ORIGINAL ARTICLE

Correlation of Stump Length with Temporo-Spatial and Kinematic Outcome in Trans-tibial Amputees

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Author`s Contribution

[1-4]Conception and design, Collection and assembly of data, [4-5]Analysis and interpretation of the data, [6]Critical revision of the article for important intellectual content, Statistical expertise, [1-6]Final approval and guarantor of the article.

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Background: Amputation is the surgical or traumatic removal of extremity or part of body. Limb amputation is the last option to save the patient's life by removing the dead or the dying part of the limb with trans-tibial amputation commonly known as below knee amputation.

Objectives: To determine correlation of temporo-spatial and kinemetic trends with stump length in Trans-tibial amputees.

Methodology: This correlational cross-sectional study was conducted in the Gait Lab of PIPOS Peshawar after Approval from the Institutional Research Board, Isra University Islamabad. Study recruited N=180 unilateral, male, K3 and K4 level trans tibial amputees, aged 15-30 years of age using purposive sampling. The data was collected under the "Simi Motion Analysis camera system" to measure the gait parameters related to tempura-spatial variables and kinematics. The stump length and stride length was measured using the measuring tape. Correlations of patients' stump length with temporo-spatial and kinematics were determined using Pearson's correlation matrix. P-value of 0.05 was considered significant.

Results: Study sample with mean age of 25.69±4.17 years, revealed that stump length had no significant correlation with stride length (r=0.032, p=0.665), cadence (r-0.079,p=0.29), velocity (r=-0.039, p=0.6), stance phase (r=-0.068, p=0.363), swing phase (r=0.06, p=0.423), hip joint kinematics of amputated side (r=-0.06, p=0.426), knee joint kinematics ie., flexion at terminal stance (r=-0.129, p=0.085), flexion at mid swing (r=0.004, p=0.954) of amputated side , pelvic tilt (r=0.049, p=0.517) and trunk bending both lateral trunk flexion (r=0.041, p=0.588) and forward lean (r=-0.036, p=0.634) at mid stance.

Conclusion: In conclusion, the stump length had no substantial influence on the temporo-spatial and kinematic gait parameters in subjects with Trans tibial amputation

Key Words: Trans-tibial Amputation, Stump Length, Gait Parameters, Kinetics, Temporo Spatial, Below Knee Amputees.

A B S T R A C T

Introduction

Amputation is the surgical or traumatic removal of extremity or part of body. Limb amputation is the last option to save the patient's life by removing the dead or the dying part of the limb with trans-tibial amputation commonly known as below knee amputation. It involves sacrificing the foot, ankle and distal tibia and fibula with related soft tissue structures.[1] Trans-tibial amputation is very common with a high prevalence of 53% with a male female ratio of 4:1, reported in an Indian study [2], while a local study conducted on traumatic amputees in a military setup also revealed that 54.6% cases were of trans-tibial amputation [3] and a male female ratio of 3:1.[4] Trauma including bomb blast and road tract accidents, diabetes mellitus, reconstructive purposes, diseases of vascular origin and congenital diseases have been reported to be common causes in a local study.[5]

Preservation of knee joint is a key addition to the effective rehabilitation in terms of achieving smooth and efficient gait, and less energy consumption after rehabilitation, hence trans-tibial amputation is commonly done.[6] From clinicians' point of view, integrity of joint, defining the remaining muscles, intact tendon origins and insertions, to maintain a functional lever to control the prosthesis the accurate measurement of stump is very helpful. [7] This and other issues like postural control & balance strategies, make Stump length a very helpful factor to achieve good prosthetic rehabilitation in trans-tibial amputees [7, 8]. While a study by Subbarao & Bajoria revealed no significant difference in rehab outcome in patients with long compared to short stump length.[9]

As regards gait performance of amputees, five primary domains of spatiotemporal gait are important including: i) Rhythm domain which includes cadence and stride time, ii) Phase which includes temporo-phasic variables including distinct division s of gait cycle, iii) Variability including gait cycle and step variability iv) Pace which includes gait speed, step length, and stride length and iv) base of support which includes the width of step and its variability.[10] While Kinematics is the motion or movement without taking into consideration force production in the body. [11]

Clinical observation shows the difference of temporo-spatial and kinematics in different trans-tibial amputees after fitting the prosthesis. This difference compels the patient for deviation of gait [12], thus compelling the author to think about the factors that may be the responsible for this change in temporo-spatial and kinematic characteristics. Also there are variations in recommendations for the ideal tibial stump length amputation in various studies. [7, 8, 9]

Keeping in view the research gap [7, 8, 9, 12], a high prevalence of trans-tibial amputation especially traumatic amputations in Pakistan, this study was conducted with the objective to determine correlation of temporo-spatial and kinematic trends with the length of the Trans-tibial stump. This study is important since it will add purposeful data to assist clinicians in patient management and act as a base for future research.

Methodology

This correlational cross-sectional study recruited N=180 trans-tibial prosthesis users from Gait Lab of Pakistan Institute of Prosthetics and Orthotics Sciences (PIPOS) Peshawar with Approval Ref. (**929/PIPOS/19**), who presented between 1st July, 2019 to 31st December, 2019 using purposive sampling. Sample included unilateral trans-tibial amputees with K3 or K4 amputation level [13] who were males, aged 15-30 years and registered at PRSP Peshawar. Other amputees (trans femoral), bilateral and below K3 level were excluded from the study.

A sample of N=195 was calculated using OpenEpi online calculator with population a population of 1 million, frequency of 54.6% [3], absolute precision 5 and DEFF=1. However, 200 subjects were evaluated for eligibility out of which n=20 opted out of the study after refusing consent and N=180 subjects were finally part of this trial. These included n=22 cases with short stump, n=61 with medium stump and n=97 with long stump, on the basis of formula for stump length as prescribed by Subbarao & Bajoria.[9] This included short stump length with range 18.9%-28.6% of sound limb, medium stump length with range 32.3%-38.3% of sound limb and long stump length with a range of 54.2%-64.6% of sound limb.

Study was conducted following ethical approval of Institutional Research Board of Isra Institute of Rehabilitation Sciences, Isra University vide approval No 1609-M.Phil P&O-037 dated 24th October, 2018 and permission for data collection from PIPOS Peshawar vide 929/PIPOS/19 dated 17th June 2019 and informed consent of the patients.

Basic demographic sheet, Simi Motion Analysis Camera System and measuring tape were used for collection of data. Data was collected under the "Simi Motion Analysis camera system" to measure the gait parameters related to tempura-spatial variables and kinematics. The data related to 2D gait analysis was collected in "Biomechanics Gait Lab" by using active markers. These markers were placed on the anatomical landmarks of the subjects. Participants were advised to walk with comfy cadence; self-selected velocity, under the "Simi Motion Analysis camera system" to measure the gait parameters related to tempura-spatial variables and kinematics. The stride parameters were measured on a 10-meter-long pathway. The stride length was measured using the measuring tape. Impressions for measurements were taken by putting magnesium oxide under the shoes. The distance between the two consecutive heel strikes was measured and recorded as stride length (SL). Stride time (ST); the time taken by each subject to complete one stride, was determined using the stop watch. The following standard formulae were used to determine cadence and velocity of amputated and intact sides.

Velocity = Stride Length / Stride time & Cadence = Velocity / Step Length

Prior to starting the instrumental gait analysis, each subject was given opportunity to first practice walking to get used to the active markers and camera system. During a session the area for a specific camera was defined and image distortion was eliminated. The segment angles were rectified for each subject while standing in a standard anatomical position. Subjects were asked to complete several walks over gait pathway for a distance of 10 m at the self-selected comfortable velocity. The outcomes of the subsequent gait parameters were determined: Stride Length (SL), Cadence (number of steps per minute), walking speed (velocity), stance time, swing duration, knee flexion at terminal stance, knee flexion at mid-swing, hip flexion at terminal swing, sagittal rotation of hip (forward lean), frontal rotations of pelvis (pelvic tilt) and trunk (lateral trunk bending). The stump length and stride length was measured using the measuring tape.

The data was analyzed through SPSS 28. The outcomes of the demographic information of the study group were presented as percentages and means + standard deviation (SD). Correlations of patients' residual limbs' ratio with temporo-spatial and kinematics were determined using Pearson's correlation matrix. The mean difference was considered significant at the 0.05 level.

Results

Study with a sample of N=180 trans-tibial amputees comprised a 100% male population with 60% with right side amputation and 26 cases with short stump length, 45 with medium and 109 with long stump length (table I). The mean age of amputees was 25.69±4.17 years, the average height 158.61± 8.63 cm, mean weight 75.57±7.16 kg and average use of prosthesis was 3.03±1.54 years. The average length of stump was 17.37±6.08 cm. There was no significant difference in stump length for different age groups (p=0.138), body mass index (0.329), cause of amputation (p=0.099), side (p=0.123) and activity level of the patient (p=0.726). However, prosthesis duration revealed significant association (p=0.001) with most cases with long stump length noted in the category of 1-5 years. (table I).

Table I: Participant characteristics frequency versus stump length category cross tabulation. (N=180)

Variable	Group	Stump length Category			Chi-Square	
		Short (n=26)	Medium (n=45)	Long (n=109)	X^2	P-value
Gender	Male [180(100)]	26	45	109		
Age (Years)	15-20 [30(16.7)]	4	7	19	6.957	0.138
	21-25 [40(22.2)]	7	4	29		
	26-30 [110(61.1)]	15	34	61		
Body Mass Index (kg/m^2)	Underweight (<18.4) [1(.6)]	0	0	1	6.912	0.329
	Heathy (18.5-24.9) [14(7.8)]	3	6	5		
	Over weight (25-29.9) [83(46.1)]	15	19	49		
	Obesity (30 or above) [82(45.6)]	8	20	54		
Cause of Amputation	Trauma [153(85)]	24	34	95	4.635	0.099
	Disease [27(15)]	2	11	14		
Side	Right [108(60)]	17	32	59	4.195	0.123
	Left [72(40)]	9	13	50		
Prosthesis duration	1-5 [162(89.5)]	26	34	102	14.871	0.001
	6-10 [18(9.9)]	0	11	7		
Activity level of patient	K3 [134(74.4)]	21	33	80	0.639	0.726
	K4 [46(25.6)]	5	12	29		

The stump length did not reveal any significant correlation with stride length (r=0.032, p=0.665), cadence (r-0.079,p=0.29), velocity (r=-0.039, p=0.6), stance phase (r=-0.068, p=0.363) of amputated side, swing phase of amputated side (r=0.06, p=0.423), hip joint kinematics of amputated side (r=-0.06, p=0.426), knee joint kinematics ie., flexion at terminal stance (r=-0.129, p=0.085), flexion at mid swing (r=0.004, p=0.954) of amputated side , pelvic tilt (r=0.049, p=0.517) and trunk bending both lateral trunk flexion (r=0.041, p=0.588) and forward lean (r=-0.036, p=0.634) at mid stance. All these values show no relation of stump length with all these variables.

Discussion

The gait parameters of participants with unilateral Trans-tibial amputation have marked differences in comparison with normal parameters. Since the muscle forces have to be transmitted from the stump to the prosthesis for ambulation of prosthetic leg Amputees show reduction in speed, range of joint motion including knee and hip joint range and movement and raised amplitude of time of muscular activation.[14]

Table II: Correlation of Stump length with different Temporo-Spatial and Kinematic outcome variables in		
Variable Mean ± SD	Stump Length 17.37±6.08	
	R-value	P-value
Stride Length 1.25±.10	0.032	0.665
Cadance 108.3±19.14	-0.079	0.29
Velocity 1.04±6.75	-0.039	0.6
Stance Phase 63.89±6.75	-0.068	0.363
Swing Phase 36.05±6.25	0.06	0.423
Hip Flexion At Terminal Swing 15.67±7.35	-0.06	0.426
Knee Flexion At Terminal Stance 16.22±12.51	-0.129	0.085
Knee Flexion At Mid Swing 36.51±17.9	0.004	0.954
Lateral Trunk Flexion At Mid Stance -2.94±26.29	0.041	0.588
Forward Lean of Trunk At Mid Stance .711±2.40	-0.036	0.634
Pelvic Tilt -4.89±12.72	0.049	0.517

Current study examined the effect of the stump length of trans-tibial amputees on the biomechanics at post-prosthetic rehabilitation, with the hypothesis that there is an association between trans-tibial stump length with temporo-spatial and kinematical changes. The study revealed that the stump length ratio has no significant correlation with stride length (r=0.032, p=0.665), cadence (r-0.079,p=0.29), velocity (r=-0.039, p=0.6), stance phase (r=-0.068, p=0.363), swing phase (r=0.06, p=0.423), hip joint kinematics of amputated side (r=-0.06, p=0.426), knee joint kinematics ie., flexion at terminal stance (r=-0.129, p=0.085), flexion at mid swing (r=0.004, p=0.954) of amputated side, pelvic tilt (r=0.049, p=0.517) and trunk bending both lateral trunk flexion (r=0.041, p=0.588) and forward lean (r=-0.036, p=0.634) at mid stance. Thus the study hypothesis is rejected. Similarly, Subbarao & Bajoria, reported that there was no significant difference noted in results following rehabilitation among the long and short stumps in unilateral amputees which were amputated due to peripheral vascular disease.[9] Also Schuett DJ et al. [15], in their study revealed no significant difference between the parameters of through knee and transfemoral amputees. In contrast Lenka & Tiberwala reported that the amputees with longer stump have greater velocity compared to short stump length [16], while Isakove E et al. reported that stride length, stride time and ambulation speed increase with the increase of stump length.[17] While a local study revealed positive correlation between long stump length and cadence (p=0.006).[18] Since stump length also affects the residual limb length, Baum BS et al. reported that pelvic tilt excursion revealed negative correlation with residual limb length but did not correlate with temporal spatial, kinematic.[19] Also Osmani-vllasolli T et al., reported stump length was an important factor which establishes the speed of walking.[20] From the above discussion it is deduced that all the previous studies show a significant impact of stump length on walking, cadence, speed and step length, in contrast this study revealed that there is no significant impact of stump length on these variables. The possible differences that can impact the walking pattern, speed, step length and cadence may be the muscle power and activity level of the patient, components selection of the prosthesis and living environment. Patient with high muscle power and activity level will show significant results and more efficient gait and walking then the patients with weak musculature and lower activity level. Prosthesis with advanced components i-e foot and socket technology will also improve the gait pattern. Living environment that are prone to more walking will highly impact the walking pattern of the prosthetic user then the environment where the main activity of patient is just sitting. Kellems VA reported that PUCK suspension system improve the kinematic. [21]

Limitations: The kinematic data was represented in terms of rather than values which may not fully represent gait deviations. Also the variety of components (prosthetic feet and modern technology) may cause some measured differences. The researcher faced difficulty in including equal number of female participants due to the social barriers.

Recommendations: Though modern prosthetic feet and other components can reduce the extent of gait deviations but they do not eliminate them completely. Therefore, when deciding about the tibial transection level, orthopedic surgeons may try their best to obtain a residual limb with medium stump length. Secondly, while rehabilitating the residual limb after amputation, physical therapists should strive for reducing the strength asymmetry amongst the antagonist muscle groups of stumps.

Conclusion

In conclusion, the stump length had no substantial influence on the temporo-spatial and kinematic gait parameters in subjects with Trans tibial amputation.

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