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Short Report:

Study on Gait Efficiency and Energy Cost of Below Knee Amputees After Therapeutic Practices

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Abstract:
An earlier research advocated that a below knee amputee (BK) with conventional trans-tibial prosthesis attains higher gait efficiency at lower energy cost with therapeutic practices of proper time and co-ordination in compare to normal subjects of similar physical parameters and quality of life. The present study focused on comparative analysis of energy cost and gait efficiency between a group of below knee amputees and a control group (normal subjects without amputation) to indicate the consistency of the earlier findings. The subjects were selected with similar physical parameters and quality of life. Oxygen Uptake (VO_2) and Heart Rate (HR) were measured by Cosmed® k4 b2 analyzer system. Gait efficiency ($p < 0.0001$) was found higher with lower energy cost for BK amputees after therapeutic practices than control group. The therapeutic activities contributed to efficient gait pattern for amputees ensuring proper time and co-ordination with balance in consistence to the earlier research.

Key Words: Energy Cost; Gait Efficiency; Below knee amputee

Introduction:

A previous research showed that appropriate time and co-ordination of movement resulted in confident gait rhythm and balance with less energy cost for the below knee amputees.(1) Biswas D et al advocated that proper training for time and co-ordination and prescribed therapeutic practice of movements can help the amputee with below knee prosthesis to achieve their ideal gait with less energy cost in comparison to the normal subjects with non-pathological gait with similar physical parameters and quality of life.(2) It was studied earlier that the lower extremity amputees need to spend massive effort and time to attain their ideal gait efficiency. Whereas achieving the efficient locomotion acts a major role in the individual development.(3) Ambulation is practically difficult for trans-tibial amputees due to excessive energy cost. Earlier studies established elevated relation of energy expenditure and decreased gait efficiency in the transtibial amputees in comparison to the normal subjects with non-pathological gait.(4-11) Gait efficiency is defined as energy cost per distance traveled in previous research papers. (9) The lowest value is considered the Optimum efficiency at the self selected speed.(4,9) Preceding research showed the higher energy consumption in amputees with leg prosthesis than normal at comparable walking velocities.(12-14) Ganguly et al determined 33% more energy cost for transtibial amputees than the normal subjects at 50 m/min walking speed.(5) Conversely, most of lower limb amputees can attain their normal gait within their limitation of disabilities with the practice of proper time and co-ordination.

The purpose of this study was to compare the energy cost, gait efficiency of a group of physically active below knee amputees with conventional trans-tibial prosthesis after therapeutic practices versus a group of normal person with similar physical parameters (sex, age, height, and weight) and quality of life during their normal locomotion.

Method:

Fifteen Trans-tibial amputees with conventional prosthesis having patella-tendon-bearing (PTB) socket and a solid-ankle-cushion-heel (SACH) foot for more than 3 years were selected in this study with their consent to the National Institute for the Orthopaedically Handicapped, Bon-hooghly, Kolkata-90, India. The amputees were at ease with the prosthesis and did not suffer from residual limb pain, swelling, or pressure sores. The fitting and alignment of the prosthesis was examined by the resident Department of Prosthetics and Orthotics of the institute. A control group was also selected with 30 normal subjects with non pathological gait and similar physical parameters. (Table 1) All the subjects were examined physically active and well balanced according to the protocol. They were instructed not to ingest alcohol or caffeine for 24 hours prior to the study. Subjects' diet was recorded and similar diet was maintained.

Table 1: Physical Parameters of the subjects

Criteria	BK Amputees	Control Group
Age (yrs.)	44.1±5.9	43±6
Height (cm.)	159±16.5	162±14.5
Weight (kgs.)	56.5±9.2	59.6±7.3

The subjects' Quality Of Life was studied with WHOQOL-100 quality of life assessment. The assessment would be applicable cross-culturally.(15) In this study the assessment determined the similar Quality of life for both subjects. (Table 2)

Table 2: Quality of Life Assessment

Domain	Average Scores	
	Below Knee Amputees	Control Group
Physical health	23.97	24.98
Psychological	19.01	18.90
Social relationship	10	11
Environment	27.18	27.22

The subjects were guided to practice their usual gait prior to the testing until the normal gait pattern was observed. The gait of the amputees was closely observed and they were guided to attain optimum walking rhythm & balance in their usual locomotion through therapeutic practices. The amputees were trained by to improve the mobility to ensure the optimum time and co-ordination of movements. A plane surface of 30 m was fixed for subjects' walking in their usual gait. The subjects were asked to walk at self selected speed. At this time, breath by breath analysis of the subjects was carried out. A Cosmed® k4 b2 Respiratory Analyzer system (COSMED Srl – Italy) at National Institute for the Orthopaedically Handicapped, Bonhooghly, Kolkata-90, India was used for the measurement of Oxygen Uptake (VO_2), Heart Rate (HR) for all subjects. (Figure 1)

Figure 1: Cosmed® K4 B2 Respiratory Analyzer system

The subjects were given adequate time to get accustomed to the analyzer system before the test. The recorded data of the subjects' average VO_2 (ml/Min) over consecutive 60 seconds interval were processed by calculating the mean and standard deviation. Total test time was approximately 30 minutes consisting of a 3 minute warm-up period to determine that the muscles did not utilize anaerobic sources of energy, 1 minute to prime the airways, and 1 minute of exhaled gas collection. The order of experiment protocol was followed accordingly, and all information of the test was consecutively recorded at each condition. Subjects were allowed to take rest in the intervals to minimize the fatigue. Difference in VO_2 was determined for walking period of the subjects as follows:

$$\text{Difference in } VO_2 = \frac{VO_2 \text{ BK amputee} - VO_2 \text{ normal}}{VO_2 \text{ normal}} \times 100 \quad \text{(Equation-1)}$$

Thus a negative percentage indicates energy saving and positive percentage indicates higher energy cost for the subject with BK amputee. (2,16)

Distance Efficiency is an easily determined alternative criterion measure of Gait Efficiency. Gait (distance) efficiency was calculated from the ratio of the oxygen uptake to the walking velocity and may be expressed in milliliters of oxygen consumed per kilogram of body weight per meter traveled.(2,9)

$$\text{Gait Efficiency} = \frac{mlO_2/kg.min}{m/min} = mlO_2/kg.min$$

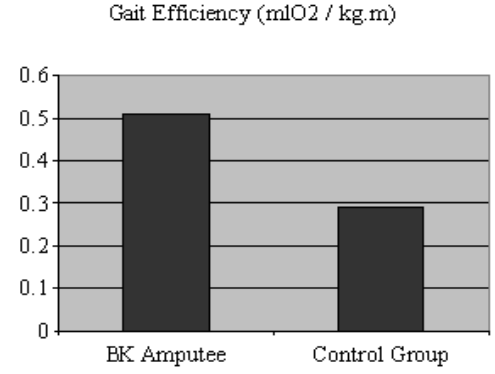
In this study, two-way analysis of variance (ANOVA) was used separately to test the level of significance of VO_2, HR, EE, velocity and gait efficiency and a level of $p < 0.05$ was adopted for the determination of statistical significance.

Results:

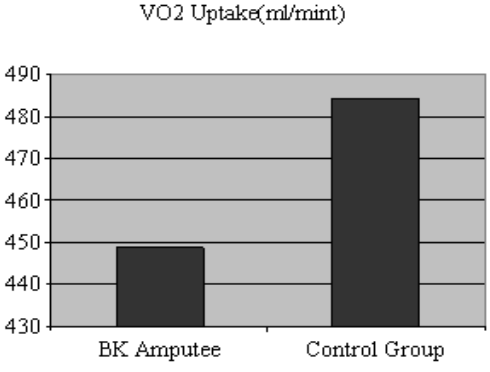
A summary of the result is given in Table 3. Average Heart rate for BK amputees and control group was 95.03 ± 17.15 beats/min ($p < 0.001$) and 83.67 ± 9.86 beats/min($p < 0.002$) respectively. The velocity of the BK amputee and control group was 17.90 ± 1.95 m/min and 27.56 ± 4.55 m/min respectively. Gait efficiency ($p < 0.0001$) is higher for the BK amputee (0.51 ± 0.12 mlO_2/ kg. m) than control group (0.29 ± 0.21 mlO_2/ kg. m). The difference in VO_2 uptake for the amputee was -7.35%.

Table 3: Average values of parameters.

Parameter	BK Amputees	Control Group
VO_2 (ml/mint)	448.65 ± 123.01	484.25±90.06
HR (beats/mint)	95.03 ±17.15	83.67±9.86
Velocity (m/mint)	17.90±1.95	27.56±4.55
Gait Efficiency (mlO_2/ kg. m)	0.51±0.12	0.29±0.21



Graph 1: Comparison of Oxygen Uptake



Graph 2: Comparison of Gait Efficiency

Discussion:

Previous research showed that appropriate time and co-ordination of movement resulted in confident gait rhythm and balance with less energy cost for the below knee amputee.(1,2) The current study was performed to compare the Energy Cost and Gait Efficiency between a group of below knee amputees with conventional trans-tibial prosthesis and a control group of normal subjects with non-pathological gait, having the similar physical parameters and quality of life. Similar physical parameters al-

lowed the subjects to be considered for comparison analysis. Both the subjects were determined to lead similar Quality of Life. This nullified any effect of the subjects' life style on their comparative performances. Thus the only difference between the subjects was due to the trans-tibial prosthesis of the below knee amputees. The subjects were certified to be physically fit. The fitment and alignment of the prosthesis was checked and found perfect. The recorded data showed consistency in heart rate monitoring for all the subjects. The subjects performed their normal gait during the test in their self selected velocity. The gait study advocated the usual gait pattern in all subjects throughout the test. The difference in VO_2 uptake was -7.35% ($p < 0.002$). (Equation-1) The negative percentage determined energy saving for the BK amputee. The Gait efficiency was found ($p < 0.0001$) higher for the below knee amputees (0.51 ± 0.12 mlO_2 / kg. m) than the control group (0.29 ± 0.21 mlO_2/kg. m). This result indicated that the below knee amputees achieved a normal and ideal gait pattern under the limitation of disabilities. The walking rhythm acted to control the stability and increase the gait efficiency as the physical parameters were normalized prior to the experiment by carefully selecting the subjects after screening. This rhythm contributed to higher gait efficiency for the below knee amputees ensuring the uniformity of different gait parameters (step time, step duration, cadence and stride length). The result showed consistency with the previous published researches that the below knee amputees attained more efficient gait pattern appropriate for their body mechanics by therapeutic practices with improved time and coordination of movements ensuring the efficient gait performance with reduced energy cost.(1,2)

Conclusion:

The current study showed consistency with the earlier research. The below knee amputees with conventional trans-tibial prosthesis attained higher efficiency in their gait performance with low energy cost in plane surface walking. The therapeutic activities and walking rhythm contributed to improve the mobility and balance of below knee amputees. This helped the amputees to achieve their optimum gait pattern within their limitation of disabilities ensuring the improved time and coordination.

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