International Journal of Health Sciences and Research
DOI: https://doi.org/10.52403/ijhsr.20210725
Vol.11; Issue: 7; July 2021
Website: www.ijhsr.org
ISSN: 2249-9571

Original Research Article

Comparative Effect between Silesian Suspension and Total Elastic Suspension on GRF Loading in Subjects with Trans-Femoral Prosthesis: A Biomechanical Study

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ABSTRACT

Background: The major function of all Suspension systems is Prosthesis retention. The suspension system prevents rotation, translation and vertical movement of the prosthesis in relation to the residual limb. The Silesian suspension and TES system that are commonly prescribed for Transfemoral amputees are believed to provide a better suspension. Nevertheless, their effect on Transfemoral amputees' gait performance has not yet been fully investigated. The main intention of this study was to understand the potential effects of the Silesian suspension and TES systems on Transfemoral amputees on gait kinetics.
Aim & Objective: To find out the effect of two types of suspension system on Gait Kinetics in subject with unilateral transfemoral amputee.
Study Design: Two group post-test Comparative Experimental study design. (Quasi Experimental).
Methods: 30 subjects with two different suspension systems such as Silesian suspension (Group-A) and Total Elastic Suspension (Group-B) was included in this study by convenient sampling method. All subjects walked with Endo skeletal design Trans femoral Prostheses gait training given called after 3 weeks. After that data regarding gait kinetics parameters was evaluated by Kistler Force Plate in dynamic position.
Result: The results revealed that there is significant difference in gait kinetics parameters that GRF (Fx) mean shows no significantly difference between Group-A and Group-B ($p = 0.582$), GRF (Fy) mean shows non-significantly difference between Group-A and Group B ($p=0.163$) and GRF (Fz) mean shows non-significantly difference between Group-A and Group-B.
Conclusion: The findings concluded that the study support the hypothesis that there were significant difference with two different suspension system on kinetic gait parameters.

Key Words: Transfemoral prosthesis, TES, Silesian suspension, Gait Kinetics.

INTRODUCTION

Standard clinical prosthetic fitting depends on amputee's mobility, comfort, and satisfaction is associated with socket fit and proper choice of suspension system [1-5].

3 dimensional gravitational momentums are involved in stance and swing phase of the prosthetic gait to provide comfort and control pistoning action on prosthetic knee [6]. Quality of prosthetic fitting depends to comfortable in containing the residual limb, stable during stance phase of gait, smooth in transition to the swing phase of gait, and acceptable appearance[7]. Suspension to socket, socket to prosthetic knee, PKJ to foot have a synergetic co-

relation on prosthetic gait and posture [8-9].Closed compact suspension reduces the common risk of unbalanced residual limb movement [10].

Customize fabric or leather Silesian straps are designed to hold the pelvis too suspend the prosthesis [11]. The Total Elastic suspension belt made of neoprene is an easily applied form of suspension that is used for individuals who use suction suspension when playing sports or engaging in high-activity leisure activities [12].

Now in Indian scenario we want to establish a clinical report to check the effect of TES Suspension in comparison to Silesian suspension in terms of GRF loading in subjects with Transfemoral amputee using prosthesis. The TES that are commonly prescribed for transfemoral amputees are believed to provide a better suspension than Silesian systems. Nevertheless, their effect on amputees' gait performance has not yet been fully investigated. The main intention of this study was to understand the potential effects of the TES and the Silesian suspension systems on Transfemoral amputees' gait performance.

MATERIALS AND METHODS

Study Location was Department of Prosthetics and Orthotics, National Institute For Locomotor Disabilities (Divyangjan), B.T. Road, Bon-Hooghly, Kolkata – 700090. The study was approved by the Ethical Committee of National Institute for Locomotor Disabilities (Divyangjans), Kolkata, India, for the period 28th February2018to 27th April 2019.

Study Population was taken from Subjects with Unilateral Trans-femoral amputation referred from OPD, NILD, Kolkata. Sample Size taken 30 Subjects with Convenient Sampling design. Study Design was Two group post -test comparative experimental study design. (Quasi Experimental). Inclusion Criteria was Unilateral Trans Femoral amputee, Age between 20 to 40 years, Cause of amputation – Traumatic, Stump length - 40% to 60% of normal segment length, Good upper extremity strength, Full ROM of Hip joint and Good Muscle Power, No Sign of phantom pain and phantom sensation

Parameters studied was GRF Vector: Fx, Fy., Fz. Study instrument was used Kistler Force Plate. Dependent Variable: GRF (Fx, Fy, Fz) and independent Variable: Silesian suspension, Total elastic suspension.

Force plates are measuring instrument that measure the ground reaction forces generated by a body standing on or moving across them, to quantify balance, gait and other parameters of biomechanics. Force platforms may be classified as single-pedestal or multi pedestal and by the transducer type: Strain gauge, piezoelectric sensors, capacitance gauge, piezoresistive etc. The gold standard high accuracy piezoelectric force plate (Type 9260AA6, Serial number464611; Kistler Instruments Winterthur, Switzerland) was used in this study.

The individuals with unilateral trans-femoral amputee reported to OPD were first screened through the inclusion and exclusion criteria. The individual fulfilling the inclusion criteria was included by the convenient sampling method in the study. The individual were explained the study procedure. The informed consent was obtained from the individual prior to the study participation. Firstly, the participant was assessed and evaluated. The demographic data were taken, each subject of Transfemoral amputee was provided with Endo-skeletal design Prosthesis with Silesian suspension and TES Suspension system. The subject with unilateral trans femoral amputee with Endo-skeletal design Prosthesis with Silesian suspension were in group A and the subject with trans-femoral amputee with Endo-skeletal design Prosthesis with TES System were in group B. Then the prosthesis was fabricated and fitted with Silesian and Total Elastic suspension. After the fitment, gait training with the prosthesis was given and the subjects were discharged. After three weeks Subject were called for follow up, and data regarding Gait Parameters was collected for both groups during walking by Force Plate. Then the data was analysed, and two individual groups were separately compared.

The force plate was supplied by Kistler group (an internationally active Swiss group of company specialized in the field of measurement) was used for data collection. After 3 Weeks of adaptation with prosthesis, Ground reaction force vectors, GRF Fx- AP (In Sagittal Plane), GRF Fy-ML (in Frontal Plane) and GRF Fz (Transverse Plane) in static position were measured by using Kistler Force Plate. Each participant was given to wear endo-skeletal design transfemoral prosthesis with shoes and suspension were provided to the subject (Silesian and TES system).

Photo1: Patient with Silesian Suspension

Photo2: Patient with Total Elastic Suspension

Prior to test all patients were given 5-10 min for understand pattern of walking over force plate and some mock trials were given to subject by walking over it so that they properly know how to stand and walk over it. Subjects were advised to 1st stand on force plate with transfemoral prosthesis, at that time arms should be parallel to the torso. Then they were taught to walk 10 meter with their self-selected walking speed with prosthesis cross over force plate with one side lower extremity application over it. Then it repeats with other side extremities, this cycle continues for 30 sec at that time. During walking both steps either right or left should be present on alternate sequence manner over the force plate in such a manner that proper weight distribute over both extremities will be uniform during gait. (Photo-1) (Photo-2).

Statistical analysis

Raw data were exported from Kistler force plate into Microsoft excel, and final data analysis was performed in SPSS Version 24.0 (SPSS Inc, Chicago, Illinois) and Graph pad prism version 5.Data p-value ≤ 0.05 was considered for statistically significant in this current study.

RESULTS

The result showed there was no significant difference in mean age, height and weight between group A (Silesian suspension user) and Group B (TES user) as f value= 1.412714956& p= 0.263227815, f value= 1.01631873 & p value = 0.488134237, f= 1.962416232 & p= 0.118707875 respectively.

The mean GRF Fx-ML of the Group-A was 0.1098± .0614. and for the Group-B was 0.4268±.0681. There was no statistically significant difference in GRF Fx-AP (Sagittal Plane) between the groups. [Numerical variables between groups compared by independent t-test; (P=0.582].

The mean RMS Fx (mean±SD) of the Group-A was 0.7076± .4095. and for the Group-B was 0.8409±.6778. There was statistically significant difference in RMS Fx between the groups. [Numerical variables between groups compared by independent t-test; (P=0.033)] .

The mean Range Fx (mean±SD) of the Group-A was 3.1218± 1.4567 and for the Group-B was 1.6258±.9954. There was no statistically significant difference in velocity between the groups. [Numerical variables between groups compared by independent t-test; (P=0.173)].

The mean GRF Fy-)AP (mean±SD) of the Group-A was 0.3033±.0507. and for the Group-B was 0.5779±.0413. There was no statistically significant difference in GRF Fy-ML between the groups.[Numerical variables between groups compared by independent t-test; (P=0.163] .

The mean RMS Fy-AP (mean±SD) of the Group-A was 1.5708±1.0644. and for the Group-B was 0.9319±.6243. There was no statistically significant difference in RMS Fy between the groups.[Numerical variables between groups compared by independent t-test; (P=0.184)

The mean Range Fy-AP (mean±SD) of the Group-A was 4.6188± 1.9844. and for the Group-B was 1.2146±.8873. There was no statistically significant difference in Range Fy between the groups.[Numerical variables between groups compared by independent t-test; (P=0.177)]

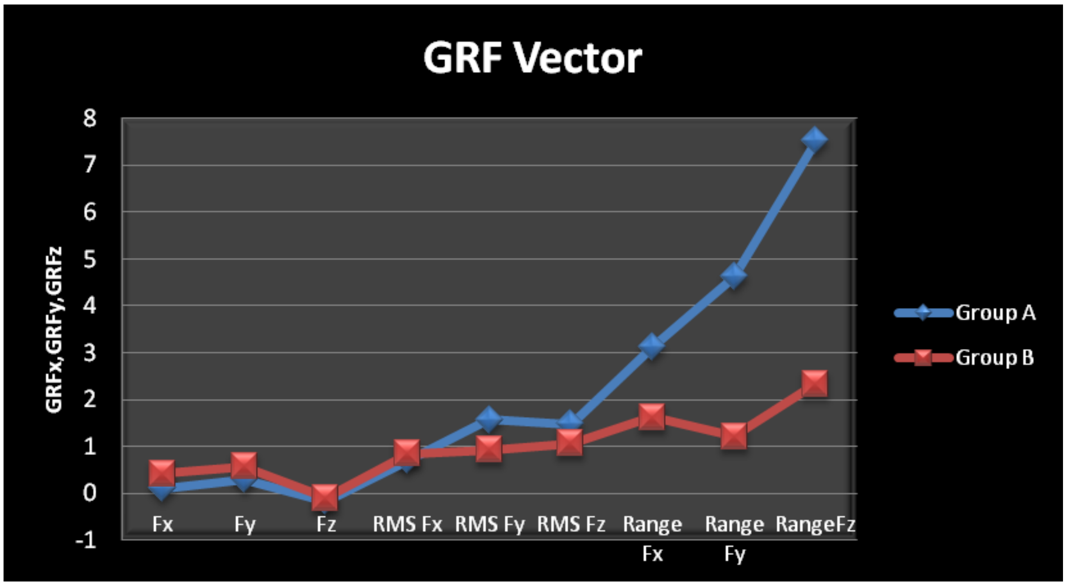
The mean GRF Fz of the Group-A was -.1655± .2158. and for the Group-B was -.0948±.1626. There was no statistically significant difference in velocity between the groups.[Numerical variables between groups compared by independent t-test; (P=0.618).

The mean RMS Fz of the Group-A was 1.4810±1.3016. and for the Group-B was 1.0604±.4884. There was no statistically significant difference in RMS Fz between the groups. [Numerical variables between groups compared by independent t-test; (P=0.248)

The mean Range Fz of the Group-A was 7.5204±7.4336 and for the Group-B was 2.3408±.6330. There was statistically significant difference in Range Fz between the groups. [Numerical variables between groups compared by independent t-test; (P= 0.071] (Table-1), (Graph-1).

Table1: GRF vector GRFx, GRFy, GRFz between groups .

Group	Mean	SD	Significance (P- value)
Group-A (GRF -Fx)	0.1098	0.0614	0.582
Group-B (GRF-Fx)	0.4268	0.0681	
Group-A (GRF -Fy)	0.3033	0.0507	0.163
Group-B (GRF-Fy)	0.5779	0.0413	
Group-A (GRF -Fz)	-.1655	0.2158	0.618
Group-B (GRF-Fz)	-.0948	0.1626	
Group-A (RMS -Fx)	0.7076	.4095	0.033
Group-B (RMS-Fx)	0.8409	.6778	
Group-A (RMS -Fy)	1.5708	1.0644	0.184
Group-B (RMS-Fy)	.9319	0.6243	
Group-A (RMS -Fz)	1.4810	1.3016	0.248
Group-B (RMS-Fz)	1.0604	0.4884	
Group-A (Range -Fx)	3.1218	1.4567	0.173
Group-B (Range-Fx)	1.6258	0.9954	
Group-A (Range -Fy)	4.6188	1.9844	0.177
Group-B (Range-Fy)	1.2146	0.8873	
Group-A (Range -Fz)	7.5204	7.4336	0 .071
Group-B (Range-Fz)	2.3408	0.6330	



Graph-1: GRF vector in pre post condition between groups.

DISCUSSION

The Trans femoral amputees always want to earn the ability to maintain a steady gait & balance without endangering their stability irrespective of their walking speed. Time-distance parameters provide information about position and timing of gait. The gait of lower limb amputees has long been studied to understand the kinetic and kinematic deviation resulting from the loss of knee, ankle and foot. The effects of Silesian and TES system on the gait of individuals with Transfemoral prosthesis have been investigated. This study attempted to examine the effect of type of Suspension on Kinematic gait parameters and ground reaction force vectors of individual with Transfemoral amputation.

Specific aimed for this prospective prosthetic clinical evidence based practice scenario was found any significant improvement in prosthetic gait with GRFx, GRFy and GRFz and it have a positive impact on improving gait parameters in transfemoral prosthesis with Silesian and TES system.

In Current evident result of this study, it also has been found that GRF (Fx) mean was increased in Group B, (p= 0.582) with no significantly changes, in RMS significantly increased (p=0.033) and Range is decreased.

Current evident result of this study also found that GRF (Fy) mean was increased in Group B (p=0.163) with no significantly changes, in RMS non-significantly decreased (p=0.184) and range is also decreased.

Current evident result of this study also found that GRF (Fz) mean was decreased in Group B, (p=0.618) with no significantly changes, in RMS non-significantly decreased (p=0.248) and Range is decreased.

In this prospective evident result expressed that in TES suspension (Group-B) is efficient component of the standard Trans femoral prosthetic intervention in respect to gait temporal parameters improvement as compare to regular Silesian suspension. In addition of that gait temporal parameters step length, stride length significantly decreased, cadence increased non-significantly and velocity increased significantly in Group B as compare to Group A. That point signifies that TES suspension having a positive impact to provide narrow based efficient gait.

Most of the studies on the effect of Transfemoral suspension on amputee are qualitative study with main focus on satisfaction and problem associated with residual limb skin. Quantitative study on the effect of transfemoral suspension is rare.

Ground Reaction force on prosthetic gait on suspension needs GRF-AP ML torque to maintain AP ML equilibrium on stance and swing phase of gait and it also provide better stability. In this current prospective evidence clinical study find out the more amount of GRF-xyz increased in group B. Also GRF x provide better ML stability, GRFy provide better AP stability in stance and swing phase of gait and in Group B GRFz provide better control on synergetic action to lock the prosthetic knee in midstance. Which is also supported by the author Raja R et al.(2017) he studied on effect of vertical ground reaction force in conventional below knee prosthesis versus modular below knee prosthesis on unilateral transtibial amputee patients the GRFz is increased while the patient is using trans tibial prosthesis with suspension and found that there is increased in GRF Fz which contradict to my study and found that post GRF Fz mean was decreased no significant (p=0.618)[13].

M L.van der Linden et al.(1999) done a study on trans femoral amputee to check the effect of various types of prosthetic feet on the biomechanics of trans femoral amputee with suction and Silesian suspension and find that stride length is significantly differed among prosthetic feet and GRF Fy was also changed which also supported my study in which it was observed there is marked change in stride length mean was significantly decreased (p= 0.002) This study showed a significant effect on Temporal Gait parameters i.e. Step length, stride length and velocity between both groups using suspension shows that suspension have changing effect between both groups, but in cadence showed that there was no significant difference means no changing effect[14].

Sonja M. H. J. Jaegers et al. (1995) observed transfemoral prosthetic gait of unilateral amputees. And reported that stride parameters of prosthetic gait kinematics parameters like step rate, stride time, stride length and walking speed are non-significantly changed as compare to normal control gait kinematics data. This is in accordance to this study without compared with normal control group data and additional git kinetics data was observed. About gait temporal data having cadence shows non-significant changes (p=0.901) and velocity show significant changes (p=0.032) but in Silesian suspension as compare to Total elastic suspension [15].

Highsmithmj et al. (2010) reported that Lower limb amputees have less efficient gait patterns that may in part be due to spatiotemporal asymmetries. Trans femoral (TF) amputees are believed to have greater gait asymmetries than transtibial (TT) amputees, but this has not been clearly established. Prosthetic and sound sides averaged together, TF amputees utilized shorter (62.2± 7.0 cm vs. 72.1 ±7.1 cm, p= 0.0007) and wider (20.7± 4.2 cm vs. 15.4 ±3.1 cm, p= 0.0008) steps that were of longer duration (0.65± 0.8 seconds vs. 0.59 ±0.04 seconds, p= 0.009) than those of TT amputees. The DoA (Degree of asymmetry) analysis indicated that TF amputee step times were more asymmetrical than those of TT amputees (DoA- 0.08 ± 0.05 vs. 0.01± 0.04, p=0.0008). TF amputees walk with greater temporal, but not spatial, asymmetry than TT amputees this is in accordance the same findings of GRF vector control prosthetic gait. In addition we find out the GRF control of gait in trans femoral prosthesis GRF-Fx was shows non-significantly changes(p= 0.582), and GRF-Fy was shows non- significantly changes (p=0.163) also GRF-Fz was decreased, shows non-significantly changes (p=0.618) [16].

Hossein Gholizadeh et al.(2014) found that comparison between two below knee suspension i.e. suction and pin lock suspension and found that Significant differences (p=0.03) were identified in the vertical ground reaction force between the two systems which is contradict my study found that vertical ground reaction force non-significantly changes occur . Two peaks can be detected in GRF; the first peak reflects the quality of shock absorption by the locomotor system during gait. Significant differences (p=0.00) were found in the vertical GRF (first peak) with both suspension systems. This study revealed that subjects walked at a speed of 0.94 m/ when using the suction and 0.93 m/s when using pin/lock systems, respectively like that step length 0.61 m/s when using suction(p=0.05) and 0.62 m/s when using pin lock suspension (p=0.02) and stride length was 1.2 m/s and 1.1 m/s when using suction and shuttle lock suspension in transtibial amputees which also support my study in which both step length and stride length was significantly change[17-21].

CONCLUSION

As per present perspective clinical evident report it concluded that Total Elastic Suspension having a significance impact on positive influences GRF force vector, improving gait as compare to Silesian suspension. It also influences to improve static balance and dynamic balance and reducing in prosthetic gait. From the outcome of this study, it can be observed that amputee’s gait performance was positively influenced by the TES system due to better suspension and fit within the socket. Overall satisfaction with prosthesis was higher with the Total Elastic Suspension due to easy donning and doffing as compared to Silesian suspension system. Efficient prosthetic suspension system must secure the residual limb inside the prosthetic socket and make donning and doffing procedures easier. Further prosthetic clinical study is needed to evaluate more amputees, and to offer a guideline for proper selection of suspension system.

Acknowledgement: None

Conflict of Interest: None

Source of Funding: None

Ethical Approval: Approved

REFERENCES

1. Kristinsson O¨: The ICEROSS concept: A discussion of a philosophy. ProsthetOrthotInt1993;17:49Y55
2. Baars E, Geertzen J: Literature review of the possible advantages of silicon liner socket use in trans-tibial prostheses. ProsthetOrthotInt2005;29:27Y37.
3. Ali S, Abu Osman, NA, Naqshbandi MM, et al: Qualitative study of prosthetic suspension systems on individuals with transtibial amputation’s satisfaction and perceived problems with their prosthetic devices. Arch Phys Med Rehabil. 2012;93:1919Y23
4. Highsmith MJ, Schulz BW, Hart-Hughes S, et al: Differences in the spatiotemporal parameters of transtibial and transfemoral amputee gait. J ProsthetOrthot2010;22:26-30.
5. Neumann ES, Wong JS, Drollinger RL: Concepts of pressure in an ischial containment socket: Measurement. J ProsthetOrthot2005;17:2-11.
6. Douglas G. Smith, MD. Atlas of Amputations and Limb Deficiencies. (409-410).
7. Michelle M. Lusardi, PT, DPT, PhD. Orthotics and Prosthetics in rehabilitation. (652-53).
8. Kristinsson O. The Iceross concept: a discussion of a philosophy.ProsthetOrthotInt1993;17:49-55.
9. McCurdie I, Hanspal R, Nieveen R. Iceross- a consensus view: a questionnaire survey of the use of Iceross in the United Kingdom. Prosthet Orthot Int. 1997;21:124-8.
10. Van de Weg FB, Van der Windt DAWM. A questionnaire survey of the effect of different interface types on patient satisfaction and perceived problems among trans-tibial amputees. Prosthet OrthotInt2005;29:231-40.
11. Schuch CM: Transfemoral Amputation: Prosthetic Management. In Bowker JH, Michael JW (eds). Atlas of Limb Prosthetics: Surgical, Prosthetic and Rehabilitation Principles. Ed 2. St Louis, Mosby Year Book 509-533, 1992.
12. KappSL :Suspension Systems for Prosthesis, Clinical orthopaedics and Related Research, Number 361, pp 55-62, 1999.
13. Raja R, Rai HR, Sridharamurthy JN, Madhouraj B, Balaji R, Raja V. To compare the effect of vertical ground reaction force in conventional below knee prosthesis versus modular below knee prosthesis on unilateral transtibial amputee patients. International Journal of Medical and Dental Sciences. 2017 Jan 1;6(1):1398-406.
14. Van der Linden ML, Solomonidis SE, Spence WD, Li N, Paul JP. A methodology for studying the effects of various types of prosthetic feet on the biomechanics of trans-femoral amputee gait. Journal of biomechanics. 1999 Sep 1;32(9):877-89.
15. Jaegers SM, Arendzen JH, de Jongh HJ. Prosthetic gait of unilateral transfemoral amputees: a kinematic study. Archives of physical medicine and rehabilitation. 1995 Aug 1;76(8):736-43.
16. Highsmith MJ, Schulz BW, Hart-Hughes S, et al: Differences in the spatiotemporal parameters of transtibial and transfemoral amputee gait. J ProsthetOrthot2010;22:26-30.
17. Engsberg JR, Lee AG, Tedford KG, Harder JA (1993) Normative ground reaction force data for able-bodied and trans-tibial amputee children during running. Prosthet Orth Int. 17, 83–89.
18. Stergiou N, Giakas G, Byrne JE, Pomeroy V (2002) Frequency domain characteristics of ground reaction forces during walking of young and elderly females. Clin Biomech. 17, 615–617.

19. Vanicek N, Strike S, McNaughton L, Polman R (2009) Gait patterns in transtibial amputee fallers vs. non-fallers: Biomechanical differences during level walking. Gait Posture. 29, 415–420.
20. Winter DA (1991) Kinematic and kinetic patterns in human gait: normal, elderly and pathological. University of waterloo press, Ontario, Canada.
21. Perry J, Davids JR (1992) Gait analysis: normal and pathological function. J Pediatr Orthoped, 12(6), 815.

How to cite this article: Paikray S, Hasan Md. Arif Raihan, Das DS et.al. Comparative effect between Silesian suspension and total elastic suspension on GRF loading in subjects with trans-femoral prosthesis: a biomechanical study. *Int J Health Sci Res.* 2021; 11(7): 171-178. DOI: *https://doi.org/10.52403/ijhsr.20210725*

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