Prosthetics and Orthotics International, 1996, 20, 51–60

Prosthetics in the developing world: a review of the literature

D. CUMMINGS

Texas Scottish Rite Hospital for Children, Dallas, USA

Introduction

Publications about prosthetics in the developing world reflect the multiple concerns of health care providers working in those countries. Following a RECAL search of related literature from 1961 to 1994, over 130 publications were collected and reviewed. Although each geographical region, country, province or city poses unique challenges, there is much overlap in the literature and most of these publications may be grouped into the following general categories:

key publications;
prosthetics in the developing world;
technical publications;
war-related injuries and prosthetic and orthotic issues;
paediatric prosthetic-orthotic care in developing countries.

Key publications

In the course of reviewing the literature, several publications which seemed to summarize the body of available literature were identified and used as the foundation for the outline above. These key articles also serve to highlight important recurring themes and issues throughout the literature.

In a review of prosthetics and orthotics in developing countries Sankaran (1984) introduces some general principles. These include a discussion of the types of devices and specific components tolerated in the developing world, quality of amputation surgery, cost, training, and production factors, and the need for devices to enable patients to squat, kneel, and sit on the floor. This overview is followed by a large table listing over 500 cities around the developing world where prosthetic/orthotic centres are located, including a brief notation of the type of work performed in each centre.

Along the path to developing and implementing appropriate prosthetic/orthotic care, one must consider multiple factors. Poonekar (1992) identifies a list of prevailing factors affecting prosthetics and orthotics in India, but these could apply to much of the developing world:

1. Economic factors
2. Social factors
3. Cultural factors
4. Climatic factors
5. Locally available forms of technology
6. Time and distance constraints
7. Psychological factors
8. Materials and resources
9. Religious factors
10. Appropriate technology.

He feels that for an appliance to be appropriate in India, it must be:

1. Low cost
2. Locally available
3. Capable of manual fabrication
4. Considerate of local climate and working conditions
5. Durable
6. Simple to repair
7. Simple to process using local production capability
8. Reproducible by local personnel
9. Technically functional (not gratuitously "high-tech")

All correspondence to be addressed to Don Cummings, Texas Scottish Rite Hospital for Children, 2222 Welborn, Dallas, TX 75219, USA.

10. Biomechanically appropriate
11. As lightweight as possible
12. Adequately cosmetic
13. Psychosocially acceptable.

The establishment of prosthetic/orthotic programmes to aid developing countries is often accomplished through a profusion of governmental and non-governmental agencies. These programmes are generally of three types: 1) research programmes aided by financial support in collaboration with institutions, agencies or organizations in a developed country, 2) programmes that introduce devices or techniques into established orthotic and prosthetic centres in a particular country, and 3) programmes designed to establish centres in countries or regions where there are no organized prosthetic/orthotic programmes. In a discussion of a practical plan for such projects Peizer (1977) suggests a three-step process. First, a programme should bring together representatives of the host country and the sponsors for comprehensive planning meetings. Even at this early stage, he suggests that input from ISPO can be helpful in regard to training, evaluation, and planning. The second phase involves site visits, ideally utilizing ISPO representatives to evaluate the capabilities, personnel, equipment and other needs of the host country. In the third step, the programme is actually designed in great detail based on the information gathered during the first two stages.

Peizer feels that this approach will help avoid many common problems. He continues his discussion with a detailed explanation of how an expert teaching team should be selected and then prepared for training missions, and how the host country can benefit most from their efforts. He emphasizes that training should be provided by experienced educators who understand the conditions under which their students must practice, and that all efforts should be geared toward a technology transfer that can actually be integrated into the host country's health care system.

From a broad perspective, any approach that involves training of new prosthetists using conventional techniques faces an uphill battle. Murdoch (1990) cites conservative estimates that 3 to 4 million people in the developing world require a prosthesis, and that care for this number would require equipping and training 50,000 to 100,000 prosthetists. Proponents of CAD CAM (Computer Aided Design-Computer Aided Manufacture), suggest that by boosting efficiency and productivity of existing prosthetists, automated manufacture of prostheses combined with modular components may help diminish this shortfall. This approach is currently being tested in Hanoi, Vietnam by the Prosthetic Research Foundation (Smith *et al.*, 1992).

At the heart of most of the literature is the dilemma of how to provide and implement appropriate prosthetic/orthotic care in the developing world, where at least 80% of those needing such care are urban and rural poor who cannot afford it. There are two very different and often conflicting approaches to the problem: the "top-down" approach of buying and implementing technology packages from the west, and the simplistic approach of traditional, primitive technology. Sethi (1989) feels that something is missing from this debate:

> . . . a distinction is not being made between science and technology. We are confusing expensive gadgetry with good science. This often is not so. It requires some very sophisticated thinking to arrive at a simple solution. It is much easier to work out a complicated and expensive solution. Indeed, whenever one encounters an expensive and complicated technology, one can take it that the basic issues have not been understood. Expensive *gadgetry* often possesses impressive "Symbolic Value" as opposed to "Use Value". What we want is more, and not less science in the developing world (p. 118).

He goes on to explain that the scientific approach should be used to evaluate technology being used and designed for the developing world, but that this approach is also subject to failure if it ignores the lifestyles and cultures of the patients being served. As an example, he traces the development of the Jaipur foot in India. He feels that the component's success lies in its gradual method of development which involved continuous interaction between the developers of the component, those who would fabricate it using cost-effective locally available materials, and the amputees who wore the foot day in and day out.

Vossberg (1988), supports a similar approach when he analyzes orthotic/prosthetic techniques in Colombia. He discusses three different levels of service available in Colombia (the government-controlled workshop, the workshop supported by non-government organizations, and the private workshop), and how each is impacted by the various forms of available orthotic and prosthetic technology. He feels that appropriate technology "... ranges on an intermediate level between a stagnant, inconsistent, labour-intensive technology and an imported, capital-intensive industrial mass-scale technology" (p. 99). Unless it can be sustained and made affordable to most patients after funding and technical support are removed, the imported "high-tech" approach appears ultimately to ignore the large poor sector of the population; whereas the artisan or primitive technology approach takes a step backwards by placing the burden of practice of a highly specialized profession in the hands of "a considerable number of self-proclaimed or short-term trained technicians ..." (p. 98).

In order to provide truly appropriate technology that copes with present and future demands, Vossberg (1988), lists a number of policy guidelines that should be considered:

- formulate new ideas and examine approaches, methods and techniques in the field of prosthetics and orthotics, which could best be applied in a distinct environment
- create a new type of orthopaedic technician who is able to initiate ideas for indigenous designs and detail their construction criteria to the production engineer
- replace a technology which is characterized by high costs and over-sophistication by one which is acceptable in terms of cost-benefit and effectiveness, technical appropriateness and environmental adaptability
- exchange the feasibility studies and research in the area of appropriate technology to intensify communication and cooperation among the concerned institutions (p. 100).

In a related publication about appropriate technology transfer, Vossberg (1985), lists practical principles of technical training and counselling in a developing country:

- give ample time to study and understand the social environment
- investigate traditional methods and materials
- define the programme's priority areas
- on the basis of these findings, develop indigenous appliances
- test these in conditions which are typical of the country
- specify the appliances by means of illustrations and descriptions
- propagate the philosophy of an appropriate orthopaedic technology (p. 84).

Prosthetics in the developing world

In 1976, the member countries of the World Health Organization (WHO) agreed to include rehabilitation in their goal of "Health for all by the year 2000". Because it was later stated that up to 90% of all disabled persons in developing countries were largely neglected, the organization decided on a rehabilitation model appropriate for use as a supplement for existing institution-based services in developing countries. This rehabilitation model has come to be known as community-based rehabilitation (CBR) (Mitchell *et al.*, 1989). Numerous articles surveyed dealt specifically with various aspects of CBR, and much of the literature dealing with prosthetics and orthotics in developing countries has been permeated with many of the concepts and terms originating in CBR.

Ideally, CBR services consist of three levels that interact to provide appropriate rehabilitation services:

1. Community level
   – services delivered by volunteer community workers, families of disabled persons, community agencies and organizations.
2. Intermediate level
   – personnel who have health-related, but not disability-specific backgrounds, e.g. general practitioners, nurses, midwives, teachers, social workers and auxiliary workers.
3. Specialized or tertiary level
   – specialists in rehabilitation medicine, special education, vocational rehabilitation and social services. (Periquet, 1989, p. 95).

Although there are numerous variations of CBR, all appear to have the following general principles in common:

1. Community resources from the nucleus for CBR delivery.
2. CBR is based on simplified and appropriate technology.
3. An effective referral and support system

should exist.

4. CBR should use the existing social and community infrastructure (Mitchell *et al.*, 1989, p. 145).

CBR appears to be here to stay for a while, and is generally an efficient, cost-effective approach to awareness and prevention of disabilities and to delivery of rehabilitation service, particularly in rural areas with no previous access (Periquet, 1989). This approach will undoubtedly continue to influence development of prosthetic services, training schemes, and cooperation between members of the rehabilitation team in developing countries. Some questions that remain to be answered are whether or not prosthetics and orthotics fit the CBR model, and if so, on which level of CBR service?

Although prosthetic rehabilitation is consistent with the WHO's goals, there are other reasons why even impoverished countries have a vested interest in developing prosthetic care. Staats (1993), observes three "action triggers" that create a powerful incentive for a country to address the needs of its untreated amputee population.

The first of these he calls the "media imperative" for action. The high profile nature of amputation, particularly those that are war related or that affect children, easily captures the hearts and imagination of the media, and through them, potential donors and humanitarian groups. The traumatic, disfiguring nature of amputation, followed by the positive results of prosthetic fitting are often dramatic, and carry a unique appeal for the media. As a result, virtually any sustained news coverage about disease, disaster, war or the aftermath of war includes at least visual documentation of the plight of the amputee. There can be tremendous political pressure, therefore, for a nation to address this highly visible problem.

This political pressure is the second action trigger discussed by Staats. He explains that since a government cannot afford the demoralizing impact upon its citizens of seeing its war veterans or civilian victims devoid of medical and prosthetic care, there is again tremendous pressure for a nation to provide prosthetic treatment or to accept outside help in this area. Finally, in some countries, Staats has observed that the sheer numbers of amputees are so high as to represent a political, economic and social disaster. Hence, in addition to media and political pressure, there also exists a volume imperative for action. Staats concludes by observing that since prosthetic care will largely remain a humanitarian effort in most developing countries – meaning that most amputees will have limited access to prosthetic care during their entire life – primary goals for prostheses should be for comfort and durability.

As a developing nation begins to address the needs of its amputee population, it will often begin to discover that "a properly rehabilitated patient usually costs a government less money than a disabled person totally dependent on government support" (Stills, 1993, p. 45). Surveys of developing nations indicate that most of these nations realize that as they develop, the physical and social rehabilitation of disabled countrymen is an essential part of a modern community. But differences in the degree and quality of care between countries are often huge. The survey by Saugmann-Jensen (1959) suggests that these differences are more related to disparity in politics and financial potential, and not to differing views on whether or not prosthetic care is justified.

Political and financial differences as well as variances in climate, population distribution, transportation, communication, medical infrastructures, educational systems, and multiple other factors combine to create stark contrasts between countries' abilities to develop and provide prosthetic care. However, one common aspect of orthopaedic care in developing countries is that prosthetic centres in the capital and other large cities are largely staffed by prosthetists trained and employing techniques acquired abroad. In smaller remote communities and rural areas, most care is substandard and offered by unqualified staff (Kaphingst and Heim[1], 1985). This apparent widespread disparity can only be improved through appropriate education.

Component production is emphasized in a chapter by Kaphingst and Heim[2] (1985), who discuss current prosthetic education and training in the developing world. The authors conclude that because of staff shortages, large patient numbers, lack of components, and immense practical and financial challenges, prosthetists in developing countries must be very creative, and probably need *more* and not less training. They recommend that training in the developing world should not be simplified, rather it should focus on more specific manual skills, and component production should be part of the curriculum.

In a series of three articles on the subject, Fishman (1986, 1987) describes what he feels are the three most serious challenges to appropriate prosthetic care in developing countries:

a) the low or marginal educational status and limited potential of the individuals selected to receive the training;
b) the corresponding role, bench-work oriented, instruction most often devoid of texts, visual aids, examinations, or trained instructors; and
c) the consequent inability of those completing the training
   i) to comprehend and apply the scientific (biomechanical) rationale to prosthetic-orthotic fittings, and
   ii) to manage the logistical complexities (personnel, space, supplies, budgeting, scheduling, transportation, security, etc.) of organizing and maintaining a facility that can consistently provide prosthetic/orthotic appliances (Fishman, 1986, p. 36).

Fishman (1986) suggests a three-tiered approach to tackling these challenges; improved educational opportunities, widespread availability of locally-made components (engineers and component manufacturers should be consulted for this), and ongoing improvement of facility management techniques and basic prosthetic orthotic skills.

Numerous publications concerned with the state of prosthetics and orthotics in the developing world focus on specific challenges, statistics, demographics and clinical results in individual countries, and a few larger volumes serve as references to services in many countries. Although these each have merit, time and space do not allow an individual review.

Technical publications

Numerous technical publications were reviewed and grouped into the general categories of: 1) fabrication techniques, 2) prosthetic feet, 3) general technical aids, 4) thermoplastics, and 5) CAD CAM. A brief synopsis of each publication is included, followed by the authors' names.

Fabrication techniques

1. Detailed text on alternative techniques for design and fabrication of trans-tibial prostheses. Includes alignment, anatomy, casting, modification, sockets (leather, aluminium, resin, and wood construction), suspension systems, and fabrication of feet (including SACH and Jaipur designs). This is an excellent text for prosthetists in developing countries as well as for prosthetists wishing to learn about methods and materials used in the developing world (Alternative limbmaking, 1989).
2. Complete manual for local production of an exoskeletal single axis knee component complete with manual lock and extension assist options. Includes drawings, photographs, and schematics (Telchow and Gehrels, 1984).
3. Tilting stubbies for bilateral trans-femoral amputees to connect and interchange with their full-length prostheses (Balakrishnan, 1981).
4. Use of cane and bamboo as alternative construction materials for prostheses, orthoses, and assistive devices (Banerji and Banerji, 1984).
5. Design of a "hanging stump" ischial bearing ring prosthesis for residual limbs in bad condition or otherwise unfittable limbs (Chand *et al.*, 1985).
6. Kinematic analysis of knee-ankle design parameters for Afro-Asian cultures where patients kneel, squat and sit cross-legged. Includes a description of a six-bar linkage system designed to facilitate squatting (Chakraborty and Patil, 1988).
7. Description of an AK prosthesis designed to facilitate squatting, and cross-legged sitting. (Chaudry *et al.*, 1981 and 1982).
8. Design of a trans-femoral prosthesis permitting squatting through modifications to conventional knees and/or adjustable knee and ankle flexion stops (Guha *et al.*, 1977).
9. Design of a trans-femoral prosthesis to enable squatting using a modified Lang single axis knee (Madhavan *et al.*, 1977).
10. Fabrication of trans-tibial and trans-femoral prostheses using indigenous materials in India. Of interest is the use of a mixture of polyester resin and cork granules for fabrication (Girling, 1968).
11. Use of locally-made components to

fabricate prostheses. The design include a SACH foot, figure 8 cuff, and a single-axis knee design (Girling and Cummings, 1972).

12. Design of a simplified low-maintenance prosthesis for use in Thailand or other countries where patients walk in water or mud (ie rice paddies). The design incorporates a laminated foot cut short to a "Chopart" configuration with no rubber components. This design purportedly aids patients walking in water or mud and resists water damage, mildew and rotting (Kijkusol, 1986).
13. Use of a peg-leg prosthesis for leprosy patients in rural areas (Kulkhari and Mehta, 1982).
14. Design of an inexpensive endoskeletal prosthesis using the Jaipur foot, conduit pipe and a hinge joint. The article also presents cost and durability concerns, and the challenges of squatting, and sitting cross-legged with a prosthesis (Mohan *et al.*, 1992).
15. A discussion on the use of local materials to fabricate prostheses and orthoses in developing countries with an emphasis upon concerns for children's devices (Oshin, 1981).
16. Fabrication of an aluminium open-ended trans-tibial prosthesis for use with the Jaipur foot. The entire process of fabrication reportedly requires about one hour, and relies upon the skills of local artisans. The article emphasizes the advantages of a highly efficient locally staffed and supplied delivery system (Ring and Sethi, 1981).
17. A general approach to providing prostheses to rural or urban poor in developing countries. The article addresses specific challenges such as barefoot walking, sitting cross-legged or squatting, hot environments, and uneven terrain. The author compares and contrasts traditional SACH feet, Muller solid rubber feet, and the Jaipur foot (Sethi, 1974).
18. Modification of the Jaipur system for trans-tibial amputees by use of high-density polyethylene irrigation pipe instead of aluminium for the socket and shank (Upadhayn *et al.*, 1988).
19. Fabrication of a laminated PTB style prosthesis for use in India. Requires use of plaster, an adjustable pylon, and thermosetting resin (Wollstein, 1972).
20. Basic techniques for an epoxy laminated PTB prosthesis. The technique described includes a directly-applied socket, plastazote liner, laminated hollow cone shank, and rubber tyre sole. A similar technique for fabricating a non-articulated trans-femoral prosthesis is described (Pfaltzgraff, 1976 and 1966).

Prosthetic feet

1. Use of tyre sidewall to construct a crutch "foot" (Broadhurst, 1988).
2. A comparison of various SACH feet with emphasis on the advantages of the Vellore SACH foot design, which includes a tyre rubber sole to improve durability and enable limited barefoot walking (Lazarus *et al.*, 1983).
3. Design of a new all terrain foot, interchangeable with the Seattle foot. The design has application for any prosthetic user who ambulates on uneven terrain or in water (Matthews *et al.*, 1993).
4. Design of a solid rubber foot ending at the MP joint area and including a proximal tapered cone into which the socket and shank, generally aluminium, are glued. The foot is intended to benefit barefoot walkers, and provides greater adjustability to uneven terrain than traditional SACH feet (Muller, 1957).
5. Performance measurement of the Jaipur foot (North *et al.*, 1974).
6. Development of the Jaipur foot (Sethi, 1972).
7. Design and development of the Jaipur foot. Focuses on the need for multiaxial ankle adaptation for uneven terrain and typical rural Indian life (Sethi *et al.*, 1978).
8. Rationale for the Jaipur foot and development of same (Technology for developing countries, 1993).

Technical aids, equipment, seating systems etc

1. Discussion of Community Based Rehabilitation and appropriate technology (Appropriate technical aids for disabled people (Bombay Seminar), 1988).
2. Unique reference manual for fabrication of mobility aids, (ie seating, positioning, beds, chairs, and walkers), using local

"primitive" materials such as bamboo, string, simple nails, etc. Because this manual uses simple drawings to depict what can be fabricated and virtually no text, it is immediately useful to local artisans with no need for translation (Caston, 1982).

3. Discussion of local production (in Africa), of assistive devices and equipment. Includes information on how to set up a workshop, a description of the Jaipur programme and how to replicate it elsewhere, and descriptions of local production of orthoses, prostheses, chairs, wheelchairs, and assistive devices for children (Appropriate aids and equipment for disabled in Africa, 1988).
4. Design of an anthropometer for use in developing countries. The article describes fabrication and use of a tool for research and prosthetic/orthotic measurement (Davies and Shahnawaz, 1977).
5. Use of plywood, metal hinges and screws to fabricate positioning splints for patients with recent onset of polio (Varma, 1988).

Thermoplastics

1. Cost benefits of thermoplastics (where available) are discussed (Oberg, 1991).
2. General criteria for use of thermoplastics as opposed to wood, iron, aluminium, or leather (Thermoplastics in prosthetics and orthotics, 1993).

CAD CAM in the developing world

1. Design and development of CAD CAM for use in developing countries. The paper focuses upon non-contact, laser imaging, software for socket modifications, moulding tool production for manufacture of lightweight plastic components, and field testing of results. The authors' concept is to use a remote residual limb scanner to send data by modem to a centralized automated fabrication facility (Walsh *et al.*, 1989).
2. Implications of CAD CAM use in developing countries. The paper includes rationale for and result of a trial CAD CAM facility in Hanoi, Vietnam (Smith *et al.*, 1992).
3. Report of an ISPO workshop on CAD CAM in prosthetics and orthotics (Murdoch, 1988).

War-related injuries and prosthetics and orthotics issues

In the aftermath of a war, countries face a great struggle for economic and social rehabilitation, and literally tens of thousands of patients may require orthopaedic appliances. In some countries like Cambodia, Afghanistan, Mozambique, Burma, Somalia, Ethiopia and Angola (to name a few), land-mines, bombs, and other ordnance may lie in a dormant state for years before causing injury. In Cambodia, for instance, it is reported that in 1990 alone, as many as 6000 people lost a leg or foot to mine explosion (Stover and Charles, 1991).

Without assistance from abroad, there appears to be very little hope that prosthetic-orthotic care will be established until many years have passed. If fighting continues for an extended length of time, it is of course virtually impossible to provide adequate prosthetic-orthotic care within the country. Angola, for instance, after more than thirty years of war is reported to have the highest per capita percentage of amputees in the world, and although the problem is being addressed, continued fighting makes service to rural amputees virtually impossible (in Focus, 1993).

Groups like the International Red Cross (ICRC) often begin initiatives to help disabled war victims in countries like Eritrea before the fighting is over (in Focus, 1993). This early relief generally requires the assistance of a team of expatriate specialists with a systematic and highly modular approach. Over time these specialists can help develop a network of workshops and provide training to local health care workers and gradually return the prosthetic-orthotic care into the nations' hands.

Most of the literature reviewed focused on the challenges of providing prosthetic care in the primitive conditions and overwhelming need following a war. More information regarding methods, techniques, appropriate materials and the establishment of long-term centres is needed.

Paediatric prosthetic/orthotic care

There is really very little published about paediatric prosthetic/orthotic care in the developing world, and certainly this is an area that needs to be more adequately addressed in the future. What is available, seems to indicate that children with congenital limb deficiencies are just about as common in developing countries as in the developed world, but there is very little expertise available both surgically and prosthetically to deal with their problems. In many cases, children with congenital limb deficiencies that would be converted to amputations in more developed countries are simply left untreated.

Sliman *et al.* (1991) discuss surgical treatment of children with longitudinal deficiencies seen at the El Kassab Institute in Manauba, Tunisia. Children with lower limb deficiencies receive amputations and prosthetic fitting when indicated, but children with upper limb deficiencies receive no prosthetic intervention. The inattention to upper limb fitting is not surprising, given the incredible ability of children to adapt, limited acceptance of arm prostheses even in developed countries, and the high degree of complexity of arm prostheses as well as the need for extensive occupational therapy to provide adequate long-term results (United Nations, 1974).

Although a formalized treatment approach for children exists in a few centres, there is an apparent lack of awareness in many parts of India, (and one can assume most of the developing world), regarding surgical treatment and/or prosthetic fitting for children (Sharma, 1991). Cost factors alone undoubtedly affect a nation's ability to provide orthopaedic devices to a population that will quickly outgrow them and require subsequent replacement. The challenge is further complicated by the high incidence of childhood pathologies in developing countries (including polio, cerebral palsy, osteogenesis imperfecta, spina bifida, club feet, inherited disorders, war injuries, and many others), and the inadequate infrastructure to care for these problems surgically, or to provide adequate rehabilitation. Nevertheless, developing countries are becoming aware of the socio-economic implications of leaving children untreated, and there is growing interest in providing prosthetic-orthotic care as well as adequate surgical intervention for this population (Hanckon, 1988; Fernandez-Palazzi *et al.*, 1991; Oshin, 1981).

Conclusion

Much of the available literature emphasizes appropriate technology, but there is often great disparity between what is considered truly appropriate. In part, this term appears to have arisen from the Community Based Rehabilitation (CBR) movement, and once again, it is unclear how prosthetic care fits in with the CBR model. Although the debate over appropriateness is an essential part of the growing process, some consensus would greatly assist current and future organizations in planning and implementing prosthetic-orthotic services and training centres.

In education, much has been accomplished toward establishing standards, but it appears that in actual practice, education in most developing countries ranges from the formal to the chaotic, and that accepted standards are rarely adhered to. The reasons for this are multiple, but one area of weakness in the literature appears to be in cohesive educational packages of texts, and illustrations designed for training in developing countries. Undoubtedly such materials exist and are utilized by various organizations, but are not readily available in this area.

The debate over appropriate technology is evident in the technical literature as well as where publications range from primitive methods to CAD CAM. Although CAD CAM and "high-tech" approaches have been the subject of controversy, it should be noted that such projects have arisen as a result of the overwhelming shortage of adequately trained individuals. Certainly the controversy over costs and sustainability are justified, but progress must start somewhere, so the burden of proof remains in the hands of such projects and their developers.

A great deal of technical literature has been written, and the large volume of literature intended for developed countries should not be overlooked as it can frequently be applied to the developing world. Gaps exist, however. There are few outcome studies, and very few documented component production techniques for developing countries. There appears to be a significant need for durable prosthetic feet as well as other components that can be manufactured in-country, and the many facilities currently fabricating their own components should collaborate with other facilities to compare results in order to aid the quest for the ideal, low cost, durable, locally manufactured system.

Perhaps above all, the literature emphasizes the enormity of the challenge of providing adequate prosthetic-orthotic care in the developing world, the many ongoing efforts to address the needs of amputees in these countries, and the need for much more communication between countries and the various programmes that are in existence.

REFERENCES

ALTERNATIVE limbmaking: the manufacture and fitting of low cost below knee prostheses./edited by A Darnborough... (*et al.,*).- London: AHRTAG 1989.

APPROPRIATE aids and equipment for disabled people in Africa; report of a seminar in Harare, Zimbabwe, March 20-26. 1988. – Broma, Sweden: ICTA, 1988.

BALAKRISHNAN A (1981). Tilting stubbies: technical note. *Prosthet Orthot Int* **5,** 85-86.

BANERJI B, BANERJI JB (1984). A preliminary report on the use of cane and bamboo as basic construction materials for orthotic and prosthetic appliances. *Prosthet Orthot Int* **8,** 91-96.

BROADHURST M (1988). A low-tech crutch foot. *Appropriate Technol* **14(4),** 8-10.

CHAKRABORTY JK, PATIL KM (1988). Kinematic analysis of knee-ankle mechanism for an above knee prosthesis. *Mech Res Commun* **15,** 261-268.

CHAND N, SRIVASTAVA RK, MAISH AR (1985). Hanging stump prosthesis without socket for bad above-knee stumps: technical note. *Prosthet Orthot Int* **9,** 154-156.

CHAUDHRY KK, GUHA SK, VERMA SK (1982). An improved above-knee prosthesis with functional versatility. *Prosthet Orthot Int* **6,** 157-160.

CHAUDHRY KK, GUHA SK, VERMA SK (1981). Modular concept in a multi-functional above knee prosthesis. *Eng Med* **10,** 155-158.

DAVIES BT, SHAHNAWAZ H (1977). An anthropometer for use in developing countries: equipment note. *Ergonomics* **20,** 317-320.

FERNANDEZ-PALAZZI F, DE GUTIERREZ DP, PALADINO R (1991). The care of the limb deficient child in Venezuela. *Prosthet Orthot Int* **15,** 156-159.

FISHMAN S (1986). Clinical prosthetic-orthotic services in the developing world. *AOPA Almanac* **34(9),** 18-19.

FISHMAN S (1986). Prosthetics and orthotics in the developing world – education. *AOPA Almanac* **34(5),** 36.

FISHMAN S (1987). Prosthetics and orthotics in the developing world – international assistance programs. *AOPA Almanac* **36(4),** 36-37.

IN FOCUS (1993). Angola. *Ortholetter* **1,** 7-8.

IN FOCUS (1993). Eritrea. *Ortholetter* **2,** 4-6.

GIRLING J (1968). A method of constructing artificial limbs in India. *Prosthet Int* **3(4/5),** 32-36.

GIRLING J, CUMMINGS G (1972). Artificial-limb fabrication without the use of commercially made components. *Prosthet Int* **4(2),** 21-25.

GUHA SK, CHAUDRY KK, MADHAVAN PG *(et al)* (1977). Above knee prosthesis permitting squatting. *Med Life Sci Eng* **15,** 25-33.

HANEKON JM (1988). A survey of children attending a rehabilitation centre in Harare. Implications for rehabilitation. *Centr Afr J Med* **34,** 149-153.

KAPHINGST W, HEIM S[1] (1995). Education and training in prosthetics in the developing world. In: Amputation surgery and lower limb prosthetics./edited by G Murdoch, R Donovan.–Oxford: Blackwell Scientific. p436-439.

KAPHINGST W, HEIM S[2] (1985). Cultural considerations and appropriate technology in orthopaedics for developing countries. In : Amputation surgery and lower limb prosthetics./edited by G Murdoch, R Donovan.–Oxford: Blackwell Scientific. p384-389.

KIJKUSOL D (1986). Simplified, low cost below-knee prosthesis. *Prosthet Orthot Int* **10,** 96-98.

KULKARNI VN, MEHTA JM (1982). Observations on peg-prostheses in leprosy. *Lepr India* **54,** 110-116.

LAZARUS MS, SUDARARAJ GD, SELVAPADIAN AJ (1983). Comparative study of prosthetic feet with Vellore modified prosthetic foot. *J Rehabil Asia* **24(1),** 5-10.

MADHAVAN PG, CHAUDHRY KK, GUHA SK (1977). New concepts in AK prostheses. *Med Life Sci Eng* **3,** 97-102.

MATTHEWS D, BURGESS E, BOONE D (1993). The all-terrain foot. *J Prosthet Orthot* **5,** 29-30.

MITCHELL RA, ZHUO D, WATTS GH (1989). Emerging patterns of disability distribution in developing countries. *Int Disabil Studies* **11,** 145-148.

MOHAN D, SETHI PK, RAVI R (1992). Mathematical modelling and field trials of an inexpensive endoskeletal above-knee prosthesis. *Prosthet Orthot Int* **16,** 118-123.

MULLER GM (1957). A simple prosthesis for rural amputees. *J Bone Joint Surg* **39B,** 131.

MURDOCH G. CAD/CAM and the developing world. Report of ISPO Workshop on CAD/CAM in Prosthetics and Orthotics, Seattle WA, June 1988.

MURDOCH G (1990). Editorial. *Prosthet Orthot Int* **9(1),** 1-2.

NORTH JF, JONES D, GOVAN NA... *(et al)* (1974). Performance measurement of the Jaipur foot. Paper presented at the Congress: ISPO Interbor, APO, Montreaux, Oct 8th-12th, 1974. 24pp.

OBERG K (1991). Cost-benefits in orthopaedic technology by using thermoplastics in developing countries. *Prosthet Orthot Int* **15,** 18-22.

OSHIN TA (1981). Indigenous substitutes for modern prostheses and orthoses. *Prosthet Orthot Int* **5,** 144-146.

PELZER E (1977). Planning prosthetic and orthotic programmes to aid developing countries. *Prosthet Orthot Int* **1**, 119-124.

PERIQUET AO (1989). Community-based rehabilitation in the Philippines. *Int Disabil Stud* **11**, 95-96.

PFALTZGRAFF RE (1966). A simplified below-knee prosthesis. *Bull Prosthet Res* **10(5)**, 48-57.

PFALTZGRAFF R (1977). Principles for fabrication of simple lower limb prostheses. In: The disabled in developing countries, proceedings of a symposium on appropriate technology and delivery of health and welfare services for the disabled in developing countries, Oriel College, Oxford, 26-30 September 1976.–London: Commonwealth Foundation. p26-28.

POONEKAR P. Prosthetics and orthotics in India. In: Report of a research planning conference – prosthetic and orthotic research for the twenty-first century. Bethsheda, Maryland, 23-25 July 1992.–National Institute of Child Health and Human Development. p233-239.

RING RD, SETHI PK (1981). A rapid-fit limb using alternative technology in India. *J Biomed Eng* **3**, 318-319.

SANKARAN B (1984). Prosthetics and orthotics in developing countries. *Int Rehabil Med* **6**, 85-101.

SAUGMANN-JENSEN J (1959). A preliminary report on the economical aspects of providing prostheses, braces and technical aids. *Prostheses Braces Tech Aids* **4**, 8-11.

SETHI PK (1972). A rubber foot for amputees in underdeveloped countries. *J Bone Joint Surg* **54B**, 177-178.

SETHI PK (1974). Lower limb prosthesis for amputees in rural areas. In: Surgical rehabilitation in leprosy./edited by F McDowell, CD Enna.–Baltimore, Williams & Wilkins. p396-402.

SETHI PK (1989). Technological choices in prosthetics and orthotics for developing countries. *Prosthet Orthot Int* **13**, 117-124.

SETHI PK, UDANAT MP, KASLIWAL SC *(et al)* (1978). Vulcanized rubber foot for lower limb amputees. *Prosthet Orthot Int* **2**, 125-136.

SHARMA VP (1991). The care of the limb deficient child in India. *Prosthet Orthot Int* **15**, 143-145.

SLIMAN N, MRABET A, DAGHFOUS S... *(et al)* (1991). The care of the limb deficient child in North Africa. *Prosthet Orthot Int* **15**, 152-155.

SMITH D, BOONE D, HARLAM J... *(et al)*. Implications of modern prosthetic technologies in developing countries. In: Report of a research planning conference – Prosthetic and orthotic research for the twenty-first century, Bethsheda, Maryland, 23-25 July 1992.–National Institute of Child Health and Human Development. p217-225.

STAATS TB (1993). Fellowship report on cross cultural issues for appropriate technology prosthetics in developing countries.–Washington, DC: World Rehabilitation Fund.

STILLS ML (1993). Practising O&P in a developing country. *O&P Almanac* **42(7)**, 45.

STOVER E, CHARLES D (1991). The killing minefields of Cambodia. *New Scientist* **19 October**, 26-30.

TECHNOLOGY for developing countries? (1993). *Ortholetter* **1**, 2-4.

TELCHOW M, GEHRELS J (1984). Debre Zeit calf knee component. Tanzania Training Centre for Orthopaedic Technologists/German Agency for Technical Co-operation.

THERMOPLASTICS in prosthetics and orthotics (1993). *Ortholetter* **1**, 5-6.

UNITED NATIONS. Report of the United Nations interregional seminar on Standards for the Training of Prosthetists: organized by the United Nations and the Government of Denmark with the co-operation of the International Committee on Prosthetics and Orthotics of the International Society for Rehabilitation of the Disabled, Holte, Denmark, 1-9 July 1968 – New York: UN.

UPADHAYA M, SHARMA SR, SHARMA S (1988). Structural modification of "Jaipur foot" with high density polyethylene shank. *J Rehabil Asia* **29(1)**, 13-16.

VARMA V (1988). Simple splints. *J Rehabil Asia* **29(1)**, 1-7.

VOSSBERG A (1988). The choice of prosthetic and orthotic technique for less developed countries: analysis and perspectives in Colombia. *Prosthet Orthot Int* **12**, 96-100.

VOSSBERG A (1985). The development of orthopaedic appliances and low cost aids in "least developed countries". *Prosthet Orthot Int* **9**, 83-86.

WALSH NE, LANCASTER JL, FAULKNER VW *(et al)* (1989). A computerized system to manufacture prostheses for amputees in developing countries. *J Prosthet Orthot* **1**, 165-181.

WOLLSTEIN LJ (1972). Fabrication of a below-knee prosthesis especially suitable in tropical countries. *Prosthet Int* **4(2)**, 5-8.

WORLD HEALTH ORGANIZATION. Resolution on Disability Prevention and Rehabilitation (A29-68).- Geneva: WHO, 1976.

A full list of the literature reviewed for this article is given in Appendix 2 of the Report of the Consensus Conference on Appropriate Prosthetic Technology in Developing Countries.