ORIGINAL ARTICLE

Comparison of trauma and diabetes mellitus-induced transtibial amputees in terms of gait parameters and functional capacity

Neşe Tosun,[1] Fatih Erbahçeci[2]

[1]Department of Therapy and Rehabilitation, Gaziantep University, Gaziantep-*Türkiye*

[2]Department of Musculoskeletal Physiotherapy and Rehabilitation, Hacettepe University Faculty of Physical Therapy and Rehabilitation, Ankara-*Türkiye*

ABSTRACT

BACKGROUND: The aim of this study was to compare gait parameters, balance, weight-bearing symmetry, functional capacity, functional mobility, prosthesis satisfaction, and quality of life between individuals with diabetes mellitus-induced and traumatic transtibial amputations (TTAs).

METHODS: Ten individuals with traumatic transtibial amputation and 10 individuals with diabetes mellitus-induced transtibial amputation were included in the study. All participants in both the trauma and diabetes groups used a vacuum-assisted suction suspension system (VASS) and a carbon composite foot transtibial prosthesis. Gait analysis and weight-bearing symmetry were assessed using a computerized gait analysis system. Balance was evaluated with the Biodex Balance System (BBS), functional capacity with the Six-Minute Walk Test (6MWT), functional mobility with the Timed Up and Go Test (TUG) and the Stair Climbing Test (SCT), prosthesis satisfaction with the Trinity Amputation and Prosthesis Experience Scale (TAPES), and quality of life with the Short Form-36 (SF-36).

RESULTS: When comparing the traumatic and diabetic groups, significant differences favoring the trauma group were found in the following parameters: stride length (SL) (p=0.004), amputated limb step length (ASL) (p=0.019), non-affected limb step length (NSL) (p=0.005), balance assessment parameters of general postural stability (p=0.000), anteroposterior (A-P) postural stability (p=0.000), mediolateral (M-L) postural stability (p=0.007), SCT performance (p=0.000), and the activity restriction subsection of TAPES (p=0.029). No significant differences were observed in gait velocity, cadence, step width, weight-bearing percentage of the amputated and non-affected limbs, TUG performance, SF-36 scores, or the psychosocial adjustment, prosthesis satisfaction, and daily use time subsections of the TAPES.

CONCLUSION: In this study, the use of a VASS prosthesis in both traumatic and diabetic amputees had a positive effect on outcomes in the diabetic group, resulting in comparable results to those of the traumatic group. The fact that diabetic amputees used their prostheses as frequently as traumatic amputees, remained active, and benefited from the choice of prosthesis and suspension system provides valuable insights for healthcare professionals as a facilitating factor in rehabilitation.

Keywords: Amputee; diabetes mellitus; trauma; transtibial; gait.

INTRODUCTION

Amputation, the surgical removal of part or all of a limb, is performed for various reasons, including trauma, infection, and disease. Amputation surgery has significantly evolved throughout history, with innovations in surgical techniques, anesthesia, and postoperative care contributing to improved prognosis for patients undergoing the procedure.[1]

Cite this article as: Tosun N, Erbahçeci F. Comparison of trauma and diabetes mellitus-induced transtibial amputees in terms of gait parameters and functional capacity. Ulus Travma Acil Cerrahi Derg 2025;31:259-268.

Address for correspondence: Neşe Tosun
Department of Therapy and Rehabilitation, Gaziantep University, Gaziantep, Türkiye
E-mail: nesetosun@hotmail.com

Ulus Travma Acil Cerrahi Derg 2025;31(3):259-268 DOI: 10.14744/tjtes.2024.83923
Submitted: 19.09.2024 Revised: 10.12.2024 Accepted: 30.12.2024 Published: 03.03.2025

Lower extremity prosthetics play a crucial role in the rehabilitation and quality of life (QoL) of amputees,[1] possessing a robust lineage of progression and evolution as advances in engineering intersect with a nuanced understanding of user requirements. Over the decades, significant focus has been directed toward enhancing the practicality, comfort, and aesthetics of lower limb prosthetics to improve the QoL for individuals with limb deficiencies. The historical advancements in amputation practices, alongside the refinement of prosthetic designs, demonstrate a commitment to supporting communities affected by limb loss.[2]

Trauma is one of the primary causes of transtibial amputations and is the leading cause of amputation in developing countries. Additionally, complications of diabetes mellitus frequently necessitate transtibial amputation, as is the case with vascular disease.[3]

Joint angles, stride length, and stride symmetry are often altered when transtibial amputees (TTAs) are compared to individuals without amputations. The biomechanical differences in amputees affect both the efficiency and smoothness of overall gait.[4] Furthermore, the use of prostheses and suspension systems may influence gait-related parameters such as stride length, cadence, and stance phase duration.[5] After a transtibial amputation, typical findings include reduced walking speed and alterations in the stance and swing phases of gait, leading to changes in muscle activation patterns and joint movements.[6]

Balance is another critical element affected after transtibial amputation. Amputation below the knee results in a significant loss of sensory receptors, which can lead to deficiencies in somatosensory feedback and further impair postural control and stability in individuals with TTA.[7]

Transtibial amputation is associated with changes in load distribution, weight-bearing patterns, and muscle activation. Both socket fit and suspension systems are essential for optimizing load distribution and minimizing pressure points within the residual limb.[8]

Individuals with TTA experience severe physical dysfunction, reduced functional mobility and capacity, and limitations in activities of daily living.[9]

QoL and satisfaction with prostheses are crucial aspects of the lives of individuals with TTA.[10] Gait deviations and reduced gait efficiency can directly impact prosthesis satisfaction and overall QoL.[11]

Some gait studies on individuals with TTA have shown that the type of prosthesis and suspension system can influence gait parameters such as stride length, stride symmetry, and velocity. The design, fitting, and type of prosthesis, along with the suspension system used, may alter gait biomechanics and walking efficiency.[12] An appropriate suspension system that provides stability and comfort can ultimately improve overall satisfaction and QoL.[13] Satisfaction with the prosthesis is a key element in the successful rehabilitation of individuals with TTA. The type of suspension can influence socket comfort, mobility, and balance confidence. Additionally, satisfaction with the prosthesis and suspension system is positively correlated with functional outcomes.[14]

Pistoning is minimized in the vacuum-assisted suspension system (VASS) compared to all other suspension systems. The VASS is preferred for individuals with increased suspension requirements due to high activity levels.[15] Through the elevated vacuum mechanism, this system more effectively reduces changes in residual limb volume, improves adhesion, decreases forces exerted on the residual limb, and enhances proprioception compared to a one-way vacuum system.[16]

Several studies in the literature have compared traumatic and diabetic TTAs in terms of gait, balance, weight-bearing symmetry, functional mobility, functional capacity, QoL, and prosthesis satisfaction. However, no studies have been found that evaluate these parameters collectively. Furthermore, in most existing studies, there is little or no information regarding the specific prostheses or suspension systems used by the amputees. The aim of this study was to compare gait, balance, weight-bearing symmetry, functional mobility and capacity, QoL, and prosthesis satisfaction in individuals with traumatic and diabetes mellitus-induced transtibial amputation using a VASS transtibial prosthesis. The use of the same type of suspension system in all participants' prostheses aimed to provide more objective results by eliminating the influence of different suspension systems on the evaluation outcomes.

MATERIALS AND METHODS

This study was conducted at Hacettepe University Faculty of Physical Therapy and Rehabilitation, Department of Musculoskeletal Physiotherapy and Rehabilitation and Gaziantep University Şahinbey Research and Practise Hospital, and was approved by the Hacettepe University Non-Interventional Clinical Research Ethics Committee on 07/05/2019 and was deemed ethically appropriate according to the Declaration of Helsinki, with decision number 20129/12-22.

Participants

The study included individuals aged 18-65 years who had undergone unilateral transtibial amputation surgery and were able to walk independently with a prosthesis. The inclusion criteria were as follows: voluntary participation, amputation due to diabetes mellitus or trauma, the ability to walk at least 10 meters independently without a walking aid, absence of phantom sensation or pain, gross lower limb muscle strength at or above average, prosthesis use for at least one year, normal mental capacity, and active prosthesis use for at least five hours per day. Exclusion criteria included upper limb amputation, bilateral lower limb surgery, the presence of a primary neurological disease that adversely affected walking and balance, or the use of a walking aid.

Assessments

All assessments were conducted by the same evaluator and in the same order. Computer-assisted assessment methods were used in gait and balance evaluations to increase the objectivity of the data obtained within the scope of the study. The following assessments were performed on the study participants:

Demographic Information: Demographic data, including age, weight (kg), height (cm), gender, and occupation, were collected.

Gait Analysis: A 3-meter-long Ultrasensor 3D Platform LAC I (Diasu by Sani Corporate via Giacomo Peroni 400 00100, Roma, IT) sensor walkway was used to measure the time-distance parameters of gait.[17] Participants walked three times on the walkway and returned wearing their daily shoes. Half-footprints corresponding to the start and end of the force plates were excluded from the recorded steps. The average values from the three walking trials were used. Step width, stride length (SL), amputated limb step length (ASL), and non-affected limb step length (NSL) were recorded in centimeters (cm). Cadence was measured as the number of steps per minute, and velocity was recorded in centimeters per second (cm/sec).

Weight Bearing: Weight-bearing distribution was assessed using a computerized gait analysis system, and the percentage of total weight borne by the amputated and non-affected limbs was recorded.

10-Step Stair Climb Test (SCT): The Stair Climb Test is a measurement tool used to assess functional ability in clinical and research settings.[18] The time taken to ascend and descend 10 steps was recorded. This test has been found to be valid and reliable for lower-limb amputees.[19]

Timed Up and Go Test (TUG): This evaluation tool is used to assess fall risk and mobility. It measures the time required for the participant to rise from a chair, walk 3 meters, and sit down, recorded in seconds. This scale is valid[20] and reliable [21] for lower-limb amputees.

Six-Minute Walk Test (6MWT): A valid and widely used scale for assessing the functional capacity of lower-limb amputees in both clinical and research settings. It measures the distance walked in six minutes, recorded in meters.[22]

Trinity Amputation and Prosthesis Experience Scale (TAPES): This scale provides detailed information about prosthetic adaptation, functionality, and overall health. It consists of two parts, with the first part including subsections on psychosocial adjustment, activity restriction, and prosthetic satisfaction.[23]

Short Form-36 (Medical Outcomes Study 36-Item Short Form Health Survey) (SF-36): This is a widely used and valid scale for assessing health-related quality of life. It is applicable to a broad range of ages, illnesses, and treatments, covering general health concepts. It is frequently used in both clinical and research settings.[24]

Balance Assessment: The Biodex Balance System [Biodex Balance System SD®, Biodex Medical Sistems, Inc., USA] is designed to objectively assess balance and balance-related parameters. It includes test and training modes. In test mode, it evaluates fall risk, sensory integration of balance, bilateral comparison, postural stability, stability limits, and motor control parameters. In this study, the postural stability test was used, where higher scores indicate greater deviation and poorer balance control.[25]

Statistical Analysis

To determine the sample size for the study, a power analysis was conducted using the G*Power program to achieve 90% power with a 5% Type I error and a 10% Type II error. As a result of this calculation, it was determined that each group should include at least nine participants. This study was conducted with 10 individuals who had undergone amputation due to with diabetes mellitus and 10 individuals who had undergone amputation due to trauma and used a prosthesis.

Data analysis was performed using IBM SPSS 25.0 software (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, New York: IBM Corp. USA). Since the total number of participants in the study was fewer than 30, normality testing was not conducted, and a non-parametric test was used. For descriptive statistics, the mean was used as a measure of central tendency, and the standard deviation as a measure of dispersion. The Mann-Whitney U test was used to compare data between individuals with traumatic and diabetes mellitus-induced TTA.

RESULTS

This study investigated whether there was a significant difference in physiotherapy and rehabilitation-related assessment outcomes between traumatic and diabetic TTA who used a prosthesis. The study included 10 participants with traumatic TTA and 10 participants with diabetes mellitus-induced TTA. All participants in both the trauma and diabetes groups were male. There was no significant difference between the groups in terms of body mass index (BMI), height, weight, and daily prosthesis use time; however, a significant difference was found in terms of age. All amputees in both the trauma and diabetes groups used a VASS and a carbon composite foot transtibial prosthesis. The demographic characteristics of the study participants are presented in Table 1.

Gait, weight-bearing symmetry, balance, functional mobility, functional capacity, prosthesis satisfaction, and QoL were assessed, and the differences between the groups were compared.

Table 1. Demographics of participant groups

Cause of Amputation	Traumatic group	Diabetic group	U	z	p
N	10	10			
Gender					
Male	10	10			
Female	–	–			
Weight (kg)					
X±SS (min.-max.)	83.7±10.39(65-100)	85.5±17.17(60-117)	46.5	-0.265	.796
Height (cm)					
X±SS (min.-max.)	172.2±4.92(165-182)	171.4±8.53(158-185)	45.5	-0.342	.739
BMI (kg/m^2)					
X±SS (min.-max.)	28,25±3,58 (22.49-33.8)	28.93±4.14(20.76-34.19)	41	-0,68	.529
Age (years)					
X±SS (min.-max.)	41.2±8.89(20-55)	56.5±9.29(37-65)	10.5	-2.989	.002
Daily Prosthesis Use (hours)					
X±SS (min.-max.)	14.2±2.78(9-18)	11.4±3.41(6-15)	24.5	-1.946	.052
Prosthesis usage period (months)					
X±SS (min.-max.)	57.40±14.21(26-78)	37.70±27.17(12-96)	24	-1.969	.052

p≤0.05. BMI:Body mass index.

Table 2. Comparison of gait parameters between groups

Cause of amputation	Traumatic group		Diabetic group		Mann-Whitney U Test		
	X±SS	Min.-Max.	X±SS	Min.-Max.	U	z	p
Step width (cm)	19.95±2.32	17.46-23.91	19.92±2.78	13.92-23.55	48	-0.151	.912
SL (cm)	133.76±14.03	104-147.53	111.16±17.96	76.43-128.55	12	-2.873	.004
ASL (cm)	67.23±6.89	54.60-75.37	57.82±11.77	37.13-70.00	19	-2.343	.019
NSL (cm)	66.29±7.72	48.03-74.25	56.37±6.23	41.66-63.00	13	-2.798	.005
Cadence (steps/min)	100.82±4.78	92.91-110.57	105.58±11.46	91.53-129.54	37	-0.983	.326
Velocity (cm/sec)	112.61±14.46	80.52-125.83	97.47±17.42	69.42-123.05	27	-1.739	.082

p≤0.05. SL: Stride length; ASL: Amputee Extremity Step Lenght; NSL: Non-Affected Extremity Step Lenght.

When gait parameters were compared between the groups, a significant difference was found in favour of the traumatic group for SL, ASL, and NSL. No significant difference was found for step width, cadence, and velocity. The values of the gait parameters (step width, SL, ASL, NSL, cadence, and velocity) were compared, and the results are shown in Table 2.

The balance and weight-bearing scores of the groups were compared, and the results are shown in Table 3. When comparing the balance parameters, a significant difference was found in favour of the trauma group for all values, whereas no significant difference was found in weight-bearing percentages.

The functional mobility and functional capacity scores of the groups are presented in Table 4. When comparing the results of the 6MWT and SCT, a significant difference was found in favor of the trauma group, whereas no significant difference was found in the TUG results.

The QoL scores of the groups were compared, and the results are shown in Table 5. No significant difference was found in any of the subsections when comparing the QoL scores.

The prosthesis satisfaction and compliance scores of the groups were compared, and the results are shown in Table 6. When comparing the TAPES scores, a significant difference was found in favor of the trauma group in the activity restric-

Table 3. Comparison of balance and weight-bearing evaluations between groups

	Traumatic group		Diabetic group		Mann-Whitney U Test		
	X±SS	Min.-Max.	X±SS	Min.-Max.	U	z	p
General Postural Stability	0.30±0.07	0.20-0.40	0.57±0.17	0.40-0.80	3	-3.632	.000
A-P Postural Stability	0.20±0.07	0.10-0.30	0.44±0.13	0.30-0.70	3	-3.632	.000
M-L Postural Stability	0.15±0.05	0.10-0.20	0.27±0.11	0.10-0.41	15	-2.774	.007
Amputee Limb Weight Bearing (%)	48.20±3.51	42.15-54.20	48.11±5.21	41.33-58.05	47	-0.227	.853
Non-affected Limb Weight Bearing (%)	51.80±3.51	45.80-57.84	51.73±5.14	41.95-58.67	48	-0.151	.912

p≤0.05. A-P: Anterio-posterior; M-L: medio-lateral.

Table 4. Comparison of functional mobility (Timed Up and Go Test [TUG] and Stair Climbing Test [SCT]) and functional capacity (Six-Minute Walk Test [6MWT]) between groups

Reason for amputation	Traumatic group		Diabetic group		Mann-Whitney U Test		
	X±SS	Min.-Max.	X±SS	Min.-Max.	U	z	p
6MWT (m)	487.20±104.22	309.00-657.00	298.90±81.02	189.00-408.00	8	-3.175	.001
SCT (sec)	14.30±3.58	10.23-22.46	27.85±9.90	17.51-46.00	5	-3.403	.000
TUG (sec)	10.35±4.34	7.22-21.12	14.43±4.80	6.20-22.08	24	-1.965	.052

p≤0.05. 6MWT: Six Minute Walk Test; TUG: Timed Up and Go Test; SCT: Stair Climbing Test.

Table 5. Comparison of quality of life (QoL) scores between groups

	Traumatic Group		Diabetic Group		Mann-Whitney U Test		
	X±SS	Min.-Max.	X±SS	Min.-Max.	U	z	p
Physical Functioning (PF)	74.00±25.69	15.00-100.00	54.50±31.13	0.00-95.00	28.50	-1.63	0.105
Role Limitations Due to Physical Health (RP)	75.00±40.82	0.00-100.00	40.00±33.75	0.00-100.00	24.50	-2.02	0.052
Role Limitations Due to Emotional Problems (RE)	73.33±40.98	0.00-100.00	53.33±50.18	0.00-100.00	41.00	-0.76	0.529
Vitality (VT)	59.50±29.48	5.00-95.00	51.00±25.91	15.00-90.00	39.00	-0.83	0.436
Mental Health (MH)	61.20±28.29	0.00-96.00	58.40±22.17	32.00-88.00	45.50	-0.34	0.739
Social Functioning (SF)	73.75±30.87	0.00-100.00	58.75±27.67	0.00-100.00	30.00	-1.55	0.143
Bodily Pain (BP)	67.25±37.72	0.00-100.00	61.75±28.75	20.00-90.00	40.00	-0.77	0.481
General Health (GH)	60.50±28.91	5.00-90.00	39.50±29.58	5.00-100.00	30.00	-1.52	0.143

p≤0.05.

tion subsection. However, no significant difference was found between the groups in the other subsections.

DISCUSSION

When comparing the assessments of individuals with traumatic and diabetes mellitus-induced TTA, the results for SL, ASL, NSL, balance, functional capacity, and functional mobility (SCT) were better in the traumatic amputation group. This difference became more apparent as the complexity of activities increased. Other parameters showed similar results between diabetic and traumatic amputees.

Walking is a vital activity for amputees to maintain their daily lives. Walking at a faster pace is crucial for safely navigating certain situations in daily life, such as crossing the street, while slower walking speeds may indicate an increased risk of falls.[26] Measurement of gait velocity is a commonly used

Table 6. Comparison of prosthesis satisfaction and compliance scores between groups

	Traumatic group		Diabetic group		Mann-Whitney U Test		
	X±SS	Min.-Max.	X±SS	Min.-Max.	U	z	p
Psychosocial Adjustment	54.00±5.23	47.00-62.00	54.00±5.75	43.00-60.00	49.500	-0.038	0.971
Activity Restriction	6.00±5.81	0.00-19.00	12.50±7.74	3.00-25.00	21.500	-2.160	0.029
Prosthetic Satisfaction	40.70±5.64	30.00-50.00	34.00±11.13	14.00-49.00	28.500	-1.630	0.105
Daily Prosthesis Use (hours)	14.20±2.78	9.00-18.00	11.40±3.41	6.00-15.00	24.5	-1.946	0.052

p≤0.05.

method for assessing the walking ability of amputees.[27] Studies have shown that cadence, stride length, and velocity in amputees are generally lower than normal values observed in healthy individuals.[26,28]

In diabetic amputees, SL,[29,30] NSL,[31] and ASL[29,31] have been found to be reduced, consistent with the findings of our study. This outcome may be attributed to factors such as reduced joint position sense, impaired proprioception, balance difficulties, the higher average age of diabetic TTAs compared to traumatic TTAs, and more cautious prosthesis use among diabetic amputees. When comparing walking speeds between traumatic and diabetic TTAs, studies without standardization of prosthetic components[31,32] or those using conventional prosthetic components have reported slower walking speeds in the diabetic group.[30] However, a study by Nakajima et al.,[29] in which participants used total contact sockets, reported no significant difference in velocity, which aligns with our findings. Studies have shown that the VASS prosthesis used by the amputees in our study offers several advantages, including reducing residual limb volume changes, providing a more symmetrical gait,[33] minimizing pistoning between the residual limb and socket,[33,34] increasing weight-bearing on the amputated limb, improving walking ability and functional mobility, and enhancing prosthesis satisfaction.[14] It was concluded that the long duration of daily prosthesis use and high prosthesis satisfaction among diabetic amputees had a positive effect on gait. Additionally, the use of an active vacuum prosthesis contributes to a better stump-socket fit. Although the diabetic amputees in our study had a shorter SL than those with traumatic TTA, it is assumed that they compensated by walking with a higher cadence than the trauma group. Even though this difference was not statistically significant, it suggests that diabetic amputees developed a gait strategy that suited them, influencing their gait biomechanics, increasing gait velocity, and ultimately allowing them to reach the same walking speed as the trauma group.

A study on weight-bearing symmetry reported that transtibial and transfemoral amputees exhibited longer swing phase duration, shorter stance phase duration, and shorter single-support phase duration, spending more time on the non-affected limb.[35] In other words, their gait was asymmetrical, as they tended to avoid transferring weight to the prosthetic side to maintain stability during both static and dynamic activities. In a comparative study by Eissa et al.,[36] which examined transtibial and transfemoral amputees alongside healthy individuals, the percentage difference in weight distribution between the non-affected and amputated limb and the percentage difference in force exerted on the intact and amputated limb during gait were found to be significantly different between amputees and healthy individuals. However, these same two parameters did not differ between transtibial and transfemoral amputees. In our study, consistent with the literature, the weight-bearing percentages of individuals with traumatic and diabetes mellitus-induced unilateral TTA on the non-affected and amputated limbs during walking were found to be similar. Although previous studies have reported differences in weight-bearing symmetry between healthy individuals and amputees in dynamic conditions, our findings suggest that several factors may have contributed to the absence of a difference between the traumatic and diabetic groups. These factors include the relatively younger age of the participants, similar daily prosthesis use duration between groups, long daily prosthesis wearing times (traumatic TTA: 14 hours, diabetic TTA: 11 hours), active lifestyles, transtibial amputation level, use of a vacuum-assisted suspension system prosthesis, and load distribution balance for functional outcomes.

Balance in amputees is influenced by factors such as the cause of amputation, amputation level, and comorbidities. Compared to healthy individuals, lower limb amputees experience impaired gait[27] and balance[37,38] deficits due to dysfunctions in musculoskeletal system and sensory impairments, including superficial sensations (e.g., light touch) and deep sensations (e.g., joint position sense and proprioception). The loss of sensory feedback and muscle control in the amputated limb, along with the reduced range of motion in the prosthetic foot, further contribute to impaired postural control in individuals with TTA.[39]

In the study by Hermodsson et al.,[37] it was reported that when balance scores of the traumatic and vascular TTA groups were compared while looking straight ahead in an upright standing position with both feet close together and arms at the sides, the vascular group exhibited greater oscillation in the lateral direction, while no difference was observed in the antero-posterior (A-P) direction. In contrast to the findings by Hermodsson et al.,[37] our study found a significant difference between the two amputee groups in medio-lateral (M-L) direction. The discrepancy in M-L postural stability findings between the two studies may be attributed to differences in data collection methods.

Molina-Rueda et al.[40] evaluated stability limits using a computerized dynamic posturography device and obtained results that support our study. Their study compared vascular unilateral TTAs with healthy individuals and non-vascular unilateral TTAs, concluding that stability limits were significantly reduced in the vascular group.

Another study reported that vascular amputees shifted their body weight more toward the non-affected side in both the anteroposterior and mediolateral directions as a compensatory strategy to maintain stability.[41]

Visual and sensory inputs from the lower extremities are important for balance control. The fact that balance impairment is more pronounced in diabetic amputees compared to traumatic amputees may be related to neuropathy[42] and retinopathy,[43] which are common complications in diabetic patients and affect the sensory system. Following transtibial amputation, proprioceptive input from the foot and ankle is lost, which is essential for motor control of balance and gait. It is concluded that the loss of active joint movement control due to amputation and impaired sensory feedback in diabetic amputees negatively affect balance.

In a study by Burger et al.[9] on transtibial and transfemoral amputees in relation to functional capacity, participants walked for nine minutes, and the distance covered was recorded, revealing a statistically significant difference. The lower functional capacity observed in vascular amputees compared to the traumatic group may be attributed to to the greater impact of chronic disease in the vascular group, potentially exacerbated by advancing age. Since vascular disease is a chronic condition, and all amputees in this group were over 60 years old, the progression of the disease may have contributed to the observed differences In a study by Atic et al.,[44] a significant difference in favor of the traumatic group was observed when comparing the distance walked in the 6MWT between traumatic and vascular amputees.

Additionally, 61 traumatic amputees and 29 non-traumatic amputees (including individuals with diabetes mellitus) were assessed using the Two-Minute Walk Test, with results showing a significant advantage for the traumatic amputee group.[45]

When the results of the 6MWT, used to assess functional capacity in our study, were analyzed, a significant difference in favor of the traumatic group was found, consistent with the literature. This difference is believed to result from factors such as better balance, favorable gait parameters (SL, NSL, ASL) in the traumatic group, the inability of the diabetic group to receive sensory feedback from the ankle joint due to reduced deep sensations such as proprioception, and higher energy expenditure in diabetic amputees compared to traumatic amputees.[15,30,46,47]

In a study evaluating functional mobility, traumatic amputees required an average of 13.9 seconds to complete the TUG, while amputees with peripheral vascular disease required 18.7 seconds, with no statistically significant difference found between the groups.[9] Jayakaran et al.[48] also compared TUG results between traumatic and vascular amputees and reported no significant difference. The TUG and SCT are tools that evaluate functional abilities relevant to daily life activities. It is believed that factors such as active lifestyles, long daily prosthesis wear time, good QoL, and comfortable, pain-free prosthetic-assisted mobility contribute to the TUG results in diabetic amputees. Additionally, symmetric and controlled gait patterns and balance-related mechanisms may explain why diabetic amputees require more time to complete the SCT. Since stair climbing is a more complex and energy-intensive task compared to TUG, this may further account for the observed differences.

In a study assessing QoL using the eight subscales of the SF-36, a significant difference in favor of the traumatic group was reported when comparing mean scores between vascular and traumatic TTAs.[44] Similarly, Jayakaran[49] assessed vascular and traumatic unilateral TTAs using the EuroQoL (EQ-5D™) scale and found that individuals with vascular amputation had significantly lower QoL scores. Demet et al.[50] assessed health-related QoL using the Nottingham Health Profile and compared the results of traumatic and vascular amputees, reporting that vascular amputees had more negative outcomes in the physical disability and social isolation subscales. In contrast to previous studies in the literature, our study found no significant difference between the diabetic and traumatic groups in any subscale of the SF-36 when comparing QoL parameters.[51,52] Given that diabetic amputees often experience impaired gait and balance, reduced functional capacity, and diminished functional skills, they are typically expected to have lower QoL due to the negative impact on activity and social participation. However, in our study, factors such as diabetic amputees wearing their prostheses for an average of 11 hours per day, using VASS prostheses, being satisfied with their prostheses, feeling physically well, and actively participating in social life are believed to have contributed positively to their QoL.

Studies on vascular lower extremity amputees have reported low levels of prosthesis satisfaction.[23] One study comparing the TAPES scores of traumatic and vascular lower extremity amputees found a significant difference in favor of the traumatic group.[44]

In our study, statistical comparison of TAPES scores revealed a significant difference in favor of the traumatic group only in the activity restriction subscale. It was concluded that the difference in activity restriction was due to the high difficulty level of the questions in this section, which included activities such as running, lifting a heavy object, engaging in high-intensity sports, climbing multiple flights of stairs, and trying to catch a bus. No significant difference was found between the psychosocial adjustment and prosthesis satisfaction subsections of the TAPES. The main factors reported to increase prosthesis satisfaction and psychosocial adjustment include the use of a VASS prosthesis, which has been shown to increase comfort, reduce pain,[53] improve compliance with the prosthesis,[14] and minimize pistoning between the residual limb and the socket.[33,34] When selecting a prosthesis and suspension system, it may be beneficial to consider not only the functional requirements of the amputee but also their satisfaction with the prosthesis. In our study, no difference was observed between traumatic and diabetes-related amputees in terms of prosthesis satisfaction and psychosocial adjustment. Factors such as younger age, long daily prosthesis use, good quality of life, active prosthesis use, and social integration were considered important contributors to these findings.

CONCLUSION

In our study, the use of a VASS prosthesis in diabetic amputees helped them achieve results similar to those of traumatic amputees. This improvement enhanced their adaptation to social life, increased activity levels, and contributed to their psychological well-being. A more comprehensive study focusing on the causes of amputation, levels of amputation, and the effects of different suspension systems will aid in the optimal selection of prosthetic systems. It is believed that the ability of diabetic amputees to use their prostheses for as long as traumatic amputees, their active lifestyles, and the appropriate selection of prosthesis and suspension systems will greatly assist healthcare professionals in rehabilitation planning.

Ethics Committee Approval: This study was approved by the Hacettepe University Non-Interventional Clinical Research Ethics Committee (Date: 07/05/2019, Decision No: 20129/12-22).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: F.E.; Design: F.E., N.T.; Supervision: F.E.; Resource: F.E., N.T.; Materials: F.E., N.T.; Data Collection and/or Processing: N.T.; Analysis and/or Interpretation: N.T.; Literature Review: F.E., N.T.; Writing: F.E., N.T.; Critical Review: F.E.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

REFERENCES

1. Ham R, Cotton L. The history of amputation surgery and prosthetics. In: Limb amputation. Boston, MA: Springer US; 1991. p. 1-11. [CrossRef]
2. Cherelle P, Mathijssen G, Wang Q, Vanderborght B, Lefeber D. Advances in propulsive bionic feet and their actuation principles. Adv Mech Eng 2014;6. [CrossRef]
3. Imam B, Miller WC, Finlayson HC, Eng JJ, Jarus T. Incidence of lower limb amputation in Canada. Can J Public Health 2017;108:e374-80. [CrossRef]
4. Silverman AK, Fey NP, Portillo A, Walden JG, Bosker G, Neptune RR. Compensatory mechanisms in below-knee amputee gait in response to increasing steady-state walking speeds. Gait Posture 2008;28:602-9. [CrossRef]
5. Baker R, McGinley JL, Schwartz MH, Beynon S, Rozumalski A, Graham HK, et al. The gait profile score and movement analysis profile. Gait Posture 2009;30:265-9. [CrossRef]
6. Pedrinelli A, Saito M, Coelho RF, Fontes RB, Guarniero R. Comparative study of the strength of the flexor and extensor muscles of the knee through isokinetic evaluation in normal subjects and patients subjected to trans-tibial amputation. Prosthet Orthot Int 2002;2:195-205. [CrossRef]
7. Seth M, Lamberg E. Standing balance in people with trans-tibial amputation due to vascular causes: A literature review. Prosthet Orthot Int 2017;41:345-55. [CrossRef]
8. El Ghailassi I, Hashim NA, Abd Razak NA, Osman NA, Gholizadeh H, Astuti SD. Investigation of EMG parameters for transtibial amputees while treadmill walking with different speeds: A preliminary study. IEEE Access 2024;12:27356-67. [CrossRef]
9. Burger H, Marincek C. Functional testing of elderly subjects after lower limb amputation. Prosthet Orthot Int 2001;25:102-7. [CrossRef]
10. Brunelli S, Bonanni C, Foti C, Traballesi M. A literature review of the quality of life, health status and prosthesis satisfaction in older patients with a trans-tibial amputation. Can Prosthet Orthot J 2020;2:33640. [CrossRef]
11. Au SK, Weber J, Herr H. Powered ankle-foot prosthesis improves walking metabolic economy. IEEE Trans Robot 2009;25:51-66. [CrossRef]
12. Al-Fakih EA, Abu Osman NA, Mahmad Adikan FR. Techniques for interface stress measurements within prosthetic sockets of transtibial amputees: A review of the past 50 years of research. Sensors (Basel) 2016;16:1119. [CrossRef]
13. Seth M, Beisheim EH, Spencer MT, Horne JR, Sarlo FB, Sions JM. Self-reported socket comfort, mobility, and balance-confidence of individuals with transtibial amputation using pinlock vs suction suspension. Prosthet Orthot Int 2021;45:214-20. [CrossRef]
14. Çerezci Duygu S, Külünkoğlu B, Erbahçeci F. A comparison of the effects of pin and vacuum-assisted suspension systems in individuals with transtibial amputation. J Prosthet Orthot 2023;35:25-31. [CrossRef]
15. Waters RL, Mulroy S. The energy expenditure of normal and pathologic gait. Gait Posture 1999;9:207-31. [CrossRef]
16. Markatos K, Karamanou M, Saranteas T, Mavrogenis AF. Hallmarks of amputation surgery. Int Orthop 2019;43:493-9. [CrossRef]
17. Diasu. 3D ultrasensor baropodometric & stabilometric platform. Available from: https://diasu.com/wp-content/uploads/2019/03/3D-UltraSensor-Baropodometer-Technical-card.pdf. Accessed Feb 17, 2025. [CrossRef]
18. Dobson F, Hinman RS, Hall M, Terwee CB, Roos EM, Bennell KL. Measurement properties of performance-based measures to assess physical function in hip and knee osteoarthritis: A systematic review. Osteoarthritis Cartilage 2012;20:1548-62. [CrossRef]
19. De Laat FA, Rommers GM, Geertzen JH, Roorda LD. Construct validity and test-retest reliability of the climbing stairs questionnaire in lower-limb amputees. Arch Phys Med Rehabil 2010;91:1396-401. [CrossRef]
20. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39:142-8. [CrossRef]
21. Resnik L, Borgia M. Reliability of outcome measures for people with lower-limb amputations: Distinguishing true change from statistical error. Phys Ther 2011;91:555-65. [CrossRef]
22. Ülger Ö, Topuz S, Bayramlar K, Erbahçeci F, Yakut Y, Şener G. Diz altı amputelerde klasik yürüme eğitimi ve Biodex Gait Trainer 2TM ile yapılan yürüme eğitiminin karşılaştırılması. Fizyoter Rehabil

2009;20:70-5. [CrossRef]
23. Topuz S, Ülger Ö, Yakut Y, Gül Şener F. Reliability and construct validity of the Turkish version of the trinity amputation and prosthetic experience scales (TAPES) in lower limb amputees. Prosthet Orthot Int 2011;35:201-6. [CrossRef]
24. Bilir Kaya B, İçağasıoğlu A. Reliability and validity of the Turkish version of Short Form 36 (SF-36) in patients with rheumatoid arthritis. J Surg Med. 2018;2(1):11-6. [CrossRef]
25. Akhbari B, Salavati M, Mohammadi F, Safavi-Farokhi Z. Intra- and inter-session reliability of static and dynamic postural control in participants with and without patellofemoral pain syndrome. Physiother Can 2015;67:248-53. [CrossRef]
26. Highsmith MJ, Schulz BW, Hart-Hughes S, Latlief GA, Phillips SL. Differences in the spatiotemporal parameters of transtibial and transfemoral amputee gait. J Prosthet Orthot 2010;22:26-30. [CrossRef]
27. Lamoth CJ, Ainsworth E, Polomski W, Houdijk H. Variability and stability analysis of walking of transfemoral amputees. Med Eng Phys 2010;32:1009-14. [CrossRef]
28. Robinson JL, Smidt GL, Arora JS. Accelerographic, temporal, and distance gait factors in below-knee amputees. Phys Ther 1977;57:898-904. [CrossRef]
29. Nakajima H, Yamamoto S, Katsuhira J. Effects of diabetic peripheral neuropathy on gait in vascular trans-tibial amputees. Clinical Biomechanics [Internet] 2018 Jul56:84-9. [CrossRef]
30. Waters RL, Perry J, Antonelli D, Hislop H. Energy cost of walking of amputees: the influence of level of amputation. J Bone Joint Surg Am 1976;58:42-6. [CrossRef]
31. Parker K, Hanada E, Adderson J. Gait variability and regularity of people with transtibial amputations. Gait Posture 2013;37:269-73. [CrossRef]
32. Hermodsson Y, Ekdahl C, Persson BM, Roxendal G. Gait in male trans-tibial amputees: a comparative study with healthy subjects in relation to walking speed. Prosthet Orthot Int 1994;18:68-77. [CrossRef]
33. Board WJ, Street GM, Caspers C. A comparison of trans-tibial amputee suction and vacuum socket conditions. Prosthet Orthot Int 2001;25:202-9. [CrossRef]
34. Segal AD, Orendurff MS, Klute GK, McDowell ML, Pecoraro JA, Shofer J, et al. Kinematic and kinetic comparisons of transfemoral amputee gait using C-Leg and Mauch SNS prosthetic knees. J Rehabil Res Dev 2006;43:857-70. [CrossRef]
35. Nolan L, Lees A. The functional demands on the intact limb during walking for active trans-femoral and trans-tibial amputees. Prosthet Orthot Int 2000;24:117-25. [CrossRef]
36. Eissa M, Zayat SAF El, Ghit MM, Gomaa B. Symmetry of Body Weight Pressure Distribution on Sound Limb Foot of Unilateral Amputees During Walking. AIMJ 2023;4:17. [CrossRef]
37. Hermodsson Y, Ekdahl C, Persson BM, Roxendal G. Standing balance in trans-tibial amputees following vascular disease or trauma: a comparative study with healthy subjects. Prosthet Orthot Int 1994;18:150-8. [CrossRef]
38. Viton JM, Mouchnino L, Mille ML, Cincera M, Delarque A, Pedotti A, et al. Equilibrium and movement control strategies in trans-tibial amputees. Prosthet Orthot Int 2000;24:108-16. [CrossRef]
39. Kolářová B, Janura M, Svoboda Z, Kolář P, Tečová D, Elfmark M. Postural Control Strategies and Balance-Related Factors in Individuals with Traumatic Transtibial Amputations. Sensors (Basel) 2021;21:7284. [CrossRef]
40. Molina-Rueda F, Molero-Sánchez A, Carratalá-Tejada M, Cuesta-Gómez A, Miangolarra-Page JC, Alguacil-Diego IM. Limits of stability in patients with vascular (due to diabetes) and nonvascular unilateral transtibial amputation: a cross-sectional study. Int J Rehabil Res 2017;40:227-31. [CrossRef]
41. Agrawal V, O'Toole C, Gaunaurd IA, Gailey RS. Analysis of weight distribution strategies in unilateral transtibial amputees during the stand-to-sit activity. Ergonomics 2016;59:121-9. [CrossRef]
42. Wheeler S, Singh N, Boyko EJ. The Epidemiology of Diabetic Neuropathy. In: Diabetic Neuropathy. Totowa, NJ: Humana Press; p. 7-30. [CrossRef]
43. Thomas RL, Dunstan F, Luzio SD, Roy Chowdury S, Hale SL, North RV, et al. Incidence of diabetic retinopathy in people with type 2 diabetes mellitus attending the Diabetic Retinopathy Screening Service for Wales: retrospective analysis. BMJ 2012;344:e874. [CrossRef]
44. Atiç R, Aydın A. Comparison of the demographic and clinical characteristics, functional status and quality of life of lower extremity amputees to identify the reason for undergoing amputation. J Back Musculoskelet Rehabil 2018;31:973-9. [CrossRef]
45. Ghazali MF, Abd Razak NA, Abu Osman NA, Gholizadeh H. Awareness, potential factors, and post-amputation care of stump flexion contractures among transtibial amputees. Turk J Phys Med Rehabil 2018;64:268-76. [CrossRef]
46. Blessey RL, Hislop HJ, Waters RL, Antonelli D. Metabolic energy cost of unrestrained walking. Phys Ther 1976;56:1019-24. [CrossRef]
47. Czerniecki JM, Morgenroth DC. Metabolic energy expenditure of ambulation in lower extremity amputees: what have we learned and what are the next steps? Disabil Rehabil 2017;39:143-51. [CrossRef]
48. Jayakaran P, Johnson GM, Sullivan SJ. Turning performance in persons with a dysvascular transtibial amputation. Prosthet Orthot Int 2014;38:75-8. [CrossRef]
49. Jayakaran P, Perry M, Hale L. Comparison of self-reported physical activity levels and quality of life between individuals with dysvascular and non-dysvascular below-knee amputation: A cross-sectional study. Disabil Health J 2019;12:235-41. [CrossRef]
50. Demet K, Martinet N, Guillemin F, Paysant J, André JM. Health related quality of life and related factors in 539 persons with amputation of upper and lower limb. Disabil Rehabil 2003;25:480-6. [CrossRef]
51. Samuelsson KA, Töytäri O, Salminen AL, Brandt A. Effects of lower limb prosthesis on activity, participation, and quality of life: a systematic review. Prosthet Orthot Int 2012;36:145-58. [CrossRef]
52. Langford J, Dillon MP, Granger CL, Barr C. Physical activity participation amongst individuals with lower limb amputation. Disabil Rehabil 2019;41:1063-70. [CrossRef]
53. Arndt B, Caldwell R, Fatone S. Use of a Partial Foot Prosthesis With Vacuum-Assisted Suspension: A Case Study. JPO 23:82-8. [CrossRef]

ORİJİNAL ÇALIŞMA - *ÖZ*

Yürüyüş parametreleri ve fonksiyonel kapasite açısından travma ve diabetes mellitus nedenli transtibial amputelerin karşılaştırılması

AMAÇ: Bu çalışmanın amacı diyabetik ve travmatik transtibial amputelerin (TTA) yürüyüş parametreleri, denge, ağırlık aktarma simetrisi, fonksiyonel kapasite, fonksiyonel mobilite, protez memnuniyeti ve yaşam kalitesi sonuçlarını karşılaştırmak.

GEREÇ VE YÖNTEM: 10 travma 10 diyabet nedenli TTA birey çalışmaya dahil edildi. Travma ve diyabet gruplarında yer alan amputelerin tamamı aktif vakum sistem (AVS), karbon kompozit ayaklı transtibial protez kullanmaktaydı. Yürüyüş analizi ve ağırlık aktarma simetrisi bilgisayarlı yürüyüş analizi sistemi, denge Biodex Denge Sistemi (BBS), fonksiyonel kapasite Altı Dakika Yürüme Testi (6MWT), fonksiyonel mobilite Zamanlı Kalk Yürü Testi (TUG) ve Merdiven Çıkma Testi (SCT), protez memnuniyeti Trinity Amputasyon ve Protez Deneyim Ölçeği (TAPES) ve yaşam kalitesi Kısa Form-36 (SF-36) ile değerlendirildi.

BULGULAR: Travmatik ve diyabetik grup sonuçları karşılaştırıldığında yürüyüş parametrelerinden çift adım uzunluğu (ÇAU) (p=.004), ampute ekstremite adım uzunluğu (AAU) (p=.019), sağlam ekstremite adım uzunluğu (SAU) (p=.005), denge değerlendirmesinin parametreleri olan genel postural stabilite (p=.000), anterio-posterior (A-P) postural stabilite (p=.000), medio-lateral (M-L) postural stabilite (p=.007), SCT (p=.000), TAPES'in aktivite kısıtlanması alt bölümü (p=.029) parametreleri arasında travmatik grup lehine anlamlı fark bulundu. Hız, kadans, adım genişliği, ampute ve sağlam ekstremite ağırlık taşıma yüzdeleri, TUG, SF-36 ve TAPES (Psiko-sosyal Uyum, Protez Memnuniyeti, Günlük Kullanım Süresi alt bölümleri) parametreleri arasında anlamlı fark bulunmadı.

SONUÇ: Çalışmamızda travmatik ve diyabetik amputelerin aktif vakum sistem protez kullanmaları özellikle diyabetik amputelerin sonuçlarına olumlu yansımış, travmatik amputelerle yakın sonuçların ortaya çıkmasına katkı sağlamıştır. Diyabetik amputelerin protezlerini travmatik amputeler kadar uzun süre kullanmaları, aktif olmaları, protez ve suspansiyon sistem seçimi rehabilitasyonu kolaylaştırıcı faktör olarak ilgili sağlık profesyonellerine farklı bir bakış açısı sağlayabilir.

Anahtar sözcükler: Ampute; denge; diabetes mellitus; transtibial; travma; yürüyüş.

Ulus Travma Acil Cerrahi Derg 2025;31(3):259-268 DOI: 10.14744/tjtes.2024.83923