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Original Research Article

A Study to Compare the Difference in the Amount of Energy between the Two Most Commonly Used Assistive Devices (Prosthesis and Axillary Crutches) in Adults with Transtibial Amputation by Indirect Calorimetric Method at the Self-Selected Speed in Plane Surface Walking

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Abstract:

Aim: The aim of the present study was to compare the difference in the amount of energy between the two most commonly used assistive devices (prosthesis and axillary crutches) in adults with Transtibial amputation by indirect calorimetric method at the self-selected speed in plane surface walking.

Methods: The present study was conducted in the Department of Physical Medicine and Rehabilitation. 50 unilateral TTA took part in this study. They were advised to walk in level ground surface using ‘‘prosthesis’’ and ‘‘crutches without prosthesis’’ individually. The environmental conditions were maintained the same throughout the study.

Results: There were 80% were male and 20% were female. The mean age of the participants was 32.18 ± 4.36. The VO2 uptake and EE comparisons were highly significant for both prosthesis and crutches without prosthesis walking. The VO2 uptake data showed more symmetry in prosthesis walking compared to crutch walking without prosthesis. The EE/min data showed more symmetry in prosthesis walking compared to crutch walking without prosthesis. The results for HR indicated that the patients were in a comfortable range throughout this study.

Conclusion: The data on energy cost indicates that all below knee amputee groups walk with less effort by using prosthesis. It may be concluded that crutches without prosthesis may not be used as a permanent rehabilitative measure in transtibial amputations.

Keywords: Axillary Crutch; Energy Cost; Telemetry Unit; Transtibial Amputees.

Introduction

Overground walking speed is commonly used to quantify a human subject’s mobility improvement after being fit with a new prosthetic leg or after undergoing physical therapy or rehabilitation from stroke, other injury, or movement disorder. [1,2] Walking speeds are estimated using a variety of tests in the lab, for instance, using the 6 minute walk test [3] or the 10 m walk test [4], in which the tests are framed as cardiovascular endurance tasks with the subjects being asked to walk as far as possible in the given duration. In healthy adults with no movement disorders, the preferred speed for walking in a straight line was recently shown to be distance-dependent5: the speed is systematically lower for shorter distances. This distance-dependence can be explained by the larger energetic cost of speeding up and slowing down for shorter distances. [5] This distance dependence of walking speed is also relevant because a considerable percentage of daily walking occurs in short bouts [6], especially in amputees. [7,8]

When prosthesis design alone does not appear to fully account for the metabolic cost of walking with limb loss, another potential contributing factor that has received less attention is fitness (e.g. muscle strength). When subjects with and without limb loss are closely matched for age and fitness, they often walk with similar metabolic costs. For example, relatively young military Service Members with limb loss due to traumatic injuries can walk with a passive transtibial prosthesis with metabolic costs that do not differ significantly from able-bodied Service Members. [9,10] Youngº in the limb loss population typically refers to ages ~ 18±44 years [11], or well below the typical ªOlder Adultº threshold of 60±65 years. A potential

mechanism for these results is that while limb loss removes the ability of the lost muscles to directly perform mechanical work at the ankle, which may necessitate energetically costly compensations elsewhere, it also removes the ability of these muscles to consume metabolic energy, and the ankle plantar flexors account for about a quarter of the total metabolic cost of walking. [12] With sufficient fitness, perhaps these energy savings outweigh the costs of compensatory adjustments.

This mechanism is difficult to test in human subjects due to the obvious difficulties in obtaining longitudinal data pre- and post-limb loss. Consequently, the effect of maintaining pre-limb loss muscle strength on the metabolic cost of walking post-limb loss is unknown. Optimal control simulations can be useful in such situations where obtaining data from live humans is impractical or impossible [13] and in situations where multiple objectives are relevant in the control problem, e.g. metabolic cost, gait deviations, symmetry, balance, joint loading, etc. [14]

The aim of the present study was to quantify and compare the difference in energy cost between the two most commonly used assistive devices (prosthesis and axillary crutches) in adults with Transtibial amputation by indirect calorimetric method at the self-selected speed in plane surface walking.[15-16]

Materials and Methods

The present study was conducted in the Department of Physical medicine and Rehabilitation, PMCH, Patna, Bihar, India for five years and 50 unilateral TTA took part in this study. They were advised to walk in level ground surface using ‘‘prosthesis’’ and ‘‘crutches without prosthesis’’ individually. The environmental conditions were maintained the same throughout the study. The patients were normal psychologically with no anxiety, stress, fear etc. They were taught to walk with their own self-selected walking speed for either prosthesis or crutch walking. They were advised to take their normal diet at least 2 days before the test.

Our Inclusion Criteria Include:

- Transtibial amputee with minimum muscle strength of Grade 3+ around the knee joint;
- Only unilateral amputees of either side will be considered;
- Origin of amputation: traumatic; the amputee must be a prosthetic user for a minimum period of one month;
- Type of prosthesis: transtibial exoskeletal prosthesis with PTB socket with cuff suspension with such foot fabricated and fitted by same CPO; age range: 25–45 yrs;
- Full ROM in knee and hip joints; adequate upper extremity strength (minimum Grade-4 as per Manual Muscle Testing);
- Stump length: minimum 8 cms from tibial plateau;
- No contracture in the proximal joints (knee and hip, etc.);
- No neuroma or edema;
- Must be a community ambulatory (at least K2 level);
- They should be ready to participate in this study on their own.

Similarly we have excluded:

TTA with contracture and weak (less than grade 3) knee power; complicated stump (pain, wound, etc.); cause of amputation: peripheral vascular disease (PVD); patient with inadequate ROM and strength in contra lateral limb; patients with neurologic disorders, or other related psycho-logical problems;

- Patients with cardiovascular and respiratory problems;
- Musculoskeletal disorder that might alter gait characteristics.

Procedure

A detailed explanation of the procedure was given after which the subjects signed the informed consent. The fitting and efficacy of the prosthetic system as well as the height of the crutches and positions of handgrip. The amputees were already accustomed to walk with both prosthesis and crutches in their normal life. Prior to the test there was 5 min of rest period for accommodation to the system. Two tests were performed during the study and were randomized in order: in Test I the physically fit TTAs performed a gentle walking session with prosthesis consisting of an easy 30 meters (with rest periods of 10 min separating each walk), on three separate occasions. Sessions were identical. During three (test retest) sessions a Cosmed K4 b2 portable gas analysis system was used. The mean of the three trials was taken for analysis;

in Test II then after a rest period of another 30 minutes again these amputees underwent another test of gentle walking with bilateral axillary crutches without prosthesis consisting of a easy 30 meters (with rest periods of 10 min separating each walk), on three separate occasions. Again the mean of three trials was taken for analysis.

- Then comparative study was done between Test I & II.

Parameters

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

- **VO_2 uptake (ml/min):** The rate of O_2 uptake attained during exercise of large muscle groups. It is an indicator of physical fitness also called maximal aerobic capacity;
- **O_2 cost:** The amount of energy required to perform the task. During level walking the O_2 cost is the amount of O_2 consumed per kilogram of body weight per unit distance traveled (mL/kg/m) or rate of O_2 consumption divided by walking speed. Also called physiologic work;
- **EE per minute (EE/min):** The rate of energy required for a given activity per minute. It is expressed in terms of Kcal/ min;
- **HR and O_2 pulse:** The number of beats per minute is called the HR. The rate of O_2 consumption divided by HR is called the
- **O_2 pulse:** It indicates the exercise efficiency of active muscle. In this study these two will be only used for the monitoring purposes; walking speed: the distance in meter travelled per minute. It is expressed in meter/min.

Instrumentation

The instrumentation is as follows:

- The efficiency of the prosthesis will be tested by Respiratory Analyser System Cosmed1 K4 b2 (Cosmed-spl-Italy)[15,16]
- Stopwatch.

Data analysis

Data was managed on an Excel spreadsheet. SPSS.10 statistical software was used for data analysis. Statistically, the results were analyzed using the t-test. Paired t-test was used to compare the gait efficiency between the prosthesis walking and crutch walking. The significance level of $P < 0.05$ was fixed.

Results

Table 1: Comparison of demographic data

Subject characteristics	Mean±SD
Age in years	32.18 ± 4.36
Sex N (%)	
Male	40 (80)
Female	10 (20)
Stump Length (cm)	16.48 ±3.72
Weight (Kg)	59.26 ± 4.796

There were 80% were male and 20% were female. The mean age of the participants was 32.18 ± 4.36.

Table 2: Comparisons of VO_2 uptake, EE/min, heart rate & self-selected velocities (SSV) for prosthesis and crutches without prosthesis walking

Parameters	Prosthesis walking (Mean±S.D)	Crutch walking without prosthesis (Mean±S.D)	P value
VO2 uptake (ml/min)	252.5006±52.058	306.8018±72.838	< 0.05
EE/Min (Kcal/min)	1.3386 ±0.402	2.5694 ±1.033	< 0.05
Heart rate (Beats/min)	82.0755 ±5.869052	91.27 ±7.401	< 0.001
Velocity (Meter/min)	63.85 ± 2.898	60.58 ±2.652	< 0.05

The VO2 uptake and EE comparisons were highly significant for both prosthesis and crutches without prosthesis walking. The VO2 uptake data showed more symmetry in prosthesis walking compared to crutch walking without prosthesis. The EE/min data showed more symmetry in prosthesis walking compared to crutch walking without prosthesis. The results for HR indicated that the patients were in a comfortable range throughout this study.

Discussion

Many studies have shown the effect of different types of crutches on energy efficiency with different crutch gaits. McBerth et al. found that use of a cane or crutches with two-point alternating and three points partial weight bearing gaits required about 33% more energy than normal walking. The swing through and three-points non-weight bearing gaits required about 73% more energy than normal walking. [17] In a comparison between underarm axillary crutches and elbow crutches, Fisher and Patterson had found no significant difference between them. [18] In another study, Lee noticed that oxygen consumption was less for axillary crutches than elbow crutches. [19]

There were 80% were male and 20% were female. The mean age of the participants was 32.18 ± 4.36. The VO_2 uptake and EE comparisons were highly significant for both prosthesis and crutches without prosthesis walking. The VO_2 uptake data showed more symmetry in prosthesis walking compared to crutch walking without prosthesis. The EE/min data showed more symmetry in prosthesis walking compared to crutch walking without prosthesis.

The results for HR indicated that the patients were in a comfortable range throughout this study. Although there is a considerable body of literature on the physiologic EE of amputee gait in different prosthetic components or different types of crutches, a direct comparison of the results of the different studies is difficult for the following reasons. First, many comparison had been done for young or usually traumatic amputees with older or usually vascular amputees, and there are significant differences between these two groups with respect to gait performance. Secondly, there is often no distinction between amputees who use upper-limb assistive devices and those who do not. Although the oxygen uptake method has been shown to be a reliable method and is used by many, the previous instruments are cumbersome, more patient unwillingness, and not available in many clinics. [20] Other disadvantages include no breath by breath data can be obtained and therefore rapid changes in ventilation or VO_2 cannot be studied and secondly the method is time consuming due to the requirement of sampling and analysis after collection. [21]

Waters et al [22] found that the rate of oxygen consumption, HR, respiratory quotient was significantly increased in all group of amputees when using a crutches and without prosthesis. Tachycardia was found to be increased in all patients using crutches. All the amputee subgroups averaged between 120 and 125 heartbeats per minute. The results of this study also revealed the same findings in oxygen consumption only but not for HR. We found that throughout our study whether using prosthesis or crutches without prosthesis, the patients were within the comfortable range. (Mean HR for prosthesis walking and crutch walking was 82 and 91 beats/min respectively). This indicates that in comparison to previous reports, the patients were in a comfortable range throughout this study. The difference of this result with respect to the previous studies is may be due to the fact that, prior to the test the initial resting phase was meant for the accommodation to the system and in between the two tests the patients were rested for 30 minutes. By this time the patient's normal resting HR comes to a baseline level. However in a comparison between prosthesis and crutch walking, it was observed that the prosthesis walking was 6% more stable in regards to HR than crutch walking. In another study by Jessie [23], the authors concluded that the energy cost of walking with prosthesis is less than that expended when walking without it using crutches or a walker. Our study also revealed the same findings. In comparing the VO_2 uptake for both prosthesis and crutches, significant differences were observed ($P < 0.005$). The comparison for EE/min values also showed a significant difference ($P < 0.00001$). It was observed that the prosthesis walking in self-selected velocities in level surface is 21% more efficient in terms of VO2 uptake and 92% more efficient in terms of EE/min as compared to crutch walking in case of unilateral TTA.

The results of this study can be clinically applied in view that, the crutches without prosthesis should not be used as a permanent rehabilitative measure in case of patients with unilateral transtibial amputations. Crutch walking without prosthesis with a three-point gait pattern (as it requires less effort as compared to swing through crutch assisted gaits) in unilateral amputees may be a primary or secondary means of transportation when an adequate prosthesis is unavailable or inadequate. Crutches may be considered for times when the amputees choose not to wear their prosthesis or for occasions when they are unable to wear their prosthesis secondary to edema, skin irritation, or poor prosthetic fit.

Conclusion

The data on energy cost indicates that all below knee amputee groups walk with less effort by using prosthesis. It may be concluded that crutches without prosthesis may not be used as a permanent rehabilitative measure in transtibial amputations. The hypothesis of this study that prosthesis is more effective in conserving energy in case of unilateral Trans tibial amputees than crutches without prosthesis for walking activities is well supported by the results of this study. The data on oxygen consumption, HR, and EE per minute clearly indicated that all below knee amputee groups walk with less effort by using prosthesis.

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