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FRONTAL PLANE ANALYSIS AT KNEE IN TRANSTIBIAL AMPUTATION

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ABSTRACT

To study and compare frontal plane kinetics and kinematics at knee joint during the gait cycle in persons with transtibial amputation using Patellar tendon bearing (PTB) suprapatellar (SP) cuff suspension and PTB supracondylar (SC) suspension, with SACH foot. Instrumented gait analysis was performed in 30 persons having unilateral transtibial amputation of traumatic origin using either PTB prosthesis with SP cuff suspension or SC suspension with SACH foot. The reports obtained were used for statistical analysis by using student's unpaired t-test with CI 95% and p-value <0.05 and, by percentage comparison.Statistically significant differences were found in knee excursion at mid stance (p= 0.02) , 47% of persons using PTB SC suspension have shown abnormal varus moment at knee at mid stance in frontal plane. Whereas 80% of persons of both group have shown abnormal power generation at knee at weight acceptance.This study identified abnormality in frontal plane knee excursion and knee moment in PTB-SC group which may be due to interface used in PTB-SC socket designs.

KEY WORDS:Transtibial amputation, patellar tendon bearing,suprapatellar cuff, supracondylar suspension.

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INTRODUCTION

"Normal walking is an amputee's need" Bipedal walking is a defining human characteristic requiring anatomical integrity and normal function of the nervous and the musculoskeletal system. Disorders affecting any level of this complex mechanism will lead to abnormal gait disturbances [1]. One such disorder affecting musculoskeletal system is lower limb amputation.Lower limb amputation accounts for about 85% of 200-500 millions of major amputation performed every year worldwide [2] . Although there is loss of plantar sensation,free ankle and foot mobility, and selective muscular control of these joint [3] amputation at Transtibial level is the most important especially in adults[4].With the knee preserved the amputee has retained a potential for greater function [3,4]. Realizing this potential however depends on optimum prosthetic support In 1959, patellar tendon bearing sockets was invented by the prosthetic research group in the University of California for transtibial amputees [5,6,7]. The introduction of PTB Supra-Patellar cuff suspension prostheses, represented a considerable advance in the prosthetic treatment of the below knee amputees [8]. But it provides minimal medio-lateral stability.[9,10] Moreover, tight circumferential cuff on lower thigh just over the patella causes pressure atrophy of thigh muscle, presumably because of interference with the nutrition and metabolic activity of the affected part [11]. Later in 1980's self-suspending PTB with supracondylar suspension [9] with high medio-lateral wall [12,13], providing added stability in frontal plane was devised. But there is no universally accepted procedure or set of recommendations for prescribing brim configuration, wedge or suspension type, or socket type (hard vs. soft)[14].The PTB-SC socket usually has a liner made up of Evazote. Though at mid stance limb being in single stance and COG being at its highest, demands for greater stability in frontal plane.[15,16] Yet after an extensive review of literature it is found that transtibial prosthetic gait with respect to suspension in frontal plane is still poorly understood. So the purpose of present study was to observe if there were any compensations and asymmetries in the angular movements, kinetics measures, in frontal plane at knee of persons using two commonly prescribed transtibial prostheses. The results would help in determining which suspension system, namely, PTB with supra-patellar cuff suspension or PTB with supracondylar suspension is superior for use in persons with unilateral Transtibial amputation.

MATERIALS AND METHODS

After the approval of synopsis by the Ethics committee of the All India Institute of physical medicine and rehabilitation Mumbai and the Maharashtra University of Health Sciences, persons having a unilateral transtibial amputation of traumatic origin, of any side using either PTB- SP suspension with SACH foot or PTB- SC suspension with SACH foot, were identified. 30 willing persons satisfying the selection criteria were recruited for the study after taking informed written consent.The study design was experimental with convenient sampling. Persons, age ranged 20-50yrs with unilateral trans- tibial amputation of traumatic origin[17], conditioned stump i.e. without skin irritation, swelling or neuroma, who had been using the prosthesis for more than 3 months.[18] and walked without the use of any assistive device, were included in the study. Persons with co-morbidities such as diabetes, hypertension, psychiatric problems, neurological problems, and musculoskeletal problems such as knee osteoarthritis any contracture or deformities at hip and knee, stump length less than 3inches[19], under weight and obese individual, any observational gait deviations such as pistoning were excluded from the study. All persons had been given conventional exercise programme and gait training in the Physiotherapy department after fitting of trial and finalised prosthesis. At the time of data collection all persons were using finalised exoskeletal prosthesis approved from the Prosthetic and Orthotic clinic of the Institute. The persons using PTB-SP suspension and

SACH foot were assigned to group- A and those using PTB-SC with SACH foot were assigned to group-B. All the persons in both groups were examined as per the clinical evaluation proforma which includes demographic information, stump evaluation, Range of Motion using goniometer, Muscle power as per Medical Research Council grading (MRC) [20] and observational gait analysis with the help of video-recording in sagittal and frontal plane. All persons in both the groups were male. There were few females satisfying the inclusion criteria but they refused to participate as they have to be in the minimal clothing for gait analysis.

Preparation of the system

The system was calibrated with axes, wand and plate sequence to define the capture volume for the study. Subject folder with standing and walking file was prepared in the 'SMART CAPTURE' software.

Preparation of the Person

After the clinical evaluation, the persons were prepared for the study. The subjects were instructed to use minimal clothing for accurate marker placement. Anthropometric measurements measured with pelvimeter were recorded. Retroreflective markers were placed on the body as per the Davis protocol [21]. Spherical marker placements were as follows:- C_7 spinous process, both acromial processes, both ASIS, S_2, both greater trochanters, both lateral femoral condyles, both head of fibula, both lateral malleoli, dorsum of both fifth metatarsal head. 2 Hemispherical markers on each footwear overlying heel. Markers on the prosthesis were placed taking the reference from sound leg. For the positioning of the lateral bar at thigh, a line was identified between greater trochanter marker and femoral condyle marker then the lateral bar was put ina perpendicular way in between them so that all the three markers were in the same plane. Similarly, for the positioning of the lateral bar at leg, a line was identified between head of fibula marker and lateral malleolus marker then the lateral bar was put in perpendicular way in between them so that all the three markers were in same plane. Each subject was made to stand on a force plate for 5 sec with arms folded to capture the standing parameters.The anthropometrics measures taken earlier were entered in the standing file and saved. The heel markers were then removed for the walking acquisition. Subjects were instructed to walk on 6 m walkway, at his/her self-determined comfortable speed in each time starting from a pre-defined point.. This walkway had 2 force plates concealed midway. 3-4 trials were carried out before the final acquisition in walking. A trial was considered successful if the subject lands the foot of interest on the force-plate and the file was saved. After successful acquisition in standing and walking the subjects were freed from markers. Then 'SMART TRACKER' and 'SMART ANALYSER' software was utilized to acquire the data of spatiotemporal, kinematics, and kinetic parameters. Thus, the report was generated from data collected. The reports thus obtained were used for statistical analysis. Comparison of spatio-temporal parameters and frontal plane kinematics, between the knee of prosthetic leg of both groups was done using student's unpaired t-test.Kinetics parameters were expressed in percentage and compared across the groups.

RESULTS

The statistical analysis revealed that in demographics PTB-SP group had a mean statistical significant difference from PTB-SC group for No. of Years of prosthetic use (p=0.02) (Table1), in spatio-temporal parameters statistically there was no Significant difference between the groups. (Table 2).Whereas in frontal plane kinematics statistical significance was reached for knee excursion at stance phase (p=0.02) (Table 3). Percentagewise distribution revealed that13% of persons in PTB-SP group and 47% of persons in PTB-SC group had shown abnormal moment of adduction at knee in frontal plane (Table 4). In normal gait at weight acceptance there is power absorption (K_1) and at mid stance there is power generation (K_2) this study showed that 80% and 87% of both groups have exhibited abnormal K_1 andK_2 respectively (Table 5).

Table 1
Comparison of Demographics between groups

Characteristics	PTB-SP (n=15) (Mean + S.D.)	PTB-SC (n=15) (Mean +S.D.)	t-value	p -value (p<0.05)	S/NS
Age (yrs.)	34+11	32 + 11	0.45	0.66	NS
Height(cm)	167 + 8.3	170 + 6.22	-1.07	0.29	NS
Weight (Kg)	61 + 9.8	63 + 8.5	-0.52	0.61	NS
BMI (Kg/m^2)	22.40 + 3.83	22.20 + 3.77	0.15	0.89	NS
Stump length (cm)	12.30 + 1.78	12.67 + 1.40	-0.71	0.48	NS
No. of Years of prosthetic use	13.49+10.59	3.52 + 3.42	3.37	0.002	S
No. of prosthesis used	6.53 + 5.42	1.93 + 1.49	3.17	0.004	S

Table 2
Comparison of Spatio-Temporal parameters between groups in prosthetic leg

Parameters	SPATIO TEMPORALPARAMETERS (Mean+S.D)		t-value	p-value (p<.05)	S/NS
	PTB-SP (n=15)	PTB-SC (n=15)			
Stance- phase %	57.247+3.195	58.653+4.173	1.037	0.31	NS
Swing-phase %	42.75+3.20	41.35+4.17	1.037	0.31	NS
Single stance %	35.94+4.17	35.19+3.20	0.553	0.585	NS
Step-length(m)	0.598+0.084	0.588+0.087	0.318	0.75	NS
swing-Velocity(m/s)	2.287+0.353	2.009+0.473	0.333	0.74	NS
Cadence (steps/min)	99.587+8.199	93.807+12.08	1.533	0.136	NS
Step-width(m)	0.21+0.03	0.22+0.04	0.37	0.72	NS

Table 3
Between Group comparison of frontal plane kinematics of prosthetic leg at Mid-stance

Parameters	Mean+S.D. PTB-SP (n=15)	PTB-SC (n=15)	t-value	p-value (p<.05)	S/NS
Relative knee angle(º) at MS	4.0+6.322	3.40+11.602	0.176	0.86	NS
Knee excursion in stance phase	8.87+5.24	14.70+7.40	-2.49	0.02	S

Table 4
Knee Moment of Prosthetic leg in PTB - SP and PTB-SC at Mid –Stance in Frontal Plane

At Mid-Stance	PTB - SP (n=15) No. of persons showing (%)		PTB-SC (n=15) No. of persons showing (%)	
	Normal Moment	Abnormal Moment	Normal Moment	Abnormal Moment
Moment at Knee	13(87%)	2(13%)	8(53%)	7(47%)

Table 5
Between Group comparison of percentage of persons showing abnormal power in Prosthetic leg at stance period

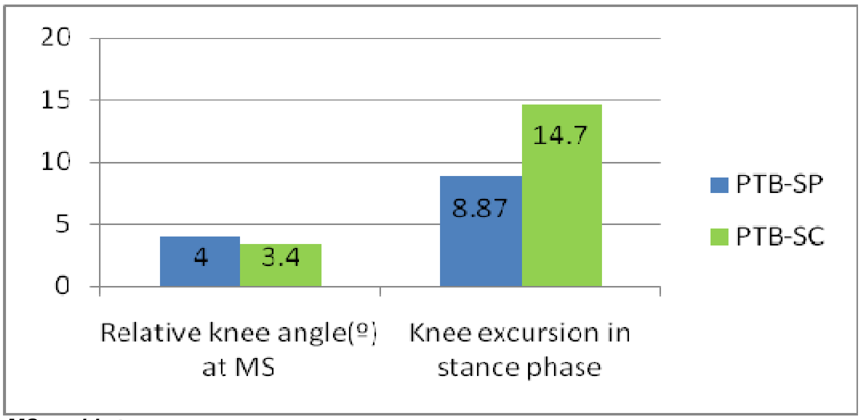
Power (W/Kg)	Group-A (n=15) No. of persons showing (%)		Group-B (n=15) No. of persons showing (%)	
	Normal power	Abnormal power	Normal power	Abnormal power
K_1 (W/Kg)	3(20%)	12(80%)	3(20%)	12(80%)
K_2 (W/Kg)	2(13%)	13(87%)	2(13%)	13(87%)

DISCUSSION

Persons of PTB-SP group were using prosthesis for significantly more years (table 1) may be because they were habituated to use it and were not willing to change it to relatively newer design (PTB-SC)[13] as they reportedly felt more secure with the cuff suspension. Also, PTB-SC is being prescribed only since few years in the institute. The increased knee excursion at stance phase (graph 1) as well as abnormal knee moment (graph 2)(increased adduction moment) at mid stance in frontal plane in PTB-SC group may be due to the soft interface between residual limb and socket. The material used for the interface is Evazote .it is a soft, compressible material which may deteriorate over time with resultant loss of intimate fit [22] E.C.T. Barrs et al. in 2005 did a literature review of the possible advantages of silicon liner socket use in trans-tibial prostheses in western countries. They found that silicone create an air seal against the patient's skin providing suction suspension and close adhesion of the liner to the stump[23]. Power generation instead of power absorption at the timing of K_1 (graph2) i.e. at weight acceptance in both groups may be to compensate for the lost ankle muscles . As per Winter et al 1988 [24] plantar flexors are required during weight acceptance phase. In prosthetic limb this strong plantar flexors are absent so for propelling the weight forward over the stationary foot there may be the concentric activity of knee extensors at weight acceptance. This is in concordance with the findings of Gittter et al 1990[25] , Enrico Nucibella 2010[26], who in their studies concluded that for compensating the forward propulsion moment that occur in normal individual, there is increase contributions from the hip and knee musculature of prosthetic side of unilateral transtibial for forward propulsion at weight acceptance phase. At the timing of K_2(graph2) i.e. at mid stance, power absorption instead of power generation was exhibited in both groups. The stance phase is reduced on prosthetic side. So for controlling the fast acceleration of tibia there may be eccentric activity of knee extensors to decelerate the tibia and to maintain the stability resulting in power absorption at K_2.

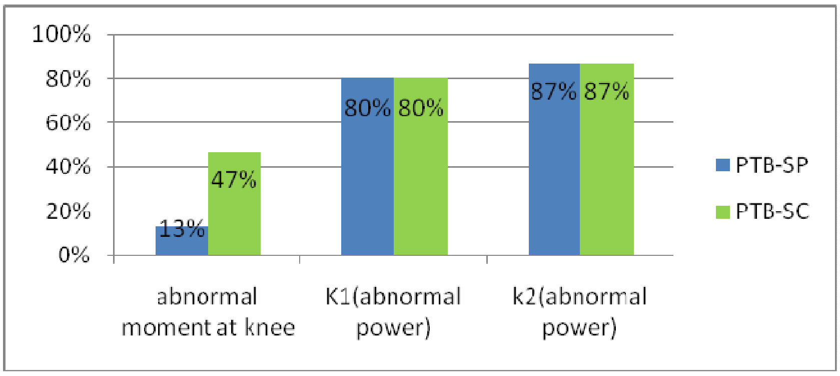
Graph 1

Between Group comparison of frontal plane kinematics



MS = mid stance

Graph 2
Frontal plane kinetics (Abnormal moment and abnormal power at knee)



CONCLUSION

This study identified abnormality in frontal plane knee excursion and knee moment in PTB-SC group. This may be due to interface used in PTB-SC socket designs. It is suggested to change the material of interface used in PTB-SCfrom Evazote, a bulky, soft and compressible material to silicon. Silicon liners commonly given by International companies are known to have an intimate fit, and do not lose this property with time.

LIMITATIONS

The study is not supported by kinesiological EMG of vastus lateralis, vastus medialis and hip abductors of prosthetic leg of persons of both groups.

FUTURE SCOPE

Furtherstudy needs to be carried out in persons usingPatellar-tendon bearing (PTB) with supra-patellar cuff suspension and persons using PTB with supracondylar suspension with silicone liners along with the kinesiological EMG for vastus lateralis and vastus medialis and hip abductors of prosthetic leg.

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