International Journal of Clinical & Biomedical Research
Vol 7, Issue 2, 2021.

Sumathi Publications
Original Article

Comparison of electromyographic activity of quadriceps muscle in persons with unilateral traumatic transtibial amputation using patellar tendon bearing supracondylar endoskeletal prosthesis with the unaffected limb in weight bearing positions

Naik Dipti D[1], Dolas Vaibhav[1]

[1]Physiotherapy Department, All India Institute of Physical Medicine & Rehabilitation, Mumbai, Maharashtra, India

Abstract

Background: Comparison of electromyographic activity of quadriceps muscle in persons with unilateral traumatic transtibial amputation using patellar tendon bearing supracondylar endoskeletal prosthesis with the unaffected limb in weight-bearing positions. Method: 30 individuals aged 18-60 years were assessed using surface electromyography with functional level K3 according to the K-level functional assessment scale to compare the activity of quadriceps of the affected side using patellar tendon bearing supracondylar endoskeletal prosthesis with the unaffected side. The data were analyzed using paired t-test. Result: There was a significant difference in the activity of VMO and VLO muscles of the quadriceps in high sitting positions. There was also a significant difference in the activity of VMO muscle in single-limb stance and bipedal stance. However, there was no significant difference between the activity of VLO muscle in bipedal stance, but there was a reduced activity of VLO muscle in the prosthetic limb in single-limb stance. Conclusion: The quadriceps activity was reduced in the affected limb in a high sitting position, single limb stance, and bipedal stance. However, no difference in the muscle activity was noted in the VLO muscle in bipedal stance.

KEYWORDS: Trans tibial amputation; Patellar tendon bearing supracondylar prosthetis; Surface electromyography

Introduction

Amputation is a procedure in which a part of a limb is removed due to trauma or any other illness [1]. In people with lower-limb amputations, it is believed that gait alteration increased loading on the intact extremity. Lower extremity amputation is also associated with significant changes in body composition, such as muscle atrophy and weakness in the thigh muscles, and decreased local bone mineral density (BMD). Amputation is typically equated with a loss of a spouse, loss of one's perception of wholeness, and even death. This may result in a patient being severely affected emotionally and result in a poor quality of life. It is a catastrophic injury and an irreversible act that is sudden and emotionally devastating for the victim. It may cause distress not only due to loss of body parts but also due to role limitation and need for adjustment for changed lifestyle options[2]

The lower extremity provides both support and mobility for the body as a whole. Fulfilling this requires good muscle balance of lower extremities [2]. This ability to control our body position in space emerges from a complex interaction of muscle and neural system. This is called postural control and is a product of postural stability and postural orientation [3].

The symmetrical weight distribution does not fully reflect balance restoration. As such, it can be expected that the stiffness characteristics of the prosthetic feet also influence performance on standing balance. In non-amputees, the dynamic balance control indicates the combined

Correspondence: Dr Naik Dipti, Physiotherapy Department, All India Institute of Physical Medicine & Rehabilitation, Mumbai, Maharashtra, India. E-mail: diptinaik7@gmail.com

eISSN: 2395-0471
pISSN: 2521-0394
DOI: 10.31878/ijcbr.2021.72.01

stabilizing effect of all muscle and connective tissues crossing the ankle. In amputees, the dynamic balance control reflects the utilization of the prosthetic ankle stiffness (PAS) in balance control. Weight distribution might well indicate the confidence and/or comfort of the amputee subjects to load the prosthetic leg [4].

Limb loading is symmetrical when body weight is loaded equally on both lower limbs. It requires less energy for functional activities such as walking and standing. When the patient gets a prosthesis w.r.t C.O. G, he takes time to improve proprioception. This process of weight-bearing is a gradual process. This altered loading on the weight-bearing joints leads to cartilage degradation and synthesis and leads to secondary problems such as back pain and knee pain [5]. There are various factors for asymmetrical loading such as residual limb pain, contralateral limb pain, and psychological issues such as post-traumatic stress disorder (PTSD).

The main objective is the rehabilitation of amputees is to restore or improve their functioning, which includes their return to work. Full-time employment leads to beneficial health effects. People with lower limb amputation have problems like walking, running, and kicking. To return to work, people need suitable and comfortable prostheses, which may also prevent absence because of sickness and increased work efficiency [6].

It has also been observed that the quadriceps play a vital role in standing and walking are one of the most affected muscle amputees [3]. In a recent ultrasonography study, it had been reported that distal femoral cartilage was found to be thinner on the amputee side when compared to the intact leg in patients with unilateral transtibial amputations [7]. Previous literature has reported that amputees have quadriceps muscle atrophy and thinner distal femoral cartilage. In transtibial (T T) amputees, caused by loss of proprioceptive feedback, principally from the ankle joint and relative structures, the residual limb is less active in walking or standing activities. On the other hand, the gait of T T amputees is asymmetrical, with more time spent on the support phase of the non-amputated limb (and consequent overload of this limb)[8]. However, a significantly little evidence is available on the activity of quadriceps in various loading positions which may influence limb loading asymmetry. Therefore, it is essential for us to understand the activity of quadriceps in persons with traumatic transtibial amputation.

Material And Methodology

Study design: A cross-sectional observational study

Ethics approval: Study was approved by the Institutional Ethics Committee

Locus of study: Physiotherapy department of tertiary health care center with the pre – requisite infrastructure.

Study duration: Six months

Sampling technique: Convenience sampling method.

Sample size calculation: Following the statistics of the study, the sample size calculation was done using open EPI software.

(DEFF*Np(I-p)]/[d2 /z21-a/2*(N-1)+p*(1-p)]

The total population was 3392, and the percentage of frequency outcome was 37%. According to the software, with a confidence level of 95%, the sample size was 325. However, because of limited availability of time, a sample of 325 is not feasible. So, a convenience sample of 30 is taken.

Inclusion criteria: Age- 18-60 years, persons with unilateral traumatic transtibial amputation using PTB-SC endoskeletal prosthesis and Functional level - K3 (K-level functional assessment scale)

Exclusion criteria: Amputation due to any vascular, diabetic, tumor or due to any other cause, stump length less than 1/3rd and more than 2/3rd of the unaffected leg, any clinical manifestations of orthopedic or neurological conditions, presence of neuroma or phantom limb and phantom pain sensation and using walking aids.

Subject withdrawal criteria: Any person is at liberty to withdraw at any point of time on any ground whatsoever.

Operational définitions: PTB-SC endoskeletal Prosthesis: Patellar tendon bearing supracondylar socket has high medial and lateral sidewalls that extend above and over the femoral condyles, providing enhanced mediolateral stability and self- suspension of the prosthesis with metal shank [4].

K level functional assessment scale: The MCFL or K-level is defined by the patient's ability to perform transfers, negotiate low-level environmental barriers such as curbs and stairs, and vary their cadence. It contains five levels. It is ranging from the K0-K4 level, each level describing the prosthetic functional level.

Maximum voluntary isometric contraction: MVIC is a fundamental method with high reliability that is used to measure and evaluate muscle activity. Moreover, MVIC can be substituted for the normalization of electromyography (EMG) data, which is used to measure muscle conditions in many studies. As such, MVIC has become a critical standard in patient evaluation and studies involving muscle activity.

Surface electromyography: A technique in which electrodes are placed on the skin overlying a muscle to detect the electrical activity of the muscle.

Methodology:

Thirty subjects (29 males and one female) were selected in the study. Each subject was explained about the study in the language they understand. Before the study, the subjects were demonstrated the assessment positions.

Demographic data of the patient was recorded. Each participant was assessed using surface electromyography (SEMG). Self-adhesive EMG electrodes were used to record surface EMG activity of vastus medialis oblique and vastus lateralis oblique muscle.

The placement of the electrodes was a) VMO- 4cm superior and 3cm medial to the superomedial patellar border & oriented 55 degrees to the vertical line. b) VLO- 10cm superior & 6cm lateral to the superior border of the patella and oriented 15 degrees to the vertical line. c) Ground electrode placed over thigh[10]

Maximum voluntary isometric contraction (MVIC) testing in high sitting (90° knee flexion) using a spring balance. The subject was asked to sit on a plinth and instructed to extend the knee against the resistance given by spring balance. Unaffected and affected limb was tested. The amplitude recorded from the electromyographic activity of muscle was used to normalize the data using the formula: Recorded amplitude/ MVIC x100

Fig 1. MVIC using SEMG of VMO & VLO of affected side and unaffected side

Amplitude was recorded in the following weight-bearing positions. 1. Bipedal stance 2. 2. Single leg stance

EMG activity was recorded for 1 min in all three positions. Three trials were taken for each position. An adequate amount of rest period was given between each trial. Maximum amplitude

Fig 2. SEMG of VMO &VLO in bipedal stance of affected side unaffected side

was recorded, and an average of three trials was taken.

Fig 3. SEMG of VMO &VLO in single-leg stance of the affected side and unaffected side

The data obtained were normalized with MVIC and was used to compare the electromyographic activity of muscles from both the limbs in weight-bearing positions in the study subjects using statistical analysis.

Outcome measure: Amplitude from the quadriceps muscle activity was recorded using surface EMG(SEMG) and was measured in microvolts(μv)

Statistical analysis: Data were analyzed using the GraphPad statistical software. The data passed normality using the Shapiro Wilk test. Differences in the overall activity between VMO and VLO were analyzed with paired t-test. The activity of VMO and VLO of the affected side was compared with the unaffected side in bipedal stance and single-limb stance.

Results

Table 1: Characteristics of age and height.

Variable	Mean ±SD
Age (years)	35.77±12.51
Height (cm)	169.5±2.63

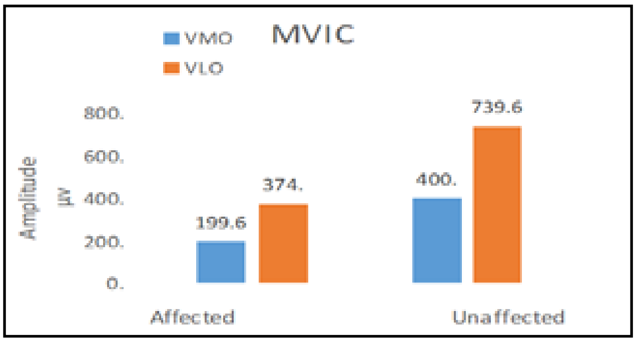

Fig 4. Caracteristics of maximum voluntary isometric contraction

Table 2. Characteristics of affected and unaffected side VMO and VLO activity in Bipedal stance and single-limb stance.

Amplitude (%)	Bipedal stance		
	Weight Distribution (kgs)	VMO	VLO
Affected	28.87 ±7.26	44.97±8.1	42.5±6.1
Unaffected	38.6±11.1	52.53±5.7	43.9±6.1
P value	<0.0001	<0.0001	0.4180
Single limb stance			
Affected		50.3±8	45.67±7.88
Unaffected		73.4±8.3	57.5±10.03
P value		<0.0001	<0.0001

Comparison between the values of means of an affected and unaffected limb in bipedal stance was made. By applying Paired t-test, it was found that there was a statistical significant difference between the weight distribution (p value<0.0001). There was a statistically significant difference in the means of the affected and unaffected side VMO (P value<0.0001). However, there was no statistically significant difference between the affected and unaffected side VLO activity in bipedal stance. Comparison between the values of means of affected and unaffected limbs in single-limb stance was made. By applying Paired t-test, it was found that there was a statistical significant difference in means of the affected and unaffected side VMO and VLO (p value<0.0001).

Table 3. Presentation of confidence interval

Postions (n=30)	Lower bound (%)		Upper bound (%)	
	Affected	Unaffected	Affected	Unaffected
Bipedal Stance				
VMO	41.95	50.39	47.98	54.67
VLO	40.25	41.67	44.82	46.26
Single limb stance				
VMO	47.34	70.26	53.32	76.60
VLO	42.72	53.75	48.61	61.25

There was a significant difference in the electromyographic activity of the affected and unaffected side VMO and VLO when testing was done in high sitting for normalization of the data (P value<0.0001). There was also a difference in the weight distribution (P value<0.0001), implying that loading on the affected side was significantly reduced as compared to the unaffected.

There was a significant difference in the electromyographic activity of the affected and unaffected side VMO in both single-limb stance and bipedal stance (P value<0.0001). There was no significant difference in the activity of VLO of bipedal stance, but there was a significant difference in the electromyographic activity of the affected and unaffected side VLO in single-limb stance.

Discussion

The main aim of the study was to compare the electromyographic activity of quadriceps muscle of affected limb with the unaffected limb in two different positions, namely, bipedal stance and single-limb stance, in patients with traumatic transtibial amputations using patellar tendon bearing endoskeletal prosthesis.

The person with amputation returns to his level of routine activity and becomes a regular prosthesis user. The amputated limb thigh musculature in transtibial amputees frequently displays signs of profound muscle wasting. Generally, there is a wasting of thigh musculature, primarily quadriceps, following amputation due to disuse and de-loading. As a result, the ratio of quadriceps to hamstring strength is disturbed, which further leads to a reduction in strength and endurance of the involved muscles.[9]

The boundary-value of physiological asymmetry in loading of the limbs average healthy individual is 10% [10]. During different positions in our study, it was found that there is increased weight distribution on the unaffected limb. Asymmetrical lower limb loading can be explained by listing the following reasons – devoid of ankle movement and due to prosthesis socket [11] Persons with unilateral transtibial amputation have strength discrepancies between limbs, with their uninvolved limb being more substantial than the prosthetic limb. This leads to asymmetrical bodyweight distribution with their center of pressure (COP) shifted anterolaterally towards the uninvolved limb. Because individuals with a TTA are more susceptible to these asymmetries, they are also more susceptible to diminished gait efficiency and joint degradation [12].

In this study, it was found that the activation of vastus lateralis was less as compared to vastus medialis in bipedal and single-limb stance. The MVIC testing was done in high sitting,[13] in which the activation of VLO is more as compared to VMO. However, the testing was done in standing, in which the activation of VMO is higher as compared to VLO. The reason for less recruitment of fibres on the affected side was, the distribution (percentage) of type 1 fibres is reduced in amputated limb as compared to the non-amputated limb, and there is a corresponding increase in the distribution of type II fibres which is indicative of low fatigue resistance capacity [14,15].

The study shows a significant difference in the activity of quadriceps in bipedal stance and single-limb stance. In single-limb stance, despite full weight bearing on the affected limb, the activity of quadriceps muscle was less as compared to the unaffected limb. According to the author J-M Viton, transtibial amputees must deal with the loss of the afferent inflow mainly from proprioceptors residing in the amputated portion of the leg and foot plantar cutaneous receptors [7]. Afferent impulses from the muscles and joints are essential in the maintenance of type 1 fibres which over a long period may cause an altered fibre distribution between type I and type II. Hence leading to lesser activation of quadriceps activity on the affected side [16].

Conclusion

There is increased weight bearing on the unaffected side as compared to the affected side. There is decreased electromyographic activity of quadriceps on the affected side as compared to the unaffected side in bipedal stance and a single-limb stance

Conflict of interest : Nil

Source of funding : Nil

References

1. Ghosh Das P, Lahiri S. Prevalence and aetiology of amputation in Kolkata, India: A retrospective analysis. Hong Kong Physiotherapy Journal; 2013;31(1):36-40
2. Anamika Sahu, Rajesh Sagar, Siddharth Sarkar, and Sushma Sagar. Psychological effects of amputation: A review of studies from India. Industrial Psychiatry Journal 2016;25(1): 4-10
3. Anne Shumway-Cook. Motor Control. Lippincott Williams & Wilkins. 4th ed; 2012
4. Aruin AS1, Nicholas JJ, Latash ML. Anticipatory postural adjustments during standing in below-the-knee amputees. Clinical biomechanics 1997; 12(1):52-9
5. Physical Medicine and Rehabilitation: Principles and Practice, Volume 1, 4th ed
6. Ku, Pei Xuan Abu Osman, Noor Azuan Wan Abas, Wan Abu Bakar. Balance control in lower extremity amputees during quiet standing: A systematic review. Gait and Posture; 2014; 39: 672-82
7. Viton M. Equilibrium and movement control strategies in trans-tibial amputees. 24th ed. Prosthetics and Orthotics International; 2000;24(2):108-16
8. E I, O K. Trans-tibial amputee gait: Time-distance parameters and EMG activity. 24th ed. Prosthetics and Orthotics International; 2000; 24(3):216-20
9. Kim, Hyunhee Song, Chang Ho. Comparison of the VMO/VL EMG Ratio and Onset Timing of VMO Relative to VL in Subjects with and without Patellofemoral Pain Syndrome. Journal of Physical Therapy Science 2012; 24(12):1315-17
10. Cowan SM, Bennell KL, Hodges PW. The test–retest reliability of the onset of concentric and eccentric vastus medialis obliquus and vastus lateralis electromyographic activity in a stair stepping task. Phys Ther Sport. 2000;1(4):129-36
11. Chihuri, Stanford Wong, Christopher Kevin. Factors associated with the likelihood of fall-related injury among people with lower limb loss. Injury Epidemiology 2018;5(1):42
12. Burger H, Isakov E, Krajnik J, Gregoric M,Marincek C. Knee muscle activity duringambulation of trans-tibial amputees. Journal of Rehabilitation Medicine; 2001;33(5):196-9
13. Meldrum, Dara Cahalane, Eibhlis Conroy, Ronan Fitzgerald, Deirdre Hardiman, Orla. Maximum voluntary isometric contraction: Reference values and clinical application. Amyotrophic Lateral Sclerosis. 2007;8(1):47-55
14. O'Keefe, C. Muscle Activation Patterns in the Trans Tibial Amputee. Monash Rehabilitation Technology Research Unit; J Neuroeng Rehabil. 2012; 9:55
15. Jeffrey R Cram. Atlas for electrode placement. CRAM'S Introduction to surface Electromyography, 2nd ed. : Jones and Bartlett publishers; 1998;365-6
16. Nolan, L, Ramstrand, N, Rusaw, Hagberg, K. Bilateral electromyogram response latency following platform perturbation in unilateral transtibial prosthesis users: Influence of weight distribution and limb position. 4th ed. The J Rehabilitation Res & Dev 2013.50(4):531-44