Impact of Prosthesis Fit on Nutritional Health of the Lower Limb Amputee

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Abstract

Socket designs ensure optimum fit between the user and the device (prosthesis), as an interface between the human – machine system. The type that an amputee is "fit with" depends on the shape of the residual limb, the length of the residual limb, activity level, prognosis, and individual preference. Patient satisfaction and function relies on pressure and force distribution (Biomechanics) on the socket-residual limb interface. The most determinant factor of prosthetic use lies in the design of the prosthetic socket and fit depends on the degree to which the prosthesis fits the stump. Well planned socket designs and careful consideration of stump presentation had set an achievement platform for the prosthetic user by maximizing range of motion, stability during the performance of daily activities, and comfortably distributing the forces exerted on the residual limb during movement and suspension. A study was conducted to analyze the health issues and their impact on the use/ acceptance of prosthesis among select amputees'. Physiological factors, obesity, age, nutritional status and co-morbidities were found to impose mechanical implications related to accessibility and well being concepts. The study highlighted prosthetic fitting to be more challenging with increased load (obesity) to transmit through the prosthetic socket in limited pressure–tolerant anatomical areas. Hence nutritional and physiotherapy intervention on effective and efficient prosthetic use was done to enhance their health and well -being.

Keywords: *Socket, Prosthesis, Bio mechanics, Co-morbidities, Obesity*

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1.Introduction

Health and well – being have pervaded the minds and hearts of human beings as inextricable entities. Unfortunately the thrust on maintaining them remains backstage. Amidst such a situation there is a huge population remaining immobilized due to various circumstances. Nevertheless the statistic on amputees' sequel to those reasons keep surmounting day by day. Limitations in body structure and function due to the removal, affect the activity level, and thereby, the participation of the individual in the society [1]. Reliance on prosthesis for effective rehabilitation and returning to normal living also is on the increase. Socket and suspension are the two components which decide the 'proper fit' for the users. Socket designs ensure optimum fit between the user and the device (prosthesis), as an interface between the human – machine system. The most determinant factor of prosthetic use lies in the design of the prosthetic socket and the fit in turn on the degree to which the prosthesis suits the stump. The type that an amputee is "fit with" (comfortable with) depends on the shape of the residual limb, the length of the residual limb, activity level, prognosis, and individual preference. Quality of Life (QoL) is increasingly being recognized as an important outcome for rehabilitation programs [2]. Patient satisfaction and function relies on pressure and force distribution on the socket-residual limb interface [3]. To ensure this the amputees need to maintain good health and nutritional status, which but is impossible as they tend to gain weight and become obese or overweight. Physical fitness thus becomes imperative for an amputee to effectively enjoy the experience of the prosthesis. These aspects motivated the concerned study.

2.Materials and Method

A ***micro level investigatory study*** was taken up by collecting secondary data on amputees registered in four hospitals and three prosthetic centers in Coimbatore City enclosing a total area of 4850 $km^{2.}$. The locale of the study was Coimbatore City chosen adopting convenience sampling. The number recorded for a period of five years from 2009 – 2013, showed the presence of 3726 amputees, among whom 85 per cent were men. Further analysis showed 2313 among the total group as lower limb amputees, again displaying predominance of men. By March 2015 (in a two years gap), the City had enlisted 928 additional amputees with 819 male and 109 female victims. The second phase of the study therefore recorded 669 more amputees, over and above the recorded 2313 to have joined the lower limb amputee cohort among whom 571 were men and the rest women. Within a span of seven years (2009 -2015), Coimbatore was found to shoulder 4654 amputees with **65 per cent** (2982) belonging to the lower limb amputee category – a really alarming statistic (data from chosen sources alone). These findings formed the baseline for furthering the study on all 2982 amputees with lower limb amputation as the study sample. For an in-depth study 142 samples who were fitted with prosthesis and were visiting three renowned Prosthetic centres were chosen adopting convenience sampling [8].The broad objectives framed for conduct of the study thus included:

- *Examining the impediments to amputees to lead normal living and to maintain normal health with their prosthetic fit*
- *Knowing the functional capability of the prosthesis users in terms of mobility*

3. Results and Discussion

3.1 Profile of the sample

From among the 2982, almost *27 per cent* (800) had *refused to go in for prosthesis.* Hence the remaining *73* per cent (2182 in number) were found to have been prescribed with prosthesis. Among the select amputees 41 – 60 years group (45%) predominated followed by the 21 – 40 age range (30%). Those above 61 also were present (18%). A majority of them were male (86%). Causes for amputation was found to be alarming as presented in Table.1

Table.1 Major causes for amputation

Reasons	Causes	Number of causes
Etiological	Surgical	8
	Medical	6
	Others	2
Causes	Reasons	No of amputees
Surgical	RTA	924
	Crush injuries	364
Medical	Diabetic	532
	Gangrene	119
Others	Cancer	16
	Congenital	14

Table.2 Site of amputation and limb amputated

Site of Amputation	Percent reporting (n =2182)	Limb amputated (%)	
Transtibial	49	Right	55
Transfemoral	47	Left	41
Bilateral	04	Both	04

The causes recorded for amputation pointed to three major etiological reasons, namely, medical (6 causes), surgical (8 causes) and others (2). Among surgical reasons RTA and Crush injuries ranked high (924 and 364 respectively). Amputation due to medical reasons recorded patients with Diabetes (n= 552) and gangrene (n= 119) as toppers. Though represented in lesser number the data received was agonizing since it entailed victims under all major categories. Once the causal factor was established the site of amputation was found out (Table.2)

Data recorded for site of amputation showcased 49, 47 and four percent respectively to have undergone *transtibial (below knee), transfemoral (above knee)* and *bilateral (both the limbs)* (shown in fig.1) amputation. Totally 55 per cent had lost their right limb, 41 per cent their left limb and four per cent both the limbs. Among the types above knee was mainly due to medical and a majority of the other two due to surgical reasons- *a significant finding*.

Transfemoral **Transtibial** **Bilateral**

Figure-1-Locus of Amputation

Exoskeleton **Endoskeleton**

Figure-2 Types of Prosthesis

3.2 Prosthesis prescribed

Among the 142 samples chosen all three types of amputees featured – transtibial (59%), and transfemoral (30%) who were unilateral amputees and the rest were bilateral. Causal factors for amputation revealed medical (40%) and surgical reasons (54 %). Among medical reasons peripheral vascular diseases (Diabetes/ dysvascularity and Thromboangitis Obliterans – 58 and 42 % respectively) surfaced as known etiology. Two basic types of prosthesis were prescribed, namely Exoskeletal and the Endoskeletal design. The

former is the conventional model, while the other was the much sophisticated modular model, which was quite expensive. Fifty one per cent among transtibial and 28 per cent among transfemoral were fitted with exoskeletal limbs.

Some deciding factors (highlights) for proper fit/comfort with prosthesis

- *Body weight and age* of amputee - determining factors in the *frequency of repairs* (Improper socket fit, pressure and ulceration of the soft tissues etc) of lower-limb prostheses
- Prosthetic limb users require more energy than a normal individual to recompense for the prosthetic devices
- The reliability of prosthesis type (Endo or Exo) would depend on definite level of activity and weight of the patient

Total contact (least expensive) or open ended sockets were used in fabrication of below – knee prosthesis along with a Jaipur foot. For transfemoral, ischial bearing and ischial containment sockets were used.

3.3 Perspectives on User's Perception

Those in productive age (43%) followed by young adults (37%) were found to be the most affected group. A good 84 per cent were men. Increase in age was found to be directly proportional to incidence of amputation – ***a*** *very pathetic situation*. User – specific reasons like outgrowing socket size (20 years) and age related bone degenerative changes (60 years) had forced them to go for change in prosthesis within 6 -12 months. The decision of 67 per cent to change their job to suit their demands for lowering physical workload was justifiable. Age factor coupled with co morbidities and stump status determined the extent of walk permitted by their doctors.

3.4 Status quo sequel to amputation

There are certain physiological aspects that amputees endure sequel to amputation. This can be immediate, intermittent or long term. Though they do not have a direct association between the nutritional statuses of the amputees, certain regulations/ restrictions imposed definitely have a say in their endurance patterns. They are categorized under the following subheadings:

a. **Physiological experiences**
b. **Adaptation constraints**
c. **Rehabilitation problems**

a.Physiological experiences: Findings concerning this aspect is discussed under the following sub headings:

i. Duration of disability endured: Table.3 presents the duration of disability endured by the selected sample.

A good proportion (40%) endured trauma for almost five years, while 26 and nine percent had suffered recording up to ten years and above respectively. Living with an amputated limb is never an issue of compromise. The duration of amputation had direct influence over the Quality of life and the satisfaction level of the rehabilitative individual. Amputation for a long period of time is associated with secondary physical conditions, including osteoarthritis, osteoporosis, back pain, and other musculoskeletal problems [4].

These conditions are believed to result from increased forces on the intact limb and altered body mechanics that occur, secondary to limb loss and/or prosthesis use. More than 80 per cent of the samples showed evidences for their low calcium density profile and treatment regimes for their back pain. Transfemoral amputee gains more weight after the surgery due to the change in the body composition changes in lipid metabolism, adjusted body mass index (BMI) after the 1st year post amputation [5]. The transfemoral were found to be enduring the trauma for more duration than the others. These points prove that the nutritional status especially with regard to essential minerals was very low leading to onset of osteoporosis and osteoarthritis.

Table.3 Duration of disability endured

Particulars		Percent Responding (n = 142)			
		Duration of disability (in months)			
		Less than 12	12-60	61-120	More than 121
n		**36**	**57**	**37**	**12**
Overall percent		25	40	26	9
Gender	**Male**	86	82	89	83
	Female	14	18	11	17
Age (in years)	**< 20**	19	6	-	-
	21-40	42	47	30	-
	41-60	39	47	54	-
	>61	-	-	16	100
Level	**TF**	31	21	**38**	**50**
	TT	58	65	57	42
	Bi lateral	11	14	5	8

ii. Phantom sensation: Phantom sensation was expressed as present by 81 per cent of male members and 67 per cent of women amputees. Phantom sensation was expressed as present by 81 per cent of male members and 67 per cent of women amputees. It was perceived as painful requiring medicines by almost all irrespective of the age range and by TF, TT and bilateral (76, 84 and 100 %) respectively. Though it is more of a psychological feeling, its impact on normal living can never be ignored.

iii. Condition of contra - lateral limb: Another important aspect was the condition of the contra lateral limb (the healthy limb). As the samples were positioning their posture/ gait many at times over the healthy limb, they ran a greater risk of inflicting damage to that limb which could even lead to amputation of that limb too. Co morbidity problems further aggravated the issue. Almost 30 per cent irrespective of other factors had expressed feeling cramps, having ulcers and or sustained pain in their healthy limb, which was not a good sign of well being, but a red signal to their poor nutritional status.

iv. Obesity and Overweight: Abnormal weight gain or excessive fat accumulation (Overweight and obesity) pose risks even to healthy individuals. Obesity was quite common and rampant among transfemoral (n=43) and bilateral (n=15) amputees. When an amputee is obese or overweight, they become linked to an intensified risk of many chronic diseases and co-morbidities. The repetitive strain disorders caused due to obesity also affected the prosthetic prescription significantly. Such weight gain (static measurement) actually had altered the weight load on the anatomical structures which had shown its influence on the prosthesis during the gait cycle. This had brought about a variation in the level of activity of these patients as more energy was expended in performing an activity. The entire process thus functioned in a vicious cycle. To hold a resourceful gait, energy consumption is reported as a crucial parameter. This was influenced by the components used and the design of the prosthesis, and anatomical structures. Being obese / overweight, the amputees had been advised calorie restriction (to reduce weight exerted on the device) which hindered with their effective use of the prosthesis.

b. Adaptation constraints

A major point of consideration in fitting the prosthesis is the etiology of amputation which lays individualistic constraints. The “One size fits all” concept can never stand good here.

Selection of socket and suspension – the two essential components in prosthetic fit - receive utmost care and caution. A minor difficulty or stress if experienced by the amputee in initial fit can end up in rejection of the prosthesis. Socket acts as an interface between the residual limb and prosthetic components. The most important bottleneck in the human-machine interface, till today is the design of the socket. Large numbers of prosthetic users reject their prostheses and express lower satisfaction level, mainly due to the sub-optimal interaction between the residual limb tissues and the prosthetic socket [6].

Concentration of force in general had caused stretches on the skin leading to injury of residual limb and hence found not suitable for short residual limbs. In case of a poor design, the prosthetic user tends to abandon the prosthesis. Thereby a well designed and considerate prosthetic socket is decisive for its users [7]. Another constraint is poor socket fit, mainly attributed to obese amputees who invariably endured major volume

fluctuations. Volume management in such patients was therefore considered a deciding factor in prosthetic prescription requiring multiple socket replacements from initial stages itself to ensure a good interface between the residual limb and the socket.

***Suspension system*:** The system used to attach prosthesis is called suspension system. Transfemoral amputees found it difficult to bear weight on the bottom of their residual limb. In order to do so, they had to support their body weight on the ischial tuberosity (seat bone), the soft tissue of the limb, and the gluteal tissues. A majority hence had opted for total elastic suspension (82%), probably the one which could give them maximum user comfort. As transfemoral amputees have exclusive requirements warranted by their anatomical disparities, it is argued that they are the most preferred to render support on those lines. Bilateral cohort preferred different sockets and suspension for either limbs to suit their comfort and convenience.

Along with health issues like muscle loss, calorie restriction and co morbidities adapting to such foreign body components had impacted both their physiological as well as psychological responses and were found to manifest as changed personality styles, non-cooperation for rehabilitative measures and general living standards.

c. Rehabilitation problems

After a lower limb amputation, the main goal of rehabilitation is to restore mobility, the most relevant ability for regaining their quality of life. While nine per cent had refused to walk, majority of 55 per cent never practiced use of assistive mobility devices to walk. Acceptance of the predicament and a futuristic vision differed among the samples. These had visible inputs on how they carried themselves and in their attitudes. Single cane, mono crutches and walkers were the assistive devices used by 45 per cent who needed assistance for ambulation while 35 per cent were wheel chair dependent. Only 59 per cent agreed to be doing donning and doffing (fitting and removing prosthesis) by selves. Others were dependent. Many had procrastinated prosthetic fitting inflicting self harm after healing of the wound post- amputation. Hence lag period prescribed was not adhered to. Gait training was also found not to have been taken seriously. A good 67 per cent had resorted to change type of jobs requiring less physical workload. Changing sockets frequently was also reported. Physiological aspects like obesity and shrunken stump (because of delay in approaching the centers) required change in sockets. Improper fit, mishandling and preference for exoskeletal limb had also contributed.

4. Discussions

Major takeaways from the study

Amputees were unable to perform required physical activity and were less mobile. Regardless of age, patients with more medical problems had poor ambulation. The energy cost of ambulation being greater for amputees than for non amputees, had ended up in obesity and/or overweight. Further, amputation to some extent had led to muscle loss which had slowed down the rate at which the body could burn calories. Excess weight thus accumulated had compounding orthopedic and cardiovascular effects on the amputees. Transfemoral cohort suffered more than the others by virtue of adding excess body weight during convalescence. Rehabilitation goal for an amputee should help restore the ability to perform everyday activities in an easy, natural, and comfortable manner. Poor nutritional and health status coupled with negative feelings about their physique had left many to remain non cooperative for effective rehabilitation. Obesity and overweight cold be singled out as major causal factors impacting prosthesis fit on nutritional health of Lower Limb Amputees.

5.Conclusion

Maintaining good food habits and general health, keeping Blood sugar levels and BP under control and cautious of safety in travel/drive can help many avoid this predicament of amputation in their lives. An amputee suffers problems with maintenance of centre of gravity and may often fall if not careful. Prosthesis and assistive devices can help in gait management only minimally. It is in the hands of the amputee to restore/ regain his or

her normal self through self-care prospects. Having an eye on their nutritional requirements (for calories, proteins and minerals) and health status can be of great help to rehabilitate faster. Becoming obese or overweight due to lapse in energy balance has to be curtailed. If amputee doesn't reduce their calorie intake as they get older, they may gain weight and may end up as a liability for themselves. Counseling and physiotherapy on these lines definitely could fetch good returns.

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Conflict of Interest: The authors declare that they do not have conflicts of interest.

References

[1]. Edward N. Brandt, Jr., and Andrew M. Pope, Chapter -5 Functional Limitations Research in Rehabilitation Science and Engineering. Enabling America- Assessing the Role of Rehabilitation Science and Engineering, Authored by Edward N. Brandt, Jr., and Andrew M. Pope, Committee on Assessing Rehabilitation Science and Engineering, Division of Health Sciences Policy, Institute Of Medicine, National Academy Press, Washington, D.C, 1997, pages -100-101.

[2]. Sinha, Richa and Heuvel, Wim and Arokiasamy, Perianayagam Factors affecting quality of life in lower limb amputees, Prosthetics and orthotics international, March, Volume-35, (2011) 90-96, https://doi.org/10.1177/0309364610397087.

[3]. Gh. Pirouzi, N. A. Abu Osman, A. Eshraghi, S. Ali, H. Gholizadeh, W.A.B. Wan Abas, "Review of the Socket Design and Interface Pressure Measurement for Transtibial Prosthesis", The Scientific World Journal, Article ID 849073, (2014) 9 pages, https://doi.org/10.1155/2014/849073.

[4]. Gailey Robert, Allen Kerry, Castles Julie, Kucharik Jennifer, Roeder,Mariah Review of secondary physical conditions associated with lower-limb amputation and long-term prosthesis use, Journal of Rehabilitation Research and Development, Volume 45, December, Issue No. 1,(2008) Pages 15 – 29 https://doi.org/10.1682/JRRD.2006.11.0147.

[5]. Todd A. Kuiken, MD, PhD, Nicholas P. Fey, PhD, Timothy Reissman, PhD, Suzanne B. Finucane, MS, CCRC, PTA, and Gregory A. Dumanian, MD, Plast Reconstr Surg Glob Open. 2018 Jan; 6(1): e1632, Published online 2018 Jan 12, https://doi.org/10.1097/gox.0000000000001632 PMCID: PMC5811293,PMID: 29464163.

[6]. Paternò, Linda and Ibrahimi, Michele and Gruppioni, Emanuele and Menciassi, Arianna and Ricotti, Leonardo. Sockets for Limb Prostheses: A Review of Existing Technologies and Open Challenges ,IEEE Transactions on Biomedical Engineering Volume PP, January, (2018) Pages-1-1, https://doi.org/10.1109/TBME.2017.2775100.

[7]. Chris Lake. "The Evolution of Upper Limb Prosthetic Socket Design, JPO Journal of Prosthetics and Orthotics Volume 20(3):85-92, July 2008, Pages- 85-92, https://doi.org/10.1097/JPO.0b013e31817d2f08.

[8]. Sarasvathi and Visalakshi Rajeswari, Accessibility and Adaptability of Limb Prosthesis an Ergonomic Concern. http://hdl.handle.net/10603/184729.