

A Study of Metabolic Cost Index during Walking and Stair Climbing in Bilateral Transfemoral Amputee

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ABSTRACT

Introduction: The rehabilitation of bilateral lower limb amputees is generally more intensive than that of unilateral amputees and poses a great challenge to both the rehabilitation team and the amputees themselves. Bilateral amputees who are fitted with standard full length prostheses find it difficult to walk fast or climb up and down stairs. Usually stubbies, or short prostheses with non-articulated rocker bottoms, are also provided. Stubbies enables the amputee to use Indian type toilets with the help of a low level folding portable commode; in addition, it helps the amputee to work outdoors in gardens and fields. Stubbies particularly suitable for bilateral amputees in developing countries like India.

Objective: To find out the effect of stubbies with gait training in bilateral transfemoral amputee as well as to measure Metabolic cost index during walking and stair climbing in bilateral trans-femoral amputee using stubbies.

Design: Post test control group design.

Participants: Subjects with bilateral transfemoral amputation (N=10; 8 men, 2 women; age, 36.5±5.64 years; range, 25 –45 years) and able bodied subjects (N=10 ; 8 men , 2 women; age, 34.5±5.99 years; range, 25-45 years) .

Intervention: Research participants were fitted with stubbies at NIOH, Kolkata and after the fitment of prosthesis, training for donning & doffing was given and a course of gait training for four week was given.

Main Outcome Measures: Objective measurements of energy efficiency were obtained. The Prosthetic assessment form was used to gather subjective information from the participants.

Results: The result of the present study shows statistically significant between the two groups which says that in bilateral trans-femoral amputee the metabolic cost index is quite higher than the normal able bodied. In results it was found that the VO₂ uptake, Heart rate, VCO₂ and Energy Expenditure per minute (EE/min) comparisons were highly significant for both bilateral trans-femoral amputee and normal able bodied in walking (p<0.05) and also in stair climbing (p<0.05) condition.

Conclusions: The use of stubbies is a safe, practical and effective method of improving gait as well as less energy consumption than amputee patient in early rehabilitation program. It has also a clinically significant effect on the indoor mobility of users. These findings have implications for the standards of care and clinical use in rehabilitation program.

KEYWORDS: Transfemoral amputee, Stubbies, Prosthesis, walking, stair climbing, Energy expenditure, Physical effort, Rehabilitation

INTRODUCTION

There is meager data regarding the overall incidence and etiological background of lower limb amputation in India. According to World Health Organization, India has the highest number of road accidents in the world with 16.8 fatal injuries per 100,000 population, and 38.9 non-fatal injuries per 100,000 population as per the data from 2006 ¹. From these figures, it can be postulated that traumatic road accidents would be a significant cause of lower limb

amputation. A cross-sectional study reported vehicle accidents as the major cause of amputation ².

The rehabilitation of bilateral lower limb amputees is generally more intensive than that of unilateral amputees and poses a .great challenge to both the rehabilitation team and the amputees themselves. The major cause of bilateral amputation of the lower limb is an obstructive arterial

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disease. Other causes mentioned in the literature are trauma, infections, tumors and frostbite⁵⁻⁷.

Moreover, the difficulties present during ambulatory rehabilitation are twofold for the bilateral Trans-femoral amputee. Because of the loss of knee function, only the strongest and most determined bilateral Trans-femoral amputee can expect to regain ambulatory control when using conventional bilateral leg prostheses¹⁴. Studies show that most bilateral Trans-femoral amputee find prosthetic walking to be overtly stressful, physically draining, and for some impracticable, particularly among the elderly and physically unfit, who choose a wheelchair as the preferred mode of transportation, hopeful that this will alleviate all or a portion of these dilemmas. In some cases this is true; however, there is another prosthetic possibility, one that is more energy efficient and less physically demanding, and one that most bilateral leg amputees will have already experienced during the initial stages of ambulatory rehabilitation i.e., stubbies^{15,16}.

Stubby prostheses (also referred to as “stubbies”) are short, nonarticulated prosthetic devices which have been suggested as an alternative to full-length articulated prostheses in patients with bilateral trans-femoral amputation. Previous advocates of stubbies have stressed the following advantages related to their use: (1) lowered height and center of gravity, improving safety and reducing the danger of serious falls; and (2) eliminated prosthetic knee joint, improving patient stability. For the new amputee patient, stubbies condition the amputated limbs, particularly aiding in avoiding flexion contracture. The more contemporary designs include standard sockets, no articulated knee joints or shank, with modified rocker bottoms or SACH feet turned backward to prevent the individual from falling. Pylons and/or knee adapters can be added to the setup depending on the individual’s desired height and/or motion, and suspension is achieved through the use of waist bands and/or suspenders¹⁶⁻¹⁹.

Stubbies are relatively easy to use and, though restrictive in their range of ambulation, allow for relative ease of locomotion with less energy cost to the amputee. In fact, using stubbies can reduce heart rate and oxygen use by 7 to 23 percent and can increase walking speed by up to 25 percent.¹⁸ They are particularly helpful in the early stages of rehabilitation, since they can help to prevent contracture and/or abduction and promote healing in the residual limb. Although stubbies are generally used as training devices to determine an amputee’s ability to move to a standard, full-length prosthesis, they are also used daily by amputees across the world^{16, 18}.

Although patients will experience significant energy expenditure as they begin walking on “shorties” it will still requires substantially less energy than walking on full length prosthesis. Stubby prostheses offer potential advantages over conventional prosthetic devices in terms of safety, stability, and energy efficiency.⁽⁴⁵⁾ Although cosmesis is compromised in the process. these short non articulated pylon prostheses may be a viable option to consider in bilateral trans-femoral or knee disarticulation amputee patients under the following circumstances: (A) as a training tool to determine whether progression to full-length articulated devices is feasible; (B) as permanent prostheses

for the patient whose primary need for ambulation is within his own home; (C) for the elderly bilateral amputee in whom ambulation is feasible but safety and energy efficiency are of particular importance; and (D) as a definitive device in the patient who expresses a preference for them^{2,7,16,17,18}.

Metabolic cost index may be influenced by stubbies prosthesis. Sufficient literatures are not available regarding gait or walking efficient in bilateral trans-femoral amputees using stubbies. In practice in low economic country, it has been noticed that, stubbies are the standard prescription in bilateral trans-femoral amputees. Hence it is essential to explore further research on stubbies efficiency in most important activity of user like walking and stair climbing. Therefore the current study will focus on to measure the metabolic cost index in bilateral trans-femoral amputee wearing stubbies prosthesis and compare it with normal able bodied person.

AIM & OBJECTIVES

To investigate the Metabolic Cost Index during walking and stair climbing in bilateral trans-femoral amputee with normal able-bodied.

To find out the effect of stubbies with gait training in bilateral trans-femoral amputee.

To measure Metabolic cost index during walking and stair climbing in bilateral trans-femoral amputee.

HYPOTHESIS:-

There is significant difference in Metabolic Cost Index between bilateral trans-femoral amputees with normal able-bodied subjects.

NULL HYPOTHESIS:-

There is no significant difference in Metabolic Cost Index between bilateral trans-femoral amputees with normal able-bodied subjects.

SIGNIFICANCE OF STUDY:-

The study is going to quantify the difference of metabolic cost index between bilateral trans-femoral amputees with normal able-bodied subject. The result may help to fabricate the appropriate stubbies for bilateral trans-femoral amputee and give a insight to clinician to prescribe diet as well therapist will plan for better therapeutic intervention for strengthening of hip joint.

METHODOLOGY:

STUDY AREA: National Institute for the Orthopaedically Handicapped, Kolkata.

STUDY DURATION: 12 moths

STUDY POPULATION: Subjects with bilateral trans-femoral amputation.

STUDY DESIGN: Post test control group design.

INCLUSION CRITERIA:

- Both male and female
- Age range: 25-45 yrs
- Only bilateral trans-femoral amputee was considered.
- Full ROM of Hip joint and strength minimum more than 4 in MMT.

- Good upper extremity strength (3+ MRC grading)
- No contracture in the proximal joints.
- No sign of phantom pain and phantom sensation.
- Able to understand the command.

EXCLUSION CRITERIA:

- No other associated Neurological or Orthopaedical condition.
- Complicated stump (pain, wound, etc)
- No significant pathology in cardiopulmonary.
- No agree to participate in this study

ETHICAL ISSUES:

On the basis of earlier studies with stubbies, the risk of participation has to be minimal. The study was approved by ethical committee of West Bengal University of Health Sciences, Kolkata.

OUTCOME MEASURE:

The efficiency of the prosthesis was tested by K4 b² by using different variables for gait efficiency like:

- VO₂ uptake (ml/min): The rate of O₂ uptake attained during walking, stair climbing and other activity as per the study protocol.
- VCO₂(ml/min) : Rate of elimination Carbon Dioxide
- Energy expenditure per minute (EE/min): The rate of energy required for a given activity per minute.
- Heart Rate (HR) and O₂ pulse: The number of beats per minute is called the heart rate. The rate of O₂ consumption divided by heart rate is called the O₂ pulse. It indicates the working efficiency of activity. In this study these two parameters were used for the monitoring and analysis purposes.

STUDY TOOLS & INSTRUMENTATION:

- The efficiency of the Stubbies was tested by Respiratory Analyser System COSMED @ K4 b² (Cosmed-spl-Italy)
- Stop Watch

COSMED K4b²

The K4 b² is the first COSMED portable system for intrapulmonary gas exchange analysis on true breath by breath basis. Sport Medicine, Research, Human Performance, Gait Lab, Occupational health, Cardiology, Cardiac Rehabilitation, Clinical Nutrition and any application that requires the measurement of the cardio-respiratory response either in the field or in the lab. Total weight of 800g

- Integrated LCD for calibrating and showing data during field testing without the need of a PC, Powerful rechargeable batteries that can be exchanged during the test.

The K4 b² is a versatile system. Whether in the lab or in the field, tests can be carried out in three different configurations:



COSMED K4b²



STUBBIES



STAIR CLIMBING



FITTING OF PROSTHESIS

STUDY PROTOCOL:

1. The environmental conditions was maintained the same throughout the study. No data was taken in rainy or extreme hot and humid environmental conditions.
2. Subjects were asked to walk with k4b2 after proper adaptation and walking with stubbies without assistive device
3. 2 Minute walk test on self selected velocity on plane surface
4. Electric Stair Climber for Stair Climbing
5. 30 minutes rest between each test mentioned in procedure

STUDY PROCEDURE & AND DATA COLLECTION

Study was conducted on case to case basis of 10 participant's bilateral trans-femoral amputee population attending outpatient, Inpatient Rehabilitation ward of N.I.O.H, Kolkata. All the patients were selected based on first come first serve basis, then allocated into two groups of 10 each. Group A was the experimental group (stubbies). Group B was the control group (Normal able bodied).

Firstly, the participant was assessed and evaluated. The demographic data like age, gender, side of amputation, height and weight will be taken. Each subject with bilateral trans-femoral amputation was provided stubbies. After the fitment of prosthesis, training for donning & doffing was given and a course of gait training for four week was given. Patient was called after completion of gait training, intervention data regarding energy expenditure was collected for all 2 groups during walking and stair climbing. Finally patient was discharged with the stubbies.

Subjects were advised to walk in level ground surface using stubbies(shown in figure 5.3 and 5.4).individually for practice and training to adopt the prosthetic device.

Thorough pretest medical health screenings including cardio-vascular functions were assessed before K4b2 test, the following screening test was recommended in my study:

- Symptoms suggesting cardiac or pulmonary disease
- Angina or other forms of discomfort at rest or during exercise
- Unusual shortness of breath at rest or during exercise
- Dizziness or light-headedness
- Other unusual signs or symptoms that may preclude testing
- Risk factors for coronary heart disease
- History of major cardio respiratory events
- Current medications

The patients were normal psychologically with no anxiety, stress, fear etc. They were taught to walk with their own self selected walking speed with the stubbies. They were advised to take their normal diet at least 2 days before the test.

The fitting of stubbies and efficacy of the prosthetic system were evaluated and approved by the Prosthetics & Orthotics Department, N.I.O.H, Kolkata. Prior to the test there was 5 minutes of rest period for accommodation to the system.

RESULTS

A total number of 10 bilateral trans-femoral amputees were recruited for the study with age range from 25 to 45 years. There were 8 male and 2 female patients in the study. There was no drop out during the study. Data were collected at the post training of gait training session.

Group A & Group B during Walking in plane surface

Comparison of VO2 uptake rate between Group A & Group B during Walking in plane surface.

VO2 uptake	Mean± SD	t-value	p-value
Group A	244.87±31.16	-16.23647572	5.65964E-08
Group B	382.21±16.71		

Comparison of VCO2 rate between Group A & Group B during Walking in plane surface

VCO2 uptake	Mean± SD	t-value	p-value
Group A	135.21±12.68	-20.45235227	7.45341E-09
Group B	252.34±12.50		

Comparison of Heart Rate (HR) uptake rate between Group A & Group B during Walking in plane surface

HR	Mean± SD	t-value	p-value
Group A	81.1±8.36	-11.10909654	1.48129E-06
Group B	115.8±5.15		

Comparison of Energy expenditure between Group A & Group B during Walking in plane surface

EE	Mean± SD	t-value	p-value
Group A	1.876±0.20	-7.584872837	3.3794E-05
Group B	2.652±0.29		

Group A & Group B during stair climbing

Comparison of VO2 uptake rate between Group A & Group B during stair climbing

VO2 uptake	Mean± SD	t-value	p-value
Group A	309.4±35.1	-18.5665	1.75E-08

Comparison of VCO2 uptake between Group A & Group B during stair climbing

VCO2 uptake	Mean± SD	t-value	p-value
Group A	192.4±19.2	-18.3826	1.91E-08

Group A: - Bilateral trans-femoral amputee Informed consent patient were advised to follow the command of the researcher in doing of donning and doffing of stubbies prosthesis and undergone through a course of 4 week gait training. After completion of training now the patient were assessed through the cosmed K4b2 metabolic analyzer in following method:

In first 2 minute data were collected during the patient in walking condition in a plane surface and in another 2 minute data were collected during stair climbing.

Group B: - Normal able bodied

In this group the normal population was selected and there was no intervention program for this group. Data were taken same as the procedure follow in Group A.

STATISTICAL ANALYSIS

- Statistical analyses were performed using the Microsoft office excel 2007 software.
- Related t test was used to analyses for comparing of both groups.
- Related t test for a significant t value was applied to specify where significant differences occurred.
- A probability level of p<0.05 was accepted as significant.
- Data were presented as arithmetic means ± standard deviation (X±SD).

Comparison of Heart Rate between Group A & Group B during stair climbing

HR	Mean± SD	t-value	p-value
Group A	101.3±11.8	-8.6844	1.14E-05
Group B	142.3±8.3		

Comparison of Energy expenditure between Group A & Group B during stair climbing

EE	Mean± SD	t-value	p-value
Group A	2.17±0.14	-23.3145	2.34E-09
Group B	3.92±0.25		

DISCUSSION

This study provides novel data on the diversity in metabolic cost index (oxygen uptake, carbon dioxide uptake, heart rate and energy consumption) characteristics and perception of walking in people with differing levels of bilateral trans femoral amputations when compared with walking in a Normal Able bodied group. All Bilateral trans-femoral amputee studied here had undergone prosthetic rehabilitation and were considered by their limb fitters to be successful walkers. The data revealed that in a (relatively small) group of bilateral trans-femoral amputee, walking speeds, prosthetic gait training, exercise heart rates and perceptions of walking ability/performance were highly variable ³².

The result of the present study shows statistically significant between the two groups which says that in bilateral trans-femoral amputee the metabolic cost index is quite higher than the normal able bodied. In results it was found that the VO₂ uptake, Heart rate, VCO₂ and Energy Expenditure per minute(EE/min) comparisons were highly significant for both bilateral trans-femoral amputee and normal able bodied in walking(p<0.05) and also in stair climbing(p<0.05) condition. This suggests that the change in VO₂ uptake can directly affects the HR, EE/min values and vice-versa ⁶⁸. This well-established fact had been employed in many previous studies of the energy costs of both bilateral trans-femoral amputee and normal able bodied. (Cordrey et al,1957; Ganguli and Bose, 1974; McBeath et al., 1974; Dounis et al., 1980; Ghosh et al.,1980; Fisher and Patterson. 1981; Hinton and Cullen, 1982) ³⁹

From the current study it reveals that the VO₂ uptake, VCO₂, HR and EE is higher in the bilateral trans-femoral amputee with stubbies than the normal able bodied. This results accords with the literature led by Crouse²¹ et al (2001), This study found that ambulation with stubbies was more energy efficient than ambulation with full-length prostheses. Oxygen uptake was 24% higher, minute ventilation was 32% higher, and heart rate was 14% higher when the subject ambulated with full-length prostheses. When comparing the subject with bilateral trans-femoral amputee while wearing stubbies to controls, heart rate was 33% higher, oxygen uptake was 47% higher, and minute ventilation was 29% higher. While wearing full-length prostheses, heart rate was 52% higher, oxygen uptake was 80% higher, and minute ventilation was 70% higher than in the control subjects ³⁰

In walking condition the result of the study showed that there is an increase of 56% higher oxygen consumption, 42% higher Heart Rate and 40% higher energy expenditure in bilateral trans-femoral amputee with stubby than normal population. This might have happened due to the readjustment in autonomic nervous activity apparently carried out and/or the cardiac contractile force might have

increased in the walking condition. Oxygen consumption and EE in bilateral trans-femoral participants showed a tendency to increase with walking than metabolic rest condition. This literature also supported by Orendurff et al, 2001, Huang et al 1986 described that Patients with bilateral trans-femoral with stubby consume higher level of oxygen and EE to perform same intensity of work as compared to normal population ^{18,33}.

In Stair climbing condition the result of the study showed that there is an increase of 62% higher oxygen consumption, 40% higher Heart Rate and 80% higher energy expenditure in bilateral trans-femoral amputee with stubby than normal population. This might have happened due to, in stair climbing the concentric action of muscle requires more potential energy than in walking on the plane surface. The increase in oxygen cost for stair climbing probably results from additional energy to resist or brake the body from gravity's pull while trying to achieve a proper and safe walking rhythm.

CONCLUSION

A patient recovering from bilateral trans-femoral amputee faces many challenges. Ambulation with prostheses (stubbies) after bilateral-trans femoral amputee requires significant energy expenditure and results in a slower walking speed than normal. On the basis of the findings of this study, it can be concluded that Stubbies are relatively easy to use, comparatively physiological comfort in comparison full height prosthesis and allow for relative ease of locomotion with less energy cost to the amputee. In fact, using stubbies can reduce heart rate and oxygen use by 7 to 23 percent and can increase walking speed by up to 25 percent. They are particularly helpful in the early stages of rehabilitation, since they can help to prevent contracture and/or abduction and promote healing in the residual limb. Although stubbies are generally used as training devices to determine an amputee's ability to move to a standard, full-length prosthesis, they are also used daily by amputees across the world.

Thus the use of stubbies is a safe, practical and effective method of improving gait as well as less energy consumption than amputee patient in early rehabilitation program. It has also a clinically significant effect on the indoor mobility of users. These findings have implications for the standards of care and clinical use in rehabilitation program.

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