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Impact of Exoskeletal Prosthesis on Energy Expenditure in Female Amputees during Walking with Two Different Level of Amputation

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ABSTRACT

Background: The process of rehabilitation is to restore function and to regain an acceptable level of functioning and social participation. In case of amputation, to reach this goal, prosthesis is used to compensate for the functional loss. The level of amputation is a very useful factor in terms of energy expenditure.

Methods: 30 Female eligible subjects 15 transfemoral and 15 transtibial amputees were included in the study as per convenient sampling. In group A subject with unilateral transfemoral amputation were provided exoskeletal Transfemoral prosthesis and in group B subject with unilateral transtibial amputation were provided exoskeletal transtibial prosthesis. After the Treatment procedure data was collected in K4b2 Metabolic analyzer system.

Results: The result of the present study shows statistically significant difference between the two groups i.e. unilateral transfemoral and transtibial female amputee. Energy consumption of transfemoral subjects is higher than transtibial subject and in results it was found that comparisons were highly significant for both unilateral transfemoral and transtibial subjects ($p<0.05$)

Conclusions: This study concluded that Transfemoral amputees using exoskeletal prosthesis spend more energy than transtibial amputees.

Keywords: Transfemoral female amputee, Transtibial female amputee, Exoskeletal Prosthesis, Traumatic amputation, Energy consumption,

INTRODUCTION

Amputation can be performed as a disarticulation of a joint or as a transaction through a long bone. The level of amputation is usually named by the joint or major bone through which the amputation has been made. Limb amputation can be considered as both a life-saving procedure and a life changing event. [1] 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 populations as per the data from 2006. [2] According to a survey on 1983, every year 23,500 amputees are added to the amputee population in India, of which 20,200 are males and 3,300 are females. [3] Trauma was the leading cause of amputation in all age groups except for those in their 60s. In fact, in each of the younger groups from the teens to the 30s, amputation due to trauma accounted for more than 70% of all amputations. [4]

The main purpose of the rehabilitation process is to restore function and to regain an acceptable level of functioning and participation. To reach this goal, prosthesis is used to compensate for the functional losses. [5,6] Prosthetic rehabilitation in adults with lower limb amputation depends on different factors like amputation level, anatomic and functional condition of the amputed limb, weight, activity level, quality of prosthetic appliances and cardiorespiratory function. [7] The influence of the prosthetic design on the mechanics of gait, which may cause the amputee to deviate from a normal gait pattern and increase energy expenditure during walking, It is well recognized that persons with lower extremity Amputation who walk with prosthetic devices have greater Energy requirements to travel a given distance than do able bodied Individuals during normal walking. [8]

It is generally accepted that more proximal amputation is associated with more energy consumption while walking. [11] The physical demands of prosthetic walking for people with unilateral transtibial and with transfemoral amputations have been reported in several studies. Some researchers used a bulky and cumbersome metabolic cart to measure EE during walking. The metabolic cart makes it difficult to keep pace with patients without interfering with them when they walk on level ground. [9]

The purpose of the study is going to quantify the effect of energy expenditure between two levels of female amputee by using exoskeletal transfemoral and transtibial prosthesis. The result may help to fabricate the appropriate lightweight prosthesis.

MATERIALS AND METHODS

Study was conducted on case to case basis of 30 participants in between 15 unilateral transtibial amputee and 15 transfemoral amputee population attending OPD of N.I.L.D, Kolkata. All the subjects were selected based on inclusion criteria like age between 20-50 years, only female amputees, unilateral traumatic transfemoral and transtibial amputees, medium stump length(transfemoral:35-60% of femur and transtibial:20-50% of tibia)etc, We kept the subject with unilateral transfemoral amputee in group A and the subject with transtibial amputee in group B. Each subject of transfemoral amputee had provided Exoskeletal Transfemoral prosthesis with quadrilateral socket, with constant friction knee joint, Ranger foot and Silesian suspension, subject of transtibial amputee had provided with exoskeletal prosthesis with PTB socket with Ranger foot and cuff suspension.

Figure 1: K4b2 System (Respiratory Analyzer System COSMED ® K4 b^2 (Cosmed-spl-Italy)
Fig -2 - Casting Procedure

After the Prescription the demographic data like age, gender, side of amputation, height and weight was taken. Then Prosthesis was fabricated and fitted. After the fitment of prosthesis, subject got discharged. After four weeks Subject has called for follow up. At that time data regarding energy expenditure were collected for both the groups during walking by k4b2 metabolic analyzer. Then the data was analyzed and compared between two individual groups.

STATISTICAL ANALYSIS

Data was managed on an excel spread sheet. SPSS window version 23 statistical software was used for data analysis. Test of normality was done using Shapiro-Wilk test, which revealed data were normally distributed ($p>0.05$) between the groups. Independent 't' test was used to analyze the energy expenditure between transfemoral and transtibial amputee. Statistical significance was taken at $p\leq0.05$ with 95% confidence interval.

Table 1: Result of demographic data of group A and group B -

Amputee type	Age(mean± SD)	Height(mean±SD)	Weight(mean±SD)
Transfemoral	30.93 ± 3.84	161.62 ± 6.23	60.26 ± 4.04
Transtibial	32.33 ± 3.88	161.53 ± 7.88	58.4 ± 2.89

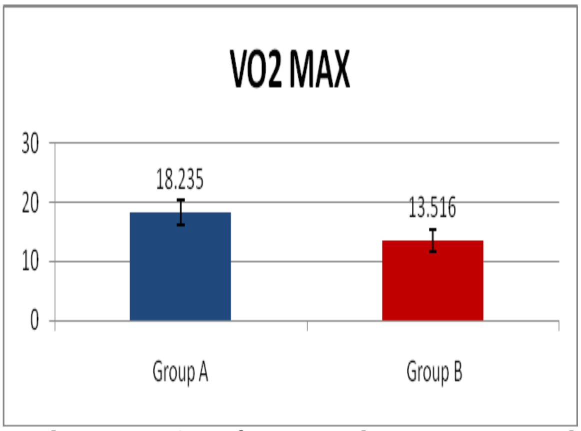
RESULT

VO2 MAX

Data for VO2 Max after completion of 4 weeks of intervention in Group A and Group B are given in Table 2 that represented graphically by graph I. The variable vo2 max was compared using independent T-test. Data shows significant difference between two groups. ($p<0.05$, $t=7.022$)

Table 2: Comparison of VO2 max between two different Group A and Group B

	VO2max(ml/kg/min) Mean ±SD	t-value	P-value
Group A	18.23 ±2.14	7.022	.000
Group B	13.51 ± 1.71		



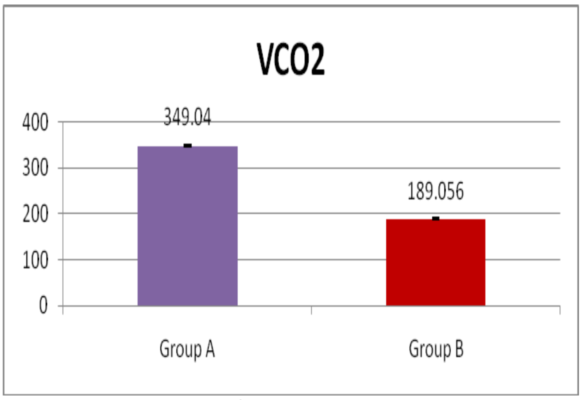
Graph I: Comparison of VO2 Max between group A and group B

VCO2

Data for VCO2 after completion of 4 weeks of intervention in Group A and Group B are given in Table 3 that represented graphically by graph II. The variable VCo2 was compared using independent T-test. Data shows significant difference between two groups. ($p<0.05$, $t=6.268$)

Table 3: Comparison of VCO2 Between two different Groups A and B

	VCO2 (ml/min) Mean±SD	t-value	p-value
Group A	349.0405±82.7363	6.268	.000
Group B	189.0567±63.97543		



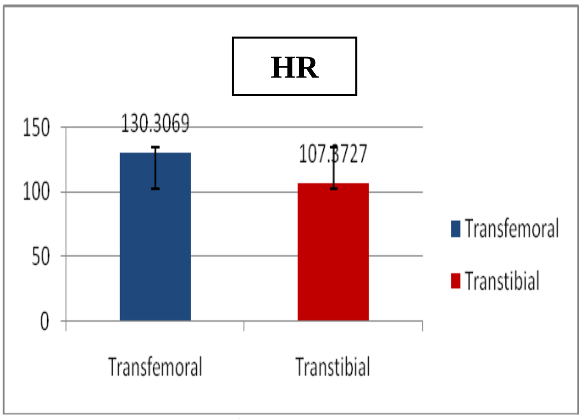
Graph II: Comparison of VCO2 between group A and group

HEART RATE

Data for VCO2 after completion of 4 weeks of intervention in Group A and Group B are given in Table 4 that represented graphically by graph III. The variable HR was compared using independent T-test. Data shows significant difference between two groups. ($p<0.05$, $t=5.924$)

Table 4: Comparison of HR Between two different Groups A and B

HR	Mean±SD	t-value	p-value
Group A	130.3069±9.762288		
Group B	107.3727±10.27273	5.924	.000



Graph III: Comparison of HR between group A and group B

DISCUSSION

Most of the previous studies explain and show effect of various types of endoskeletal prosthesis on metabolic process. [11,12] But in developing countries as India the patients are from rural area and low economic group. They are generally fitted with low cost exoskeletal prostheses. Limited number of studies and data are available to show the energy consumption in female amputee using exoskeletal prosthesis. The study includes 30 numbers of subjects with unilateral transtibial and transfemoral amputees without sex consideration. The other physical factor like height, weight were not considered except age and stump length .The hypothesis was that there is a significant difference on energy expenditure during walking with exoskeletal prosthesis in different level of amputation. The results support the hypothesis. This study provides novel data on the diversity in energy expenditure (oxygen uptake, carbon dioxide uptake, heart rate and respiratory quotient) characteristics and perception of walking in people with transfemoral and transtibial amputations when compared with Normal Able bodied group at walking. In this study, we aimed to determine whether, in subjects with unilateral transfemoral amputee expends more energy than normal able bodies and also from transtibial amputee. And transtibial amputee from normal able bodies when measured during walking in a level surface with exoskeletal prosthesis. All Unilateral trans-femoral and transtibial amputee studied here had undergone prosthetic rehabilitation and were considered by their limb fitters to be successful walkers. Both groups of subjects are walk in self-selected comfortable speed.

The result of the present study shows statistically significant between the two groups which says that in unilateral trans-femoral and transtibial amputee the energy expenditure is quite higher than the normal able bodied. And also transfemoral amputee spends more energy expenditure than transtibial amputee. In results it was found that the VO2 max(ml/kg/min), Heart rate, VCO2 and Respiratory quotient comparisons were highly significant for both unilateral trans-femoral and transtibial amputee and normal able bodied in walking($p<0.05$). This suggests that the change in VO2 max can directly affects the HR, and vice-versa. [19]

In walking condition the result of the study showed that there is an increase of 16% higher oxygen consumption in transtibial amputee than normal able bodies and, 56% higher oxygen consumption in transfemoral amputee than normal population. This might have been due to amputees physical condition residual muscle fatigue. This literature also supported by Schmalz T et al (2001)the oxygen consumption of transtibial amputees increases by 25% compared with non-amputees and that of transfemoral amputees by 55_/65% It should be noted that metabolic energy consumption is highly dependent on the amputee’s physical condition. It can be assumed that the metabolic energy consumption of patients who sustained amputation due to dysvascularity exceeds those who sustained traumatic amputation by an average of 20_/35% more. [11] And the result was also supported by Sonja M. II(1993)studied with 2 groups of transfemoral amputee. Group 1 is slower walking speed and group 2 is higher walking speed by using a treadmill with parallel bars (Enraf Nonius, type 47 1). Oxygen uptake was measured using an Oxyconb gas analyzer. Compare two groups with the normal1 subjects. Both groups of amputee subjects showed a higher oxygen uptake $V0_2$ at the same walking speed. The difference in oxygen uptake increased with the walking speed. The mean heart rate (HR) of both group amputee subjects was significantly higher than the mean heart rate of normal subjects at rest and at early walking speeds. [20]

CONCLUSION

This study concludes that subjects with transfemoral amputation using exoskeletal prosthesis spend more energy than subjects using transtibial prosthesis. However prosthetic design, components and anatomical structures may influence the energy expenditure. Energy consumption is a vital parameter for efficient gait so during fabrication of a prosthesis various parameters has to be taken care of like weight of the prosthesis, type of components etc. As the number of subjects in this study is less, more number of studies is required for better prescription.

Conflict Of Interest

The author does not have any conflict of interest regarding research, authorship and publication of this article.

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