenced; and, secondly, to provide knowledge of the causes of amputation with a view to implementing measures of prevention and to emphasizing the economic importance of systematic prevention.

Available statistics show that the number of amputees in certain Western countries varies between 0.5% and 1.25% of the population. An idea of the extent of the problem of the civilian amputee may be gained from the following figures: during the Second World War, approximately 20 000 persons suffered amputation in the Armed Services of the USA, and 120 000 civilians lost their limbs from accident and disease during the same period.

It was agreed that one of the methods of obtaining statistical information should be the formation of some central body in each country which could collect the necessary figures from the various organizations concerned with the supply of prostheses, such as the Armed Services; the ministries of social affairs, veterans, and health; State industrial organizations; insurance societies; welfare and benevolent organizations, and limb-makers' trade associations. It necessarily follows that statistics should be obtainable in those countries in which there are already one or more limb-fitting centres.

At present, it would seem from the information provided by the participants that satisfactory statistical information is rarely available from hospitals. It was suggested that all hospitals should be asked to supply information on amputations in the same manner as that already adopted by many for cancer and other specified diseases. The minimum information required at this stage from the hospitals would be confined to the numbers and levels of amputation.

Causation

It was generally agreed that amputations of the upper extremity resulted to a greater extent from accidental causes than from disease, whereas amputations of the lower extremity resulted in some countries more largely from disease. Preliminary analysis of records giving the causes and circumstances leading to amputation in the United Kingdom showed that, among accidental causes, those due to traffic accidents were responsible for a high proportion of lower-extremity amputations, whereas industrial accidents caused a majority of the upper-extremity amputations. Almost similar circumstances obtained in Ceylon.

Of the causes of lower-extremity amputations from disease, a relatively high proportion was accounted for by cardiovascular disorders, at any rate in the Western countries. It would seem that this could partially be explained by the gradually increasing expectancy of life in these countries.

The incidence of amputations due to congenital malformations, especially with respect to the upper extremity, was noted, but no general comparison could be made. (For more detailed analysis of available statistics, see Annex 1, page 28.)

The Conference felt that these preliminary studies could only serve as an indication of the importance of the problem. It was agreed that a need exists for more careful statistical studies into the causes and circumstances leading to amputations rendered necessary both by disease and by accidents. This information, when available, will no doubt assist in establishing means of prevention and in demonstrating to society as a whole the value of such measures.

Prevention

It was agreed that many amputations were preventable, but the Conference felt that it should not enter into detailed discussions upon this matter. It considered that prevention could be effected by the provision of antibiotics, blood transfusion, and adequate transport facilities for the injured, which make it possible to resort to more conservative surgical techniques. It emphasized the need for the provision of safety precautions and safety education in all circumstances, particularly in industrial establishments. The need for more safety education in the schools to render children more safety-conscious was also stressed. The more widespread development of industrial-accident insurance systems which increase the insurance premiums for the employer who neglects to make provision for the systematic prevention of accidents within his organization was also considered an important preventive measure.

2. BASIC PRINCIPLES AND PRACTICES FOR THE REHABILITATION OF THE AMPUTEE

Participants were unanimous in their recognition of the importance of team work and the need for the closest co-operation between the many individuals concerned with the total rehabilitation of the amputee. They emphasized that rehabilitation does not merely consist in the supply of an artificial limb but involves surgery, psychological preparation and follow-up, physical after-treatment, the careful selection and prescription of the most suitable prosthesis for the individual, its fitting and final approval, followed by adequate training in its use, and follow-up. Emphasis was laid on the importance of vocational guidance and training for those unable to return to their occupations, together with correct selective placement.

A. Medical Aspects

Surgical treatment

Optimum stump lengths

It became clear that the physical differences between the larger-boned people of the West and the typically smaller-boned people of the East must be recognized and taken into account in considering the optimum length of the stump.

With regard to the West, the report of the Working Party on Artificial Limbs of the Brussels Treaty Organization, which met in Utrecht in 1953 and at which five nations were represented, was considered; it had expressed broad agreement with the British practice of having 10-12 inches (25-30 cm) above-knee stumps (measured from the top of the great trochanter), 5½ inches (14 cm) below-knee stumps (measured from the inner edge of the tibial plateau), 8 inches (20 cm) upper-arm stumps (measured from the top of the acromion process), and 7 inches (18 cm) below-elbow stumps (measured from the tip of the olecranon). The Conference considered these recommendations too rigid and drew attention to more functional methods of stump-length determination.

For instance, the method employed in Germany and the USA of calculating stump length as a percentage of the total length, thereby making it applicable to any size or age of amputee, has much to recommend it.

In smaller-boned people, where the orthodox stump lengths were inevitably too long, limbs could advantageously be measured from the distal joint, in order to ensure adequate room for the fitting of the necessary mechanical joint at a symmetrical level.

Some participants felt that amputation, with the exception of that below the knee, should generally be carried out as distally as possible in order to give better leverage when a prosthesis is fitted on. It was, however, pointed out that in cold climates long stumps, especially in below-knee and below-elbow amputations, are liable to circulatory difficulties. It was also recognized that, even if it is possible to make satisfactory prostheses for stumps amputated just above the wrist, ankle, or knee joints, such prostheses are usually not easily available in most countries at the present time.

The Conference therefore felt that no general recommendation could be given for the optimum stump length and recommended that further study be made into this problem, taking into account all relevant factors, especially the anatomy and physiology of the stump in relation to climate, occupation, and prosthetic technicalities.

Special amputations

Amputations through the wrist, formerly condemned, are now returning to favour in several countries. Recent American, British, and German experience has shown the practicability of fitting a cuff which gives a secure forearm grip and yet allows active pronation and supination. The hand or hook is incorporated into the cuff, maintaining normal length. Alternatively, the conventional disconnecting mechanism can be recessed into the hand to ensure that the total length of the prosthesis shall not exceed that of the natural forearm and hand. Very short below-elbow stumps can be fitted with useful functional limbs of special types.

Through-hip amputations are undesirable but may be inevitable in cases of malignant tumours above the knee level. Through-knee disarticulations are particularly useful for elderly persons, because the amputation is rapid, the shock is less, the muscle and fascial sheaths are not disturbed, and the crucial anastomosis is not interfered with. End-bearing is a most satisfactory method of weight-bearing for such a stump, and no such stumps have been found to deteriorate. Furthermore, disarticulation is also favoured for young children and adolescents in order to preserve the growing epiphysis. The artificial limb for such an amputation has been unpopular among limb-makers, but a satisfactory prosthesis can be fitted.

At the ankle the Syme amputation is regaining popularity.

The Pirogoff amputation has been found serviceable in Germany, where it is considered essential that the weight-bearing soft tissues of the heel must lie axially. Secondary deformity is prevented by arthrodesis between the calcaneus and tibia. Chopart's amputation, if performed, should have a similar weight-bearing end, and deformity is prevented by a subtalar arthrodesis. These amputations do not, however, meet with general favour.

Amputation techniques

Guillotine amputations in general are to be condemned but may be unavoidable in exceptional emergencies, e.g., when life is at stake. A second amputation is usually needed. Nerve trunks should be cleanly divided without traction, crushing, or infiltration. In the majority of countries, muscle is divided at the same level as the bone. Deep fascia should be carefully sutured in an envelope around the stump. Subcutaneous fat, carrying blood-vessels to the flap, should be preserved.

German practice has, however, returned to the old custom of suturing muscles and deep fascia around bone and of forming slings comprising antagonistic muscle groups. It is claimed that this prevents muscle atrophy

and allows active muscle contractions, which are important in suction-socket or adherency prostheses. Excessive muscle bulk should always be avoided, and in below-knee amputations it may be an advantage to excise the soleus muscle.

Cineplasty and the Krukenberg operation

These operations continue to be carried out in a few countries. Cineplasty by the pectoral tunnel method for short upper-arm stumps or shoulder disarticulations and biceps tunnel for below-elbow stumps have proved advantageous in selected cases. The Krukenberg stump is unsightly but it has advantages, especially for the blind. A prosthesis is not necessary; good power, functional activity, and sensation can be retained under conditions in which a prosthesis would rapidly deteriorate. Such a stump is, however, not acceptable to many patients on aesthetic grounds.

Post-amputation treatment

Great emphasis was laid upon the importance of combined psychological and physical treatment of the patient who, through amputation, has suffered severe mental and physical trauma. The provision of the most highly developed prosthesis cannot compensate for the lack of psychological readjustment. It was, however, emphasized that, whenever possible, the psychological approach should be made to the patient prior to amputation.

Psychological

The psychological readjustment of the amputee is not, however, confined solely to him but concerns his relatives, his friends, and the general public. In many areas the public attitude towards the amputee increases the difficulties of readapting him as a member of the community. Such traditional attitudes, based on prejudice and lack of information, must be fought by education and propaganda, by films and publications. It is appreciated that several societies and organizations are active in this field.

An amputation is inevitably a trauma, physical and mental. The psychological disturbance can, however, be reduced by the right approach to the amputee, i.e., adequate information must be provided and confidence in the medical staff must be established.

Although the physician is responsible for the psychological preparation and treatment, the whole staff, including nurses and physiotherapists, must be instructed in the right handling of these problems.

The mental trauma connected with the amputation has a complex basis of which each component should be considered :

- (1) The loss of a major part of the body, inducing a feeling of inferiority and dependency in the patient, and fear of the opinion of his family, friends, and community.
- (2) The loss of functions and abilities (for example, the ability to walk, to dress, and to write).
- (3) Fear and doubt in the patient concerning his ability to be completely rehabilitated.
- (4) Loss by the patient of his previous economic standing and security.

As regards the possibility of limb-fitting, rehabilitation, and ultimate economic security, informing the amputee on these matters is considered the best preparation and treatment.

Several ways have been found to yield good results. In prosthetic centres, the example of other amputees already at a more advanced stage of rehabilitation is most convincing. Intelligent amputees may be an outstanding help to the medical staff, explaining possibilities and instructing the new amputee in all the common problems. Several participants reported that inexpensive home-made films have been found successful.

In hospitals where the staff are working along these lines and where the different stages of rehabilitation are combined in a logical plan, the services of a psychiatrist are seldom required.

The psychological problem of parents of a child amputee does not greatly differ from that caused by other disabilities in childhood (e.g., poliomyelitis or cerebral palsy). The parents may suffer from a guilt complex feeling that congenital malformations may have been inflicted as a penalty for some previous sin. Accidental amputations may, rightly or wrongly, be ascribed to carelessness of either the mother or the father. The parents may consider the child amputee weak, over-protecting it and thus increasing future difficulties. At the other extreme, they may reject the child. They may also fear that subsequent children may have a similar congenital disability.

The scientific facts should be explained to the parents in order to help them overcome any guilt complex. They should be taught how to behave towards the child. By the parents' avoiding both over-protection and rejection, the child will be taught to become independent.

Physical

Correct post-surgical physical treatment is considered essential. The purpose of the physical treatment is :

- (1) to make the stump fit for a prosthesis in the shortest time ;

- (2) to improve circulation and restore the muscle power ;
- (3) to improve the general physical condition of the patient ;
- (4) to preserve and train the functional abilities of the stump.

Measures recommended are :

- (1) correct bandaging of the stump after removal of the sutures ;
- (2) active exercises of the stump with increasing controlled resistance after removal of the sutures ;
- (3) general muscle training and joint mobilization ;
- (4) early balance exercises, etc., for leg amputees, writing exercises for arm amputees ; simple temporary appliances may be used in this phase.
- (5) prevention or treatment of joint contractures—an important problem.

Contractures are frequently developed before amputation, especially in vascular diseases in the legs. The whole staff must be aware that the right posture of the patient and of the stump is important. A contracture may develop quickly. Surgical techniques may temporarily increase the tendency to contracture by suturing certain muscle groups too tightly (e.g., the hip flexors). Prolonged sitting has frequently resulted in flexion contracture. The use of pillows to support stumps after amputation is strongly condemned.

After-care is concerned not only with the patient's stump, but also with his general condition. This is especially true of patients suffering from diabetes, Buerger's disease, arteriosclerosis, or malignancy. Any general constitutional disease should be kept as fully under control as possible. Only if the above are carried out will the patient be physically and mentally fit to withstand the stresses and strains of wearing an artificial limb.

Selection, prescription, and fitting of the prosthesis

In contrast to the old established practices of direct reference of the patient after the amputation by the surgeon to the limb-maker, the Conference agreed that the artificial limb should be prescribed by a physician with special training, generally in consultation with a team of other specialists, if available.

The types and varieties of artificial limbs are many. Any of these varieties will suit some patients, but no one variety will suit all ; the types differ in material, design, method of fitting, and method of suspension and control.¹ A basic knowledge of all these types and their functional

¹ For more detailed discussions in this connexion, see Annex 2 (page 34).

value is essential. An incorrect selection will militate against the patient's subsequent rehabilitation.

The fitting of the artificial limb is of the utmost importance. Bad fitting alone may undermine the patient's rehabilitation. Great responsibility is thus thrown upon the limb-fitter, who requires long training and experience. It was felt by the participants that research into the problem of fitting, in order to reduce the field to be covered by experience and tradition alone, is most important if prosthetic services on a world-wide scale are to be improved.

Training in the use of the prosthesis

Training in the use of the artificial limb is essential. Patients coming from a distance for arm or leg training should be housed in suitable hostels or lodgings.

It is an advantage for leg amputees to undergo walking training in groups. The training can be given in suitably equipped walking-training schools, in the physiotherapy department of hospitals by those trained to do so, or in limb-fitting or rehabilitation centres. Wherever it is given, it is an advantage that it should be near a limb-fitting centre with workshops attached. During this early training period, changes take place in the stump which may demand immediate attention, such as the adjustment of sockets by the limb-fitter.

Basically, the training comprises instruction in balance, normal progression, the acts of turning, stooping, walking on sloping and rough surfaces, stair climbing, and learning to rise after a fall, together with all the usual domestic activities.

For arm training, a workshop is required in which the amputees learn the functional value of an artificial arm. Present practice in the United Kingdom in this connexion may be adapted to suit local conditions. The arm amputees first learn to perform with the artificial arm the activities of daily living, such as domestic and toilet activities, dressing, turning taps, using light switches, opening doors, and so on. They then practise typing, draughtsmanship, and, for women, sewing and knitting. Carpentering activities, including cabinet-making, are undertaken and so are garden pursuits. Special hobbies are encouraged. Cycle riding and car driving are practised. During this training the vocational aptitude and interests are studied for future vocational training and placement.

Equipment for training

In the equipment of walking-training schools, emphasis should be laid upon simplicity and avoidance of elaborate equipment. All that are needed

are : walking rails for adults, and rails at a lower level for children and double-thigh amputees using short pegs ; a platform with an approach by steps on either side, the steps being of differing height and depth ; white lines painted upon the floor at widths of, for example, 9 inches and $4\frac{1}{2}$ inches (23 and 11 cm) ; mattresses and simple wooden benches or forms ; a supply of medicine balls for remedial exercises.

In arm-training schools the equipment could consist of a collection of gadgets used in everyday life ; carpenter's benches with vices, together with the usual range of carpenter's tools ; a range of gardener's tools ; typewriters, draughtsman's equipment, sewing machines, etc.

Follow-up adjustment and repair

It often happens that, on return to their homes or employment, leg amputees develop bad habits which require correction, and arm amputees find that the appliances issued to them fail to meet all their requirements. Adjustment of the socket or repair of the prosthesis calls for the services of both the limb-fitter and the limb-fitting doctor. It has been suggested that a routine check-up should be made on each recent amputee three months after fitting, a second check after another six months, and then every six to twelve months for the remainder of the amputee's life. Conditions of the stump and local travel facilities will generally determine the frequency of the follow-up visit.

In some countries a mobile repair service has been developed to serve the amputee as well as other types of disabled person.¹ Although a postal repair system involving the mailing of the damaged prosthesis to a repair centre without personal appearance of the amputee has been found satisfactory in some countries, it was felt that this system would not be generally suitable for most countries. When fitting adjustments are required, personal attendance is always necessary.

B. Vocational Aspects ²

Up to this point, the amputee's rehabilitation will have been primarily a medical and prosthetic matter and he will now be ready for the stage of vocational rehabilitation. The restoration of the disabled to the fullest possible degree of capacity is, however, an integrated process, and the

¹ Further details concerning such a service developed in North Africa by the French Government may be obtained from the Social and Occupational Health Section of the World Health Organization, Geneva.

² This section (with modifications) is largely taken from an unpublished working document (WHO/Prosth.Conf./14) prepared by the International Labour Office.

interest and responsibilities of the medical officer do not cease after the amputee has been trained and placed in employment.

The technical means by which this vocational rehabilitation is effected are provided by vocational guidance, training, and selective placement. Without adequate vocational rehabilitation services, the most effective medical rehabilitation may well fail to achieve its object, because the amputee may not be able to retain or secure suitable employment. The aim of vocational rehabilitation is the satisfactory resettlement of each individual amputee. In some cases, amputees may be able to return to their former occupations, and this may be achieved without difficulty on the conclusion of medical rehabilitation by the placement services or the former employer. In more difficult cases, successful resettlement may depend on special vocational guidance and training as a prelude to selective placement.

Vocational guidance and training

Vocational guidance is concerned with advising on a choice of occupation, after taking into account all the relevant factors in individual cases. It cannot be too strongly emphasized, however, that vocational training is not an end in itself, nor is it a synonym for vocational rehabilitation. It is not a magic carpet which automatically transports the disabled person from a state of unemployment and depression to a state of secure, well-paid employment. Vocational training is only necessary for providing the background of skill, experience, and knowledge for those who are unable to return to their former occupations and who will profit from training. All available evidence goes to show that the majority of disabled persons can be successfully resettled by selective placement without the need for specialized training. It is important, however, that adequate vocational training arrangements should be available for those who need them and can profit from them.

Selective placement

Satisfactory placement in employment of a disabled person can best be achieved by careful selection of work, based upon a full medical assessment of capacity and full knowledge of personal factors. In considering the employment prospects, the basis of selection should be the ability of the person and not the disability. Consideration should be given, in the light of medical information, to the functional loss caused by disability and to the residual working capacity. It is undesirable that a disabled person should be placed in employment which is below his capacity merely because it happens to present a ready opportunity for placement.

Selective placement is based on the recognition of individual differences among jobs in respect of their requirements and among the disabled in respect of their skill, knowledge, ability, motivation, interests, and physical capacity. Those concerned with selective placement must have information regarding the skill requirements and the physical and environmental demands of the job, as well as the physical capacities, interests, and skills of the applicant. Selective placement generally includes one or more reassessments of the disabled person after he has started work. These fulfil the dual purpose of ensuring satisfactory resettlement of the disabled and of providing a check on the accuracy and efficiency of the working methods of the placement service.

The participants agreed that a fully rehabilitated amputee should be able to work as well as a normal individual in a great variety of occupations and that he should not be discriminated against while seeking employment merely because of his amputation. The Conference noted with concern that unfair advantage is still sometimes being taken of amputees regarding their employment. It therefore emphasized the great need for educating the public, including the employers and trade unions, with a view to overcoming the common prejudices and to securing fair employment for the amputees.

3. REQUIREMENTS FOR THE FORMATION AND DEVELOPMENT OF A LIMB-FITTING SERVICE

The facilities available in different countries vary widely. Those countries which have been involved in two world wars have made provision for the supply of prostheses to veterans and for their rehabilitation. As a rule, however, civilian amputees do not receive similar care in some countries. It is therefore desirable that the same or comparable facilities should be made available to all amputees. It was the opinion of the participants that where resources and facilities are limited close collaboration and co-operation between the military and civilian authorities responsible for the rehabilitation of the amputee should be furthered to the highest possible degree, so that maximum service can be rendered to the amputee population as a whole.

Specialized hospitals or departments in a hospital

Primary amputations will unquestionably continue to be carried out in general hospitals in most countries. There is evidence, however, that admission of amputees to specialized hospitals or to hospital departments with a complete rehabilitation unit, where re-amputation, if necessary,

and limb training are provided for on an adequate scale, has great advantages. In such specialized hospitals or departments, unrivalled experience is gained by surgeons and all paramedical personnel and the psychological effect afforded to the amputee through group training induces a spirit of hope, emulation, and increasing confidence. It is desirable that such hospitals or departments should either be attached to or work in the closest liaison with nearby limb-fitting centres.

The limb-fitting centre

The importance of the establishment of a limb-fitting centre in the total service for the rehabilitation of the amputee cannot be overrated. It is in such a centre that limb-fitting and training is carried out under close supervision by trained, experienced, and interested personnel.

The recommendations which follow refer to optimum requirements which, it is recognized, may not be attainable in some countries for some time to come. Nevertheless, the inability to achieve the optimum should in no way prevent the formation of a centre on more modest lines. A start can be made with a medical officer trained in limb-fitting, a physiotherapist or walking instructor, and a workshop with a limb-fitter and a few assistants. In some countries an effective start on these lines has already been made.

Lay-out

In some countries it will be necessary to provide one or more limb-fitting centres—preferably attached to hospitals—with full rehabilitation facilities for amputees. In addition, there can be provided, according to need, certain subcentres or fitting and repair depots where simple adjustments and minor repairs can be carried out. In those countries in which distances are great and the numbers to be handled would not justify the provision of such subcentres or repair depots, the provision of a mobile fitting and repair service is strongly recommended.¹

A lay-out for a large limb-fitting centre is given in Annex 3 (page 40) as an example.

Personnel

The size of the problem to be handled will determine the number of personnel necessary, but the staff of a centre should provide for the following, all of whom should be selected not only for their professional and

¹ Further details concerning such a service developed in North Africa by the French Government may be obtained from the Social and Occupational Health Section of the World Health Organization, Geneva.

technical efficiency, but also for their ability in inspiring hope and confidence and in giving encouragement to their patients for the future :

Medical officer trained in limb-fitting

Walking-training instructor, physiotherapist, or both

Arm-training instructor, occupational therapist, or both

Technical inspector

Leg fitter with assistant in wood, leather, and metal work and plastics

Arm fitter with technical assistants

(In many cases the work of the leg and arm fitters may be combined in one person)

Office staff

If personnel concerned with social, psychological, and vocational aspects of rehabilitation cannot be had from other agencies, they must be included in the staff.

Equipment

The equipment desirable for a limb-fitting centre is given in Annex 3 (see page 40).

4. TRAINING OF PERSONNEL

The Conference felt strongly that the training of technical personnel is one of the most important problems in the establishment of a satisfactory prosthetic service. *Lack of such well-trained personnel at all levels still forms the main hindrance in the provision of an adequate service for amputees in many countries.*

The Conference did not feel disposed to enter into detailed discussions on curricula for training different types of technical personnel but preferred to make a few general observations with regard to their training.

Medical and allied personnel

Limb-fitting medical officers

Discussions took place concerning the selection of medical officers to undertake prosthetic work. In view of the fact that orthopaedic surgeons are not available everywhere, it will be necessary to utilize the services of others. Orthopaedic surgeons who ultimately specialize in prosthetic work on a large scale may find it increasingly difficult to continue to practise the whole field of orthopaedic surgery.

It is considered that an orthopaedic surgeon who wishes to specialize in prosthetic work will require at least six months' training in a well-established limb-fitting organization, while physicians with no previous orthopaedic background should have a minimum period of one year's instruction, in which training in basic orthopaedics should be included.

Although the curriculum for medical students is now very full, it is considered that it should include a few lecture-demonstrations on basic amputee problems in order that all doctors, wherever they may practice, will have a better understanding of the needs of the amputee.

Nurses

All student nurses should receive instruction in the basic nursing and treatment of amputees, such as the physical treatment of the stump, its positioning while the patient is confined to bed, and the methods usually adopted for bandaging stumps. Special demonstrations should be made available to graduate nurses who have been considered suitable for work at limb-fitting centres.

Physiotherapists

Student physiotherapists and post-graduates should all be given training in the psychological and physical problems of amputees; in addition, if they are to undertake such activities as walking training, they will require some instruction on the basic design and function of artificial legs. Such instruction can be provided by the medical officer trained in limb-fitting.

Walking instructors

Walking instructors may be amputees with special training, or they may be trained remedial gymnasts or physiotherapists with special experience in prosthetic work.

Arm instructors

It may be desirable to utilize the services of a qualified arm amputee as an arm instructor. A trained occupational therapist would be desirable in most cases.

From whichever type the staff are selected, it is important that they should have a sympathetic understanding of the problems of the amputee.

Prosthetic personnel

Exact information concerning the number and qualifications of technical personnel is not available. In those countries which have furnished information, training has been carried out along three lines: (1) formal

training, (2) apprenticeship, and (3) use of self-taught persons. In many instances the art of limb-fitting has been handed down from father to son and is difficult to acquire. It was pointed out that in one country a fitter worked as an apprentice for five years followed by two years as an assistant fitter, and that only after seven years' experience did he undertake fittings alone. It is important that fitters should be chosen not only for their craftsmanship but also for their personality. It is recommended that a systematic plan of training be carried out under the supervision of a central advisory body (see section 6, page 23). Training should be along two lines: (1) limb-fitting, and (2) limb-making. In some situations the functions of both types of training may have to be combined.

Other recommended measures include a code of standards for the trade, closer co-operation among medical and other rehabilitation personnel with prosthetic technicians, and improved relationships among prosthetic technicians.

The Conference felt that the limited vocational opportunities and the importance of this training to the seriously handicapped warrant the use of public funds for this type of technical training.

5. SIMPLIFIED ARTIFICIAL LIMBS

Basic principles

A simple limb without excessive mechanism, it was agreed, would be desirable for occupational, functional, and economic reasons in many circumstances in countries which have not yet attained high technological development. More complex limbs may be necessary both for bilateral upper-extremity amputees, who require considerable function for independence, and for amputees with very short stumps.

Participants felt that there would be no reluctance on the part of limb-makers in such countries to produce simple types, since there would be a great shortage of makers and those available would already be overloaded with work.

The issue of a relatively simple artificial limb, as opposed to a more complicated mechanized variety when both are available, would be influenced by the specific needs and conditions of the amputee. Economic conditions, occupation (as well as hobbies and sports, even in technologically advanced countries), and environment would, in many circumstances, demand waterproof, dustproof, and non-corrosive construction and the use of materials which would not soften from moisture or perspiration and would not be attacked by fungus or insects. Under such

demands, a patient would prefer a device offering uncomplicated stability and minimum functional movements and control, with less emphasis on aesthetic qualities. Under urban conditions with less exposure to water, mud, and dust, more mechanized devices might be indicated. (Urban patients would be in a position to wear shoes and to protect the appliance against fungus or other attack.)

In general, it was felt that a simple prosthesis capable of local repair should first be issued to the amputee. In most cases, after major shrinkage of the stump had occurred over a period of six months to a year, a second and more mechanized limb might also be issued for urban wear. The amputee, in general, should return to the limb shop or limb-fitting centre, or a mobile repair service should reach him, depending upon local circumstances. (These mobile repair services usually deal with braces as well as with prosthetic appliances.) Personal contact between the amputee, the limb-fitter, and the limb-fitting doctor would be highly desirable whenever adjustment of the socket or repair of the prosthesis was required.

The Conference agreed that, in order to evolve a simplified artificial limb, the following principles should be stressed :

- (1) simplicity and ease of construction and possibility of local repair ;
- (2) durability ;
- (3) adaptability to local conditions of living and occupation ;
- (4) inexpensiveness of primary cost and repair.

The Conference expressed the wish that further research and experimentation should be undertaken in all countries and believed that mutual exchange of information in this connexion would lead to improvements in the existing types of simplified artificial limbs.

Utilization of local materials

A proper balance between the use of local materials by trained local craftsmen and the importation of partially fabricated materials would be influenced by individual local conditions. In general, the major basic parts could be produced locally, perhaps with the aid of local forestry administrations, who could develop local supplies of light yet strong wood. In view of the high primary cost of factories to manufacture specialized mechanisms such as knee-locks or arm components, it would generally be economical to import such standard parts from countries where they are already available through mass production.

There is as yet little or no experience with plastic laminates for use in prosthetic devices, but the participants felt that there was a likelihood that, with proper development and careful testing, the manufacture of

appliances from such synthetic substances might be cheaper and more satisfactory in years to come than the use of wood or moulded leather. Plastic laminates, if well made, might prove to be sanitary and durable and might easily be moulded over modified plaster models of the stump.

Design and type

The design and type of a simplified prosthesis to be recommended from a range of possibilities must to a certain extent be a matter of local concern, for the device must be suited to local requirements. The Conference stressed that each limb-fitting doctor should be familiar with all possibilities and that each limb-maker should be competent to build any of several varieties.

Lower-extremity prostheses : Peg legs

The simple peg fitted with a rubber cap like a crutch tip has long been used quite successfully on hard ground. It has the advantage of being simple and light but the well-known disadvantages of penetrating soft ground and of requiring a locked knee-joint for an above-knee prosthesis, since the peg is unstable.

The peg end or foot. A rocker type of foot with a more adequate bearing area on the soft ground than a peg has been used successfully in many countries for at least a generation. The sole of the foot is slightly convex and is preferably covered with a firm rubber or synthetic rubber such as is used for heels of shoes. The foot is shortened compared to an anatomical foot, lacking the equivalent toe piece, and with no ankle joint.

Several varieties are available. The Dollinger foot, developed in Germany during the First World War, has also been successfully used in Japan in recent years. The moulded-rubber foot used in some Western countries, shortened to eliminate the toe piece, is used successfully in Ceylon. An experimental design, adapted from Canadian experience, has been suggested to provide a firm anterior or push-off section corresponding to the ball of the normal foot. Compression of a laminated sponge-rubber heel portion gives the equivalent of plantar flexion.

It should be possible to use any of these designs with a sandal or shoe, including a filler for the toe fastened to a stiff insole and comparable to the prosthesis for a partial foot amputation. The forward part of the rocker foot might be flattened to provide firm support on the ground when the user is in a squatting position. The general shape of the foot should be rounded on all corners to permit withdrawal from very soft mud and to minimize the risk of catching the foot in under-brush or deep grass. These devices are illustrated in Annex 5 (see page 45).

The socket. The socket is a most essential part of a prosthesis. Fitting should meet all standards for a more mechanized prosthesis as far as local means of craftsmanship are available. This principle applies to peg legs as much as to any other design. The socket may be carved from wood, moulded from leather (preferably with nylon coating—see Annex 4, page 43), or perhaps, under proper circumstances, moulded from plastic laminates. Although in many technologically less advanced countries craftsmanship in wood-carving attains very high standards, the local carvers may require much special instruction in the underlying bone anatomy of limbs as well as practical training and experience in fitting stumps. Thus, it should be practicable in some cases to start a prosthetic programme by the use of plaster casts, with leather or possibly plastic laminates moulded over modified plaster models of the stump.

The shank or shin portion. The shank may be made from any of several proven designs. A solid peg or pillar of round cross-sections, one or more inches in diameter, can be formed from hard wood. A tubular construction of greater diameter but thin walls will be mechanically stronger for a given weight and may more easily be connected to a socket for below-knee amputation. A flat board with its greatest dimension in the anterior-posterior direction may be shaped to conform to the silhouette of the human leg and may easily form a tongue inserted into a slot or groove in the knee-block of an above-knee prosthesis to form a simple knee-joint.

Brace-like side-bars may easily be attached to the rocker foot, or to a peg or tube, and to any type of socket for either above-knee or below-knee prostheses. Standard joints with adequate length of bars above and below the joint can be carried in stock and used interchangeably for orthopaedic braces or the simple prosthesis.

The shank of any type should permit adequate support at or just below the knee in order to permit kneeling on soft ground. A cross-member or anterior brace cuff or band just at or just below the knee should be used.

Knee joints. The knee joints for below-knee prostheses should permit accurate alignment and would normally be used without a lock, particularly with the broad base of a rocker foot rather than the small tip of a peg leg. For the above-knee prostheses with pegs or most rocker feet used today the joints should permit simple locking during standing and walking. The tongue and groove type of joint can be fitted with any simple, manually operated lock. A very large range of knee motion is necessary for both above- and below-knee amputees to permit squatting, and the above-knee socket and shank should be mechanically stable during squatting.

Regardless of the type of knee joint and lock, the design should permit immersion in water and exposure to mud and dust. Interchangeable standard bushings and washers capable of operating without lubrication and under wet conditions are recommended. Nylon or nylon-graphite (Nylatron) bushings and washers have been used successfully in braces and can readily be adapted to this simple prosthesis. Worn bushings can be replaced by the amputee himself at negligible expense and without mechanical knowledge.

Alignment. Alignment between the socket, shank, and rocker foot (and the thigh corset in the case of below-knee prosthesis) should follow the rules for "standard" prostheses. The alignment should maintain knee stability as long as possible in the stance phase of walking even if a mechanical knee-lock is used in above-knee prosthesis. Principles of alignment, as they are gradually becoming understood for conventional prostheses, are probably very much the same for rocker-type feet as for conventional feet with mechanical ankle joints.

Suspension. Suspension of the prostheses to the body should follow conventional lines. The amount of harnessing is, in general, inversely proportional to the skill of fitting and to the alignment of the socket and the remainder of the limb. Breakages and repairs of mechanical joints rise tremendously with inadequate alignment. Incorrect alignment also leads to excessive harnessing, causing further repair costs. Therefore, every effort should be made, even in technologically less advanced countries, to develop as rapidly as possible an adequate knowledge and skill in fitting and alignment on an anatomical basis.

Upper-extremity prostheses

There is really no "simplified" artificial arm beyond the simple cuff into which tools can be inserted. In fact, there is no single arm suitable to all. The principle proposed is an armamentarium of devices and components from which the most suitable ones can be selected.

The heavy-duty work arm, preferably made from standardized, mass-produced components, is generally most suitable for heavy agricultural work by unilateral amputees throughout the world. (For further details, see Annex 2, page 34.)

Most bilateral amputees should be given, on at least one side, a harness-controlled prosthesis permitting voluntary elbow flexion and voluntary control of a *split hook* (preferred to a hand) with easy passive adjustment of the wrist rotation mechanism. Bilateral above-elbow amputees should be able to control the elbow lock from the harness. (A turn-table above the elbow is particularly desirable for the bilateral above-elbow amputee,

so that he may work close to his body. He should be able to reach his mouth with at least one terminal device.)

Sockets for upper-extremity prostheses have been successfully made of moulded leather (preferably coated with nylon) or metal or carved wood covered with raw hide, or of moulded plastic laminate.

The harness should be as simple and strong as possible. Again, the more skilful the fitter, the less the total amount of harness required for a given function. A bilateral arm amputee should be able to don and remove his prosthesis unaided. Leather coated with nylon, and cotton, nylon, and other synthetic webbing, have been used successfully even for heavy-duty work. Buckles and other hardware should permit heavy loads and should be non-corrosive.

The fitting and harnessing of the prostheses should be systematically checked both before and after training, since minor modifications in harness may greatly affect their usefulness and the ease of training.

Details of other types are reviewed in Annex 2 (see page 34).

6. ADMINISTRATIVE PROBLEMS

The proper development of a better prosthetic service calls for leadership in each country. By leadership is meant guidance and help, not the issue of strict and inflexible directives.

National committee or council

The field of prosthetics lies between health, labour, and social insurance. Several government departments should therefore share the administrative responsibility for the total service. It was therefore suggested that a national committee or council be appointed to co-ordinate the activities of all public and private bodies concerned and to initiate further developments. This committee or council should become a part of, or work in close collaboration with, existing national committees or councils concerned with the whole field of rehabilitation of the disabled. The membership of such a committee or council should include medical and non-medical technical experts as well as representatives of all interested agencies.

The Conference considered it essential to include a medical man with special training and experience in this field in the above committee. If, however, such a doctor is not available, it was felt that the first step should be the training of such a specialist. He should have a broad basic medical training and should, in addition, have an interest in mechanics and experience in industry, labour, or both. If he has had some orthopaedic training, it would be an additional advantage. He might be appointed, for

instance in some countries, as a "prosthetic consultant" to the ministry of health.

Technical sub-committees could be formed to deal with specific technical matters, whenever necessary.

The Conference proposed that this national committee or council, wherever established, should serve as an advisory body and, as such, perform, among others, the following functions:

(a) Survey and study the whole field of prosthetics in relation to the total rehabilitation of the amputee with a view to implementing, as far as possible, the recommendations given in other parts of this report.

(b) Bring about, as a major aim, the prevention of accidents and diseases necessitating amputation.

(c) Ensure the provision by all hospitals of basic statistical data on amputations (see section 1, page 3) and, in addition, obtain detailed information on the causes and circumstances leading to amputation, so that analysis of such information could lead to the recommendation of measures for effective prevention.

(d) Encourage the recruitment of a sufficient number of highly trained and specialized personnel and, where such personnel are not available, arrange for such training to be started. This includes not only doctors, nurses, physiotherapists, occupational therapists, walking and arm instructors, limb-fitters, vocational counsellors, and staffs of employment exchanges, but also the different types of technicians in the workshops.

(e) Educate public opinion so that there is better understanding of the amputee's functional abilities with his prosthesis and, in consequence, a lessening of the difficulties which he often experiences both in daily life and in seeking employment.

(f) Concern itself with problems of financial aid to dependants during rehabilitation of the amputee and possible equalizing benefits and tax exemptions because of extra expenses (e.g., clothes, taxis) which the amputee may have to incur.

(g) Establish certain administrative and technical arrangements, such as the approval of the prosthesis by the doctor, its identification, suitable guarantees by the limb-maker regarding the quality of the limb, the supply of accessories, and so forth.

Improving production standards

In some countries artificial limbs are approved and supplied only if made according to specifications stated in contracts between limb-makers and the responsible authorities. While this system undoubtedly helps to

create more standardization, greater simplicity, and better quality in some countries, it may not be applicable at all in other countries. It must be carefully handled so as not to curb progress and improvements.

For the time being, the Conference would advise that control of standards be based on the prescription and final approval of prostheses by recognized or authorized medical experts. The authorities responsible for paying for prosthetic devices may also want to establish technological inspection of the quality of the production in the different firms.

The most important step in improving production would be to establish better personnel-training facilities (see section 4, page 16).

Financing of a prosthetic service

It was pointed out that even in the countries with the highest standard of living an amputation, from an economic point of view, was a major catastrophe for the individual. The total cost involved could completely undermine the very economic and social structure of the family, since insurance against such hazards is not generally feasible.

The Conference, therefore, recommended that the treatment and rehabilitation of the amputee should be made economically possible for all amputees in all countries.

Customs barriers

To improve quality and reduce prices, mass-production methods could be used for many prosthetic parts. In a rare type of amputation even the whole artificial limb may have to be made abroad by one of the larger firms.

The Conference would advise that an attempt be made to abolish all national customs barriers on prostheses and parts. It is the conviction of the participants that such abolition would have no adverse effect on indigenous limb-making industries.

International standardization

The Conference felt a considerable need for the development of international standards for certain parts of prosthetic devices. The wrist rotary and bisection unit and knee joints of above-knee limbs were especially noted as examples. It was felt, however, that only after careful technological and functional study could such standards be agreed upon and gradually become universally acceptable.

7. RESEARCH

All the participants felt that research is extremely important in this field. In the past this has been limited by inadequate financial support. Ultimate financial savings resulting from research would be considerable.

It was noted with satisfaction that, as research is now being carried out in a number of countries, it might be important to establish an international information service to make results of research known to all concerned, in order to avoid duplication of effort and expense.

In one country, the limb-makers have agreed to make a special contribution of 0.5% of the cost of each limb to be paid to a research fund, administered under a sub-committee of the national research council of that country. In other countries research funds are provided by the national government. Limb-makers in some countries have also developed their own research departments.

The Conference recommended that funds be made available in all countries for research to be undertaken under the guidance of the national committees or councils referred to previously. Some of the lines along which research should be undertaken or continued are given below :

1. Causation of amputation, with a view to prevention
2. Anatomical fitting of limbs for thigh amputation
3. Improvement in the fitting of below-knee prostheses
4. Improvement of the stability of artificial knee-joints for above-knee prostheses
5. Improvement of the adjustability of artificial knee-joints to the varying requirements of amputees
6. Production of a mechanically sound polycentric joint for below-knee prostheses
7. Production of a simple but efficient elbow mechanism for above-elbow prostheses
8. Investigation into the serviceability of material used in limb manufacture
9. Continued research into the value of plastics, glass laminates, and other materials locally available for use in artificial-limb construction.

8. PRINCIPAL PROBLEMS FOR INTERNATIONAL CONSIDERATION AND ACTION

1. The Conference considered effective international co-operation essential in the highly specialized field of prosthetics. It was recognized that an exchange of information among prosthetic specialists in various countries had taken place on a limited basis in the past. The Conference wished, however, to emphasize the necessity of obtaining the utmost benefit from the limited resources available for international activities in this field by utilizing, under a well co-ordinated joint programme, the resources of such international organizations as the United Nations, ILO, and WHO, and international non-governmental organizations such as the International Society for the Welfare of Cripples and the World Veterans Federation. It was believed that considerable progress can thus be made in raising the standard of prosthetic services.

2. In view of the importance of full co-ordination of research activities undertaken in various countries and of efficient dissemination of information, it is desirable that the information service (including translation facilities) referred to in section 7 should be established as soon as possible. This task was considered particularly suitable for international non-governmental organizations, such as the International Society for the Welfare of Cripples and the World Veterans Federation.

3. The need for international programmes for the training of prosthetic personnel was emphasized. Scholarships and fellowships and international training courses were considered specially suitable for international action.

4. The Conference stressed the importance of providing experts to advise various countries on the organization of prosthetic services. It was hoped that technical assistance programmes operated by international organizations would, in the future, make such consultant services available to an increased number of countries.

5. It was considered that WHO should continue and intensify its efforts to promote preventive measures with respect to chronic disabilities, among which amputations were considered an important group.

6. The Conference was strongly of the opinion that the abolition of national customs barriers for prosthetic appliances would bring about more economical production methods and would ensure the availability of high-quality appliances, particularly in smaller countries where large-scale production of certain appliances is not feasible.

Annex 1**REPORTS ON THE CAUSES OF AMPUTATION ***

It would seem that at present it is impossible to obtain exact statistics from any source relating to the incidence of amputation and its causes. Some countries have, however, submitted statistics which, while not purporting to be comprehensive, or even approaching complete accuracy, may be considered to indicate a trend, despite the fact that the numbers upon which they are based are small.

If they achieve no other purpose, these statistics may call attention to certain causes of amputation which indicate the need for consideration to be given to the means of prevention.

United Kingdom of Great Britain and Northern Ireland

Some statistical information has been submitted by the United Kingdom. This information has been rendered available by virtue of the fact that (1) a "Register of Disabled Persons" is maintained by the Ministry of Labour, and (2) the prosthetic services covering the rehabilitation of amputees are a national responsibility being co-ordinated and directed by a division of the Ministry of Health based at Roehampton.

(1) *Registration.* The registration of the disabled is not compulsory, and while it is not known how many fail to register, it is known that, for the year 1953, 856 612 persons were registered as disabled, of whom 69 342 are shown as having undergone some form of amputation, though whether major or minor is not known.

(2) *Prosthetic services.* It is known that approximately 35 000 war pensioner amputees from the two world wars are living and have been supplied with prostheses; also that, since the introduction of the National Health Service Act in 1948, 35 000 civilians have been provided with prostheses, and the average intake of primary civilian amputees is between 3000 and 4000 per annum.

* Taken from unpublished working documents (WHO/Prosth.Conf./9, 15, 20, and 21) and edited by Dr. R. Langdale Kelham, Principal Medical Officer, Artificial Limbs and Appliances, Ministry of Health, London, England; WHO Consultant.

The coding system

At each of the 29 limb centres in the country, the limb-fitting medical officer completes a prescribed form for each amputee: these forms are sent to Roehampton where they are dealt with by a coding staff using one of the several different types of coding systems. So far over 20 000 amputees have thus been coded. Of these 20 000 cases, an analysis has been made of the records of 2500 lower-extremity amputees (2000 from the Roehampton Centre and 500 from the Leeds Centre, drawn at random), and of 1475 upper-extremity amputees (of which 180 were from Roehampton and the remainder from 15 limb centres, all drawn at random). A cross-check has been made by a scrutiny of several hundred individual case-files. This analysis has brought to light an interesting and marked divergence of causes leading to amputation, as between upper and lower extremities.

Table I shows a high proportion of lower-extremity amputations resulting from disease as compared with those of the upper extremity, while upper-extremity amputations are proportionately greater in the case of congenital malformations and accidents.

TABLE I. AMPUTATION BY CAUSE AND SITE IN THE UNITED KINGDOM

Cause of amputation	Upper Extremity		Lower extremity	
	number of cases	percentage	number of cases	percentage
Disease	141	9.6	1 400	56.0
Congenital malformations	247	16.7	69	2.8
Accidents	1 087	73.7	1 031	41.2
Total	1 475	100.0	2 500	100.0

The diseases resulting in amputation have been analysed and are shown in Table II.

Accidents

Among the amputations resulting from accidents, those due to industrial accidents numbered 840 (or 77.3%) in the case of the upper extremity, and only 298 (or 28.9%) in the case of the lower extremity.

Accidents resulting in lower-extremity amputations are analysed and shown in Table III. These figures show a high proportion of traffic accidents (50%) compared with other types. Of the amputations due to

**TABLE II. AMPUTATIONS BY ORIGINATING DISEASE AND SITE
IN THE UNITED KINGDOM**

Nature of disease	Upper extremity		Lower extremity	
	number of cases	percentage	number of cases	percentage
Malignancy	44	31.2	98	7.0
Tuberculosis	28	19.9	217	15.5
Thrombosis and arterio-sclerotic gangrene	11	7.8	441	31.5
Osteomyelitis	10	7.1	448	32.0
Diabetic gangrene	—	—	154	11.0
Poliomyelitis	4	2.8	42	3.0
Unidentified	44	31.2	—	—
Total	141	100.0	1 400	100.0

**TABLE III. LOWER-EXTREMITY AMPUTATIONS DUE TO ACCIDENTS
IN THE UNITED KINGDOM**

Nature of accident	Number of cases	Percentage
Traffic	516	50.0
Home	89	8.6
Sport	53	5.1
Railway	36	3.5
Unspecified	39	3.8
Total	733	71.1
Industrial	298	28.9
Grand total	1 031	100.0

traffic accidents, 334 (64.7%) affected pedestrians, 143 (27.7%) affected motor cyclists, while 39 (7.6%) were due to car accidents affecting the driver or pedestrians. Of accidents arising in and about the home, 53 cases were due to falls, 26 to chance blows, 7 to burns, and 3 resulted from amateur chiropody. Of the sporting accidents, 36 occurred on the football field and 8 occurred while shooting.

With regard to accidents other than industrial resulting in upper-extremity amputations, it has not been found possible to effect a complete analysis of the 1087 arm amputations. An analysis has, however, been

made of 180 arm-amputee records taken from the Roehampton Centre only, of which 55 cases fell within the accident group, excluding the industrial causes. The breakdown of this number is shown in Table IV. Traffic accidents are again the highest, followed by home accidents. Of the latter, firework accidents affecting children form a substantial proportion.

TABLE IV. UPPER-EXTREMITY AMPUTATIONS DUE TO ACCIDENTS OTHER THAN INDUSTRIAL, FROM THE ROEHAMPTON CENTRE, UNITED KINGDOM

Nature of accident	Number of cases	Percentage
Traffic	22	40.0
Home	16	29.1
Sport	3	5.5
Railway	4	7.3
Unspecified	10	18.2
Total	55	100.0

Ceylon

Statistics have been provided from Ceylon concerning 156 amputees dealt with in the Limb-Fitting Centre at Colombo. They have been grouped under the main headings of disease, congenital malformations, and accidents, and further segregated into upper- and lower-extremity amputations (see Table V).

Although the total number upon which the statistics are based is small, nevertheless they provide some information which shows a close approximation to other reports.

TABLE V. AMPUTATION BY CAUSE AND SITE, AT THE LIMB-FITTING CENTRE, COLOMBO, CEYLON

Cause of amputation	Upper extremity		Lower extremity	
	number of cases	percentage	number of cases	percentage
Disease	15	25.4	57	58.8
Congenital malformations	10	16.9	4	4.1
Accidents	34	57.6	36	37.1
Total	59	100.0	97	100.0

Disease

On breaking down the frequency of disease as shown in the statistics, the results appear as shown in Table VI.

**TABLE VI. AMPUTATION BY ORIGINATING DISEASE AND SITE,
AT THE LIMB-FITTING CENTRE, COLOMBO, CEYLON**

Nature of disease	Number of upper-extremity cases	Number of lower-extremity cases
Malignancy	5	13
Tuberculosis	1	1
Osteomyelitis	2	2
Gas gangrene	5	4
Cardiovascular disorders	—	9
Diabetes	—	11
Elephantiasis	—	5
Leprosy	2	4
Others (chronic ulcers, etc.)	—	8
Total	15	57

Accidents

34 cases of upper- and 36 cases of lower-extremity amputations following accident are given, but the statistics provided do not permit of analysis. However, as in the case of the report from the United Kingdom, the total figures for upper and lower extremity show a similar relationship in that diseases tend to affect more the lower extremity and accidents more the upper extremity (see Tables I and V).

Pakistan

Statistics have been provided from Pakistan, based upon an investigation of 104 amputees dealt with at the Artificial Limb Centre, Lahore. No differentiation between upper- and lower-extremity amputation was given.

Although the figures are small, a broad general picture can be drawn for comparison with other reports. Table VII gives the percentages of amputation resulting from disease and accidents.

TABLE VII. AMPUTATION BY CAUSE, AT THE ARTIFICIAL LIMB CENTRE, LAHORE, PAKISTAN

Cause of amputation	Number of cases	Percentage
Disease	35	33.7
Accident	69	66.3
Total	104	100.0

Disease

The principal diseases necessitating amputation and their relative frequency are shown in Table VIII.

TABLE VIII. AMPUTATION BY ORIGINATING DISEASE, AT THE ARTIFICIAL LIMB CENTRE, LAHORE, PAKISTAN

Nature of disease	Number of cases	Percentage
Gas gangrene	16	45.7
Cardiovascular disorders	14	40.0
Diabetes	5	14.3
Total	35	100.0

Accidents

Traffic accidents account for the highest proportion of all accidents in this series, being considerably greater than industrial accidents when compared with the report from the United Kingdom. The analysis of accidents is shown in Table IX.

TABLE IX. AMPUTATION BY NATURE OF ACCIDENT, AT THE ARTIFICIAL LIMB CENTRE, LAHORE, PAKISTAN

Nature of accident	Number of cases	Percentage
Traffic	48	69.6
Burns	11	15.9
Industrial	6	8.7
Railway	4	5.8
Total	69	100.0

Annex 2

REVIEW OF EXISTING TYPES OF PROSTHESES

In the last thirty years an enormous number of different types of artificial limbs have been developed, so that a proper evaluation of all the different ideas they embody can hardly be made by any one medical consultant on his own knowledge.

There has been a very marked development in the functional results achieved by the prosthetic services, and the participants think that it is most important to investigate the question to what extent these results have been due to fitting, alignment, construction of mechanical parts, or the training given to the amputee during his rehabilitation.

Socket Fitting

There was general agreement among the participants that the great progress in functional results achieved by the prosthetic services has been due to better and more anatomical fitting of sockets.

The fitting of the socket should give a minimum of free movement between the stump and the artificial limb. The shape of the socket must not interfere with the mobility of the joints. It should provide for the best use of the muscle power present in the stump.

The Conference agreed that the so-called "conventional fitting" or "plug fitting" by a conical-shape socket for lower-extremity prostheses should be rendered obsolete, and that the greatest effort should be made to investigate the best form of anatomical fitting. The knowledge of anatomical fitting should be disseminated widely by the proper training of limb craftsmen. Suction is only an additional means of retaining a socket on the stump, and if excessive, will damage the stump. Proper anatomical fit conserves muscle power and therefore provides a firmer adhesion of the prosthesis to the stump.

Harness controls for fixation and stabilization, as, for example, hip joints and hinges in above-knee prostheses, can, by good fitting, be omitted in many cases.

Types of Limbs Available for Lower-Extremity Amputations

Limbs for above-knee amputations

Materials used

Wood covered with raw hide is at present the most favoured material for proper fitting.

Since plastics meet the same requirements in manufacture as leather, and are in many features superior to leather, their use has widely increased in recent years, although it is still in the field-testing stage. Fibre has been used in several countries.

Light metal is especially favoured in the United Kingdom and widely used in France, but its use depends upon specially trained metal workers and complicated machinery and tools and is therefore limited to where these facilities are available. Germany and the United States of America in general prefer wood and plastics to light metal.

Shoulder harness and pelvic bands

By proper fitting and alignment, certain harnessing may be rendered superfluous. Shoulder-harness control, hip joints with or without locks, and similar supporting and safety methods, should be required only in very short stumps or other exceptional cases. A "Silesian bandage" or similar simple form of harness may often give an additional safety feature, even when the suction socket or adhering socket is used.

Knee joints

There is general agreement that most of the innumerable knee-joint designs for above-knee artificial limbs provide but a limited improvement, which by no means can be compared with the functional improvement gained by better fitting and alignment. Limitation of the number of knee-joint designs with special technical features would lead to standardization, mass production, and easy repair in all countries. The technical features should be based upon simplicity of construction and repair, stability, and durability, even in the presence of moisture, dust, or grease.

Automatic-locking knee-joints or joints with strong friction-brake in weight-bearing can add to the stability, but they cannot, at the present time, be recommended in every case. This stability is necessary for most double above-knee amputees, for very short stumps, and for cases with severe muscle paralysis. They may also be advisable for special vocational purposes.

The so-called "physiological" or "anatomical" artificial knees at present available give a very limited amount of additional stability. With a backward-gliding functional axis, they prevent buckling only in the very first few degrees of flexion. Some of these designs have enabled the amputee to acquire a more graceful gait. As this feature also depends on alignment and especially on training, proper investigation should be made into the relative value of these technical devices. Recent research in different countries has shown the need for improving the adjustability of artificial knee-joint action during the swing phase to the differing requirements of the amputee, e.g., in walking or running at various speeds.

Limbs for below-knee amputations

Materials used

Detachable leather sockets fulfil special needs in very short or sore stumps, and under conditions where craftsmanship in leather-work is superior to that in wood-work.

Knee joints

In most countries, uniaxial knee joints are used. It is difficult to place them correctly so that they correspond to the gliding axis of the anatomical joint. In some countries research has been carried out in the construction and testing of polycentric knee joints. Up to the present, these joints have not stood up very well to the strain imposed.

Ankle joints for above- and below-knee amputations

There was general agreement that special care should be taken to provide both above- and below-knee prostheses with ankle-joint mechanisms or their substitutes which are simple and unaffected by water, dust, or grease. Lateral motion can be obtained either at the level of the ankle joint or by cushioning and rounding the heel of the foot. A complex metal construction for the purpose of carrying out the few degrees of lateral motion does not seem to be advisable. In many cases a sufficient and well-controlled amount of extension and flexion of the ankle, as well as lateral movement, can be achieved with ankle-joint designs which incorporate a synthetic-rubber block. If vulcanized to metal plates for fixation to the shin and foot, these joints are extremely durable even under rough conditions.

Types of Limbs Available for Upper-Extremity Amputations

The varying requirements depend on character, personality, social standing, activities, and vocational placement, and are thus more complicated than for lower-extremity amputees.

A greater variety of artificial arms, terminal devices, and other parts to meet the functional needs of the amputee must therefore be available, and standardization is likely to be more difficult than with lower-extremity amputees.

Materials used

In upper-extremity prostheses, light metal, plastic, wood, and leather are in full competition according to the varying production facilities, the load which is put on the prosthesis, and the purpose for which it is designed. Plastics have proved extremely effective in meeting the special requirements of modern above- and below-elbow prostheses with harness for active control of the terminal devices and elbow joints.

Limbs for above-elbow amputations

There will always be a place for the simple and durable heavy-duty arms in many occupations, agricultural as well as industrial, but modern industry tries to reduce manual work to a minimum. Other types of artificial arms are needed, therefore, on an increasing scale, to meet the great variety of activities at home, in the office or workshop, and during sport and recreation. Many efforts have therefore been made to construct better artificial arms, hands, and other terminal devices. It must be emphasized, however, that none of these designs can cover all needs, and special selection must be made in every individual case in order to decide which lost function of the amputee needs to be restored most urgently.

Elbow mechanisms

Elbow mechanisms have to withstand an enormous amount of stress when used for heavy work. The different heavy-duty steel devices with simple hand-operated locks to control both the rotation above the elbow and the position of the elbow which have been in use since the First World War in the United Kingdom and Germany have proved their effectiveness and stability in unilateral amputations. These heavy-duty arms are primarily designed for use with different passive appliances which can be changed by snapping them into the wrist or forearm bisections.

Friction elbow-locks with active control demand great precision in manufacture and frequent supervision. Positive elbow-locks are therefore more dependable, although the locking positions are limited. Turn-tables are frequently necessary and can be locked either by friction or by positive lock. It is important to produce strong, reliable cables of metal, nylon, or Perlon, and proper cable housings which do not break and offer a minimum of friction without interfering with or damaging clothing.

Bisections

A rotary snap-in type of mechanism is normally fitted at the level of the anatomical wrist, but for heavy-duty working arms a bisection nearer to the end of the stump may be desirable in addition in order to shorten the lever arm.

Limbs for below-elbow amputations

In below-elbow amputation, long stumps provide a very useful length for active rotation, which can easily be transmitted to a properly fitting screwdriver type of socket, and frequently prostheses for such stumps do not require a special wrist bisection. However, wrist bisections are necessary to allow rotation of the terminal device with shorter stumps and in most cases are passively operated with the sound hand or by holding the terminal devices fixed by some other means.

Active wrist-rotation units with gear step-up to be changed in position from the side of the stump only and locking from the side of the terminal device are being field-tested in the United States of America and show promising results in medium-length below-elbow stumps.

Terminal devices

Many different types of passive terminal devices or appliances are available, but the number used is limited by inconvenience in carrying and time consumed in changing appliances. Sometimes a specialized appliance for work may be left at the work place after replacement by a more versatile device for general use.

A ring or C-shaped hook or both should be considered for very heavy work. These can be supplied without, or preferably with, a rotation joint at the wrist, which can be clamped or locked in varying positions, and provisions should also be made to permit selection of free rotation. Sometimes a wrist-flexion device or a ball-and-socket joint may be desirable. Various types of claws, which can be passively strapped or clamped to the handles of spades or tools, have also been traditionally used for farm work, mining, and other heavy duties.

The mechanical split hook permits voluntary control of prehension without calling the other hand into use, thus increasing the effectiveness of an arm amputee, but it requires more complicated harnessing and an operating cable. It has been successfully used for more than a generation in many countries. For very heavy duty the split hook should be made of stainless steel, but for the activities of daily life, office work, and recreation, lighter split hooks can be made from duralumin and are more suitable, especially for women and children. Split hooks permit a combination of the various types of grasp possible for the human hand; their thin shape permits entering pockets, and their versatility is particularly useful to bilateral arm amputees.

Forward flexion of the humerus and the stump in a below-elbow amputee can control the hook (or mechanical hand) by tensing a cable anchored across the back to the opposite shoulder. The stump and shoulder-girdle movements are used in above-elbow amputees to control the active motion both of the elbow joint and of the positive or friction elbow-lock. Active opening or closing of the terminal devices is gained without interference of these three motions by using a specially designed harness. In many cases, however, only two cables and power sources are necessary if two actions from one cable (such as bending the elbow and operating the terminal device) need not be performed simultaneously. Proper evaluation has to be made in order to test and further develop these possibilities.

The old-fashioned so-called cosmetic or non-functional arm and hand constructed in former years is of limited value as it deprives the amputee of many activities which he could perform with his stump alone. Recently, modern plastics have been used to produce a much more natural-appearing cosmetic arm and hand designed for dress or social purposes only. These hands copy every feature of the human skin in colour and surface.

Mechanical hands, controlled from a harness and interchangeable with the split hook (or passive appliances), provide at least some function by motion of one or more fingers. Such hands have been produced in great variety and are certainly useful for social and professional purposes. Most of these types have been used with a leather glove, but plastic gloves recently developed in the USA show a much more natural appearance and can be worn over a functional hand.

Cineplasty surgery adds new sources of power which improve the function or simplify the harnessing. A detailed study of all these individual cases should be made in order to compare their efficiency.

Annex 3**LAY-OUT AND EQUIPMENT
OF A LARGE LIMB-FITTING CENTRE ***

The Conference recommended that the lay-out and equipment of a large limb-fitting centre should aim at the following requirements, as far as possible and where applicable.

General requirements

The centre should be a composite building, preferably on the ground-floor only, attached to, or in the grounds of, a hospital.

All doorways and passages which will be used by patients should be of above-average width to permit of the easy passage of all types of wheel-chairs.

Ramps or slopes should be provided instead of steps or stairs.

Toilets which will be used by patients should all be equipped with hand-rails for the use of bilateral leg amputees.

All the floor coverings of parts of the centre to which patients have access should be of a non-skid type, e.g., cork linoleum.

Floors of the wood-block type are desirable in workshops in order to deaden noise.

Special requirements

The centre should comprise the following :

A reception hall and counter, leading off which should be provision for light refreshments for patients

Male and female waiting-rooms with toilet accommodation

Surgeon's consulting-rooms

Fitting-rooms for male and female patients

Walking-training school, with toilets nearby

Arm-training school, with toilets nearby

Limb-makers' workshops, plaster-cast rooms, and offices, together with storage rooms

A general limb store for housing limbs and accessories

* Taken from unpublished working document WHO/Prosth.Conf./4.

A wheel-chair store near the reception hall
Administrative offices and registry for the staff
Toilet accommodation for the staff

Equipment (in broad groups)

Surgeon's consulting-room

Desk, chairs, telephone
Hot and cold water laid on
Examining couch and screens
Weighing machine and height-measuring stick
Sphygmomanometer
Stump-measuring stick
Goniometer
Cupboards, etc.

Fitting-rooms

Walking rails, at each end of which should be long mirrors,
1½-2 metres (5-6½ feet) tall
Walking sandals for gauging height of limb
Chairs and low stools
Measuring tape

Plaster-cast room

Sink and water laid on
Supply of plaster bandages
Paper for drawings and profiles
Stockinette
Plaster-cutting knives and malleable metal strips
Goniometer
Measuring platform with adjustable overhead arms
Hard couch
Hair clippers and razor

Plastics working equipment

Beakers, glass, and rubber
Screwdriver
Knives
Wrenches
Measuring tape (metal with spring return)
Draw-knife
Dividers, 6 inches (15 cm)
Electric oven

Limb-makers' workshop

- Work-benches with wood and metal vices
- Wood and metal drills
- Wood-pulling tools
- Metal beater
- Buffing machine
- Leather- and webbing-working equipment, sewing machine
- Spraying and painting equipment
- Stocks of spare limb parts and fitting tools

Limb-makers' workshop store

- This should contain limb racks and storage boxes

General limb store

- Shelves for storing different sizes of stump socks
- Crutches
- Walking-sticks
- Stick and crutch rubbers
- Gloves
- Limb racks
- Limb boxes for despatching limbs
- Inspection table for examining limbs coming in for repair

Technical inspector's office

- Office furniture
- Supply of measuring gauges, etc.
- Scales and measuring tools
- Filing cabinets

Walking-training school

- Walking rails with polished hardwood top-rail
- Shorter rails for children and bilateral thigh amputees using short pegs
- Steps of differing height and breadth, with hand-rails each side
- Ramps
- Overhead walking-bars
- Stump-exercising pulleys
- Mattresses and benches

Arm-training school

- Carpenter's benches
- Sets of carpenter's tools

Draughtsman's equipment
Office equipment and typewriters
Gardening equipment and tools
Sewing and knitting equipment
A set of various types of taps, switches, and door handles, mounted on a board

Annex 4

METHOD OF APPLYING A NYLON FILM TO LEATHER WORK *

General

Nylon is one of a group of synthetic plastics technically referred to as polymeric amides. Nylon has a high softening point, approximately 450°F (232°C). Nylon filament has a specific gravity of 1.068 and a tensile strength of about 53 000 pounds per square inch (about 3700 kg per cm²). Moulded nylon has a specific gravity of 1.04, a tensile strength of about 9000 pounds per square inch (about 630 kg per cm²), a flexural strength of about 13 000 pounds per square inch (about 910 kg per cm²), and a compressive strength of about 15 000 pounds per square inch (about 1050 kg per cm²).

Preparing the nylon solution

To prepare the nylon solution for the coating of leather work, 20 g of nylon flake¹ and 6 g of hexachlorophene are placed in 200 ml of 85% solution of isopropyl alcohol in water. The mixture is then heated to 145°F (62.8°C) and maintained at that temperature until all the nylon is in solution.

Caution. To avoid fire hazard, heat the solution in a pot of water and *not directly over an open flame*. Constant stirring facilitates the solution of the nylon in the isopropyl-alcohol water mixture. Avoid sparks from motor brushes on any stirring device. Once the nylon has dissolved, separation and settling of the nylon from the solution will very likely occur after some days, although the hexachlorophene retards the coagulation as well as having bacteriostatic and fungicidal action. To redissolve

* Taken from unpublished working document WHO/Prosth.Conf./16, Appendix A.

¹ The nylon material used in coating leather work is nylon flake FM-6501, which is obtainable from E. I. du Pont de Nemours & Co., Inc., Nylon Division, Wilmington, Del., USA.

the coagulated nylon, reheat the entire mass to 145°F (62.8°C) until solution occurs. More hexachlorophene up to a weight equal to that of the nylon would improve resistance to settling but would weaken the film. During any heating process, in preparing the solution or in redissolving the nylon, it may become necessary to restore the original amount of isopropyl-alcohol solvent. It will be necessary therefore to maintain an approximate ratio of 200 ml of isopropyl alcohol (85% solution in water) to 20 g of nylon flake FM-6501. (This is at the rate of 1.2 gallons of solvent to 1.0 pound of nylon.) To prevent evaporation, a capped glass jar is used for storage.

Application of nylon to leather

Before applying the nylon coating, the leather must be thoroughly cleaned with isopropyl alcohol and then allowed to dry for five minutes in a circulating-air oven at approximately 140°F (60°C). (Any oily spots will prevent the nylon from sticking.) The nylon solution is very carefully brushed on the harness, covering all leather parts with a very thin but uniform coating. An ordinary varnish brush of hog bristles is satisfactory. It will be found convenient to use a brush with the bristles from 1 inch wide by 1½ inches long (2.5 × 3.8 cm) to 1½ inches wide by 2 inches long (3.8 × 5 cm). Three to five top coats of the nylon solution, depending on the application, are applied in this manner, allowing approximately five minutes between applications. After the final coat, the leather must be allowed to dry for at least 15 minutes in a circulating air oven at 140°F (60°C). Using this technique and five coatings, a nylon film approximately 0.008 inch (0.2 mm) thick will be obtained. For upper-extremity harnesses, it may not be necessary to apply as many as five coats, but it is recommended that at least three coats be used.

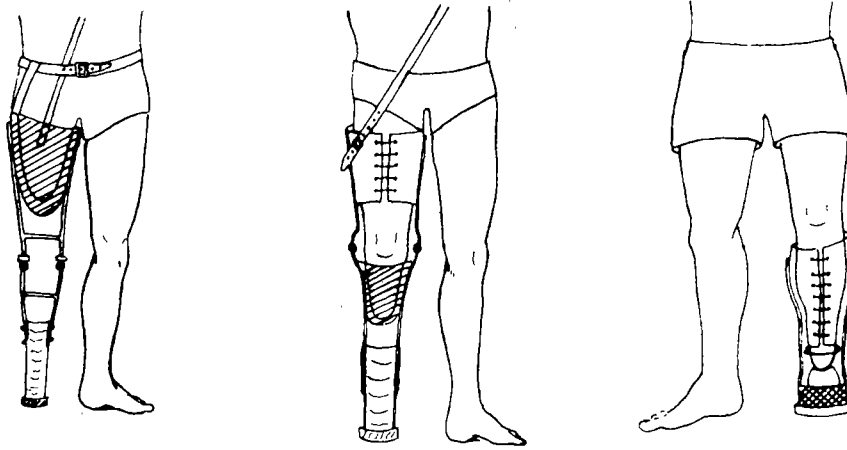
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Annex 5

ILLUSTRATIONS OF SIMPLIFIED ARTIFICIAL LIMBS

FIG. 1-2. SIMPLIFIED PROSTHESES USED IN CEYLON *

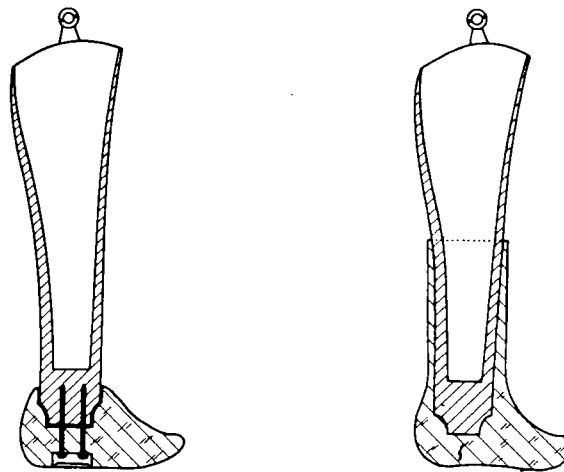


A

B

C

Prostheses for above-knee (A), below-knee (B), and Syme (C) amputations, using pegs protected by rubber caps. Locked knee-joints are needed in A, because the peg is unstable and tends to sink into soft ground.

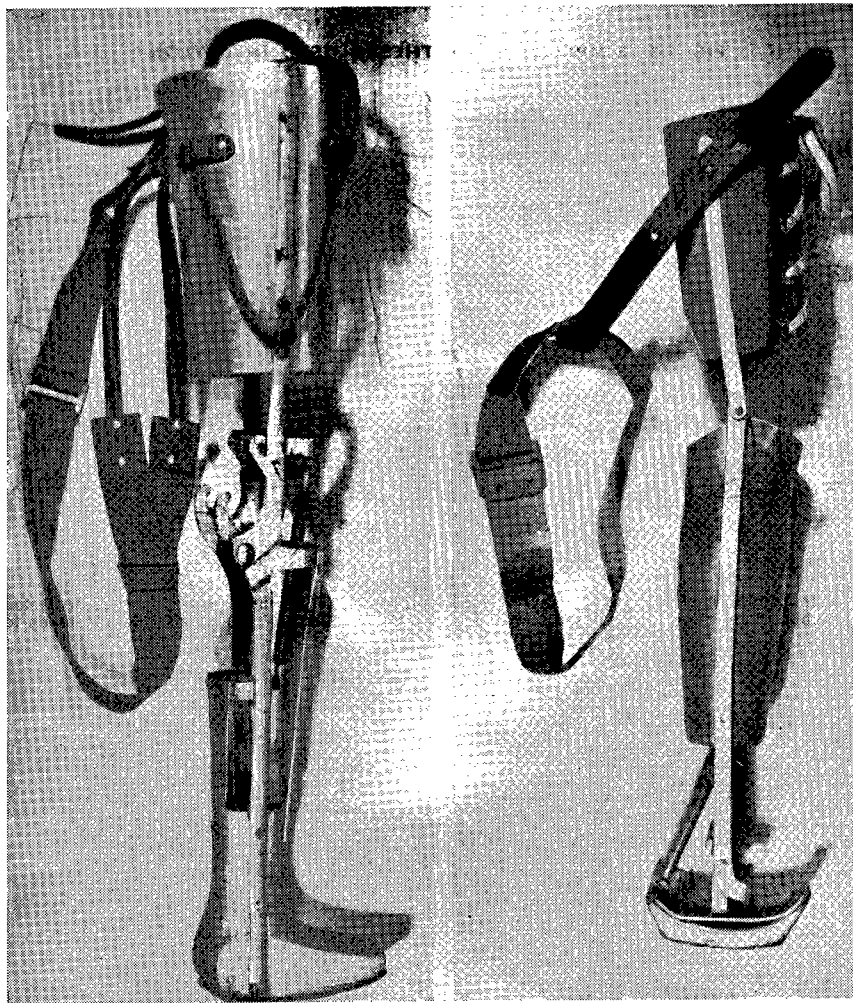


D

E

Simplified wooden shanks and moulded-rubber feet for artificial limbs. The feet are shortened as compared to a normal foot, and the "toe" part is round. Extension of the rubber as a sock (as in E) makes the prosthesis more waterproof. No ankle-joint is used, but a lock is needed at the mechanical knee-joint of an above-knee prosthesis in order to prevent knee buckling at heel contact. A broad area of the rocker-type foot reduces the sinking into soft ground.

* Submitted by Mr G. M. Muller, Surgeon-in-Charge, Orthopaedic Clinic, Colombo.

FIG. 3. SIMPLIFIED PROSTHESES FOR LOWER EXTREMITY USED IN JAPAN *

These prostheses use a short rocker-foot for broad bearing-area and stability. Knee-joints of above-knee limbs should be locked. No ankle-joint is used. In the device shown on the right, a section of a rubber tire (automobile type), supported by a metal plate, is used as a sole.

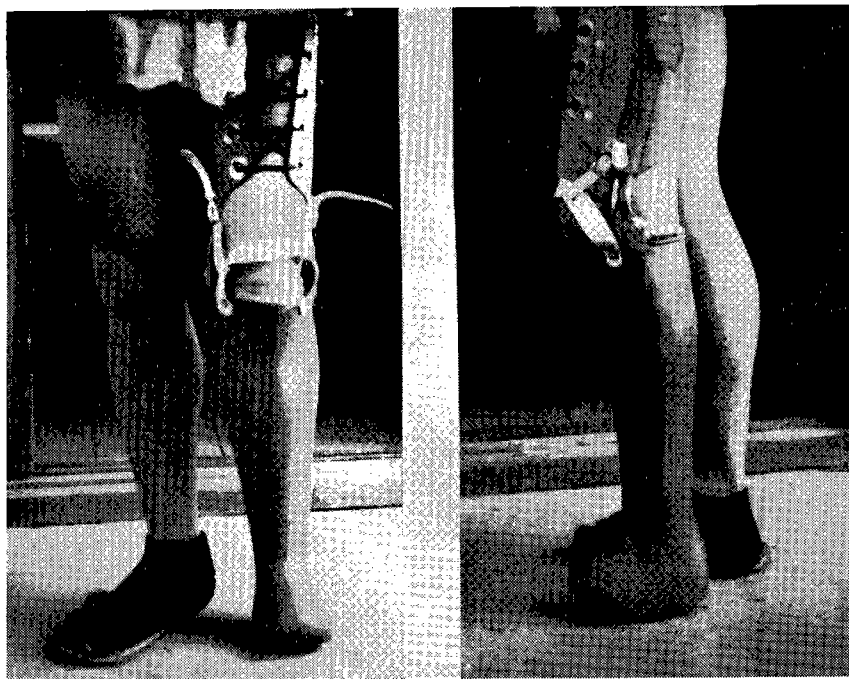
* Submitted by Dr M. Hiyeda, Vice-Director, National Rehabilitation Centre for the Handicapped, Tokyo.

FIG. 4. SIMPLIFIED PROSTHESIS FOR LOWER EXTREMITY USED IN JAPAN *

This prosthesis uses a short rocker-foot for broad bearing-area and stability. Knee-joints of above-knee limbs should be locked. No ankle-joint is used.

* Submitted by Dr M. Hiyeda, Vice-Director, National Rehabilitation Centre for the Handicapped, Tokyo.

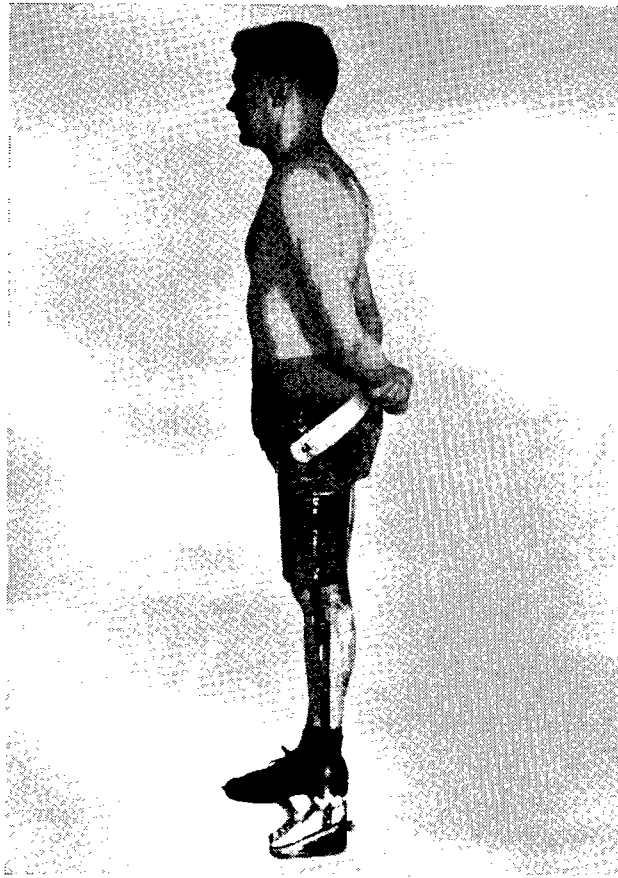
FIG. 5. SIMPLIFIED PROSTHESIS FOR LOWER EXTREMITY USED IN JAPAN *



This prosthesis uses a short rocker-foot for broad bearing-area and stability. Knee-joints of above-knee limbs should be locked. No ankle-joint is used.

* Submitted by Dr M. Hiyeda, Vice-Director, National Rehabilitation Centre for the Handicapped, Tokyo.

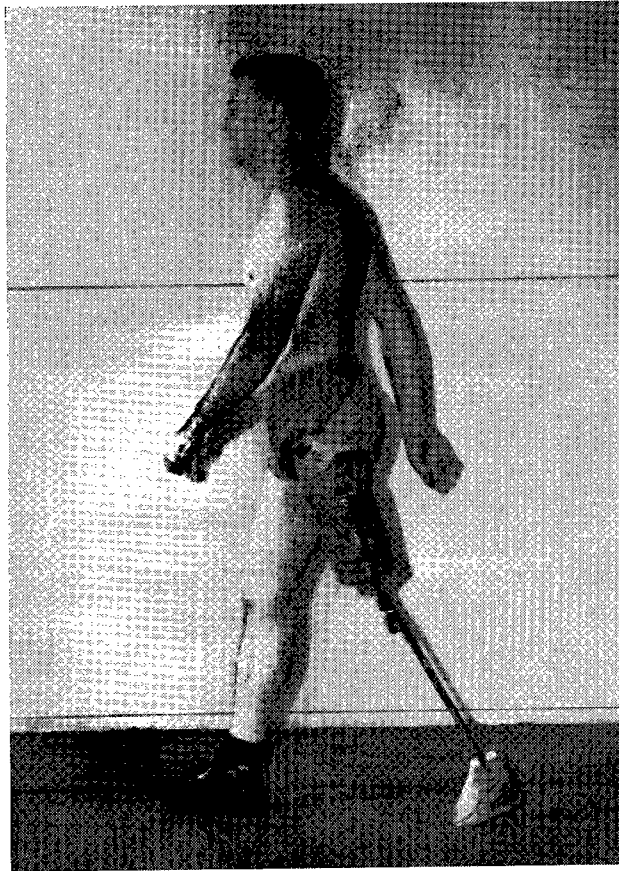
**FIG. 6. EXPERIMENTAL SIMPLIFIED PROSTHESIS
FOR ABOVE-KNEE AMPUTATION ***



A strong wooden core rigidly fastened to the shank without an ankle-joint extends to the ball of the foot, giving alignment stability for the free knee-joints in the stance phase. The laminated, waterproof, sponge-rubber heel wedge compresses at heel contact. Brace-like stainless steel side-bars are used. Nylon bushings and washers in the knee joint, easily and cheaply replaced, prevent wear on the individually fitted side-bars. The side-bars are reinforced and the plastic or Celastic suction socket is supported by a stainless steel band. The modified "Silesian band", passing below the opposite iliac crest and returning to the anterior surface of the socket, both helps to support the prosthesis and controls rotation and abduction.

* Submitted by E. F. Murphy, Ph.D., Chief, Research and Development Division, Prosthetic and Sensory Aids Service, Veterans Administration, New York, USA.

**FIG. 7. EXPERIMENTAL SIMPLIFIED PROSTHESES
FOR ABOVE-KNEE AMPUTATION ***



This figure shows the free knee-joints in the side-bars during walking. A reinforcing cross-band between the two upper side-bars, just below the knee joints, both reinforces the bars and provides support during kneeling. The amputee can also help to balance himself in the squatting position by holding this bar with one hand and the post or other support with the other. Absence of a conventional toe-piece creates a slight limp due to lack of support beyond the position shown in the illustration but minimizes the risk of stubbing the "toe" in underbrush. The broad surface of the foot compared to a conventional peg leg provides support on soft ground. The anterior surface of the ball of the foot should be bevelled so as to provide good support in the squatting position.

* Submitted by E. F. Murphy, Ph.D., Chief, Research and Development Division, Prosthetic and Sensory Aids Service, Veterans Administration, New York, USA.

Annex 6

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