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ORIGINAL ARTICLE

Prevalence of secondary prosthesis use in lower limb prosthesis users

Cody L. McDonald[a], Alison Kahn[a], Brian J. Hafner[a] and Sara J. Morgan[a,b,c]

[a]Department of Rehabilitation Medicine, University of Washington, Seattle, WA, USA; [b]Research Department, Gillette Children's, St. Paul, MN, USA; [c]Department of Rehabilitation Medicine, University of Minnesota, Minneapolis, MN, USA

ABSTRACT

Purpose: Prostheses designed for daily use are often inappropriate for high-level activities and/or are susceptible to water damage and mechanical failure. Secondary prostheses, such as activity-specific or back-up prostheses, are typically required to facilitate uninterrupted participation in desired life pursuits. This study estimated the prevalence of secondary prosthesis use in a large, national sample of lower limb prosthesis users (LLPUs).

Methods: We conducted a secondary analysis of survey data from three cross-sectional studies that assessed mobility in LLPUs. Descriptive statistics were used to determine the percentage of secondary prosthesis users and percentages of LLPUs that used different type(s) of secondary prosthesis(es). Secondary prosthesis users and non-users were compared to identify differences in participant characteristics between groups.

Results: Of participants in the analysis ($n = 1566$), most (65.8%) did not use a secondary prosthesis. The most common secondary prosthesis types were back-up (19.2%) and activity-specific prostheses (13.5%). Secondary prosthesis users differed significantly from non-users with respect to gender, race, and other characteristics.

Conclusions: Results suggest that secondary prosthesis use for most LLPUs is limited and may differ based on users' demographic and clinical characteristics. Future research should determine how LLPUs' health-related quality-of-life outcomes are affected by access to and use of secondary prostheses.

➤ IMPLICATIONS FOR REHABILITATION

- Secondary prostheses, including activity-specific, back-up, and shower prostheses, have the potential to improve function, mobility, and participation for people who use lower limb prostheses.
- Most lower limb prosthesis users do not use secondary prostheses, and access to these devices may be related to users' demographic and clinical characteristics.
- Rehabilitation professionals play a key role in facilitating prosthesis users' access to secondary prostheses and should advocate for those who need them.

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Artificial limbs; amputation; sport prosthesis; running prosthesis; back-up prosthesis; shower prosthesis; water prosthesis

Introduction

Lower limb prostheses serve to restore ambulatory mobility for many individuals with lower limb amputation. Provision of a lower limb prosthesis requires the selection of appropriate prosthetic componentry (e.g., prosthetic knees and feet) based upon the person's amputation level, individual characteristics, lifestyle, and preferences [1]. A variety of prosthetic components have been designed to optimize aspects of balance, mobility, and participation for people with lower limb amputation. However, no prosthetic technology presently available can adequately mimic all functions of the biological lower limb [2,3]. Additionally, most prostheses provided for daily use are not mechanically designed for high-impact activities such as running and jumping [2].

Therefore, lower limb prosthesis users (LLPUs) are often forced to accept compromises in their daily prosthesis by using devices that are optimized to function under select conditions but limit mobility in other situations [4]. For example, prostheses with powered ankles provide active push-off while walking and natural ankle positioning when seated; however, most feet with powered ankles are not typically suitable for high-impact activities such as sports or running [3]. Inherent limitations in modern prosthetic technology thus often necessitate use of secondary prostheses to expand an LLPUs' functional capabilities. For example, activity-specific (e.g., sport or recreation) prostheses are secondary prostheses that expand functional capabilities for running or sports [5,6]. However, insurance coverage for such devices is uncommon [7] because many third-party payers limit coverage for secondary prostheses [8,9]. As a result, exercise and sport activities that have the potential to improve physical, cardiovascular, and mental health among LLPUs are often pursued infrequently or abandoned altogether [2,10].

In addition to functional limitations associated with contemporary prosthetic technologies, prostheses require regular maintenance, repair, and eventual replacement [11,12]. For individuals with a single prosthesis, servicing, repairing, or replacing the prosthesis often results in reduced mobility and temporary reliance on assistive technology (e.g., a wheelchair or crutches). A reduction in mobility, even for the short time needed to service, repair, or

CONTACT Cody L. McDonald codym@uw.edu Department of Rehabilitation Medicine, University of Washington, 1959 NE Pacific Street, Box 356490, Seattle, WA 98195, USA

replace a prosthesis, can adversely affect an individual's ability to care for oneself, fulfill family responsibilities, and/or perform effectively at work. To address these temporary yet disruptive periods of time, some LLPUs use a "back-up" prosthesis or prostheses. Back-up prostheses are often acquired informally over time rather than prescribed by a physician. For example, individuals may keep an older prosthesis that is no longer optimal for daily use but can be worn temporarily in short-term, emergency, or in-home situations. Back-up prostheses can also be assembled from the functional components of multiple old prostheses.

Another limitation increasingly inherent to contemporary prostheses is the potential for damage when the device is submerged in water or exposed to saltwater. Susceptibility to damage from water is particularly common for prosthetic components with microprocessor control, motors, or other electronic features. If the prosthesis needs to be in or near water, LLPUs may acquire "shower prostheses" comprised of components resistant to water. For example, shower prostheses provide stability while bathing or in water [13], and may also serve temporarily as a back-up when necessary.

For most LLPUs, optimization of function and mobility following lower limb amputation (e.g., efficient bipedal ambulation, safe showering and bathing, and participation in desired exercise and sport activities) requires secondary prostheses in the form of a back-up, shower, or activity-specific device [14]. However, the body of evidence on the prevalence of secondary prosthesis use among people with lower limb amputation is limited. Most research on secondary prostheses has focused on comparisons between activity-specific devices (e.g., running prostheses [15–17] or prostheses designed for water use [13,18,19]). Very little evidence is available on how many LLPUs have secondary prostheses of any kind or if there are individual characteristics that are associated with secondary prosthesis use. Therefore, the goal of this study was to estimate the prevalence of secondary prosthesis use among a large, national sample of LLPUs and to assess differences in demographic and clinical characteristics between those that use and those that do not use secondary prostheses.

Methods

Study design

We conducted a secondary analysis of cross-sectional survey data collected between December 2011 and January 2020. Data were collected via online or paper surveys from LLPUs who participated in one of three mobility-related studies [20–22]. A University of Washington Institutional Review Board reviewed and approved all study procedures.

Participants

LLPUs who participated in prior survey studies [20–22] related to mobility were included in this study. Eligibility criteria for participants in the prior studies were age 18 years or older, unilateral or bilateral lower limb amputation, regular lower limb prosthesis use, and the ability to read, write, and understand English. Recruitment strategies for the prior studies included posting flyers in clinics nationwide, advertising in consumer magazines, posting notices on the Amputee Coalition website, and sending invitations to people from across the US who had previously expressed interest in limb loss research.

Outcomes

The primary outcome for this study was reported use of any of several types of secondary prostheses. To assess secondary prosthesis use, participants were asked, "In addition to the prosthesis you wear most days, do you use a different prosthesis for:" and response options were "a back-up", "sports and/or recreation", "showering or bathing", "any other reason", and "I do not use a different prosthesis". Respondents could report use of more than one type of secondary prosthesis. Participant characteristics were also collected, including age, race, ethnicity, gender, Veteran status, etiology, and time since amputation. Mobility was assessed using the Prosthetic Limb User Survey of Mobility (PLUS-M) 12-item short form [23,24]. The PLUS-M is a self-report instrument that asks respondents to rate their perceived ability to perform various activities (e.g., walking short distances, stepping up and down curves, walking while carrying a shopping basket, and hiking 2 miles on uneven surfaces).

Analysis

Unique datasets from all three studies were combined for this analysis. Frequencies and percentages were calculated to determine the prevalence of secondary prosthesis use in the sample. Descriptive statistics were used to report characteristics (e.g., demographic information, clinical characteristics, and PLUS-M scores) for the total sample and for groups based on secondary prosthesis use and the type of secondary prosthesis used. Secondary prosthesis users (i.e., those who reported use of at least one secondary prosthesis) and non-users were compared based on sample characteristics using independent *t*-tests or Chi-square tests, as appropriate for the type of data ($\alpha = 0.05$). The same comparisons were performed between non-users and groups based on the type of secondary prosthesis (back-up, sport and recreation, showering and bathing). Statistical analyses were performed using SPSS Statistics Version 28 (International Business Machines Corporation, Armonk, NY).

Results

Overall

A total of 1566 unique participants were included in the analysis. Participants in the sample had an average age of 54.0 (14.2) years and the majority identified as men (69.5%). Most participants had an amputation from non-dysvascular causes (61.9%) and unilateral amputation below the knee level (56.6%) (Table 1). The majority of participants (65.8%) reported not using any type of secondary prosthesis. For secondary prosthesis users, the most common types were back-up and sport/recreation prostheses, which were used by 19.2% and 13.5% of the overall sample, respectively (Table 2).

Differences in participant characteristics between secondary prosthesis users and non-users

Secondary prosthesis users were significantly younger ($t(1561) = -4.17$, $p < 0.001$) than non-users. In addition, a significantly greater proportion of secondary prosthesis users were men ($\chi^2(1) = 5.90$, $p = 0.02$) and Veterans ($\chi^2(1) = 11.11$, $p < 0.001$) compared to non-users. Secondary prosthesis users and non-users also differed significantly with respect to the proportional distributions within race ($\chi^2(6) = 13.43$, $p = 0.04$), amputation level ($\chi^2(2) = 31.73$, $p < 0.001$), education ($\chi^2(4) = 40.28$, $p < 0.001$), and employment

Table 1. Participant demographics and clinical characteristics for lower limb prosthesis users included in the study sample and subgroups based on reported secondary prosthesis use.

	Total sample, $n = 1566$		Does not use a secondary prosthesis, $n = 1031$		Uses ≥1 secondary prosthesis, $n = 535$		
Characteristic	*n*	%	*n*	%	*n*	%	*p*-value
Gender							0.02
Women	474	30.3%	333	32.3%	141	26.4%	
Men	1089	69.5%	696	67.5%	393	73.5%	
Not reported	3	0.2%	2	0.2%	1	0.2%	
Race/ethnicity							0.04
American Indian/Alaskan Native	14	0.9%	10	1.0%	4	0.7%	
Asian	23	1.5%	13	1.3%	10	1.9%	
Black/African American	153	9.8%	116	11.3%	37	6.9%	
Hispanic	122	7.8%	78	7.6%	44	8.2%	
Native Hawaiian/Pacific Islander	2	0.1%	0	0.0%	2	0.4%	
White	1204	76.9%	779	75.6%	425	79.4%	
>1 race	37	2.4%	27	2.6%	10	1.9%	
Not reported	11	0.7%	8	0.8%	3	0.6%	
Veteran status							<0.001
Not active military or veteran	1262	81.4%	885	82.9%	407	76.1%	
Active military or veteran	289	18.6%	166	16.1%	123	23.0%	
Not reported	15	1.0%	10	1.0%	5	0.9%	
Amputation level							<0.001
At or above knee (TF, KD)	483	30.8%	357	34.6%	126	23.6%	
Below knee (TT, Symes)	886	56.6%	531	51.5%	355	66.4%	
Bilateral	197	12.6%	143	13.9%	54	10.1%	
Amputation etiology							<0.001
Dysvascular	596	38.1%	461	44.7%	135	25.2%	
Non-dysvascular	970	61.9%	570	55.3%	400	74.8%	
Education							<0.001
Some high school	81	5.2%	67	6.5%	14	2.6%	
High school graduate/GED	362	23.1%	250	24.2%	112	21.0%	
Some college/technical degree/AA	592	37.8%	416	40.3%	176	33.0%	
College degree (BA/BS)	330	21.1%	183	17.7%	147	27.5%	
Advanced degree (MA, PhD, MD)	196	12.5%	111	10.8%	85	15.9%	
Not reported	5	0.3%	4	0.4%	1	0.2%	
Employment status							<0.001
Employed or self-employed	527	33.7%	273	26.5%	254	47.5%	
Homemaker	38	2.4%	32	3.1%	6	1.1%	
Retired	386	24.6%	267	25.9%	119	22.3%	
On disability	471	30.1%	363	35.2%	108	20.2%	
Unemployed or seeking employment	82	5.2%	61	5.9%	21	3.9%	
Student	57	3.6%	31	3.0%	26	4.9%	
Not reported	5	0.3%	4	0.4%	1	0.2%	
Characteristic		Mean (SD)		Mean (SD)		Mean (SD)	*p*-value
Age, years		54.0 (14.2)		55.1 (13.8)		51.9 (14.8)	<0.001
Time since amputation, years		12.6 (14.1)		11.6 (13.9)		14.5 (14.4)	<0.001
PLUS-M v.1 12-item short form *T*-score		51.5 (10.1)		49.4 (9.8)		55.7 (9.3)	<0.001

AA: Associate of Arts; BA: Bachelor of Arts; BS: Bachelor of Science; GED: General Education Development; KD: knee disarticulation; MA: Master of Arts; MD: Doctor of Medicine; PhD: Doctor of Philosophy; PLUS-M: Prosthetic Limb Users Survey of Mobility; TF: transfemoral; TT: transtibial.
p Values indicate results of statistical comparisons between secondary prosthesis users and non-users. Percentages within categories may not add to 100% due to rounding.

Table 2. Types of secondary prostheses used by lower limb prosthesis users included in the sample.

Secondary prostheses used	*n*	%[a]
Backup	300	19.2%
Sport and recreation	211	13.5%
Showering/bathing	98	6.3%
Other	118	7.5%

Note that some participants reported using more than one type of secondary prosthesis (e.g., a backup and a sport prosthesis).
[a]The percentage of participants that reported using each type of secondary prosthesis is based off of the total sample ($n = 1566$).

status ($\chi^2(5) = 86.12$, $p < 0.001$) categories. More secondary prosthesis users had an amputation from non-dysvascular causes ($\chi^2(1) = 56.70$, $p < 0.001$) compared to non-users. Secondary prosthesis users also had longer times since their amputation ($t(1562) = 3.818$, $p < 0.001$) and higher PLUS-M scores ($t(1564) = 12.33$, $p < 0.001$, Table 1).

Compared to non-users, participants who used back-up, sports/recreation, or showering/bathing prostheses had significantly higher PLUS-M scores (all $p < 0.001$) and differed significantly with respect to the proportional distributions within education (all $p < 0.03$) and employment status (all $p < 0.001$) categories. Participants who used a back-up prosthesis also significantly differed from non-users with respect to time since amputation ($t(1327) = 3.27$, $p = 0.001$), gender ($\chi^2(1) = 12.46$, $p < 0.001$), Veteran status ($\chi^2(1) = 17.28$, $p < 0.001$), amputation level ($\chi^2(2) = 27.74$, $p < 0.001$), and amputation etiology ($\chi^2(1) = 22.68$, $p < 0.001$) categories. In addition, participants who used a sports/recreation prosthesis differed from non-users with respect to age ($t(1238) = -9.30$, $p < 0.001$), time since amputation ($t(1239) = 2.70$, $p = 0.007$), race ($\chi^2(6) = 22.91$, $p < 0.001$), Veteran

Table 3. Participant demographic and clinical characteristics for lower limb secondary prosthesis users by secondary prosthesis type (backup, sport and recreation, showering/bathing).

	Does not use a secondary prosthesis, $n = 1031$		Backup, $n = 300$		Sport and recreation (sport), $n = 211$		Showering/bathing (shower), $n = 98$		
Characteristic	*n*	%	*n*	%	*n*	%	*n*	%	*p* Value
Gender									Backup: <0.001; Sport:
Women	333	32.3%	65	21.7%	57	27.0%	25	25.5%	NS; Shower: NS
Men	696	67.5%	234	78.0%	154	73.0%	73	74.5%	
Not reported	2	0.2%	1	0.3%	0	0.0%	0	0.0%	
Race/ethnicity									Backup: NS; Sport:
American Indian/Alaskan Native	10	1.0%	2	0.7%	0	0.0%	0	0.0%	<0.001; Shower: 0.003
Asian	13	1.3%	5	1.7%	5	2.4%	0	0.0%	
Black/African-American	116	11.3%	28	9.3%	10	4.7%	3	3.1%	
Hispanic	78	7.6%	24	8.0%	15	7.1%	7	7.1%	
Native Hawaiian/Pacific Islander	0	0.0%	2	0.7%	2	0.9%	1	1.0%	
White	779	75.6%	231	77.0%	175	82.9%	84	85.7%	
>1 race	27	2.6%	6	2.0%	3	1.4%	3	2.2%	
Not reported	8	0.8%	2	0.7%	1	0.5%	1	0.7%	
Veteran status									Backup: <0.001; Sport:
Not active military or veteran	885	82.9%	217	72.3%	158	74.9%	73	74.5%	0.005; Shower: NS
Active military or veteran	166	16.1%	80	26.7%	51	24.2%	23	23.5%	
Not reported	10	1.0%	3	1.0%	2	0.9%	2	2.0%	
Amputation level/laterality									Backup: <0.001; Sport:
Unilateral at or above knee (TF, KD)	357	34.6%	66	22.0%	64	30.3%	5	5.1%	NS; Shower: <0.001
Unilateral below knee (TT, Symes)	531	51.5%	206	68.7%	122	57.8%	86	87.8%	
Bilateral	143	13.9%	28	9.3%	25	11.8%	7	7.1%	
Amputation etiology									Backup: <0.001; Sport:
Dysvascular	461	44.7%	88	29.3%	29	13.7%	34	34.7%	<0.001; Shower: NS
Non-dysvascular	570	55.3%	212	70.7%	182	86.3%	64	65.3%	
Education									Backup: 0.003; Sport:
Some high school	67	6.5%	12	4.0%	0	0.0%	1	1.0%	<0.001; Shower: 0.03
High school grad/GED	250	24.2%	71	23.7%	35	16.6%	18	18.4%	
Some college/technical degree/AA	416	40.3%	97	32.3%	66	31.3%	38	38.8%	
College degree (BA/BS)	183	17.7%	74	25.0%	75	35.5%	26	26.5%	
Advanced degree (MA, PhD, MD)	111	10.8%	44	14.7%	35	16.6%	15	15.3%	
Not reported	4	0.4%	1	0.3%	0	0.0%	0	0.0%	
Employment status									Backup: <0.001; Sport:
Employed or self-employed	273	26.5%	118	39.3%	127	60.2%	44	44.9%	<0.001; Shower:
Homemaker	32	3.1%	4	1.3%	2	0.9%	1	1.0%	<0.001
Retired	267	25.9%	72	24.0%	28	13.3%	27	27.6%	
On disability	363	35.2%	76	25.3%	25	11.8%	23	23.5%	
Unemployed or seeking employment	61	5.9%	13	4.3%	11	5.2%	0	0.0%	
Student	31	3.0%	16	5.3%	18	8.5%	3	3.1%	
Not reported	4	0.4%	1	0.3%	0	0.0%	0	0.0%	

Characteristic	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	*p* Value
Age,years	55.1 (13.8)	54.2 (13.8)	45.3 (14.5)	55.6 (11.8)	Backup: NS; Sport: <0.001; Shower: NS
Time since amputation, years	11.6 (13.9)	14.7 (15.3)	14.4 (12.9)	12.4 (12.4)	Backup: 0.001; Sport: 0.007; Shower: NS
PLUS-M v.1 12-item short form *T*-score	49.4 (9.8)	54.6 (9.5)	58.9 (8.7)	54.5 (8.7)	Backup: <0.001; Sport: <0.001; Shower: <0.001

AA: Associate of Arts; BA: Bachelor of Arts; BS: Bachelor of Science; GED: General Education Development; KD: knee disarticulation; MA: Master of Arts; MD: Doctor of Medicine; PhD: Doctor of Philosophy; PLUS-M: Prosthetic Limb Users Survey of Mobility; TF: transfemoral; TT: transtibial.
Note that some participants reported using more than one type of secondary prosthesis (e.g., a backup and a sport prosthesis). *p* Values indicate results from statistical comparisons between non-users and users of each type of secondary prosthesis. Percentages within categories may not add to 100% due to rounding.

status ($\chi^2(1) = 7.92$, $p = 0.005$), and amputation etiology ($\chi^2(1) = 70.33$, $p < 0.001$) categories. Finally, participants who used a showering/bathing prosthesis differed from non-users with respect to race ($\chi^2(6) = 19.79$, $p = 0.003$) and amputation level ($\chi^2(2) = 48.90$, $p < 0.001$) categories (Table 3).

Discussion

The goal of this study was to estimate the prevalence of secondary prosthesis use among a large, national sample of LLPUs. Additionally, we sought to describe characteristics of individuals who use a secondary prosthesis in order to guide future research. Overall, results from this study indicate that most LLPUs do not use a secondary prosthesis, suggesting a widespread lack of access to secondary prostheses among LLPUs.

Individuals who do use a secondary prosthesis are most likely to use a back-up or activity-specific prosthesis. Back-up prostheses were used by approximately one-fifth of participants in our sample. This finding suggests that the large majority of LLPUs are vulnerable to impaired mobility when their daily prosthesis requires a major repair, becomes ill-fitting due to volume change, or needs time-intensive component changes or servicing [12]. While impaired mobility resulting from removal of an individual's only prosthesis is often temporary, the interruption in daily life is unplanned and may have widespread consequences in their personal and professional life (e.g., inability to contribute to typical household duties, restrictions at work).

Activity-specific (e.g., sport and recreation) prostheses were used by 13.5% of participants in the sample. This category of secondary prostheses includes running prostheses as well as prostheses designed for biking, skiing, or other recreational activities. To participate in sport or recreational activities, a secondary, activity-specific prosthesis is often desired or required [6]. Without the appropriate activity-specific prosthesis, an individual may not be able to attempt or regularly participate in a new sport or recreation activity of interest [25]. However, ongoing participation in such activities is often required to justify acquisition of an activity-specific prosthesis. The situation is therefore cyclic in nature; lack of an activity-specific prosthesis leads to lack of participation and lack of participation leads to inadequate justification for an activity-specific prosthesis.

Showering/bathing prostheses were not commonly (6.3%) used by study participants, likely because a dedicated showering/bathing prosthesis may be unnecessary if other assistive technologies (e.g., shower chair, grab bars) are available to facilitate safety when showering/bathing. Varying opinions among rehabilitation providers on the necessity of shower prostheses may also contribute to the small number of LLPUs with shower prostheses [13]. Additionally, 7.5% of study participants reported use of "other" types of secondary prostheses which may include devices that fulfill multiple roles (e.g., water activity limbs that also serve as a shower prosthesis).

Health-related characteristics that are commonly related to physical function were associated with secondary prosthesis use. People who reported using secondary prostheses had higher mobility scores, were younger in age, had amputation below the knee, more often experienced amputation due to dysvascular causes, and had greater times since amputation. PLUS-M is a measure of self-reported mobility, while distal amputation levels [24], younger age [24,26,27], and non-dysvascular amputation [24,27] are associated with greater levels of mobility and activity. Although causal relationships cannot be drawn due to the current study's cross-sectional design, higher self-reported mobility scores and factors (e.g., younger age, distal amputation levels, non-dysvascular amputation etiology, longer time since amputation) that are commonly related to improved mobility were associated with secondary prosthesis use in our analysis. Further research is required to determine whether the relationship between mobility and secondary prosthesis use is causal, and if so assess the direction of causality (i.e., does increased mobility result in an individual having a secondary prosthesis or does use of a secondary prosthesis result in increased mobility?). Additionally, the secondary prosthesis user group had a longer average time since amputation than non-users, which may be explained by repurposing an older prosthesis as a back-up. Individuals who have had an amputation for longer are more likely to have extra prosthetic components available to create a secondary or back-up prosthesis.

In addition to associations between health-related factors and secondary prosthesis use, associations between secondary prosthesis use and demographic/socioeconomic characteristics were also found. As demographic and socioeconomic characteristics are not directly related to physical function, the association between these characteristics and secondary prosthesis use may be explained by social barriers. For example, individuals who identified as men were more likely to report secondary prosthesis use. This finding is consistent with those from Shutze et al. that female sex is associated with an increased likelihood of nonreferral for a primary prosthesis after vascular-related amputation [28]. Similarly, Singh et al. found that women were less likely to be successfully fitted with a primary prosthesis after amputation compared to men [29]. These challenges women experience with acquisition of a *primary* prosthesis likely also impact access to *secondary* prostheses and may be driven by gender and sex stereotypes about physical activity, ability, and participation [30–32]. Discrepancies in healthcare due to patient gender have been identified across rehabilitation professions and suggest pervasive systemic and individual gender bias [28,33–35]. Future research, however, is needed to examine the mechanisms of gender bias and resultant disparities in access to secondary prostheses.

Socioeconomic characteristics were also found to be associated with secondary prosthesis use, specifically disparities in prevalence of secondary prosthesis use by race, education, and employment. For example, a smaller proportion (24.2%) of Black or African American participants reported secondary prosthesis use compared to the proportion of secondary prosthesis users across other race categories (35.3%). Similar racial disparities in *primary* prosthetic prescription have been documented among LLPUs who have received care from the United States Department of Veterans Affairs (VA) [36]. Resnik and Borgia found a statistically significant negative association between African American race and being prescribed a prosthesis after amputation compared to White individuals [36]. People who are Black or African American also experience increased rates of dysvascular amputation [37], greater odds of amputation after a diabetic foot ulcer [38], and poorer patient outcomes across Physical Medicine and Rehabilitation [39]. Racial disparities in access to secondary prostheses may similarly be related to socioeconomic status as both education and employment were positively associated with secondary prosthesis use in the present study. Individuals with greater levels of education were more likely to use a secondary prosthesis as were those who reported being employed or self-employed. These results suggest that lack of resources for obtaining secondary prostheses is a key factor in the low prevalence of secondary prosthesis use among LLPUs. In the USA, structural racism has led to a close association between Black race and lower socioeconomic status (including less education and lower employment rates). Additionally, discriminatory institutional policies and practices, and interpersonal racism in other areas of health care have been associated with poorer treatment, access, and outcomes for Black Americans [40–42]. Future research is needed to understand if and how structural, institutional, and interpersonal racism impacts access to secondary prostheses for Black individuals.

Unlike the aforementioned characteristics, Veteran status was found to be associated with greater likelihood of secondary prosthesis use. Veterans with service-connected amputation have substantial access to prosthetic devices and components through the VA [43] which will provide and pay for advanced prosthetic technology, activity-specific prostheses, or shower prostheses, if they are prescribed. A higher percentage of Veterans in this study reported using a secondary prosthesis compared to civilians (42.6% and 32.3%, respectively); however, still more than half of Veterans in this study did not use a secondary prosthesis.

Outside of the VA system, coverage for secondary prostheses by private or public insurers is uncommon [43]. Limited or no coverage for secondary prostheses means LLPUs must generally either self-pay or rely upon donations from non-profit organizations such as the Challenged Athletes Foundation to obtain activity-specific prostheses. Inherently, activity-specific prostheses and the mobility and participation they facilitate are therefore restricted to those who have the resources and knowledge needed to obtain these devices, as evidenced by the low (13.5%)

prevalence of activity-specific prosthesis use reported by our study sample.

This study is the first to describe the prevalence of secondary prosthesis use and is also the first to identify potential disparities that require further examination as they infer inequities in access to secondary prostheses. In addition to the racial, gender, and socioeconomic disparities described above, this study highlights differences in secondary prosthesis use by age, amputation etiology, time since amputation, and self-reported mobility. Further examination of the causal relationships underlying these disparities would help identify approaches to provide more equitable access to secondary prostheses. One area of future research is examination of the role of provider bias in prescribing and advocating for insurance coverage of secondary prostheses. Providers may be less inclined to prescribe an activity-specific prosthesis to an older [44,45] or overweight [46,47] individual due to implicit or explicit bias about exercise ability. Furthermore, systemic racism and sexism require further examination to inform social policy changes to reduce inequities in prosthetic rehabilitation [48]. Lastly, the ability for LLPUs to advocate for themselves and navigate the health care system may be examined to further explore causal relationships between self-efficacy and access to a secondary prosthesis.

Limitations

This study is a secondary analysis of cross-sectional datasets. The single survey question about secondary prostheses for these studies queried respondents about secondary prosthesis *use* rather than *ownership* of a secondary prosthesis. The survey did not include questions about the condition of the secondary prosthesis(es), how LLPUs rely upon secondary prostheses, or if repercussions (e.g., financial, social, emotional) result from a lack of access to secondary prostheses. In addition, while we describe the importance of finances in obtaining secondary prostheses, our data set did not have insurance or income data. Together, these limitations restrict conclusions about secondary prosthesis ownership, experiences with secondary prosthesis use, and the connections we can draw between cost, coverage, and access to secondary prostheses. Future research is needed to assess access to secondary prostheses and outcomes related to their use. While this study identified select characteristics related to use of a secondary prosthesis, further work is needed to examine why discrepancies in secondary prosthesis use exist. Further, we did not ask respondents to provide additional information if they chose the "other" secondary prosthesis type category. Future research should clearly define and disaggregate categories of secondary prostheses to allow for more nuanced analysis. Lastly, additional research is needed to identify prescription criteria to determine who may most benefit from a secondary prosthesis.

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ORCID

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

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