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ORIGINAL ARTICLE

Fall-related events in people who are lower limb prosthesis users: the lived experience

Janis Kim[a], Cody L. McDonald[b], Brian J. Hafner[b] and Andrew Sawers[a]

[a]Department of Kinesiology, University of Illinois at Chicago, Chicago, IL, USA; [b]Department of Rehabilitation Medicine, University of Washington, Seattle, WA, USA

ABSTRACT

Purpose: To explore lived experiences, and identify common themes as well as vocabulary associated with fall-related events in lower limb prosthesis (LLP) users.

Materials and methods: Five focus groups of LLP users from across the United States were conducted remotely *via* video or tele-conferencing. Focus group transcripts were coded and analyzed using methods adapted from a grounded theory approach to identify themes.

Results: Focus group participants (n = 25) described experiences associated with fall-related events that resulted in the identification of six themes: (1) memories of fall-related events are shaped by time and context, (2) location and ground conditions influence whether falls occur, (3) some activities come with more risk, (4) fall-related situations are multi-faceted, and often involve the prosthesis, (5) how LLP users land, but not the way they go down, tends to vary, and (6) not all falls affect LLP users, but some near-falls do.

Conclusion: Consideration for where LLP users fall, what they are doing when they fall, how they fall, what occurs as a result of a fall, and how well memory of a fall persists may enhance recording and reporting of falls, contribute to development of improved fall risk assessment tools, and inspire the design and function of prosthetic componentry for patient safety.

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➤ IMPLICATIONS FOR REHABILITATION

- Falls are a common problem in lower limb prosthesis (LLP) users that can lead to adverse health outcomes.
- Concerns over near falls, not just falls, may merit greater attention from rehabilitation professionals.
- Elements of the lived experience that appear unique to LLP users include the role of prosthetic fit, function, and comfort in losing and/or recovering balance; as well as the tendency of LLP users to modify rather than stop or avoid activities associated with falls.

Introduction

Over 50% of lower limb prosthesis (LLP) users report falling at least once a year [1–5], placing them at a high risk for adverse health outcomes like injuries, reduced mobility, and diminished quality of life [4,6,7]. Attempts to reduce falls among LLP users have focused on development and validation of clinical tests to assess fall risk [8–11], design and testing of prosthetic components to improve patient safety [12–15], characterization of deficits in balance recovery strategies [16–19], and identification of risk factors to help identify potential fallers [1,4,5,20]. While advances have been made in each of these areas, the prevalence of fall-related events among LLP users have remained elevated (i.e. at or around 50%) over the past three decades [2–5]. Largely absent, yet potentially beneficial to each of these areas, is consideration of the lived experience of fall-related events among LLP users.

LLP users' perspectives on falls have not been well studied, which means that researchers' and clinicians' views on balance and fall-related health outcomes are likely to be based on their own experiences – which may or may not be applicable to LLP users. LLP users are uniquely positioned to provide a first-person account of meaningful fall-related experiences, the effect(s) those experiences have on their lives, and the vocabulary they use to describe fall-related events. Qualitative methods have been used to explore lived experiences of LLP users associated with a number of health-related constructs, including mobility [21], low back pain [22], phantom limb pain [23], and quality of life [24,25]. Yet despite the frequency with which LLP users fall [2–5], the adverse health outcomes associated with falling [4,7], and the efforts undertaken to reduce falls [26,27], efforts to solicit and document lived experiences associated with fall-related events among LLP users have yet to be undertaken as they have in other clinical populations [28–33].

A qualitative exploration of how LLP users experience falls could advance our understanding of the factors that contribute to falls, guide our ability to assess balance, and reduce fall risk [2,34]. Discussion of common lived experiences associated with fall-related events may also serve to identify vocabulary surrounding these events that is unique to LLP users. With a better

CONTACT Andrew Sawers asawers@uic.edu Department of Kinesiology, University of Illinois at Chicago, 1919 West Taylor Street, Rm. 646, Chicago, 60612, IL, USA

understanding of the circumstances LLP users perceive as threatening to their balance, and knowledge of what constitutes meaningful and significant fall-related outcomes, clinicians and researchers may be able to better document "falls that matter" in a consistent and repeatable manner. Improved recording and reporting of meaningful fall-related events could, in turn, guide the revision or development of clinical tests that increase the accuracy of fall risk assessment, motivate the design and function of prosthetic componentry to improve patient safety, and direct investigations into biopsychosocial aspects of fall-related events that are important to LLP users.

The purpose of this study was to explore lived experiences, and identify common themes as well as vocabulary associated with fall-related events in LLP users. Focus groups with LLP users were conducted in an effort to identify and characterize shared experiences associated with fall-related events. This is the first study to document fall-related experiences from the perspective of LLP users.

Materials and methods

All focus groups were held between May and August 2019 and conducted remotely *via* video or telephone conferencing to solicit fall-related experiences from LLP users living across the United States. Study protocols were reviewed and approved by a University of Illinois at Chicago institutional review board. All individuals provided written electronic informed consent prior to participation.

Participants

Focus group participants were recruited from across the United States *via* research registries. LLP users had to meet the following inclusion criteria to be considered eligible to participate: (1) 18 years or older; (2) lower limb amputation at or between the hip and ankle; (3) current use of a lower limb prosthesis; (4) history of one or more falls; (5) able to speak, read, and write in English; (6) access to internet and electronic device (e.g. computer, tablet, or smartphone); and (7) agree to have the focus group discussion recorded and transcribed. Focus group candidates were excluded from participation if they were unable to complete self-report surveys or participate in a group discussion. No prior relationships existed between study team members and study participants.

Having met all inclusion and exclusion criteria, participants were purposively sampled based on pre-specified characteristics so as to solicit a range of perspectives regarding falls relevant to all LLP users [21,22,35–37]. Specifically, we attempted to place at least two participants per focus group who were transfemoral prosthesis users, bilateral LLP users, female, older than 50 years of age, of dysvascular etiology, less than one-year post amputation, and a Veteran or service member. In addition to demographic, health, and amputation characteristics that were collected, Prosthetic Limb Users Survey - Mobility (PLUS-M) T-scores, and Activities-specific Balance Confidence (ABC) scores were obtained to characterize the mobility and balance confidence of study participants. Focus group sizes were limited to 8 participants to facilitate input from all participants [35].

Procedures

Each focus group began with the same facilitator (JK) outlining the purpose of the study, and highlighting guidelines meant to encourage productive and respectful discussion. A semi-structured approach was then used by the facilitator to promote discussion of fall-related experiences [35,38]. Six open-ended guiding questions (Table 1), developed by a team of researchers and clinicians, were used to promote discussion of shared experiences and vocabulary related to falls in LLP users. Each of the guiding questions was modeled after published guidelines used in development of patient-reported outcome measures [35,39], focus groups for applied research [38], and similar questions used in previous studies investigating falls in LLP users and other clinical populations [40–42]. Follow-up questions were used throughout each focus group to clarify guiding questions and/or participants' statements. Focus group discussions were audiotaped and transcribed by a Communication Access Real-time Translation (CART) reporter to facilitate subsequent analysis [43].

Table 1. Guiding questions.

1. Let's begin by talking about what a fall means to you. In other words, how would you describe a fall?
2. Now I would like you all to think about the last time you fell. What do you remember about the last time you fell?
3. What kind of physical surroundings do you think have caused you to fall?
4. What types of situations do you think have caused you to fall?
5. What types of activities have you been engaged in when you fall?
6. Is there a direction you most often fall?
7. Have you ever experienced something negative, like an injury or change of activities, from a fall?

The same three research team members, two researchers (PhDs, one prosthetist-orthotist, and one bioengineer) and one PhD student (physical therapist), attended each focus group. A fourth research team member (PhD, prosthetist-orthotist) participated in the data analysis and dissemination efforts. All research team members have conducted and published research on balance and falls in LLP users. Two study team members were experienced in qualitative research methods. Following each focus group, research team members met to review the topics and ideas brought up and discussed by study participants. Decisions to modify or re-arrange the order of the guiding questions were also made during these review sessions. For example, the decision to ask about a fall recall time frame (i.e. duration) in guiding question 2 was made after the second focus group.

Analysis

Focus group transcripts were analyzed using methods adapted from a grounded theory approach [44–46] to understand the fall experience of LLP users. Specifically, a systematic approach to identify the meaning of a concept from the words and actions of participants, though the coding, sorting, and integrating of data verbatim was adopted [46]. Two research team members (JK, AS) reviewed the focus group transcripts to acquaint themselves with the data. The same two investigators, working independently, and using an initial set of codes based on fall-related literature [3,40,41,47–52], prior research [2], expert opinion, and attendance at the focus groups, then applied line-by-line open coding methods to locate, code, and annotate the transcripts for terms describing different aspects of falls (e.g. fall direction, injury, environment) [21]. The initial set of codes was revised and added to during the analysis as dictated by the data, and the emergence of new ideas or concepts. Coding procedures were documented in memos, and performed using Dedoose^{TM} (Manhattan Beach, CA, USA) qualitative software. JK and AS then reviewed the coded transcripts and applied axial coding methods to organize codes into themes (i.e. experiences shared by LLP users within and

Table 2. Participant characteristics across focus groups ($n = 25$).

Characteristics	FG 1 $n = 6$ *n*	FG 2 $n = 7$ *n*	FG 3 $n = 4$ *n*	FG 4 $n = 5$ *n*	FG 5 $n = 3$ *n*	Overall $n = 29$ *n* (%)
Gender						
Female	2	2	2	3	0	9 (36)
Etiology						
Diabetes	1	1	1	0	3	6 (24)
Trauma/accident	3	4	3	4	0	14 (56)
Infection	2	1	0	0	0	3 (12)
Tumor	0	0	0	1	0	1 (4)
Other	0	1	0	0	0	1 (4)
Amputation level (may have > 1)						
Bilateral	0	2	0	1	1	4 (16)
Transfemoral	3	2	1	3	0	9 (36)
Transtibial	2	5	3	1	3	14 (56)
Knee disarticulation	1	0	0	0	0	1 (4)
Ankle disarticulation	0	1	0	1	0	2 (8)
Other characteristics						
Over 50 years old	6	6	1	4	3	20 (80)
<1 year prosthetic experience	0	0	0	0	1	1 (4)
Military veteran	1	2	1	1	1	6 (24)

Table 3. Participant amputation, prosthesis characteristics, mobility, balance, and falls.

Characteristics	Mean	SD	Median	Q1–Q3	Min	Max
Age at time of focus group	59.6	12.8	59.0	53.5–68.0	25	81
Years since first amputation	20.8	16.1	17.0	8.0–30.0	1	51
Daily hours of prosthesis wear	14.0	3.32	15.5	13.5–16.0	3	18
Daily hours of walking with prosthesis	6.98	4.87	6	3.0–8.0	2	18
PLUS-M (T-score)	51.9	7.10	51.2	47.1–57.3	38.4	67.1
ABC (/4)	2.69	0.79	2.81	2.25–3.38	0.4	3.9
Number of falls in past 6 months	1.48	1.29	1	1–2	0	5
Number of falls in past 12 months	2.63	2.32	2	1–3	0	10

ABC: Activities-specific Balance Confidence scale; PLUS-M: Prosthesis Limb Users Survey - Mobility.

across focus groups). Disagreements were discussed and consensus was reached through a third investigator (CM). Following the third focus group, review sessions included an assessment of saturation. Thematic saturation was defined as the point where no additional experiences were emerging, and the code list had stabilized [53]. After five focus groups, it was determined that saturation was achieved and data collection was concluded.

Results

Forty focus group candidates were recruited and screened. Thirty were scheduled after meeting study inclusion and exclusion criteria. Five candidates did not attend their scheduled focus groups due to changes in their personal schedules, thus 25 LLP users ultimately participated in the study (Tables 2 and 3). Five focus groups were conducted with three to eight participants and each focus group lasted between 80 to 100 min.

Focus group participants discussed a range of topics perceived as relevant to falls they had experienced, and/or falls by LLP users in general. Review and analysis of focus group transcripts resulted in the identification of six themes: (1) memories of fall-related events are shaped by time and context, (2) location and ground conditions influence whether falls occur, (3) some activities come with more risk, (4) fall-related situations are multi-faceted, and often involve the prosthesis, (5) how LLP users land, but not the way they go down, tends to vary, and (6) not all falls affect LLP users, but some near-falls do. Each of the themes, their supporting categories, and accompanying excerpts are presented below, and summarized in Table 4.

Theme 1: Memories of fall-related events are shaped by time and context

Memory of fall-related events was defined as the clarity and duration with which LLP users perceived that they could remember falls or near-falls, and their associated details. Two categories within the theme of memory were identified, timeframe and memory modifiers.

Timeframe

Participants across all focus groups described a range of times over which they believed fall-events and/or fall-related details remained memorable. The timeframes discussed could be grouped into three timespans: less than one-year, one- to two-years, and greater than two-years.

> *"I can give you details about the last fall I had because it was only a few weeks ago."* (sex: Female, age: 64 years old, level of amputation: TF, time since amputation: 8 years since amputation)

> "*How long, how far back can you remember a fall? 2 years.*" (Male, 68 years old, TF, 20 years since amputation)

> "*I can remember back into the early 2000s when I fell a number of times."* (Male, 65 years old, TT, 18 years since amputation)

When asked directly about a timeframe commonly used in falls research, 12-months [2,10,48,54], participants largely responded that a one-year timeframe seemed like a reasonable time to be able to recall details of the event.

> *"I think 12 months is a reasonable amount of time to definitely remember your falls and, you know, know when you have fallen and how you have fallen."* (Male, 54 years old, TT/TT, 5 years since amputation)

This was however, not universally agreed upon by all focus group participants.

> *"I have a hard time remembering, so 12 months is a long time."* (Female, 45 years old, TF, 32 years since amputation)

Memory modifiers

Importantly, participants described fall recall as being subject to factors that could enhance and/or diminish how memorable fall-related events were. These factors were termed memory modifiers. Memory modifiers discussed by participants included fall-related consequences (e.g. injury, embarrassment), time-stamped events (e.g. amputation, first prosthesis), and personal factors (e.g. frequency of falls, and age). These modifiers could apply to a specific fall-event or more broadly to any fall-event. Physical injury and pain, as well as damage to the prosthesis, were described across focus groups as fall-related consequences that acted to increase how memorable a fall was.

> *"What happened to me, such as an injury, after the fall. That usually is the lasting memory."* (Female, 45 years old, TF, 32 years since amputation)

Emotional consequences such as embarrassment were also reported by participants as factors that could make a fall significantly more memorable.

> *"For me it's not just the physical aspect of getting hurt. If it happens, it happens. But it's the psychological aspect of oh, now people are really staring. I'm sure they watch when I'm out in public, but now after I have fallen, it's really that heightened sense of embarrassment. That is what makes the fall more memorable to me."* (Male, 54 years old, TT/TT, 5 years since amputation)

Table 4. Themes and categories.

Themes	Categories	Representative excerpts
Memories of fall-related events are shaped by time and context	Timeframe	"*I don't remember any specifics except the last two falls which were probably, one was two months ago and one was about a year and half ago.*" (Female, 64 years old, TF, 8 years since amputation)
		"*I have fallen within the last probably six to eight months*." (Female, 57 years old, TT, 4 years since amputation)
	Memory modifiers	"*I was thinking a week or two if I didn't hurt myself or wasn't embarrassed too bad. I can't imagine remembering it for very long.*" (Female, 66 years old, AD, 30 years since amputation)
		"*I fell three weeks after my amputation. I was using crutches and I stumble[d].*" (Female, 57 years old, TT, 4 years since amputation)
Location and ground conditions influence whether falls occur	Location	"*I don't remember ever falling inside the house.*" (Female, 66 years old, AD, 30 years since amputation)
		"*They have all been here at the house lately, the ones, you know, that I'm concerned about anyway.*" (Female, 59 years old, TF, 44 years since amputation)
	Ground condition	"*The ground surface, be it indoors or outdoors, the surface that you are walking on should also be a question [you] ask [about].*" (Female, 59 years old, TF, 44 years since amputation)
		"*Very rarely do they [falls] occur on a smooth or flat surface. It's always an uneven surface, loose gravel, sand, or even on the snow.*" (Male, 54 years old, TT/TT, 5 years since amputation)
Some activities come with more risk	Walking	"*It's just been walking*." (Female, 52 years old, TF, 30 years since amputation)
		"*It [is] only walking.*" (Male, 68 years old, TT, 9 years since amputation)
	Sit to stand	"*That's when I feel the most needy, getting up from the table when I lose my vacuum*." (Male, 59 years old, TT, 8 years since amputation)
		"*The second time that I fell, it was getting up from the commode and reaching for my walker.*" (Male, 71 years old, TT, 1 years since amputation)
	Recreational activities	"*Mostly I have fallen when I'm outside gardening.*" (Female, 66 years old, AD, 30 years since amputation)
		"*Me, it's vacuuming, with the cord wrapping around my pylon.*" (Female, 59 years old, TF, 44 years since amputation)
Fall-related situations are multifaceted and often involve the prosthesis	Prosthetic related situations	"*My vacuum leg loses vacuum and I'm ridiculously unstable just getting up from the table.*" (Male, 59 years old, TT, 8 years since amputation)
		"*I was walking down these steps and my foot actually broke*." (Male, 72 years old, TT/TT, 51 years since amputation)
	Altered mental states	"*I was sitting on the edge of the bed when I had my last fall, one of the few falls I have taken in my life. Just sitting there on the edge of the bed, I don't know, maybe I was half asleep*." (Male, 76 years old, TT, 50 years since amputation)
		"*Mostly [I fall] because when I wasn't paying attention*." (Male, 59 years old, TT, 17 years since amputation)
How LLP users land, but not the way they go down, tends to vary	Fall direction	"*I think all of my falls are going forward*." (Female, 43 years old, TT, 16 years since amputation)
		"*I tend to usually fall on my side*." (Female, 66 years old, AD, 30 years since amputation)
	Involved limb	"*Usually I catch my left leg which is the prosthesis*." (Male, 69 years old, TF, 50 years since amputation)
	Impact location	"*My priority is not to damage my head or my hands. I would prefer to bang up my shoulder, or you know, my hip or my side when I fall down*." (Male, 54 years old, TT/TT, 5 years since amputation)
	Strategies to minimize injury	"*I try to take the initial hit on the prosthesis. I can get the prosthesis fixed. It's easier to fix the prosthesis than it is my bones*." (Male, 71 years old, KD, 5 years since amputation)
		"*The falls that usually go forward, I just turn my shoulder in and roll. And I don't care if it's on a hardwood floor or out in the field with a horse, I rarely if ever get hurt*." (Male, 72 years old, TT/TT, 51 years since amputation)
Not all falls affect LLP users but some near-falls do	Behavior modification	"*You just need to go a little bit slower when you are carrying a bunch of things*." (Male, 68 years old, TF, 20 years since amputation)
	Physical injury	"*I mean, I have come up with bruises, I have come up with scratches, but the rotator cuff* [injury] *is the worst thing that has happened*." (Male, 71 years old, KD, 5 years since amputation)
	Psychological state	"*Long term the effect has been that, like others, I'm far more cautious that when I'm sitting on the edge of the bed and I put my left leg, which is not amputated, on the floor*." (Male, 76 years old, TT, 50 years since amputation)

AD: ankle disarticulation; F: female; KD: knee disarticulation; M: male; TF: transfemoral; TT: transtibial.

Similarly, falls occurring in proximity to specific time-stamped events such as the delivery of their first prosthesis, being discharged home, and especially their amputation, stood out as more memorable.

> "*It would have been November of '69, my first fall came when I was a brand new amputee and the physical therapist was attempting to teach me, one, how to use crutches and, two, how to go up and down the stairs, and I fell coming down the stairs. That was my first fall.*" (Male, 76 years old, TT, 50 years since amputation)

Theme 2: Location and ground conditions influence whether falls occur

Across focus groups, participants described a host of characteristics in their physical environment that they perceived to influence fall-related events.

> *"I think [my falls are], because of maybe my surroundings."* (Female, 43 years old, TT, 16 years since amputation)

The notion that one's surrounding environment is central to fall-related events, or affects LLP users exclusively, was however not universal.

> *"I don't think the environment was frequently the cause of the fall."* (Male, 81 years old, TF, 10 years since amputation)

Two categories, location and ground conditions, were identified as features of the physical environment that were perceived by LLP users to contribute to fall-related events.

Location

Most participants described fall locations using general terms (i.e. "indoors" or "inside", "outdoors" or "outside"), specific sites (i.e. "house", "backyard", "sidewalk"), as well as location-based activities that implied one's surroundings (i.e. "vacuuming", "hiking"). Multiple participants across focus groups perceived outdoor, rather than indoor locations to be more hazardous and more common settings for fall-related events.

> *"I'm exponentially more worried about an outside fall than I am of an inside fall."* (Male, 59 years old, TT, 8 years since amputation)

Indoor locations were however cited as settings for falls by some participants owing to balance difficulties due to limitations in space, or differences in behavior.

> *"Most of the time [my falls occur] around the house here. I guess it's because they are short movements, like the space or the area."* (Female, 59 years old, TF, 44 years since amputation)

The familiarity, or lack thereof, with one's surroundings was also believed to affect the likelihood of an indoor or outdoor fall. Fall-related events at indoor locations were often attributed to the familiarity of the surroundings, leading to a level of comfort and lack of attention. Outdoor fall-related events, however, were considered by participants to arise from a level of unfamiliarity, novelty, or surprise with the surrounding physical conditions.

> *"Also, indoors, when you're not paying attention, when you're around comfortable surroundings, you start getting lax [and are more likely to fall]."* (Male, 69 years old, TF, 50 years since amputation)

> *"Definitely when I'm outside, because in my home I know where all the bumps, all the door casings, you know, carpet versus tile areas are, so I know where those are at this point in time, so I don't even think about them."* (Male, 54 years old, TT/TT, 5 years since amputation amp)

Ground conditions

Focus group participants described a variety of surfaces, terrains, and obstacles contributing to fall-related events. Surfaces and terrain were considered continuous ground conditions, requiring multiple steps to navigate, and thus distinct from obstacles, which were considered discrete and requiring a single step to negotiate. Variants of all three ground conditions were reported for indoor and outdoor locations, however, many were viewed as unique to either indoor or outdoor locations.

Focus group participants as frequently highlighted two terrain variants leading to falls or near-falls; stairs, and inclines/declines/hills/slopes. Stairs were most often brought up in the context of indoor falls, while slopes were unique to outdoor falls.

> *"Going up and down things. Even in my own home, going up a simple little two stairs, but just catch the toe of the prosthesis on that second stair."* (Female, 58 years old, TT, 22 years since amputation)

> *"We were going down kind of a steep trail and my, you know, prosthetic foot just slipped out from under me and I fell on my rear end."* (Male, 46 years old, TF, 10 years since amputation)

Going down slopes/hills, and to a lesser degree stairs, was considered by focus group participants to be more hazardous than going up.

> *"Going down is much harder, and the reason is the ankle is fixed, and so if I'm going down, I wind up stepping only on my heel and it's much less steady than if I have the whole foot underneath me."* (Male, 81 years old, TF, 10 years since amputation)

Participants also described a variety of surface conditions. Most participants agreed that slippery surfaces, followed by uneven surfaces, were problematic and increased the likelihood of a fall-related event. Slippery surfaces were discussed in the context of both outdoor (e.g. rain, ice, mold), and indoor (e.g. shower) locations, uneven surfaces, however, were restricted to outdoor locations.

> *"For me the environment that I most feel unsafe and have fallen the most is slippery [surfaces], and not just necessarily [because of] ice or rain, but if my deck has been rained on and there's an area where maybe the sun doesn't hit as much and it might get either a little mossy or the leaves have been there, it's a little bit more slick."* (Female, 52 years old, TF, 30 years since amputation)

Obstacles were viewed by focus group participants as any object that could be found on a surface, or as part of the terrain. Rugs, towels, and cords were cited frequently as indoor obstacles, while curbs, cracks, rocks, branches, and roots were seen as common outdoor obstacles.

> *"If I have fallen inside, it's usually because my prosthetic foot has gotten caught on a rug or a towel or something that, you know, is loose."* (Male, 71 years old, KD, 5 years since amputation)

> *"A rock, a tree root, even uneven surfaces I will catch my foot on. I seldom catch it on smooth carpeting."* (Male, 54 years old, TT/TT, 5 years since amputation)

Theme 3: Some activities come with more risk

Walking as well as sit-to-stand transitions were frequently perceived by focus group participants as activities that could lead to instability, a loss of balance, and falls. A variety of reasons including looseness of the socket after prolonged sitting and moving too quickly were cited as explanations for the challenge associated with sit-to-stand transitions while wearing a prosthesis.

> *"If I work at a desk for more than a couple of hours or more than, let's say, an hour without getting up and walking around the table or something like that, the socket gets loose and that's a real problem because then I am massively unstable."* (Male, 81 years old, TF, 10 years since amputation)

> *"I notice when I try to get up too quickly and move at the same time as I get up, I stumble quite often. I need to stand up and make sure my balance is there before I start off. I have actually stood up a couple of times and went to take a step and fell down, because I'm trying to do it all in the same motion."* (Male, 54 years old, TT/TT, 5 years since amputation)

Sit-to-stand transitions were also perceived as threats to balance with a potential to trigger fall-related events when participants were not wearing their prosthesis.

> *"I was getting out of bed and I just totally forgot that I didn't have two legs and I went to like walk and I just went right down."* (Male, 25 years old, TT, 7 years since amputation)

Fall-related events were also commonly experienced while walking and/or engaged in other recreational activities (e.g. hiking, exercising). Fall-related events while walking were often coupled with specific physical characteristics of the environment.

> *"The last time I fell, I was coming down my driveway which is very, very steep."* (Female, 64 years old, TF, 8 years since amputation)

Theme 4: Fall-related situations are multifaceted, and often involve the prosthesis

Experiences related to the prosthetic socket (e.g. sweat, looseness, or poor suspension) and prosthetic behavior (e.g. malfunction, unexpected movement) were situations contributing to a fall or near-fall across focus group participants.

> *"I start sweating in the socket… and I will notice it's a little bit loose, so when I walk it doesn't quite clear enough, the ground, so it hits the ground where I don't expect it and that's when I kind of stumble and fall."* (Male, 38 years old, AD/TF, 23 years since amputation)

> *"If I turn left, sometimes I don't know quite what the reason for this is, but sometimes the knee doesn't catch quite right and, Oh, my gosh. I'm going down."* (Male, 81 years old, TF, 10 years since amputation)

Shared fall and near-fall experiences attributed to prosthetic-related issues extended beyond fit and function. Nearly all participants described situations where catching their prosthetic foot or leg on an obstacle or surface resulted in a fall or near-fall. Such situations were frequently attributed to not paying attention, a lack of sensation with the prosthesis, or a sense of being rushed or hurried.

> *"That's like the amputee's nightmare, something that you don't see in the way, you know? Or like you can't feel a cord wrapped around your ankle and you go to move and it reminds you."* (Female, 59 years old, TF, 44 years since amputation)

> *"Most of my falls are just when I'm walking and paying no attention whatsoever to what I'm doing because I'm in a rush."* (Female, 45 years old, TF, 32 years since amputation)

Theme 5: How LLP users land, but not the way they go down, tends to vary

Fall-related events were characterized by similar fall patterns (i.e. fall direction and the involved leg) and injury avoidance behaviors, but different impact locations across focus group participants. Across fall directions (i.e. forward, backward, to the side), forward falls were described as most common.

> *"It's always forward, not to the side."* (Male, 68 years old, TT, 9 years since amputation)

However, not all participants described only falling forward.

> *"I have fallen in all different directions."* (Male, 46 years old, TF, 10 years since amputation)

The prosthetic leg was consistently perceived by study participants as being more susceptible to disruption, and therefore likely to initiate fall-related events. This was attributed to a lack of sensation and spatial awareness with respect to the prosthesis.

> *"My prosthetic foot has no sensitivity, so when it gets caught on something, I don't know until I'm already into a step."* (Male, 71 years old, KD, 5 years since amputation)

No single impact location was universally reported by focus group participants. Rather, participants described landing on or contacting the ground or floor with different body parts. Further, different vocabulary, both scientific and lay, were used to describe the same anatomical location (e.g. "glutes", "rear end", "butt").

> *"It varies. I have come straight down on my rear end. And also I have come down on my shoulder quite hard too, so it just varies based on what has actually transpired, whether I have tripped over the edge of a sidewalk or slipped on something or whatever."* (Male, 65 years old, TT, 18 years since amputation)

Participants also described specific strategies to minimize injury. Namely, directing their bodies into certain positions in an effort to choose or avoid impact with specific body locations (e.g. head).

> *"I know I'm going down and so I'm going to go into a position where I'm going to get least hurt."* (Male, 71 years old, KD, 5 years since amputation)

Theme 6: Not all falls affect LLP users, but some near-falls do

Focus group participants described how some, but not all falls can have consequences. Further discussion revealed that fall-related consequences (e.g. injury or embarrassment) can also occur without completely falling (e.g. near-falls can be consequential).

> *"I also don't think you need to be injured in order to call it a fall."* (Male, 25 years old, TT, 7 years since amputation)

> *"You don't have to fall in order to injure yourself."* (Male, 81 years old, TF, 10 years since amputation)

Three categories of fall-related consequences were consistently brought up across focus groups, behavior modifications, physical injury, and psychological state.

Behavior modifications

Changes in behavior due to falls were described by a majority of focus group participants. Participants described changing what they did or how they did it, often in an effort to prevent future falls. Behavioral modifications included stopping, avoiding, reducing and/or limiting participation in activities associated with fall events, or simply activities they perceived as risky.

> *"I will go ahead and stop going to, you know, to the stores to pick up a bunch of little items because it's just not worth the hassle going by a slip hazard or a trip hazard or an ice patch, something like that."* (Male, 59 years old, TT, 8 years since amputation)

Modifications to how activities were performed included changes in walking pattern, use of assistive devices, as well as increased cautiousness and attention when engaged in behaviors during which participants had previously fallen.

> *"I have learned how to walk on wet surfaces. I shorten [my steps], basically."* (Male, 65 years old, TT, 18 years since amputation)

> *"When I go outdoors and it's either slippery or it's very uneven ground, I tend to take my crutches with me so that I don't fall."* (Male, 81 years old, TF, 10 years since amputation)

Behavior modifications were viewed by focus group participants as either temporary or permanent.

> *"The only thing I try [to] do is every time I trip, I will find myself for a few days afterwards really almost exaggerating my step because I know I trip*

because my foot is just not, I'm not lifting it high enough to clear things. So for a few days after, it's always close in my mind to make sure I keep my feet up." (Male, 54 years old, TT/TT, 5 years since amputation)

"I don't go up and down my driveway by foot anymore." (Female, 64 years old, TF, 8 years since amputation)

Physical injury

Physical injuries, including damage to the body and/or prosthesis from falling to the ground or trying to avoid falling to the ground (i.e. near-fall), were perceived by focus group participants as significant consequences of fall-related events. Physical injuries were largely perceived as minor (e.g. cuts, bruises, and pain), but some, including prolonged pain and fractures, were considered more severe.

"I broke my knee and the condyles between the knee and it spiraled up my femur and I was laid outside for quite a while" (Female, 66 years old, AD, 30 years since amputation)

"I kept myself from falling, but had a lot of damage. I had multiple, like, weeks and weeks of injury, I should have fallen. I would have done better than trying to keep myself upright." (Female, 58 years old, TT, 22 years since amputation)

Psychological state

In addition to physical injury, or damage to the prosthesis, psychological aspects of falls and near-falls were also perceived by focus group participants as notable consequences of fall-related events.

"For me it's not just the physical aspect of getting hurt… it's the psychological aspect." (Male, 54 years old, TT/TT, 5 years since amputation)

Fall-related events were perceived by focus group participants to trigger emotions of embarrassment, loss of confidence, fear, and depression.

"I was deeply embarrassed and all sorts of people were rushing up to me and saying, "How can I help you? Are you feeling alright?" I said, "Get out of my way. I just fell. I'm going to take care of it myself." (Male, 81 years old, TF, 10 years since amputation)

"I would say I would be a little bit skittish, like nervous, and still would do things, but with more awareness, because I would be afraid I would fall again." (Female, 57 years old, TT, 4 years since amputation)

Discussion

The purpose of this study was to identify common lived experiences and vocabulary associated with fall-related events in LLP users. While details varied, focus group participants reported experiences associated with fall-related events characterized by several themes. Themes were found to include where the fall took place (i.e. "*location* and *ground conditions influence whether falls occur*"), what they were doing at the time of the event (i.e. "*some activities come with more risk*" and "*fall-related situations are multifaceted, often involving the prosthesis*"), how they fell (i.e. "*how LLP users land, but not the way they go down, tends to vary*"), as well as what occurred as a result of the event (i.e. "*not all falls affect LLP users, but some near-falls do*"). These shared experiences may serve to broaden our understanding of balance and falls in LLP users, generate new questions, and provide targeted concepts to address in clinical or scientific study of fall-related events.

Fall-related lived experiences described by LLP users are both consistent with and distinct from those of other clinical populations

Several aspects of LLP users' experience of fall-related events overlapped with those described by other clinical populations. Additional features were discovered to be unique to participants in our focus groups. The theme "*location and ground conditions influence whether falls occur*" had the greatest overlap across clinical populations. Similar themes have been described by people with multiple sclerosis (i.e. "challenging surroundings" [28]), Parkinson's disease (i.e. "location, environment") [32], older adults (i.e. "physical environment") [30], and by people with incomplete spinal cord injury (i.e. "environmental hazards") [29,31]. Variations on the supporting categories, "*locations*" (e.g. familiar/unfamiliar, crowded) and "*surface and terrain conditions*" (e.g. curbs, slippery, uneven, downhill, stairs) have also been expressed by these clinical populations [28–32]. Given that natural and built environments are rarely unique to any one individual or population, it is not surprising that aspects of the physical environment generalize across the lived experience of different clinical populations in the context of falls.

While no single theme was found to be exclusive to LLP users, a number of supporting concepts were. For example, discussions among several clinical populations have highlighted consequence-related themes that include psychological outcomes (e.g. fear, embarrassment), physical injuries (e.g. cuts, scrapes, fractures) [29,30,32,33], as well as activity limitations and participation restrictions [29]. Unique to the LLP users in our focus groups, however, was the description of how consequences may arise not only due to falls, but also because of near-falls. "Stumbles" or "near-misses" have been described in a handful of previous studies, both with and without LLP users [12,32,42,48], but any association with injury or other consequences remains unexplored. Future research is needed therefore to examine whether near-falls are fall-related events that lead to negative health-related outcomes in LLP users. Furthermore, while the avoidance or cessation of certain activities due to fall-related events has been described by people with incomplete spinal cord injury [29], focus group participants elaborated on this category to describe how fall-related events also resulted in modifications to how they performed activities (e.g. slower, with an assistive device, cautiously, change in gait pattern) [55].

Prosthesis use was largely responsible for rendering fall-related lived experiences specific to LLP users. The fit, function, or comfort of the prosthesis, and its propensity to be obstructed, perturbed, or move unexpectedly, appear to create lived experiences unique to LLP users. For example, while a host of other clinical populations [29–31] have described how a sense of distraction, being rushed or hurried, failing to pay attention, and tripping over obstacles shaped their experiences (e.g. "influencing factors'' [28], "attributions of falls" [30], "catching or stubbing toes [32]), focus group participants in our study noted that such situations almost always led to a disruption or obstruction of the prosthesis. These results suggest that additional research is warranted to investigate the role of attention not just on walking in LLP users [56–58], but also on falling, and specifically, research focused on the behavior of the prosthetic leg under distracted or dual-task situations.

This prosthesis-oriented experience is captured in the theme, "*fall-related situations are multifaceted, and often involve the prosthesis*". The influence of the prosthesis in shaping fall-related experiences is further evidenced when examining the themes

"*some activities come with more risk*", *and* "*how LLP users land, but not the way they go down, tends to vary*". A propensity for forward falls has also been described by other clinical populations [32]. Unique to LLP users however, was the role of the prosthesis in creating instability, loss of balance, and/or falls (e.g. looseness of the socket). Further, the prosthetic leg, rather than the intact leg, was consistently perceived by participants to more often cause a fall-related event. Parallels may be drawn here to people with spinal cord injury who use a wheelchair for mobility, and describe factors related to wheelchair design and function as contributing to their fall-related experiences [31].

The fall-related lived experience described by LLP users is neither consistently nor fully integrated into balance and falls research

Efforts to characterize the frequency and distribution of fall-related events in LLP users to date have fallen short of capturing the full scope of themes that emerged from our focus groups [2,3,34,48,59–61]. Details documenting fall-related circumstances and consequences have included partial accounts of fall locations and ground conditions (e.g. home versus community, and flat versus uneven) [2,3,34,48,59–61], basic activities at the time of fall-related events (e.g. walking or transferring) [2,7,34,48,59–61], and colloquial or biomechanical descriptions of fall "causes" and patterns (e.g. slip, trip, or collision) [2,3,7,34,48,59–61]. Additionally, a limited set of physical (e.g. injury or treatment), psychological (e.g. fear, confidence), and behavioral (e.g. activity avoidance) consequences [3,4,7,54,59–61] have been reported. Our focus group discussions suggest that key aspects of several elements of fall-related experiences common to LLP users remain undocumented. For example, the scope with which LLP users in our focus groups described the theme "*location and ground conditions influence whether falls occur*" suggests that a broader characterization of the physical environment (e.g. slippery surfaces, stairs, incline versus decline) is needed to provide a more comprehensive picture of which ground conditions contribute to falls or near-falls in this clinical population. Within the same body of literature, the theme "*how LLP users land, but not the way they go down, tends to vary*" has largely been defined by a few select biomechanical disruptions that result in falls [2,34,48,61]. Gathering additional information about strategies LLP users employ to avoid a fall or minimize damage, specific location(s) of body impact, the direction of a fall or near-fall independent of the type of perturbation, and the leg involved (i.e. prosthetic or intact), would serve to better align the recording and reporting of fall-related events with the lived experience reported here by LLP users.

Other themes central to the lived experience shared by study participants (i.e. "*fall-related situations are* multifaceted*, and often involve the prosthesis", and "not all falls affect LLP users, but some near-falls do")* remain largely unexplored within the literature [2]. Focus group discussions suggest that a full characterization of short- and long-term fall-related consequences, including physical injuries (e.g. sprain, pain, fracture), behavioral modifications (e.g. changes to how an activity is performed, or if it is performed), psychological state (e.g. fear of falling, embarrassment, anxiety) is warranted to identify and prioritize falls that are most consequential [7,54,62]. Additionally, while the discussion of fall-related consequences experienced by LLP users in the current study focused on shorter-term outcomes, research may also be warranted to explore longer-term consequences, including employment and quality of life. Similarly, experiences of "*fall-related situations are multi-faceted, and often involve the prosthesis*", including prosthetic fit and function, the locus of attention, and physical state (e.g. rushed, hurried, or tired) have yet to be studied. Therefore, current depictions of fall-related events in the literature among LLP users remain incomplete relative to how our participants described their lived experiences.

The lived experience of fall-related events described by LLP users in our focus groups also differs from how the biomechanics of falls have been studied [17,19,27,63–67]. To date, studies using discrete perturbations to evoke a loss of balance [19,27,63,66,67], and often a fall [17,66], have traditionally focused on a single fall direction, most often forward [17,63–67], initiated through an obstruction to the base-of-support, applied to either the prosthetic [64,65] or both legs [17,19,27,63,66,67], while standing [27,66,67] or walking [17,19,27,63–65], on level terrain, without additional cognitive or motor demands. Fall experiences reported in our focus groups suggest that investigations into biomechanical fall-related deficits and mechanisms should include multiple fall directions, perturbations applied to the prosthetic leg during walking and transition activities, varying surface and terrain conditions, performing concurrent cognitive or physical tasks, and a variety of situations (e.g. fatigued, rushed) that contribute to falls in LLP users. Implementing creative ways to safely study fall impact location [68,69], as well as modifications to how activities are performed (e.g. slower gait with wider and shorter steps, use of mobility aids) would serve to further align biomechanical research efforts with the lived experience described here by LLP users. Using the themes described in the present study as a guide to expand our understanding of fall-related events among LLP users may help identify critical epidemiological and biomechanical details that can drive advances in scientific knowledge, improve clinical assessment, and motivate prosthetic designs focused on patient safety.

A LLP user-specific fall survey, designed with stakeholder input, may bridge the gap between research and the lived experience

The gap between fall-related experiences described by our focus group participants and existing epidemiological or biomechanical falls research in LLP users may be attributed to shortcomings in the survey tools used to collect fall-related information. Namely, there is no validated LLP user-specific fall survey with which to record and report fall-related events in a standardized, consistent, and meaningful way. Ad hoc questionnaires used in LLP user falls research to date [2,3,13,34,48,70] are typically study-specific, narrow in scope, and do not capture the themes and concepts raised by participants in our focus groups. More extensive fall surveys, developed for other clinical populations, do exist [40,41,47,50–52,71,72]; however, they do not address important prosthetic-specific issues, include vocabulary used by LLP users when describing their falls, and often do not include near-falls, a key element in the lived experience described by LLP users. The themes and concepts described here represent a way to bridge these gaps. The perspective of LLP users captured in our focus groups can inform survey question development through the use of suitable vocabulary, and inclusion of meaningful content that reflects the lived experience associated with fall related events [21,32,73–75]. Input from stakeholders (i.e. target respondents) can thus be used to ensure survey questions are topical and incorporate population-specific content. A LLP user-specific fall survey could be used in epidemiological studies to characterize the frequency and distribution of important fall-related events in a consistent and standardized manner. This would enable better aggregation of data across studies, as well as to guide

mechanistic biomechanical falls research towards more meaningful and consequential fall-related events. The themes and supporting categories described by LLP users in our focus groups may provide the insight required to develop and test a much-needed instrument in support of efforts to understand and reduce the incidence of falls by LLP users.

The interpretation and transferability of study results may be influenced by a number of factors. First, purposive sampling was used to obtain a range of participant characteristics and fall-related experiences [35]. One trait that was underrepresented was newer prosthesis users. Only four participants had five or less years' experience, and only one had less than one year of experience with his or her prosthesis. Caution is therefore warranted when transferring the present results to newer LLP users. Additional research to explore the lived experience of falls among newer LLP users, as well as people with lower limb amputation who do not wear a prosthesis is warranted.

One of the focus groups was limited to three participants due to last minute dropouts and no-shows. The small size of this focus group (FG. 5) may have limited the breadth and depth of the discussion. It was however the last focus group conducted, by which point thematic saturation was emerging.

All focus groups were conducted by online videoconferencing or telephone. This may have had the effect of excluding individuals who were not comfortable with this medium, or individuals who were unable to access a reliable internet connection [76]. Alternatively, these approaches to conducting the focus groups allowed for a national rather than regional sample, contributing to the breadth of the lived experiences that were captured. In either case, the methods chosen to conduct the focus groups may have affected group interactions and discussions.

Study investigators attempted to limit the effect of strong personalities on focus group discussions [39,77,78] by verbally encouraging all participants to describe their fall-related experiences and reflect on those of other participants [39]. Non-verbal prompts including nods and facial expressions were also acknowledged to ensure opportunity to comment was provided. The facilitator also specifically called on each participant to answer each question. Transcripts for focus group discussions also included brief acknowledgements of agreement from study participants (e.g. "yes", "for sure"). These responses were interpreted by study investigators to mean that participants shared or agreed with the experience or perspective being discussed.

The goal of the current study was to identify fall-related experiences shared by all LLP users. It is however possible that experiences may differ based on amputation-related characteristics including level, cause, and time since amputation. Therefore, while the current study sought to identify themes that transcend level or cause of amputation, additional qualitative research seeking to understand if and how the lived experience varies as a function of amputation-related factors may inform more personalized fall risk assessments and/or interventions.

Finally, participants were not asked to review transcripts or study findings for accuracy. While this method is commonly used to improve trustworthiness of qualitative data and study findings, all focus group discussions were transcribed in real time, and later compared to audio recordings to ensure their accuracy. Further, when uncertain, the CART reporter asked participants to repeat comments that were unclear or difficult to hear during the focus group discussions.

Based on the identified themes, the lived experience associated with fall-related events in our focus group participants reflected where the event took place, what they were doing at the time of the event, how they fell, what occurred as a result of the event, as well as how long and how well memory of the event persisted. Consideration for these experiences may serve to enhance methods of recording and reporting falls and near-falls, contribute to the development of improved fall risk assessment tools, inspire the design and function of prosthetic componentry for patient safety, and prioritize research into biopsychosocial aspects of fall-related events that are meaningful to people with lower limb amputation. Future research will be directed towards the development and testing of a LLP user-specific fall circumstance and consequences survey based on experiences described by participants in this study.

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Author contributions

Study Concept and Design by A. Sawers, B. Hafner. Acquisition of data by A. Sawers, J. Kim, B. Hafner. Analysis and interpretation of data by A. Sawers, J. Kim, C. McDonald. Drafting of manuscript by J. Kim, A. Sawers. Critical revision of manuscript of important intellectual content by B. Hafner, C. McDonald. Statistical analysis by A. Sawers. Study supervision by A. Sawers.

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ORCID

Cody L. McDonald http://orcid.org/0000-0002-4722-703X

Data availability statement

All data associated with this manuscript reside with the authors.

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