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A Report on Amputees in India

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INTRODUCTION

A National Seminar on Rehabilitation Services and Reseach was held at the Medical College in Trivandrum in December, 1967. Speaking at the Seminar, Dr. P.K. Duraiswami, who was at that time the Additional Director General of Health Services, said that he was not surprised "that the problem of the Rehabilitation of the Handicapped has been given a low priority, in spite of its humanitarian aspect" because the central and state governments had to spend a large proportion of their limited funds on other health problems and population control.[1] In the same lecture he mentioned that according to plans, India will have six rehabilitation centres and 36 rehabilitation units in order to provide "effective rehabilitation service to the largest number of physically handicapped." Many of these centres and units have since seen established.

Almost 14 years later, Dr. P.K. Sethi, speaking at the Asian Meeting on Childhood Disability, confessed that "how utterly unrealistic my understanding was about this problem and I have increasingly a feeling of having wasted valuable years. I imagined, and I dare say most doctors and health administrators continue to so believe, that if we have a large number of well equipped rehabiltation centres with the latest facilities for sophisticated physiotherapy, occupational therapy and workshops for providing rehabilitation aids such as calipers, artificial limbs, and other sophisticated appliances we would be able to tackle the problem of childhood disability. We continue to lament the scarcity of such centres in our country and plead for financial assistance so that we may perform as well as the most advanced countries in the world. I am now convinced that if we continue to believe in the effectiveness of expensive institutional treatment, we shall never achieve our objectives. In fact, by diverting our limited manpower and financial resources towards building a few prestigious institutions, we shall deprive the millions of our disabled in the rural areas where the bulk of our people reside."[2]

The above two quotes show that though the problem of disabilities has been recognized in its extent and complexity for some time, there does not seem to be much agreement on how the problem should be tackled. Though Dr. Sethi feels that sophisticated institutions will not solve the problem, many other professionals in the field are convinced that without such institutions we will continue to be "backward" in our rehabilitation services. As the debate continues, so does the increase in the number of disabled in India. By the latest count, there are at least 12 million physically disabled persons in India.[3] Unless some realistic plans are formulated, these debates will not help us in the rehabilitation of these millions.

In this study, an attempt has been made to understand the issues involved by concentrating on a small section of the dis-

abled—the amputees. The latter have been chosen because they are easily recognized and detected and so the associated statistics are more likely to be accurate. Secondly, a great deal of research and development work has been done on artificial limbs, and so it would be easier to discuss alternatives in rehabilitation. Issues and solutions in other areas of disability would be at least as complex, if not more. Therefore by examining one small area of disability in detail we would get a feel for the problems in others also.

This paper has been divided into three sections. The first section deals mainly with the epidemiology of amputees in India. Most of this information has been obtained from the National Sample Survey Organization's (NSSO) Report on Disabled Persons released in March, 1983.[3] This is probably the most accurate estimate of physically disabled persons in India based on NSSO's definitions of various disabilities.

The second section deals with the kind of aids and appliances that are being given to amputees in India. This section is based on information collected by the Centre for Biomedical Engineering, Indian Institute of Technology, New Delhi, and also by The Institute for the Physically Handicapped, New Delhi. In both cases, the information has been obtained by personal visits to the various rehabilitation centres around the country.

In the last section, an attempt has been made to propose guidelines for future work in the rehabilitation of amputees.

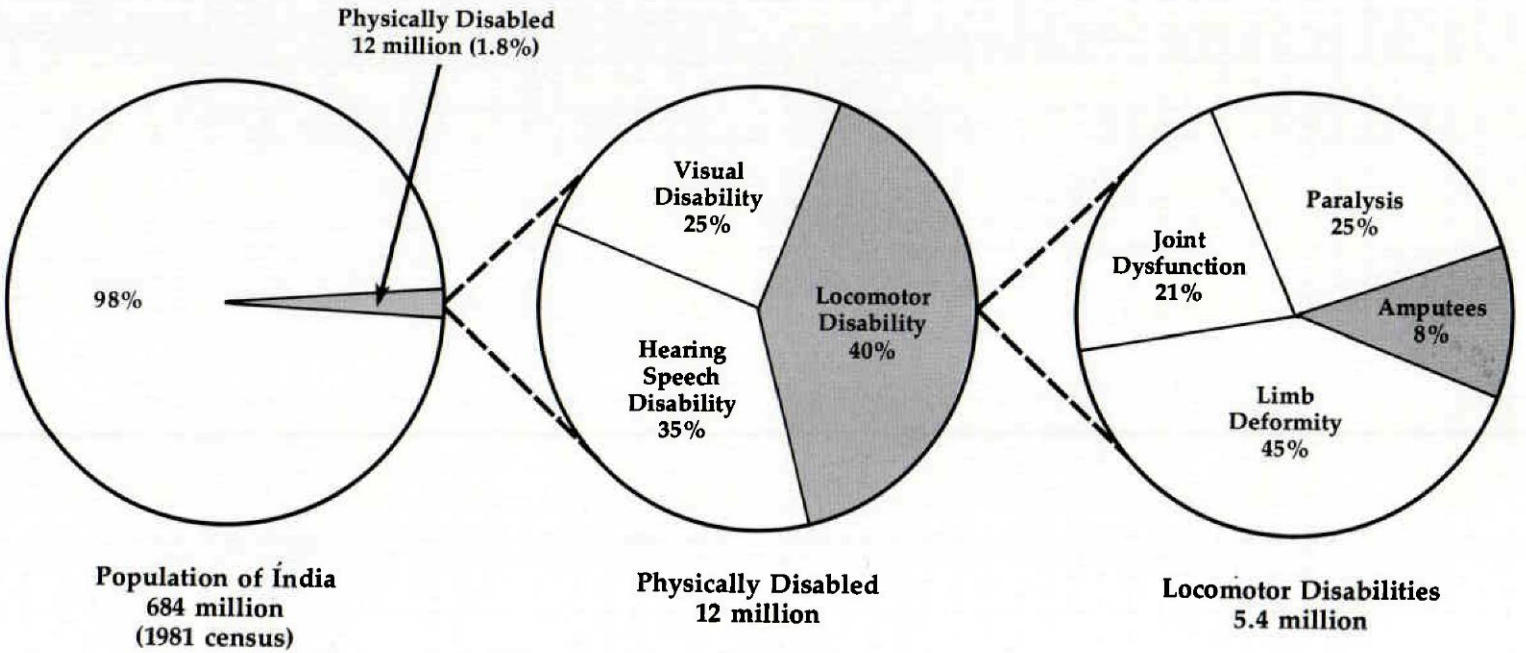
THE PROBLEM

The 1981 census[4] estimated India's population to be 683,810,051 of which 23.73 percent lived in urban areas and 76.27 percent in rural areas.[5] The National Sample Survey Organization conducted a survey of disabled persons in the period July-December, 1981, and the first report released in March, 1983 estimates that there were 12 million physically disabled persons in India. This is approximately 1.8 percent of the total population. Only acute disabilities were included in this survey since the detection was done by trained laymen and not medical experts (see text of reference for definitions of disabilities.)[3] The proportions of various disabilities are given in Figure 1. Locomotor disabilities constitute the largest proportion, and the number of amputees is estimated to be 424,000.

This is the first time that a comprehensive survey of the disabled has been carried out in India. The earlier surveys done by the NSSO in 1961 and 1974, and that done during the 1981 census, did not use clear definitions of disabilities and so their results are not comparable with the present NSSO results. Some spot studies have been carried out over the past three decades[6,7] but their definitions and estimates vary a great deal. For example, Babusenan[6] estimated a disability rate of 1.2 percent in Trivandrum including mental retardation, whereas Natarajan[7] reported a prevalence rate of 1.4 percent for the physically handicapped in Madras. Sahasrabudhe and Sancheti have reported[8] that in a recent survey of 22 villages in Pune district they discovered 1.96 percent of the population to be "handicapped," including "mental defects," but excluding cerebral palsy and leprosy. They further classified 36 percent of the "handicapped" as having "orthopaedic deformities." Because of these variations it was difficult to extrapolate for an all India figure. However, it is interesting that though Sahasrabudhe and Sancheti did not use the same definitions as NSSO, their estimates are of a similar order of magnitude as NSSO. This is probably because Sahasrabudhe and Sancheti also detected only those who were acutely disabled. Their study does not give any statistics on the number of amputees in their sample.

The prevalence rate of acutely physically disabled persons in India (1.8 percent) as estimated by the NSSO is, however, less than that reported for the severely disabled (2.8 percent) in the U.S.[9] It is not known whether this difference is owing to the different definitions of disabilities in the two studies or an actual difference in prevalence rates. In the U.S., locomotor disabilities constituted 60 percent of the

National Sample Survey Organization Estimates of the Physically Disabled Persons in India



Total number of amputees = 424,000 (0.62 per 1,000)

Figure 1.

physically disabled, whereas in India they constitute only 40 percent (Figure 1). It appears that paralysis and hemiplegia are much more prevalent in the U.S. than in India. This is probably because paraplegics and quadraplegics have a greater probability of surviving in the U.S. than in India. Amputees constitute eight percent of those with locomotor disabilities in both countries. But this is just a coincidence, because the prevalence rate of amputees in India works out to be 0.62 per 1,000 population, whereas in the U.S. and U.K. it is reported to be in the range of 1.2 to 1.6 per 1,000.[9, 10]

The proportions are higher in the U.S. and U.K. probably because more of them survive there, more congenital and other deformities are surgically operated upon for fitting prostheses, and the proportion of old persons is much higher in these countries. Amputations due to vascular and circulatory disorders and cancer are much more likely among older persons. Therefore, as the health conditions improve in India and people live longer, the prevalence of amputees in the Indian population is likely to increase further and may even become double the present rate.

Location and Sex of Amputees: Prevalence

Figure 2 shows the distribution of amputees by rural and urban areas in India. Though the urban areas in India house 24 percent of the population, only 21 percent of the amputees are located there.

The average prevalence rates in India for males and females are higher in rural areas than in urban areas. But there is a great deal of variation from state to state. In Bihar and Orissa the rates are higher in the urban areas both for males and females.[3] It is not clear why this is so, because higher rates in rural areas would appear to be due to the fact that more persons are involved in manual labor, where the risk of accidents may be higher, and also due to inadequate medical care. Females constitute only 20 percent of the total number of amputees, though they form 48.3 of the country's population.[4] In the absence of more detailed epidemiological data and information, it is not possible to understand why the ratios are so different for men and women. However, the ratios are not as different in Haryana and rural Rajasthan, where male amputees outnumber women amputees by less than a factor of two.[3] Again, it is not clear why this is so.

Figure 3 shows the distribution of amputees by state and also the prevalence rates by state. The prevalence rates vary quite a bit by state, but the total numbers in Rajasthan, Punjab, Haryana, Madhya Pradesh, Bihar, West Bengal, Maharashtra and Andhra Pradesh are around 30,000 each; Gujarat, Karnataka, Tamilnadu and Kerala around 15,000 each; Himachal Pradesh, Jammu and Kashmir, and Orissa around 3,000 each; and the most populous state, U.P., also has the maximum number of amputees, 91,000. Accurate figures for the North Eastern states are not available.

The prevalence rates in Punjab and Haryana are the highest: 182 and 244 per 100,000 persons respectively. This may be partly due to amputations caused by threshers and other agricultural machinery introduced in the last fifteen years or so.[11] But this does not seem to be an adequate explanation, as the incidence of paralysis and deformed limbs is also very high in these two states.[3] More epidemiological data are needed to understand why locomotor disabilities should have such a high prevalence rate in Punjab and Haryana.

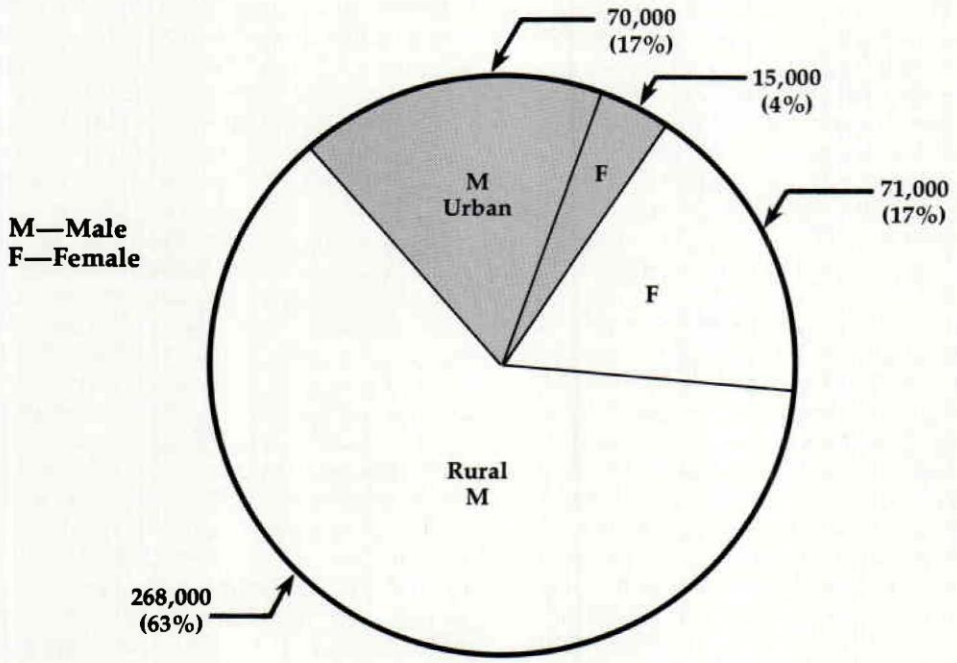
Incidence rate

Figure 5 shows the incidence rate of amputees produced in India per year. These data indicate that the incidence rate is higher in rural areas, and there are five to six times as many male amputees as female amputees every year. Every year 23,500 amputees are added to the amputee population in India, of which 20,200 are males and 3,300 are females.

Age at Onset

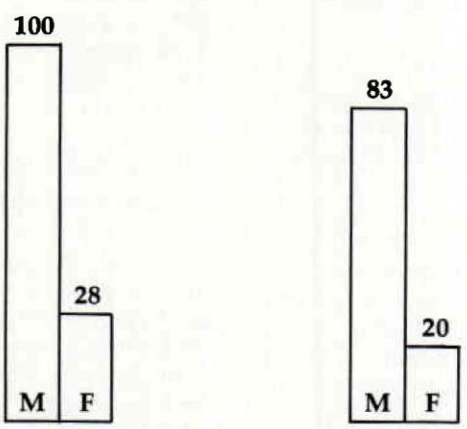
Figure 5 also shows the distribution of amputees 60 years and older by the age at which they sustained the amputation. The pattern is different in rural and urban

Prevalence of Amputees in India by Sex in Rural and Urban Areas*



Total Amputees = 424,000

a) Number of amputees by sex and location

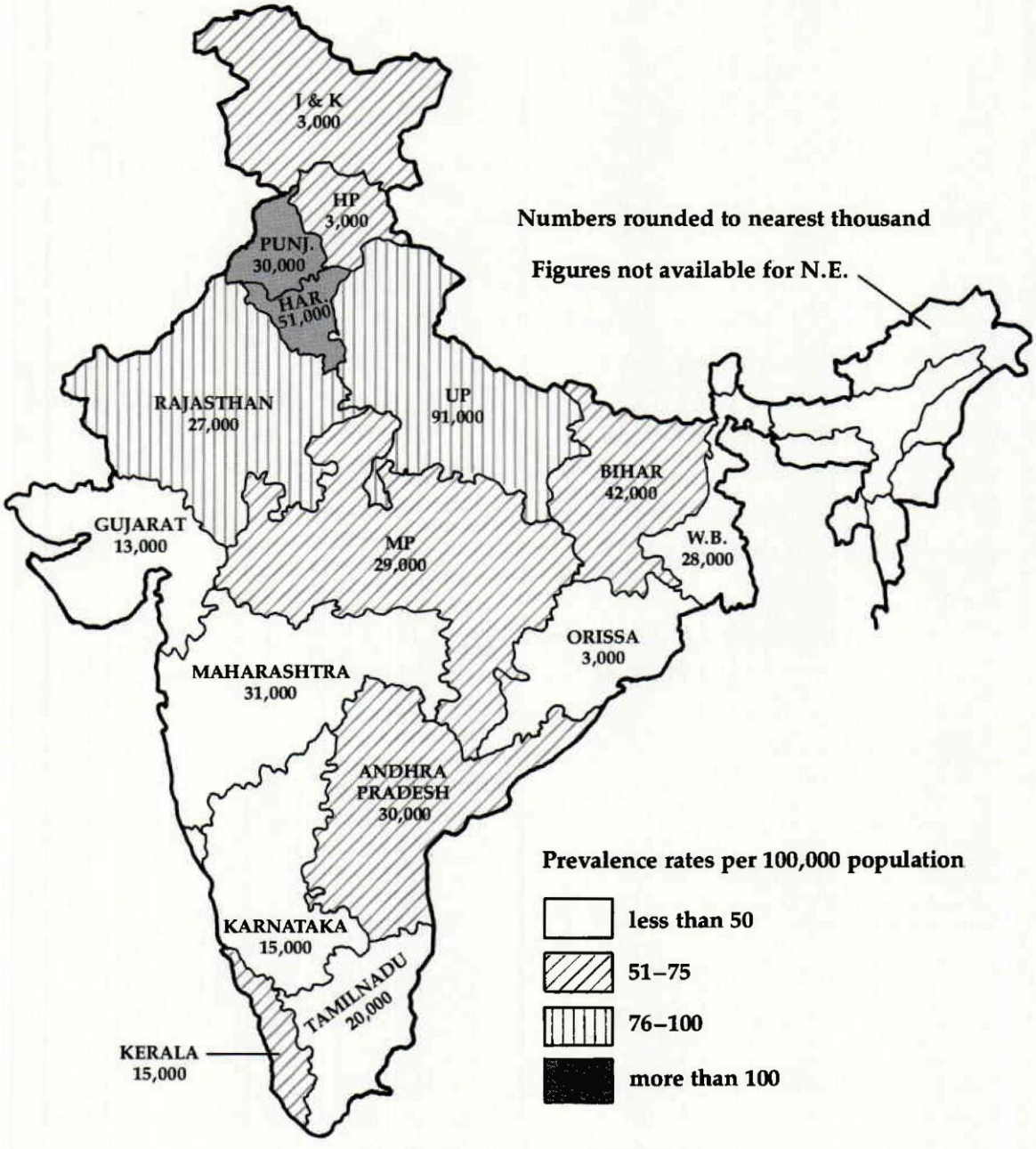


b) Prevalence rates per 100,000 population

(Source: NSSO, report on survey of disabled persons, 1983)

Figure 2.

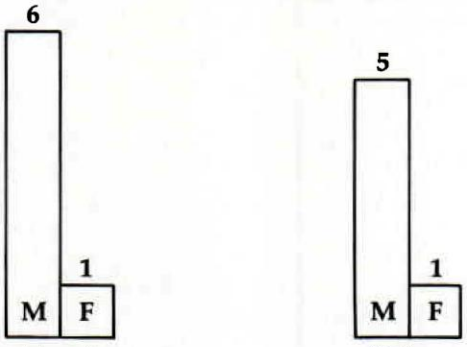
Number of Amputees and Prevalence Rates in Various States of India



(Source: NSSO, report on survey of disabled persons, 1983)

Figure 3.

Amputees Produced in One Year in India Grouped by Sex, and Geographic Location



Incidence rate per 100,000 population per year

	Male	Female
Rural	16,000	2,600
Urban	4,200	700

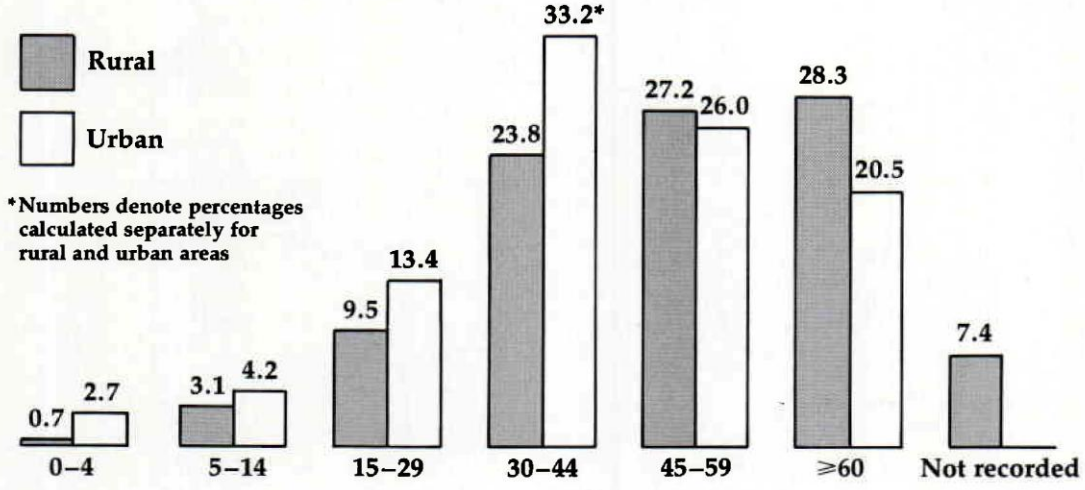
Total: 23,500

Total number of amputees produced per year

(Source: NSSO, report on survey of disabled persons, 1983)

Figure 4.

Distribution of Amputees Aged 60 Years and Above By Age at Onset of Disability



(Source: NSSO report on survey of disabled persons, 1983)

Figure 5.

areas. The number becoming disabled keeps increasing with age in rural areas, but in the urban areas the peak is reached between the ages of 30-44, and after that the proportion decreases again. In the high income countries, a large number of older people become amputees because of vascular problems and cancer,[10] but this is probably not the case here. If this were so, it would have been reflected in urban areas also where health conditions on an average may be better. The higher rate among the elderly in rural areas is probably because they may be continuing to do manual labor at older ages, and in addition they would not get good medical attention once they get injured. However, it is not necessary that the patterns are still the same as depicted by Figure 4, since these data are for persons 60 years and above, and disabilities for many of them were sustained a long time ago. To get some idea of the age of onset under current conditions, age-specific data for amputees would have to be obtained from the NSSO report, but the present information does indicate that old age amputations are not as serious a problem as in the high income countries, where impairment rates increase monotanically with age.[12]

Cause

Figure 6 shows the causes of amputation in rural and urban areas. Almost 60 percent of the amputees fall in the "other illness" and "other causes" category, and therefore these statistics do not give the complete picture of causation. It is not clear whether amputations due to infection following injury would be included in "other illness." For the country as a whole, only 11 percent of all amputations (47,000) are due to leprosy, and according to the NSSO data, 6.6 percent of those with deformed limbs (143,000) are due to leprosy.[3] Considering that the number of leprosy patients in India is in the millions, these appear to be low figures. Whether this is because of undercounting owing to a concentration of leprosy patients in specific living areas outside the enumeration blocks, or because many leprosy patients do not consider themselves disabled, is not known.

Injuries appear to be one of the major causes of disability accounting for at least 100,000 (23 percent) of the amputees. The number is probably larger, as it is possible that many of the amputations due to injury may be hidden under the "other illness" and "other causes" category.

At present, no statistics are available giving the details of the sources of injuries that result in amputations. Informal conversations with orthopaedists and managers of rehabilitation centres around the country indicate that road accidents in urban areas and agricultural and railway accidents in rural areas may be some of the more significant causes. While attention has been focused on road accidents and agricultural accidents for quite some time, the same is not true for railway accidents. This is partly because the railway statistics released to the public exclude more than 95 percent of the casualties on railway property.[13] This is because accidents are defined in such a manner by the railways that out of approximately 10,000 killed on railway property, only a few hundred fit the definitions. However, the Indian Railways does maintain an internal accounting system in which many of these casualties are acknowledged, but this report is not made public.[14]

Socio-Economic Background

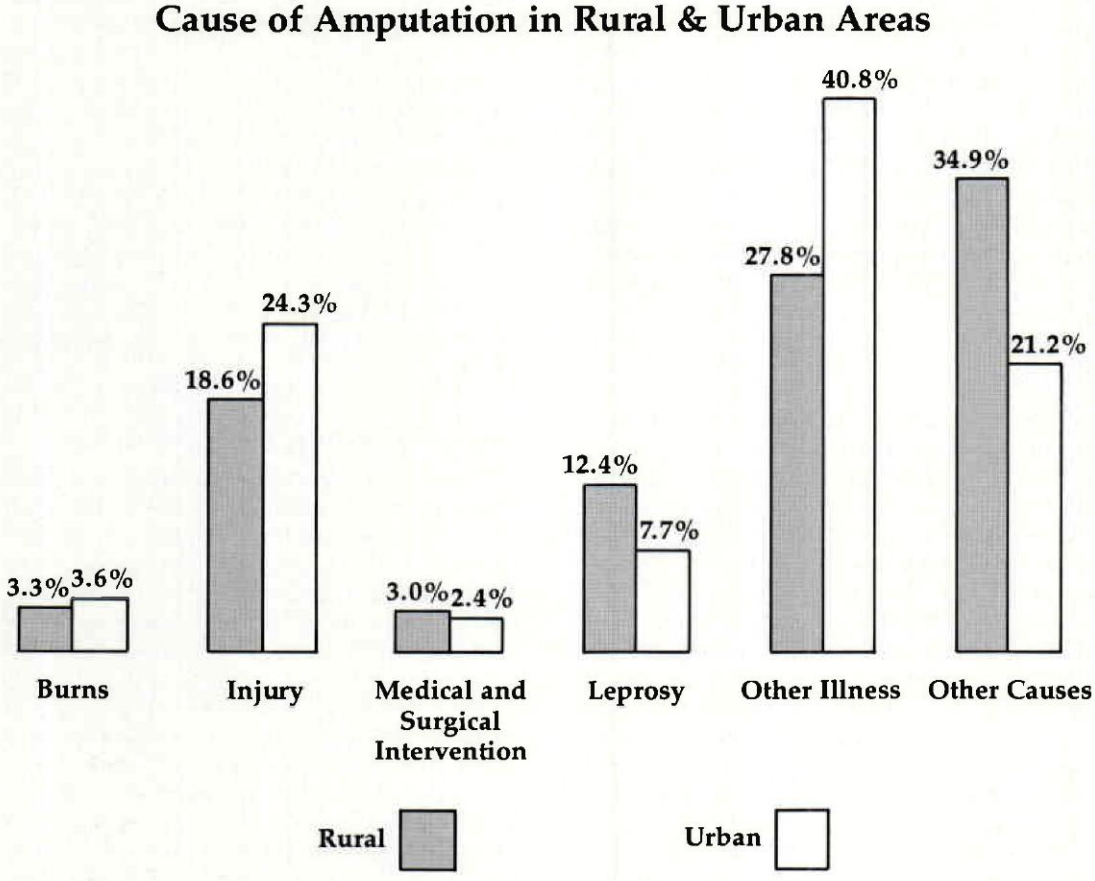
The NSSO data released until now does not give the socio-economic background of the disabled persons. However, professionals dealing with the disabled, especially the amputees, report that the vast majority of them come from very poor families. Statistics from The All India Institute of Physical Medicine and Rehabilitation, Bombay, indicate that at least 44 percent of the patients come from families with incomes less than 200 rupees* per month and another 44 percent with incomes between 400 and 600 rupees per month.[15] Similar results are reported by Sahasrabudhe and Sancheti.[8] In their sam-

*The exchange rate in March, 1986, was 12.5 Indian rupees to U.S. $1.00.

ple of the disabled from 22 villages in Pune district, 27 percent were unemployed and 87 percent were from families with per capita incomes less than 70 rupees per month. The difference in the two studies is probably due to the fact that on an average, patients in an urban hospital are likely to be richer than disabled persons identified in villages. There may be an element of under-reporting of incomes, but even if the given figures are doubled, it still does not make the disabled very rich.

Even in the high-income countries, the disabled tend to come from low-income families.[9] This is partly due to the fact that the disabled themselves may have low incomes or they may be very old. In India, however, since 80 percent of the amputees come from rural areas where average incomes are low, most of the families do not have the resources to help them financially.

In summary, India has about half a million amputees and 23,500 are added every year. Amputees in India are predominantly male, rural, poor, and in the working age group. A significant proportion of amputations are reported to be due to injuries sustained in railway and road accidents and due to agricultural equipment. There is a high variation in prevalence rates from state to state, with Haryana and Punjab being the highest, and Orissa the lowest.



(Source: NSSO, report on survey of disabled persons, 1983)

Figure 6.

THE PRESENT SITUATION

The first major limb fitting centre in India was established in Pune in 1944 by the Armed Forces, mainly for use by their own employees. I would estimate that there were approximately 50 private and public organizations in India which provide aids for amputees in 1983. Of these, six have been designated as Regional Limb Fitting Centres by the Artificial Limbs Manufacturing Corporation of India (ALIMCO), Kanpur, and 27 as Peripheral Limb Fitting Centres. The Regional Centres are located at Trivandrum, Nagpur, Jaipur, Madras, Calcutta, and Cuttack.[15]

Extent of Service

Until the late 1950's, very few limbs were available to civilians in India because the Artificial Limb Centre in Pune provided service mainly to the armed forces. Representatives from most of the main rehabilitation centres in India participated in a National Seminar on Rehabilitation Services and Research organized at the Medical College in Trivandrum in 1967. Judging from the reports submitted at that meeting,[16] it appears that in 1967 the number of amputees fitted with prostheses was not more than 100 in India (not including the Armed Forces Centre in Pune), and of these, over 90 percent were lower limb prostheses.

The situation has improved a great deal in the intervening years. The author estimates that approximately 6,000 prostheses were fitted to amputees in 1981. This estimate is based on a survey carried out by the Centre for Biomedical Engineering, IIT, Delhi, and another survey conducted by The Institute for the Physically Handicapped, Delhi. It appears that over 60 percent of the total number of limbs were fitted by two centres: Regional Limb Fitting Centre in Jaipur and the Artificial Limb Centre in Pune, each fitting approximately 2,000 limbs. The other Centres in India fitted anything from a very few to 400-500 limbs each. Even in 1981, over 90 percent of the prostheses fitted were for lower limbs.

The number of amputees fitted with limbs increased rapidly in the late 1970's mainly because of the expansion of a few centres. Taking this into account and the fact that the life of most prostheses is around five years at most, we can estimate that at most about 25,000 amputees are using prostheses today. This would be six percent of the total number of amputees in India. The actual number may be even less, as studies show that many amputees stop using their aids after some time either because the prosthesis really does not suit them or they need repairs.[17, 18] Considering that an estimated 23,500 amputees were added to the population in 1981, there is a net addition of over 17,000 amputees every year who do not receive any aids.

Quality of Prostheses

Because of the pioneering work done by the Centre in Pune, All India Institute of Physical Medicine and Rehabilitation in Bombay, and some of the Regional Centres, we are well versed with the technologies involved in traditional exoskeletal lower limb prostheses. The below-knee prosthesis with S.A.C.H.-foot is being manufactured in these Centres with a fair degree of competence and in some cases with quite ingenious forms of import substitution in materials and methods. However, the design is basically the same as adopted by the Veterans Administration in the U.S., a decade and a half back. Components for the same are being manufactured at ALIMCO, Kanpur. We, however, still do not have a good stabilized knee available in the country, and most users have complaints regarding the materials used and reliability of the products.

There has been very little real invention of or innovation in designs of prostheses in India. The only notable exception is the work done at the Regional limb fitting and Rehabilitation Research Centre in Jaipur.[17] Their outstanding success with a rubber vulcanized foot (Jaipur Foot) and an aluminum shank has helped them to provide prostheses to as many as 2,000 amputees in 1982. The innovation has cut down on fabrication time greatly, and this

in turn helps in keeping overhead low, and allows fitting of a much larger number of amputees. There has been a great deal of debate regarding the biomechanical properties of the Jaipur foot, with many questioning its efficiency. However, according to tests done at our Centre and at the University of Strathclyde,[19] the Jaipur foot compares favorably with the S.A.C.H. foot in most biomechanical aspects. There are minor variations in the two, but the Strathclyde report claims that the patient in fact, "preferred the Sethi [Jaipur] foot." At present a few endoskeletal above-knee prostheses are also being tried out at Jaipur. These prostheses use a simple single-axis pin joint at the knee, an aluminum socket, the Jaipur foot, and electric conduit pipes (mild steel) as pylons. A preliminary report[20] indicates that such a sample design may function quite well on level ground at normal speeds of walking, provided the centre of gravity is adjusted optimally. The design is still a long way from widespread application.

There have been attempts at innovation at other centres also. The main preoccupation in India has been to develop a prosthesis which allows people to squat and also sit cross-legged. While the Jaipur foot allows squatting, there is no design of an above-knee prosthesis which can be considered optimal for sitting cross-legged. An above-knee prosthesis has been developed at the All India Institute of Medical Sciences which permits squatting and sitting cross-legged, but because it is of the exoskeletal type, it has a hard external surface. A number of these are in use, and its widespread applicability will depend on the acceptability by these patients, ease of maintenance, and cost of manufacture. It is still too early to tell.

Many other centres, including those in Bombay, Lucknow, Calcutta, ALIMCO, and Madras are experimenting with designs of prostheses more suited for Indian conditions, but no one design has been particularly successful. The Artificial Limb Centre in Pune has developed an indigenous design of a stabilized exoskeletal above-knee prosthesis, but it has not gained wide acceptance, owing to failures and maintenance problems. One of the main stumbling blocks faced by all the centres is the lack of availability of appropriate materials for use in prostheses, or their high cost when available. They also suffer from a lack of expertise in the use of the newer synthetic materials.

As far as the upper extremity is concerned, the situation is much worse. Even cosmetic hands are not easily available, and very few centres are able to deal with the upper limb amputee's needs. Innovation in this area is even more limited, with work having been done mainly in Pune, Navedac Centre in Chandigarh, and ALIMCO.

Therefore, the amputees in India, in general, still have to use prostheses which have not been specifically designed for local conditions and local habits. While a much needed service is being rendered by most centres, a great deal more could be done, both in terms of quality and quantity.

The Cost of Prostheses

It is almost impossible to get an actual account of what it costs any centre to provide a prosthesis to an amputee. In government, semi-government, and charitable institutions, the costs of overhead are not evaluated realistically, and therefore the cost of a limb basically represents material costs and some nominal labor costs. Even in private institutions, many of the professionals have multiple duties and functions, and so cost evaluation becomes difficult. However, it is clear that the cost of running most centres is reasonably high, except in Jaipur. The cost of a prosthesis, both upper and lower, is probably in the range of 1,000 rupees, depending on the complexity. It is not surprising then that amputees can avail themselves of these limbs only if they are donated or otherwise obtainable for free. The reasons given for not using an aid are given in Table I.[3]

Table 1

Reason Given by Amputees for not Acquiring an Aid/Device

Reason given	Percent of Amputees
Not available	3%
Too expensive	47%
Aid not necessary for economic independence	8%
Aid not necessary for personal independence	15%
Others	27%

It is interesting that only three percent claimed that the aid was not available. The belief that aids are in fact available is not really true, as most centres cannot handle any more patients. Some have waiting lists for as long as a year. The NSSO survey also reports that of those amputees who took treatment for their disability, only eight percent were advised to obtain an aid. It is not known why this number is so low.

Prosthetic aids are obviously too expensive for the overwhelming majority of the amputees, and in the absence of a universal insurance or government subsidy system, most of them could not afford them.

The Wait

There are long waiting lists of amputees at all centres in India. This is in spite of the fact that a vast majority of the amputees do not even attempt to obtain an aid. The waiting time can only be reduced if the limb fitting process is shortened and made more efficient. Most professionals believe that the time could be reduced by increasing facilities and staff. But this would hardly be a solution, as operating costs may increase. The fabricating and fitting time has been reduced drastically in Jaipur. It would be useful if a few other facilities were developed where the fabrication time was reduced.

THE FUTURE

Over the past three years, my colleagues and I visited a large number of rehabilitation centres and units in India. What I have seen and heard leaves me terribly confused. It is a paradox that while almost every unit has at least one dedicated and experienced professional prosthetist, and physician or surgeon who is excellent by any standards, it is a rare unit which excells in innovation and research. It is my impression that there is very little in-house engineering expertise in these centres, and engineers outside these institutions are not really concerned with the interests of the disabled. Research studies dealing with amputees and their needs is almost non-existent. Most of the studies taken up are of a sporadic nature, and long term in-depth studies are almost unknown.

Secondly, it appears that we really do not know what the amputees actually want. By and large we give them what we think they need, and this usually turns out to be what we can make. Barring some experiments in Jaipur[17] and in a few other centres, there has been no systematic effort made to determine what kind of help amputees from different income groups and geographical regions really want. This lack of communication has been alluded to frequently in studies that originate in high income countries.[21-23] A report from the Office of Technology Assessment of the Congress of the United States records that "the need for technology is most often based on needs of disabled persons as perceived by professionals or program administrators instead of a blend of the disabled person's needs, desires, and capabilities, as identified with the full participation of the disabled person or a representative."[21] This problem is probably much more acute in India as the cultural and socio-economic gap between professionals and amputees, who are generally very poor, is very large. Yet most managers of rehabilitation centres around India were not really willing to discuss this problem in depth.

Unless we have some feedback from amputees about their perceived needs, it will be difficult to state categorically what our future course of action should be. This feedback will not really mean much until the amputees have choices to make and preferences to show.

In general terms it can be stated that what the amputees need are rehabilitation aids and devices in much larger numbers, at much lower costs, and without a long wait. The devices should give functional mobility for vocational needs and independence for personal needs. These would vary from one end of the country to the other, and by income and occupation within a particular region. It could lead to a large number of design variations instead of a fixed design for everyone everywhere. However, this is easier said than done. Therefore, it would be useful to examine the problems and issues facing the amputees so that we can set some priorities for the future.

Economics of Rehabilitation of Amputees

Policy makers in India often express the view that amputees should be given the best prostheses available, but they hardly ever set out the details of how this is to be accomplished. An exception to this is a project report from ALIMCO which sets out the details of a limb fitting centre where 300-360 fittings could be done per year.[15] Of the 360 fittings, 200 were expected to be orthotic devices and 160 prosthetic devices. It is also stated that these centres would be established at medical centres where many facilities are already available.

According to the report, the unit would need a floor area of 250 square meters and a capital investment of 60,000 rupees. If we allocate 50 percent of this expenditure as directly beneficial to amputees, we can assume a floor area of approximately one square meter and an investment of approximately 200 rupees per amputee. In India there are at least 23,500 new amputees every year, and a backlog of almost 400,000 amputees who do not have any aids. Therefore, if we plan on fitting at least 50,000 amputees every year we might just about catch up by the year 2000. According to the above estimates, we would need an investment in 50,000 sq. meters of space and 10 million rupees in materials. At the present construction prices of more than 1,000 rupees per square meter, this turns out to be an investment of more than 50 million rupees for establishing facilities to handle 50,000 amputees per year.

According to the same report, recurring costs for amputees should be calculated on the basis of 945 rupees per amputee. Therefore, the recurring expenditure would be almost 50 million rupees per year. In my opinion, these are gross underestimates because physicians' and surgeons' salaries, and costs of operating rooms and awards are not included in the above estimates. Even these conservative figures are far in excess of what is allocated to the Ministry of Social Welfare and Ministry of Health for the welfare of the amputees. The total Sixth Plan outlay (central) for the welfare of the handicapped is 244 million rupees under the Ministry of Social Welfare, and this includes all programming (including training, research, scholarships, etc.) for all disabilities.[24] If we consider setting up the above mentioned facilities over a 10 year period, even then the capital and recurring expenditure over a five year period would be far more than 280 million rupees, or greater than the whole budget. Amputees, however, form only three percent of the disabled population in India.

The above not very sophisticated exercise shows that either the budget allocations are woefully inadequate, or that if present models of rehabilitation are used, there is not much hope of providing prostheses to a majority of the amputees. What is clear is that if present methods of rehabilitation are followed, it will not be possible to provide prostheses even to a fraction of the amputees in India, and the ALIMCO model will end up denying prostheses to a majority of them.

Obviously we will have to redefine what we mean by the "latest and the best" in prostheses, and also redesign our in-

stitutions. I would like to suggest that we take these words at their literal best. "Latest" should mean what we design now and in the future, and not necessarily what is being used currently in the high income countries. Similarly, "best" should be that device which actually gets used by the amputee. No matter how "sophisticated" an aid is, if the amputee does not get it, it is the worst for him.

These considerations set very tough guidelines for the professionals as far as design of limbs and rehabilitation centres are concerned. The designs have to be such that not only is the cost of the prosthesis very low, but also the recurring expenditure of rehabilitation centres have to be much lower than at present. Prosthesis fitting times would have to be reduced drastically so that the same facilities can serve many more people. Staying away from home also places a very difficult burden on poor families, and that in itself can be a disincentive for them to obtain prostheses.

Technology and the Amputee

Scientists and engineers love to design things which excite them the most. Unfortunately, in the area of rehabilitation, this has resulted in a great deal of wasted effort. Agerholm[22] states that the "exclusion from the benefits of technology is seen even more strikingly in relation to 'special' devices of use only to handicapped people, and often developed at great expense on their behalf by inventors, who naively expect that those whom they could benefit will actually receive them." Agerholm's understanding comes from his experience in the U.K., where there is much more money than in India. Unfortunately, we do not have many "inventors" in India. But even the copies suffer from the same naive beliefs as Agerholm's inventors in U.K.

This poses a serious dilemma for the designer/engineer. Should he equip his laboratory with the most expensive equipment that money can buy and use the most complex computer routines to solve the most horrendous mathematical models of human movement? Or should he only worry about solving problems so that the results actually benefit the amputee? These issues are not easy to resolve.

Though the author has long believed that the most expensive gait analysis laboratories around the world have not really contributed much to prosthesis design, it is hard to conceive that they are not really useful. There was a nagging suspicion that they may actually be doing work which may prove very useful in the future. Though the issue has not been resolved to the author's satisfaction, his experience in collaborating with the Regional Rehabilitation Centre in Jaipur has been very educational.

Some time back, we were approached with a problem that the pylons being used in a simple endoskeletal above-knee prosthesis were failing and the design needed change. We thought that the Centre in Jaipur was being naive in using electrical conduit pipes in the prosthesis when much better materials were available. But when we looked around for substitutes we discovered why it was wise to use them—they were cheap and available everywhere. So we tested them in our Strength of Materials Laboratory and discovered that their strength in buckling and bending was less than one-third of what would be predicted theoretically, and that is why they were failing. However, the next larger size was strong enough to take walking loads in spite of bad quality steel and manufacturing faults.

The next thing that intrigued us was that amputees could actually walk using a very simple single-axis hinge-type knee designed at Jaipur. The question was how they could walk on this simple above knee prosthesis, and what were the limitations of the prosthesis. So we put a young student to work modelling the leg motion during the swing phase of the gait cycle.[20] We assumed the shank to be a compound pendulum swinging about the knee, and did some sensitivity analyses. We discovered in quantitative terms what prosthetists have known for some time:

that the location of the centre of gravity makes quite a difference to the movement of the leg, the absolute mass of the shank is not as critical as is the moment of inertia,and that it is possible for a simple knee to function like a normal leg at particular walking speeds on level ground. These walking speeds turn out to be the average walking speeds for adults. We could also detect that the swing of the shank was very dependent on the exact moment in time when the toe left the ground. Therefore, with some training, the amputee could use this limb quite successfully.

The above exercise has not solved all the problems connected with an above knee prosthesis. It has however, helped us understand the mechanics of the swing phase of the leg and has also given us an idea on what parameters are important in design. More importantly, it helped us in providing a service without spending too much money, and gave us a basis for doing more work.

These experiences and visits to many centres around the country give the impression that when professionals and policy makers demand the "best and the latest" in the area of prostheses and devices for the amputees, they actually set us back. In fact they pose false choices and also justify not doing anything as long as their concept of the "best" is not available.

CONCLUSION

In summary, at present the research and development effort in India is marginal in the area of prosthetic devices for amputees, and the dominant models of institutions providing services are not likely to serve more than a few of the amputees. There has to be a drastic reordering of the priorities and accompanying changes in design of both prostheses and institutions. If we do not change our ways, we will add to our stock of amputees by tens of thousands every year. If we have any intentions of giving the amputees a chance of functioning as normal members of society, we have to do much more work. Some of the areas that need urgent attention are enumerated below.

- As longevity increases in India, it is possible that the number of older amputees will also increase. This will put an additional burden on the already grossly inadequate services. All out efforts should be made to control amputations caused by injuries due to road, rail, and agricultural accidents.
- Emergency care techniques that do not depend on capital intensive equipment have to be evolved so that serious injuries can be taken care of locally and quickly. Efficient ways of burn and hemorrhage management should be taught extensively.
- Micro-studies should be carried out in various parts of the country, to determine what kind of aids the amputees consider useful and adequate, e.g., will simple pylon type lower limb prostheses with good sockets and foot-pieces be acceptable?
- Until now we did not know the prevalence rates of amputees by location in India. Now we have this data (Figure 3). Plans for establishment of rehabilitation centres should be changed so that amputees around the country have equal access to help.
- Very little thought has been given to the architectural aspects of rehabilitation centres. There are no architects who specialize in designing such institutions. Can designs be evolved which are more suited to poor people who are not very mobile? Can space be used for multiple purposes so that capital costs are brought down?
- Upper extremity amputees have suffered gross neglect. Functional arms and hands which are easy to fabricate and fit have to be developed. In the case of unilateral amputees it may be possible to develop aids for the good hand so that it can perform many of the functions which normally require two hands.
- Much more work needs to be done to develop endoskeletal prostheses, since their fabrication times are much less than exoskeletal prostheses.

- Sockets used in temperate climates are not very suitable in India. We must develop our own designs which are more comfortable in hot and humid climates.
- Prostheses designed in India should be easy to fit and have as few moving parts as possible. This will reduce the probability of failure. Poor people find it very difficult to bring a prosthesis back for repairs.
- We appear to be very weak in materials research and much more attention needs to be paid to this subject. Many designs of prostheses have not succeeded because of the use of wrong or overly expensive materials.
- In the absence of technical expertise in rehabilitation centres, efforts should be made to use engineers and technicians in associated industries.
- As many aids as possible should be designed so that local mechanists can repair them. Manuals giving such details can be prepared in regional languages.
- It should be possible to make most parts for prostheses and appliances locally. Large factories like ALIMCO should make only those products that require high precision and quality control.
- Personal care aids usually involve simple technology. Such aids should be designed for our needs. Brochures containing fabrication guidelines for such aids should be widely available.
- Buildings and vehicles should be designed so that amputees have little difficulty in using them. Guidelines for design should be established as soon as possible.

The above are some of the more urgent concerns, and the answers to some of the issues raised above will not come easily. Newspapers and magazines report only those achievements which involve very complex designs and new sophisticated technology developed in foreign countries. This warps our thinking about what is important, because the vast majority of the amputees do not ever get to use those items which may function very well in the laboratory but are too delicate and expensive to be taken out. We must leave our pre-conceived notions about rehabilitation aids for the amputees.

Unless we reject the present dominant models of amputee care in India and come up with more efficient and humane models, the number of amputees without prostheses will keep increasing. At the present rate, this means adding about 20,000 every year to the half million that are already there. The choice is abundantly clear—do we want to move forward or backward?

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