## Title

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# Falls after Dysvascular Transtibial Amputation: A Secondary Analysis of Falling Characteristics and Reduced Physical Performance.

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## Abstract

**Introduction:** Over half of all people with lower limb amputation (LLA) experience at least one fall annually. Furthermore, the majority of LLAs result from dysvascular health complications, contributing to balance deficits. However, fall-related research specific to dysvascular LLA remains limited.

**Objective:** To 1) characterize falls among adults with dysvascular LLA, using an existing Fall-Type Classification Framework and 2) to describe functional characteristics of participants across the framework categories.

**Design:** Secondary data analysis from two randomized controlled trials.

**Setting:** Outpatient setting.

**Participants:** People (n = 69) six months to five years from dysvascular lower extremity amputation, who were ≥ 50 years of age and independently ambulatory using a prosthesis.

**Intervention:** None.

**Outcome:** Descriptions of self-reported falls were collected on a weekly basis for 12 weeks, and analyzed using an existing Fall-Type Classification Framework. Fall frequencies, estimated count, and estimated proportions were compared across all framework categories, with 95% confidence intervals. Functional measures (Timed Up and Go, Two Minute Walk, Five Meter Walk, and

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average step count) were collected, and averages for each participant who experienced a fall were calculated.

**Results:** 30 participants (43.5%) reported 42 falls within 12 weeks. A variety of fall types were described. Incidence of falls were highest for intrinsic destabilization sources, from incorrect weight shift patterns, during transfer activities.

**Conclusion:** Patients with dysvascular LLA experience a variety of fall types. The high frequency of intrinsically sourced, incorrect weight shift falls during transfer activities emphasize the need to focus rehabilitation efforts on improving postural control in patients with dysvascular LLA during activities such as reaching, turning, and transferring.

## INTRODUCTION

Lower limb amputation (LLA) is associated with poor health outcomes, such as reduced strength, balance, proprioception,[1-4] low physical function,[5,6] and increased adverse events.[7-9] Over half the population living with LLA experience at least one fall annually, compared to 26% of the community-dwelling population without amputation.[10-12] Falls often lead to adverse health outcomes, such as injury,[3,13] activity avoidance,[10,14] increased medical costs,[15] and increased incidence of death.[16] Additionally, LLA due to complications related to diabetes mellitus (DM) and/or peripheral artery disease (PAD) further increases the risk of falls, through reduced balance, proprioception, and strength.[3,12,17-19] For individuals without amputation, DM and PAD are independently associated with peripheral nerve pathology, a decline in lower limb proprioception, and increased risk of falls.[18,20,21] As a result, the increased postural instability for people with dysvascular LLA poses a higher threat for falls and injury within the first seven years after LLA, in comparison to traumatic etiologies.[2,3,17,19,22,23]

Although older adults with dysvascular etiologies represent up to 80% of people with LLA,[24,25] fall-related research specific to dysvascular amputation remains limited. Current evidence for targeting interventions and clinical tests for identifying falls after LLA are generalized to all ages and etiologies for LLA.[9,10,12,17,26,27] In order to appropriately design interventions for patients at high risk for falls, it is important to classify the characteristics of falls among older adults with dysvascular LLA, and to examine fall types using common clinical evaluation tools.

A Fall-Type Classification Framework for LLA has been developed and tested with a heterogeneous sample of people with LLA.[8] As a result, interventions that target modifiable intrinsically sourced destabilizations to the base of support during walking activities (such as improving mobility and strength while navigating terrain obstacles), and prescription of prosthetic components that can safely respond to base of support disruptions were recommended interventions for people with LLA. However, the sample studied within the Framework represented relatively younger participants (average age of 50.6 years) with primarily traumatic etiology (59%) and an average of 16 years since LLA.

Therefore, the purpose of this study was to build upon the initial findings of the Fall-Type Classification Framework by characterizing falls among community-living older adults (≥ 50 years) within five years of dysvascular LLA. We hypothesized that the framework would successfully classify the incidence of falls and that category classifications would be unique to people with dysvascular LLA. A second aim was to describe participant physical function characteristics (performance measures and walking activity) across the Fall-Type Framework categories. We hypothesized that physical function characteristics would be specific to Fall-Type categories.

## METHODS

This study was a secondary analysis of fall data from two randomized control trials examining health behavior interventions for adults with dysvascular LLA [NCT01929018; NCT02738086]. The intervention in both trials was based on Social Cognitive and Control Theories of behavior change, and designed to promote exercise, walking activity, and disease self-management for people with dysvascular LLA.[28-32] Both trial protocols were reviewed and approved by the Colorado Multiple Institutional Review Board, and written informed consent was obtained. Detailed descriptions of methods, measures, and results for both trials are described elsewhere.[7,33] Data collection periods, measurements, and number of falls between study intervention and control groups were similar across both trials, allowing for combination of fall data. All measurements were collected at baseline and 12 weeks by a blinded assessor. Falls were self-reported by participants weekly over the 12-week time period, including details of how the fall occurred, prosthesis status, and location.

### Participants:

Participants were recruited from the Rocky Mountain Veterans Affairs Medical Center, the University of Colorado Health system, and other local clinical partners. Participants were included if they were ≥ 50 years of age, had a LLA between six months and five years prior to enrollment, had a diagnosis of Type II DM and/or PAD, and ambulated independently using a prosthesis. Age (>50 years) and time since LLA criteria were selected based on characteristics of dysvascular etiology for LLA.[24] Trauma or cancer related etiologies were excluded.

### Measurements:

**Falls:** During the 12-week intervention period, 30 minute interviews were conducted weekly with each participant, including a fall assessment. A fall was defined as "inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position." In the case of a reported fall, participants provided details on the event: fall location, prosthesis status relative to the limb (worn/not worn), activity at the time of fall, and cause of fall. All falls that occurred after baseline measurements and before the 12-week primary endpoint were analyzed.

**Demographics / Descriptive Data:** Descriptive data were collected for age, sex, body height, body mass, race, amputation level, time since amputation, and amputation etiology.

**Physical Function:** Clinical measures of physical function were selected based on their comprehensive representation of physical function for patients with LLA, and for their relevance and use in clinical practice.[34-36] All participants performed functional measures with their prosthesis at their home at the start (baseline) and end of the study intervention (12 weeks). Performance-based physical function (Timed Up-and-Go test [TUG],[37,38] the Two-Minute Walk test [TMW],[39] and Five Meter Walk test [FMW][34,40]) and walking activity (accelerometer-based step count)[41,42] were measured at both time points.

The TUG[37,38] is an assessment of basic mobility, and measured as the time (s) required for the participant to rise from a chair, walk 3 meters, return to the chair, and sit back down as quickly and safely as possible, using a handheld stopwatch and a 46-cm seat.[43] The TUG has established cut-off scores to indicate fall risk for people with LLA.[9,27] Each participant was provided one practice trial, and the average of two subsequent trials was reported.

The TMW is a measure of physical endurance, and measured as the total distance (m) walked over two minutes, with established validity for measuring exercise capacity in people with LLA.[39] Participants performed a single trial of the TMW on a level walkway ranging from 8-30 m, and were instructed to walk safely and cover as much ground as possible in the two minute time period. The total distance traveled in two minutes was used for the purposes of this study.

The FMW[34,40] is a measure of gait speed, and measured as the time required for a participant to walk five meters (s). Participants were instructed to walk at their “normal, everyday pace”, and the time required to walk the five meters was recorded. Results were converted to m/s for reporting gait speed. Participants performed the FMW on a smooth, level walkway, with a 3 meter acceleration and deceleration zone provided. Participants were provided one practice trial, and the average of two subsequent trials was reported.

Participants wore an accelerometer-based activity monitor (GT3X-BT, Actigraph, Pensacola, FL)[41,42] for 10 days on a waist belt during waking hours after the baseline data collection session. Validity and reliability for the monitors has been established for estimating free-living daily step count among people with LLA. [41,42,44,45] Actigraph data were analyzed using commercially available software (ActiLife 5/6[a]) to identify accelerometer wear-time and steps/day. Data were included if the participant had at least four days of >10 hours of wear time. Average daily step count was calculated for all days with valid wear time.

## Fall Classification

All falls were classified using the Fall-Type Classification Framework (Table 1).[8] The framework was developed from biomechanical theory, classifying falls by the location and source of the destabilizing force, and the resulting fall pattern. Three tiers of fall classification in this framework describe 1) falls according to the location of the destabilizing force: “Base of Support” (BOS), “Center of Mass” (COM), or “Other”; 2) falls according to the source of the destabilizing force: “Intrinsic” or “Extrinsic”; and 3) fall pattern (Table 1).

**Fall Framework:** For the purpose of this study, falls were classified sequentially through all tiers of the framework by three investigators (two primary and a third for confirmation/conflict resolution). If the fall description was insufficient for classification, it was reviewed and discussed among the investigators for potential inclusion as an amendment to the framework, or excluded for lack of detail.

**Fall Description:** Additionally, each fall was classified into three separate description categories: 1) activity (transfer/sit to stand transition, reaching/stationary activity, walking on level ground, walking on uneven ground, navigating curbs, navigating stairs, and other); 2) prosthesis status (on, off, fell off, or unclear); and 3) fall location (home or community).

### Statistical Analysis

Descriptive statistics were calculated for all participants, separated into participants who fell at least once (Fallers) and those who did not fall (Non-Fallers).

Fall frequency, proportion, and count were used as descriptors for analysis within 1) the Fall-Type Framework categories, and 2) the Fall Description categories. *Frequency* was defined as the total number of falls within each category (raw number and percentage among the total number of falls across all participants). *Proportion of participants who fell* was determined by quantifying each participant with at least one fall in each respective category relative to the total number of participants, multiplied by 100. If a participant experienced two or more falls, each fall was categorized only once within a category. Thus, proportions do not total to 100% within each tier of the framework, because participants with more than one fall in different categories were counted more than once. *Estimated count* (number of falls per participant) was determined by the total number of falls in each category relative to the total number of participants. 95% confidence intervals were calculated for all Fall-Type Framework and Fall Description categories.

Functional characteristics of participants who fell were determined by averaging the baseline TUG, TMW, FMW, and walking activity within each Fall-Type Framework tier. If a faller experienced one or more fall in a given category, their functional characteristic measurement was included once in the given category.

Proportion and counts were calculated, with 95% confidence intervals compared to a t-distribution, for each Fall-Type Framework and Fall Description category. Overlap of the 95% confidence intervals of proportions between Fall-Type Framework or Fall Description categories demonstrated no significant differences between categories. If a Faller group participant experienced a fall in multiple categories, their data were included once in each relevant category. Average TUG, TMW, FMW, and walking activity were calculated among the Fall-Type Framework categories.

## RESULT

### Fall prevalence

During the course of the two parent clinical trials, a total of 42 falls occurred for 30 participants within the total sample of 69 participants (0.61 falls/participant within 12 weeks) (Table 2). One fall was excluded due to insufficient detail. The remaining 41 falls were analyzed within the Fall-Type Classification Framework and Fall Description categories, where 30 participants reported at least one fall (43.5%), and 10 reported two or more falls (14.5%).

## Fall Description

From the 41 falls, all were classified into activity at the time of fall, prosthesis status, and fall location categories (Table 3). Four falls had insufficient detail about prosthesis status, and grouped into an “unknown” category.

**Activity at the Time of Fall:** The most common activity reported at the time of the fall was “transfer/sit-to-stand transition”, accounting for 12 of the 41 falls (29.3%). In addition, the greatest number of falls per participant (0.17 [0.08, 0.26]) and the greatest proportion of participants who fell (17.4% [8.4, 26.3]) experienced a transfer/sit to stand transition-type fall. However, there were no significant differences in the proportion of participants who fell or the average number of falls per participant across the fall activities (Table 3, Figure 1).

**Prosthesis status:** Participants were wearing their prosthesis for most falls (17 participants [56.7%], 21 falls [51.2%]). The number of falls per participant (0.30 [0.20, 0.41]) and the propotion of participants who fell while wearing their prosthesis (17 participants, 24.6% [14.5, 34.8]) was greater than all other categories of prosthesis use, but there were no significant differences in estimated counts or proportions between the prosthesis status at the time of the fall (Table 3, Figure 2).

**Location of Falls—**The majority of the falls occurred while the participant was home (22 participants [73.3%], 27 falls [65.8%]). The number of falls per participant (0.39 [0.28, 0.51]) and the proportion of participants who fell at home was greater than the number of falls per participant and proportion who fell while in the community (22 participants, 31.9% [20.9, 42.9]), but there were no significant differences in the estimated count or proportions between the fall locations. (Table 3, Figure 3).

## Fall-Type Classification Framework

41 out of the total 42 falls were successfully classified into all but one category of the Fall-Type Classification Framework: Inadequate Base of Support.

**Tier One: BOS, COM, Other falls:** The COM falls was the most commonly categorized fall type, accounting for 16 of the 41 falls (39%). The number of falls per participant (0.23 [0.13, 0.33]) and the proportion of participants with a COM classified fall (14 participants, 20.3% [10.8, 29.8]) was larger than both BOS ( 0.19 [ 0.10, 0.28], and 18.8% [9.6, 28.1]) and Other classified falls (0.17 [0.08, 0.26], and 11.6% [4.0, 19.1]), but not significantly different across tier one of the framework (Table 4).

**Tier Two: Intrinsic vs. Extrinsic:** Intrinsic sources for destabilizing forces were most prevalent, accounting for 22 of the 41 falls (54%). The number of falls per participant (0.32 [0.21, 0.43]) and the proportion of participants with a fall from intrinsic destabilizing forces , 26.1% [15.7, 36.4]) was larger than the count and proportion of falls classified as extrinsic (0.28 [0.17, 0.38], and 18.8% [9.6, 28.1]), but not significantly different across the second tier of the framework.

**Tier 3: Fall patterns:** Inadequate weight shift was the most commonly reported fall pattern, accounting for 14 of the 41 falls assessed (34%). The number of falls per participant (0.20 [0.11, 0.30]) and the proportion of participants with inadequate weight shift falls (17.4% [8.4, 26.3]) was greater than all other fall pattern classifications, but no significant differences were detected across tier three of the framework.

### Physical Function Outcomes

On average, participants who experienced intrinsically sourced falls presented with slower gait speeds (0.74 meters/second [0.29]) and required more time to complete the TUG test (25.60 seconds [18.39]) (Table 5). Participants who experienced one or more falls had an average step count of 1579 ± 1365 steps per day (Table 2).

## DISCUSSION:

The purpose of this secondary analysis was to evaluate the use of an existing Fall-Type Classification Framework by 1) characterizing falls among community-living older adults within 5 years of dysvascular LLA, and to 2) describe physical function characteristics of participants across the framework categories. The results support the use of the framework for classifying falls among people with dysvascular LLA and suggest that fall types experienced by people with dysvascular LLA may be unique when compared to previously published data. Specifically, participants experienced a variety of falls, most frequently caused by intrinsic destabilization sources, from inadequate weight shift patterns, and during transfer-related functional activities. Furthermore, these findings suggest that routine clinical functional measure outcomes may be specific to fall types after dysvascular LLA.

The incidence of falls among people with dysvascular LLA was 43.5% (0.61 falls/participant) over the course of 12 weeks. If the fall rate is consistent across a 12-month period, these data suggest that participants experience multiple (2.4) falls annually. Our results are comparable to the large range of fall incidence reported by people with LLA over the course of one year (ranging 24%-80%).[8,17,46] Fall incidence of 29% among 40 participants over 6 months[27], and 16.5% over an average of 72.6 days of inpatient rehabilitation stay have previously been reported.[23] The higher incidence of falls in the current study may be in part due to the frequent (weekly) assessment, which is higher than existing published trials among people with LLA. Falls are often self-reported, and there is currently no validated standard time period for fall recollection.[47-50] Existing research has found three month recall of falls among older adults to be more accurate than one year recall, and suggest that annual surveys may underestimate the number of falls by ≥19%.[47] Additionally, the proportion of participants who fail to recall a fall ranges between 13 and 23%.[50,51] Lower recollection of falls may in part be a result of limited injury severity, resulting in less memorable falls. Because fall-related injuries in the current study did not extend past minor bruising and stiffness, the method of weekly assessment may have contributed to greater accounts of less memorable falls.

Transfers were the most common activity at the time of the fall, accounting for 29.3% of all falls and 17.4% of all participants. These results align with research of falls by patients with LLA in the hospital setting, where the majority of falls involved transfers (ranging 20% to 71%) or reaching and standing (ranging 8% to 29%).[16,52] Falls during transfers and standing activities are also frequently reported among older adults (>65 years),[53,54] stroke,[55] Parkinson's disease,[56] and spinal cord injury populations.[57] Furthermore, the high prevalence of falls among these patient populations early after discharge from rehabilitation programs suggest that patients lack the preparation to function independently in the home environment. Existing research supports extending task-oriented exercise programs beyond early rehabilitation for these similar groups.[55]

The Fall-Type Classification Framework successfully classified 41 out of 42 falls (97.6%), proving the Framework to be both comprehensive and robust for older adults within five years of dysvascular LLA. Only one fall could not be categorized, due to lack of detail. The Inadequate Base of Support Framework category was not used. However, Inadequate Base of Support falls have been reported in other samples of participants with LLA,[2,54] therefore we do not recommend removal of this category; it is p that people with LLA among different sub-populations (e.g., age, etiology) and/or different timing since amputation may present with different fall profiles.

The most frequent destabilizing force classifications were COM (14 participants [46.7%], 16 falls [39%]), indicating that a large number of falls were initiated by a perturbation that displaced the COM beyond the limits of base of support stability, such as an incorrect weight shift, push, pull or collision. This finding is contrary to an analysis of the framework within a sample of people with primarily traumatic LLA, which found the BOS classification of falls to be most frequent.[8] One possibility for the high incidence of COM classified falls may be the limited walking activity among participants for the current study sample (1109 steps per day), so it is unsurprising that less falls were classified as BOS falls.

Although this analysis consisted of community dwelling adults between six months and five years after amputation, the high prevalence of COM classified falls among dysvascular LLA is similar to fall descriptions for people with LLA in rehabilitation or inpatient hospital settings.[16,52,58] These results suggest that between six months and five years after amputation (beyond initial prosthetic rehabilitation), dysvascular patients with LLA may not be prepared for adequate functioning in their living environment. Characteristics of the COM destabilization in this analysis represent modifiable sources that are typically addressed during rehabilitation; balance and strength training are common interventions to improve safety and independence in performing activities of daily living. These findings suggest that people with dysvascular LLA may benefit from extended training and attention on safe methods for transfers prior to and/or during the first six months to five years after amputation. In addition to a high prevalence of COM type falls, the frequency of Other type falls (13 participants [43.3%], 13 falls [31.7%]), and falls where the prosthesis was off (10 participants [33.3%], 11 falls [26.8%]), suggest that patient education and therapy around prosthesis and assistive device use may require increased attention throughout the first several years after LLA, beyond inpatient and outpatient rehabilitation. These findings also align with research on patient falls during rehabilitation after LLA, where patients who fell most frequently demonstrated significantly less use of their prosthesis.[16]

COM falls occurred from both intrinsic sources (e.g., transferring to wheel chair/bed, reaching for objects) and extrinsic sources (e.g. being bumped, walking into a door). Other falls were characterized as “no apparent biomechanical disruption between the BOS and the COM”,[8] and also occurred from both intrinsic prosthetic and physiologic factors (e.g., prosthesis fell off while walking, prosthetic suspension or knee failure, low blood sugar, excessive alcohol use) and extrinsic sources (e.g., failure of wheel chair brakes). Intrinsic falls (from personal factors, such as muscle weakness)[8] were more frequent, which is consistent with research on falls in older adults.[2,59] Patients with dysvascular LLA are often challenged with increased age, additional comorbidities, and low functional capacity; these results indicate that such intrinsic factors may contribute uniquely to the high frequency of intrinsic falls within this group.

Inadequate weight shift (reaching, turning, and transfers)[8] was the most frequent fall pattern category, and contrary to Kim et al., where slips and trips were found to be significantly more common among people with primarily traumatic LLA.[8] Among community dwelling older adults, existing evidence supports balance-challenging exercise to prevent falls.[59] Currently, therapy dose and prescription after the first year with amputation is inconsistent.[34,60] These results suggest that people with dysvascular LLA experience falls during all basic activities of daily living, and may benefit from additional therapy focused on improving balance and body mechanics throughout the first several years after LLA.

This study successfully described physical function outcomes associated with fall-types. For example, falls from intrinsic destabilizing forces were associated with lower average FMW (0.74 m/s) and higher TUG test outcomes (25.6 s). Existing research has established thresholds for identifying patients with LLA at risk for multiple falls (TUG test thresholds ranging from 9.25 to 19 s).[9,27] The results from this study suggest a potential relationship between poor functional outcomes after dysvascular LLA and fall types. Future research is warranted to understand the relationship between physical function outcomes and fall type, to assist with clinical identification of fall risk and fall type.

This study demonstrates the potential clinical benefit of using the Fall-Type Classification Framework. Within this study, participants demonstrated a variety of fall types that may be difficult to treat without guidance. However, results suggest that the framework can distinguish fall-types among patients with dysvascular LLA, with potential to guide intervention tailoring to the source of falls. For example, identifying intrinsic COM falls during inadequate weight shifts among dysvascular LLA may indicate interventions that target functional tasks such as weight shifts and transfers. The results from this analysis support use of the Fall-Type Classification Framework for addressing and treating specific fall-types experienced by patients with dysvascular LLA.

### Limitations

The majority of participants in our sample were older white males within six months to five years of unilateral transtibial amputation, and results may not generalize to other populations. Due to the length of time since amputation, and lack of access to rehabilitation records, details of participant post-amputation rehabilitation care were not available. Additionally, falls were recorded over a relatively short period of 12 weeks, representing a limited window of fall experiences and factors influencing falls (i.e., seasonal influences).

The secondary analysis of falls within the Fall-Type Classification Framework was completed retrospectively and fall interviews were not standardized based upon the framework categories. Furthermore, participants in this study were pooled from two parent trials testing health behavior interventions. Of participants who fell, 14 were assigned to an intervention arm. The potential for the intervention influencing fall type and location could not be assessed with the given study designs, and results from this analysis should be interpreted accordingly. Additionally, participant activity types and frequencies may affect fall types, however details on specific activities were not available in the parent studies. Future research would benefit from using the framework for prospective documentation of falls in clinical practice and research.

## CONCLUSION

In conclusion, the Fall-Type Classification Framework successfully categorized falls among people with dysvascular LLA. In the first five years after amputation, a variety of falls are described, with the greatest frequency caused by intrinsic destabilization sources, from incorrect weight shift patterns, and during transfer-type activities. These results emphasize the need to focus rehabilitation efforts on improving capacity of people with dysvascular LLA to perform reaching, turning, and transferring. In addition, this work examined routine clinical measure outcomes associated with fall types.

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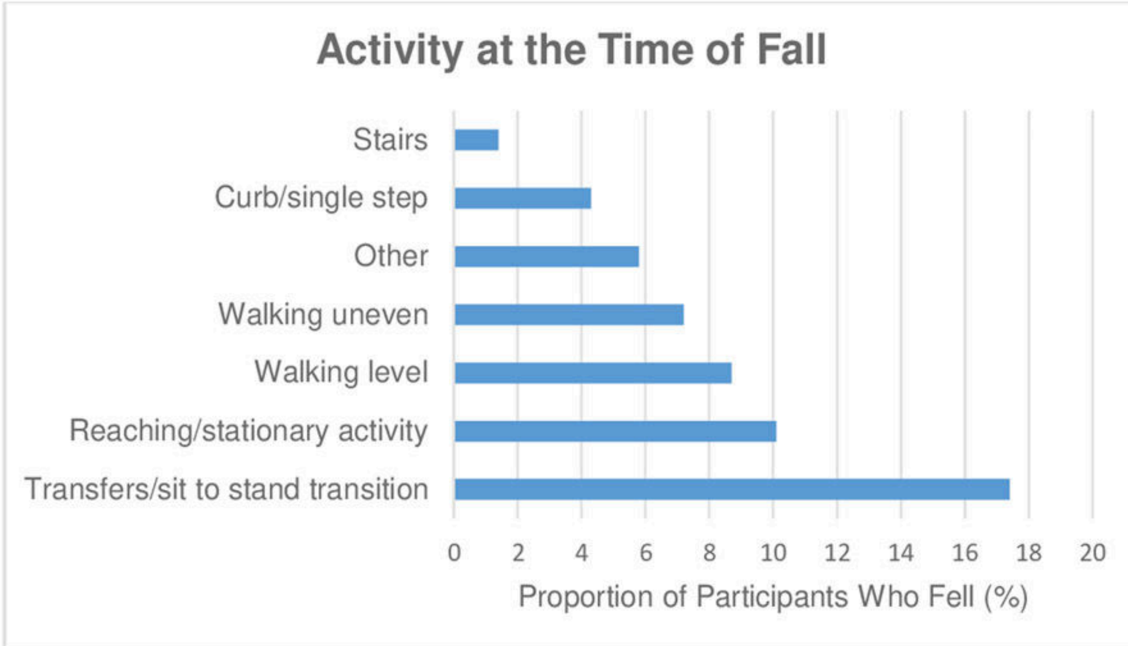


**Figure 1:**
Proportion of participants who fell during associated activities

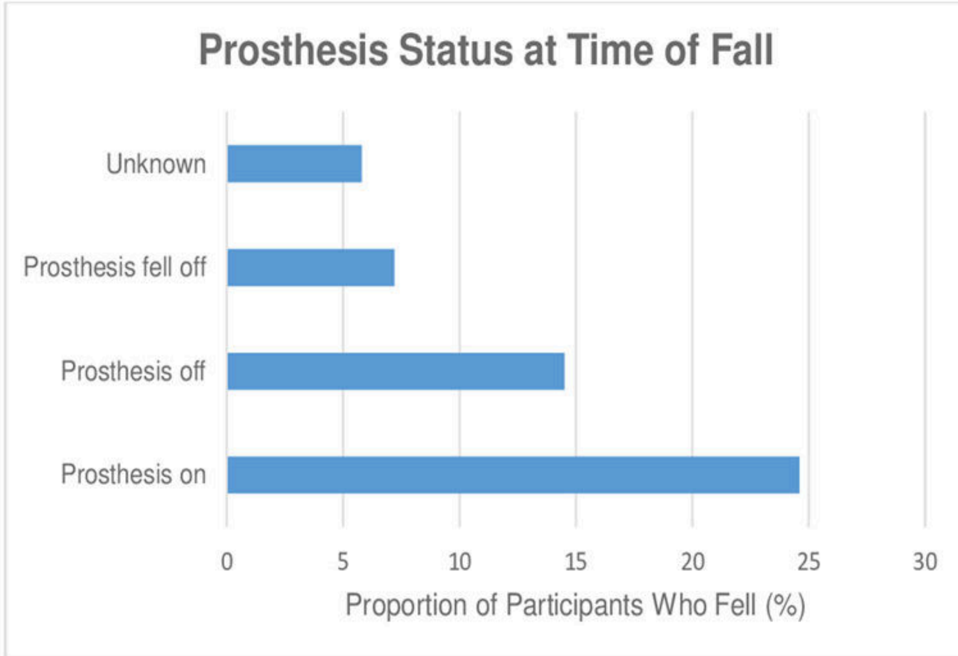


**Figure 2:**
Proportion of participants who fell in associated prosthesis status

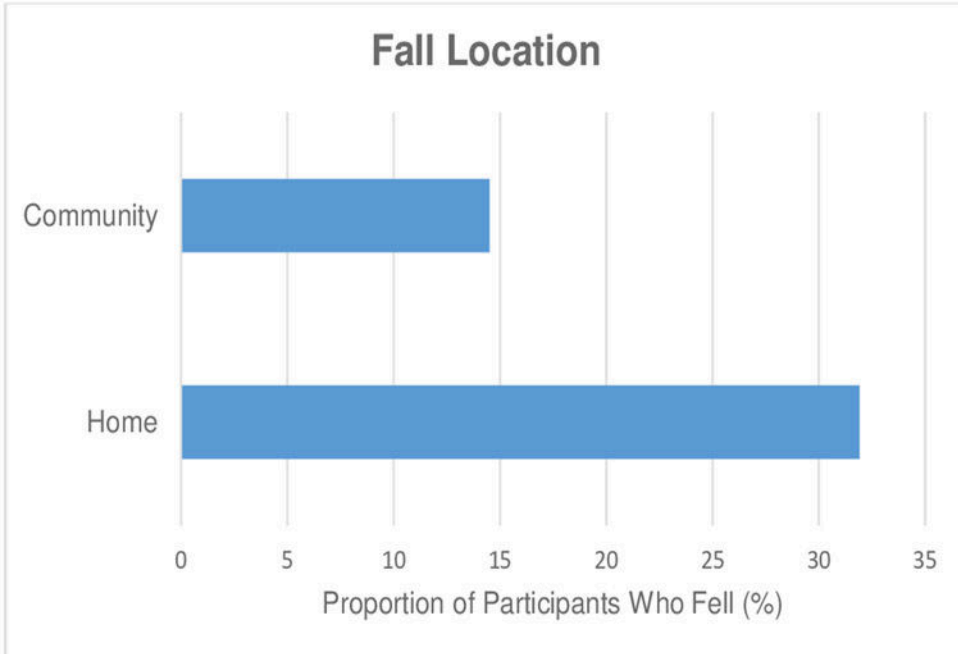


**Figure 3:**
Proportion of participants who fell in associated locations

**Table 1.**

Fall-Type Classification Framework.[1]

| Framework Category | Description |
|---|---|
| **TIER 1: Location of destabilizing force** | |
| Center of mass | Displacement of the center of mass beyond the limits of stability of the existing base of support (i.e., incorrect weight shift, push, pull or collision) |
| Base of support | Displacement of the base of support from beneath the center of mass (i.e., trip, stumble, slip, inadequate base of support) |
| Other | No apparent location for biomechanical disruptions (i.e., prosthetic, physiologic, or loss of external support). |
| **TIER 2: Source of Destabilizing Force** | |
| Intrinsic | Factors associated with the individual (i.e., muscle weakness) |
| Extrinsic | Initiated by factors associated with the environment (i.e., slippery surface, uneven surface). |
| **TIER 3: Fall Pattern** | |
| Inadequate weight shift | A self-induced shift of the center of mass beyond the existing base of support (e.g., reaching, turning, or transfer). |
| Trip | Caused by obstructed trajectory of the lower extremity on a surface (e.g., catching toe on surface from inadequate clearance, or catching foot on uneven surface) |
| Prosthetic factors | The prosthesis does not operate as intended (e.g., malfunction of components/parts of the prosthesis) |
| Slip | Due to insufficient friction between the foot and the surface (e.g., slipping on an icy surface). |
| Loss of external support | Caused by unexpected movement of a support structure (e.g., chair or walker moving unexpectedly during a transfer). |
| Push, pull, or collision | An extrinsic force applied to the center of mass (e.g., being pushed or pulled by someone from a stationary position, colliding or bumping into someone). |
| Physiologic factors | Occurring by a transient physiologic event (e.g., dizziness, seizure) |
| Inadequate base of support | An insufficient size of support surface (e.g., losing balance on a narrow step stool) |

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**Table 2:**

Demographics of Fallers vs Non-fallers

| Demographic Category | Fallers (n=30) Mean ± SD | Non-fallers (n=39) Mean ± SD | Difference, p value |
|---|---|---|---|
| Parent Study Group Assignment (n assigned to intervention group, %) | 14 (46.7%) | 21 (53.8%) | x-squared = 0.350 p=0.554 |
| Age (years) | 63.7 ± 8.51 | 65.18 ± 8.65 | 1.48, p=0.480 |
| Height (m) | 1.80 ± 0.087 | 1.78 ± 0.11 | 0.02, p=0.282 |
| Mass (kg) | 94.4 ±19.92 | 95.5 ± 22.9 | 1.10, p=0.839 |
| Level of amputation | 26 TTA[†]<br>1 TFA[‡]<br>1 TTA[†] & TFA[‡]<br>2 bilateral TTA[†] | 38 TTA[†]<br>1 KD[§] | x-squared = 6.18 p=0.186 |
| Race | 23 Caucasian<br>3 African American<br>3 American Indian/Alaska Native<br>1 unreported | 29 Caucasian<br>6 African American<br>3 American Indian/Alaska Native<br>1 unreported | x-squared = 0.527 p=0.913 |
| Time since amputation (weeks) | 57.81 ±67.97 | 68.75 ± 72.06 | 10.94, p=0.521 |
| Average timed up and go at baseline (seconds) | 20.53 ± 15.56 | 18.34 ±10.64 | 2.19, p=0.513 |
| Average two minute walk at baseline (feet traveled) | 298.2 ± 111.5 | 313.9 ± 121.58 | 15.7, p=0.582 |
| Average gait speed at baseline (meters/second) | 0.825 ± 0.278 | 0.866 ± 0.308 | 0.041, p=0.565 |
| Average step count at baseline (steps/day) | 1582.3 ± 1393.6 | 1669.7 ± 1386.2 | 87.4, p=0.796 |

[†]Transtibial Amputation

[‡]Transfemoral Amputation

[§]Knee Disarticulation Amputation

SD = standard deviation

**Table 3.**

Activity at the time of fall

| Descriptive Activity Categories | Participants who fell (n = 30) | Proportion of participants who fell (n = 69) | | Number of falls (n = 41) | Number of falls per participant (n = 69) | |
|---|---|---|---|---|---|---|
| | Number (%) | Estimated Proportion, % (SE) | 95% CI | Number (%) | Estimated Count, n (SE) | 95% CI |
| **Activity at the time of fall** | | | | | | |
| Transfer or Sit/Stand Transition | 12 (40.0%) | 17.4% (4.56) | (8.4, 26.3) | 12 (29.3%) | 0.17 (0.05) | (0.08, 0.26) |
| Reaching/Stationary Activity | 7 (23.3%) | 10.1% (3.63) | (3.0, 17.3) | 8 (19.5%) | 0.12 (0.04) | (0.04, 0.19) |
| Walking on Level Surface | 6 (20.0%) | 8.7% (3.39) | (2.0, 15.3) | 6 (14.6%) | 0.09 (0.04) | (0.03, 0.17) |
| Walking on Uneven Surface | 5 (16.7%) | 7.2% (3.12) | (1.1, 13.4) | 7 (17.1%) | 0.10 (0.04) | (0.03, 0.17) |
| Other | 4 (13.3%) | 5.8% (2.81) | (0.3, 11.3) | 4 (9.8%) | 0.06 (0.03) | (0, 0.11) |
| Curbs/Steps | 3 (10.0%) | 4.3% (2.46) | (0, 9.2) | 3 (7.3%) | 0.04 (0.02) | (0, 0.09) |
| Stair ascent/descent | 1 (3.3%) | 1.4% (1.4) | (0, 4.3) | 1 (2.4%) | 0.01 (0.01) | (0, 0.04) |
| **Prosthesis status at time of fall** | | | | | | |
| Prosthesis on | 17 (56.7%) | 24.6% (5.19) | (14.5, 34.8) | 21 (51.2%) | 0.30 (0.06) | (0.20, 0.41) |
| Prosthesis off | 10 (33.3%) | 14.5% (4.24) | (6.2, 22.8) | 11 (26.8%) | 0.16 (0.04) | (0.07, 0.25) |
| Prosthesis fell off | 5 (16.6%) | 7.2% (3.12) | (1.1, 13.4) | 5 (12.2%) | 0.07 (0.03) | (0.01, 0.13) |
| Unknown | 4 (13.3%) | 5.8% (2.81) | (0.3, 11.3) | 4 (9.8%) | 0.06 (0.03) | (0, 0.11) |
| **Location of Fall** | | | | | | |
| Home | 22 (73.3%) | 31.9% (5.61) | (20.9, 42.9) | 27 (65.8%) | 0.39 (0.06) | (0.28, 0.51) |
| Community | 10 (33.3%) | 14.5% (4.24) | (6.2, 22.9) | 14 (34.1%) | 0.20 (0.05) | (0.11, 0.30) |

SE = standard error

CI = confidence interval

**Table 4:**

Proportions of falls and average number of falls per participant in the Fall-Type Classification Framework

| Fall-Type Classification Framework Category | Participants who fell (n=30) | Proportion of participants who fell (n = 69) | | Number of falls (n=41) | Number of falls per participant (n = 69) | |
|---|---|---|---|---|---|---|
| | Number, (%) | Estimated Proportion, % (SE) | 95% CI | Number, (%) | Estimated Count, n (SE) | 95% CI |
| **TIER 1: Location of destabilizing Force** | | | | | | |
| Center of Mass | 14 (46.7%) | 20.3% (4.84) | (10.8, 29.8) | 16 (39.0%) | 0.23 (0.05) | (0.13, 0.33) |
| Other | 13 (43.3%) | 18.8% (4.71) | (9.6, 28.1) | 13 (31.7%) | 0.19 (0.05) | (0.10, 0.28) |
| Base of Support | 8 (26.7%) | 11.6% (3.85) | (4.0, 19.1) | 12 (29.3%) | 0.17 (0.05) | (0.08, 0.26) |
| **TIER 2: Source of Destabilizing Force** | | | | | | |
| Intrinsic | 18 (60.0%) | 26.1% (5.29) | (15.7, 36.4) | 22 (53.7%) | 0.32 (0.06) | (0.21, 0.43) |
| Extrinsic | 13 (43.3%) | 18.8% (4.71) | (9.6, 28.1) | 19 (46.3%) | 0.28 (0.05) | (0.17, 0.38) |
| **TIER 3: Fall Pattern** | | | | | | |
| Inadequate Weight Shift | 12 (40.0%) | 17.4% (4.56) | (8.4, 26.3) | 14 (34.1%) | 0.20 (0.05) | (0.11, 0.30) |
| Trip | 5 (16.7%) | 7.2% (3.12) | (1.1, 13.4) | 8 (19.6%) | 0.12 (0.04) | (0.04, 0.19) |
| Prosthetic Factors | 6 (20.0%) | 8.70% (3.39) | (2.1, 15.3) | 6 (14.6%) | 0.09 (0.03) | (0.02, 0.15) |
| Slip | 4 (13.3%) | 5.80% (2.81) | (2.8, 11.3) | 4 (9.8%) | 0.06 (0.03) | (0, 0.11) |
| Loss of External Support | 5 (16.7%) | 7.2% (3.12) | (1.1, 13.4) | 5 (12.2%) | 0.07 (0.03) | (0.01, 0.13) |
| Push, Pull, or Collision | 2 (6.7%) | 2.90% (4.00) | (0, 6.8) | 2 (4.9%) | 0.03 (0.02) | (0, 0.07) |
| Physiologic Factors | 2 (6.7%) | 2.90% (4.00) | (0, 6.8) | 2 (4.9%) | 0.03 (0.02) | (0, 0.07) |
| Inadequate Base of Support | 0 | 0 | 0 | 0 | 0 | 0 |

SE = standard error

CI = confidence interval

**Table 5.**

Falls and Functional Characteristics (Functional Performance Measures and Walking Activity)

| | TUG Seconds Mean (SD) | TMW Meters traveled Mean (SD) | FMW Meters/second Mean (SD) | Average Step Count Steps/day Mean (SD) |
|---|---|---|---|---|
| **Location of destabilizing force** | | | | |
| Center of Mass (n=14) | 27.47 (19.32) | 76.6 (38.0) | 0.69 (0.31) | 1188.7 (1172.7) |
| Other (n=13) | 18.83 (11.55) | 91.4 (28.2) | 0.83 (0.23) | 1478.2 (1235.6) |
| Base of Support (n=8) | 12.91 (3.82) | 104.9 (26.9) | 0.96 (0.19) | 2057.8 (1618.1) |
| **Source of Destabilizing Force** | | | | |
| **Intrinsic (n=18)** | 25.60 (18.39) | 83.5 (39.1) | 0.74 (0.29) | 1491.7 (1380.0) |
| Extrinsic (n=13) | 14.19 (6.10) | 99.9 (26.0) | 0.93 (0.24) | 1669.6 (1407.1) |
| Fall Pattern | | | | |
| Inadequate Weight Shift (n=12) | 30.12 (19.68) | 71.9 (38.1) | 0.63 (0.27) | 1231.3 (1268.6) |
| Trip (n=5) | 13.04 (5.03) | 107.2 (34.3) | 0.94 (0.21) | 2224.0 (2115.2) |
| Prosthetic Factors (n=6) | 21.46 (15.52) | 96.4 (36.9) | 0.84 (0.26) | 1478.2 (1390.4) |
| Slip (n=4) | 12.37 (0.75) | 100.0 (10.1) | 0.95 (0.19) | 1496.7 (586.23) |
| Loss of External Support (n=5) | 16.80 (8.43) | 84.6 (15.8) | 0.78 (0.20) | 1160.1 (796.5) |
| Push, Pull, or Collision (n=2) | 11.57 (1.67) | 104.5 (32.3) | 1.03 (0.42) | 933.1 (152.7) |
| Physiologic Factors (n=2) | 16.04 (5.81) | 93.3 (36.9) | 0.90 (0.29) | 2274.3 (2084.1) |
| Inadequate Base of Support (n=0) | 0 | 0 | 0 | 0 |

* indicates a significant difference in outcome from other categories within tier

CI = confidence interval