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TITLE: Needs, Preferences and Functional Abilities of Veterans and Service Members with Upper Limb Amputation

PRINCIPAL INVESTIGATOR: Dr. Linda Resnik, PhD, PT

CONTRACTING ORGANIZATION: Ocean State Research Institute

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14. ABSTRACT Purpose: The purpose of this project is to provide comprehensive cross-sectional and longitudinal data on function, needs, preferences, and satisfaction of Veterans and service members with major upper limb amputation. Scope: 1) Describe patterns of prosthesis use and abandonment in the VA and DOD; identify the impact of amputation and prosthesis use on self-reported function, activities and participation; and identify unmet prosthetic needs; 2) conduct a one year follow-up study to examine changes in satisfaction with care and prosthetic services, self-reported function and quality of life; and 3) assess the dexterity and activity performance in upper limb amputees. Findings/Progress: This reporting period (30 September 2019 - 29 September 2020) focused on completing data collection and data analyses and dissemination. We have completed 808 Aim 1 surveys, 585 Aim 2 surveys, 127 Aim 3 Visit 1 study visits, and 64 Aim 3 Visit 2 study visits. Data collection is complete for Aims 1, 2, and Aim 3. We have published 4 papers for Aim 1, 1 paper for Aim 2 and 1paper for Aim 3 and have several papers in progress.					
15. SUBJECT TERMS Upper limb amputation; upper limb amputee; quality of care; Evidence-Based Clinical Practice Guidelines; prosthetic device; care satisfaction; amputation rehabilitation; amputation outcomes.					
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1. INTRODUCTION:

Quality gaps in care of military and Veterans with upper limb amputation have been reported. In 2008, amputees receiving prosthetic care in the VA were reported to be less satisfied than counterparts receiving care in the private sector. In 2011, reported widespread dissatisfaction amongst combat Veterans with upper limb loss led to calls for efforts to evaluate needs of Veterans with traumatic upper limb amputations to improve satisfaction. Major efforts to improve quality of prosthetic care have been made since these studies were conducted. In 2009, the VA reorganized its amputation system of care, and in 2014 the VA and DoD released the Evidence-Based Clinical Practice Guidelines (CPGs) for the rehabilitation of persons with upper limb amputation. It is now time for a comprehensive study to assess the current state of quality and outcomes of amputation rehabilitation for upper limb amputees and to track quality and outcomes over time. Our objective is to provide comprehensive cross-sectional and longitudinal data on function, needs, preferences, and satisfaction of Veterans and service members with major upper limb amputation.

2. KEYWORDS:

Keyword summary: Upper limb amputation; upper limb amputee; quality of care; Evidence-Based Clinical Practice Guidelines; prosthetic device; care satisfaction; amputation rehabilitation; amputation outcomes.

3. ACCOMPLISHMENTS:

▪ What were the major goals of the project?

There are 3 major goals/aims in the approved statement of work (SOW) for this project:

Aim 1: Describe patterns of prosthesis use; identify the impact of amputation and prosthesis use on function, activities and participation; and identify unmet prosthetic needs.

Aim 2: Conduct a one year longitudinal follow-up survey to examine changes in satisfaction with care and prosthetic services, physical performance, self-reported quality of life and physical function to assess the implementation of new clinical practice guidelines (CPGs).

Aim 3: Quantify physical function using a battery of performance based tests.

The table below shows the major tasks associated with each aim/goal, the original and revised target completion date, the actual completion date (if relevant) and percent complete.

Aim	Activities	Target Completion Date	Revised Target Completion date	Completion Date	Percent Complete
Aims 1&2	Regulatory approvals	Month 3	Month 3	May 2017	100%
	Prepare study staff for survey administration	Month 9	Month 9	April 2017	100%
	Prepare study data (VA sample)	Month 7	Month 7	May 2017	100%
	Prepare study data (DoD sample)	Month 7	Month 39	December 2019	100%
	Conduct surveys (Aim 1)	Month 19	Month 19	June 2018	100%
	Conduct Aim 1 survey (DoD sample)	Month 19	Month 42	March 2020	100%
	Conduct surveys (Aim 2)	Month 31	Month 31	June 2019	100%
	Data analysis (Aims1 & 2)	Month 33	Month 54		95%
	Dissemination	Month 36	Month 60		80%
Aim 3	Regulatory approvals	Month 8	Month 8	July 2017	100%
	Prepare study staff	Ongoing	Ongoing	-----	100%
	Study coordination	Month 33	Month 42	March 2020	100%
	Data collection (Visit 1)	Month 21	Month 35	August 2019	100%
	Data collection (Visit 2)	Month 33	Month 42	March 2020	100%
	Data Analysis	Month 36	Month 54		75%
	Dissemination	Month 36	Month 60		40%

▪ **What was accomplished under these goals?**

1 & 2) Specific objectives and major activities

Specific objectives and major activities accomplished during the Year 4 (NCE) reporting period (30th September 2019 – 29th September 2020) are described below:

Aims 1 & 2

Specific Objective 1: Maintain regulatory approvals (fully met)

Major Activities:

- Submitted all study modifications and continuing reviews to HRPO
- Obtained continuing review approval from the VA CIRB, UMass IRB, USF IRB & CFI IRB

Specific Objective 2: Identify Aim 1 & 2 sample (fully met)

Major Activities:

- Identified Aim 1 participants (DoD sample)
- Prepared and mailed recruitment materials for Aim 1 participants (DoD sample)

Specific Objective 3: Complete Aim 1 data collection (fully met)

Major Activities:

- Completed Aim 1 data collection (VA sample) in May 2018
- Completed Aim 1 data collection (DoD sample) in March 2020

Specific Objective 4: Begin Aim 2 data collection (fully met, VA sample)

- Nothing new to report, goal already met

Specific Objective 5: Complete Aim 2 data collection (fully met, VA sample)

- Nothing new to report, goal already met

Specific Objective 6: Begin Aim 1 data analysis (fully met, VA sample and DoD sample)

Major Activities:

- Goal already met for VA sample
- Prepared DoD sample for analyses

Specific Objective 7: Complete Aim 1 data analysis (partially met, VA sample, fully met DoD sample)

Major Activities:

- Continued data analyses of VA sample
- Completed data analyses of DoD sample

Specific Objective 8: Disseminate Aim 1 results (partially met, VA sample)

Major Activities:

- 4 manuscripts have been published
- 1 manuscript is in press
- 3 manuscripts (Aims 1, 2) have been submitted and are under review
- 1 additional manuscript is under construction
- 2 abstracts (Aim 1 and Aims 1-3) were presented at national conferences

Specific Objective 9: Continue Aim 2 data analysis (fully met, VA sample)

Major Activities:

- Continued data analyses

Specific Objective 10: Disseminate Aim 2 results (partially met, VA sample)

Major Activities:

- 1 manuscript has been published
- 3 manuscripts (Aims 1, 2) have been submitted and are under review
- 1 additional manuscript is under construction
- 1 abstract (Aims 1-3) was presented at a national conference

Aim 3

Specific Objective 1: Maintain regulatory approvals for data collection sites (fully met)

Major Activities:

- Submitted all study modifications to HRPO
- Obtained continuing review approval from the VA CIRB, CFI, USF, and HRPO

Specific Objective 2: Complete Aim 3 Visit 1 data collection (fully met)

- Nothing new to report, goal already met

Specific Objective 3: Complete Aim 3 Visit 2 data collection (fully met)

Major Activities:

- Tracked participation and provided gift cards to Aim 3 Visit 2
- Completed Aim 3 (Visit 2) data collection – 64 visits completed

Specific Objective 4: Continue Aim 3 analysis (partially met)

Major Activities:

- Held PI Meeting in Oct. 2019 – preliminary Aim 3 Visit 1 findings were presented and key analytic questions were discussed with Aim 3 local site investigators
- Continued analyses of Aim 3 Visit 1 data, analyses of psychometric properties of our outcome metrics are in progress
- Held weekly meetings with study prosthetists to analyze prosthetic description data
- Prepared Aim 3 Visit 2 data for analysis
- Began analyses of Aim 3 Visit 2 data
- Held PI Meeting in Sept. 2020 - Aim 3 Visit 2 analysis and dissemination plans were presented and discussed with Aim 3 local site investigators

Specific Objective 5: Begin dissemination of Aim 3 results (partially met)

Major Activities:

- 1 manuscript is in press
- Additional manuscripts are under construction
- 1 conference manuscript has been published
- 2 conference abstracts were accepted (Aim 3 & Aims 1-3)
- 1 conference abstract was submitted and is under review

3) Significant Results or Key Outcomes

Data collection is complete for Aim 1, Aim 2 (VA sample) and for Aim 3.

- Aim 1 (VA sample): 808 complete

- Aim 1 (DoD sample): 5 complete
- Aim 2 (VA sample): 585 complete
- Aim 3 Visit 1: 127 complete
- Aim 3 Visit 2: 64 complete

Data analysis is complete for the Aim 1 DoD Sample from the EMED Database. Please see the Year 4 Quarter 3 report for details.

The following papers were published during Year 4:

Aim 1

- “A National Survey of Prosthesis Use in Veterans with Major Upper Limb Amputation: Comparisons by Gender”
- “Prosthesis Satisfaction in a National Sample of Veterans with Upper Limb Amputation”
- “Function and Quality of Life of Unilateral Major Upper Limb Amputees: Effect of Prosthesis Use and Type”
- “Frequency and Severity of Phantom Limb Pain in Veterans with Major Upper Limb Amputations: Results of a National Survey”

Aim 2

- “Longitudinal Study of Prosthesis Use in Veterans with Upper Limb Amputation”

Aim 3

- “Dexterity, Activity Performance, Disability, Quality of Life, and Independence in Upper Limb Veteran Prosthesis Users: A Normative Study” (In Press)

Full citations for these papers are listed in Section 6. Products.

4) Other Achievements

Infrastructure development

- Executed Year 4 subcontract awards for the 4 VA sites (Seattle, Richmond, Tampa, San Antonio), University of Massachusetts, Center for the Intrepid, and University of South Florida
- Continued regular communications to facilitate coordination and to ensure study fidelity, including:
 - Regular phone meetings held with the overall study coordinator and staff at Aim 3 data collection sites
 - Aim 3 assessors’ meetings
 - Monthly Aim 3 local site coordinators’ meetings
 - Monthly Aim 2 study staff meetings (PVAMC and University of Massachusetts)

Data

- We have held two Aim 3 PI data meetings with local site investigators (meetings held October 2019 and September 2020). During the first meeting, we presented preliminary Aim 3 Visit 1 findings and discussed key questions. During the second meeting, we discussed Aim 3 Visit 2 analyses and dissemination plans.
- To date, 9 manuscripts have been published and 4 additional manuscripts have been submitted and are under review, and several additional manuscripts are under construction. We have had three abstracts presented at national meetings and an additional abstract is under review. Also, one conference manuscript has been published and one symposium was given at a national meeting.

Stated goals not met

While we have made significant progress, we have experienced some challenges in meeting stated goals:

1. Complete data analysis for Aims 1 & 2
 - a. Goal – Month 33; Actual: Given the rich data we have collected, we have the opportunity to address many important research questions. We anticipate completing data analysis for Aim 1 by January 2021 (Month 52) and for Aim 2 by March 2021 (Month 54)

The final dataset for Aim 2 was prepared during the summer 2019. We completed our initial analyses and one Aim 2 overview manuscript has been published. We have used Aim 2 data in several papers examining change over time. These papers are still under review and we expect that additional analyses may be required to respond to reviewer comments. We hope to complete additional analyses by March 2021 (Month 54).

2. Complete Aim 3 Visit 2 data collection
 - a. Goal – Month 33 (June 2019); Actual: Month 42 (March 2020)

Aim 3 Visit 2 data collection activities were delayed because Visit 1 data collection extended into Year 3 of the award in order to meet recruitment goals. Visit 2 happened approximately 12 months after Visit 1, so we needed to extend our timeline for Visit 2 as well.

3. Complete data analysis for Aim 3
 - a. Goal – Month 36; Actual: We anticipate completing data analysis for Aim 3 by March 2021 (Month 54)

Our Aim 3 Visit 2 data collection activities were delayed. We completed Aim 3 Visit 2 data collection activities in March 2020 (Month 42), though we had anticipated that we would complete by June 2019 (Month 33). Although the primary Aim 3 Visit 1 analysis is complete, we were unable to begin preparing Visit 2 data for analysis until May 2020 (Month 44). We are planning several additional analyses to report impairments of range of motion, strength ; and to examine change in function and prosthesis use over time. We are working with a large group of

co-authors on these analyses and expect data analysis and preparation of manuscripts will continue at least through March 2021 (Month 54).

4. Complete dissemination for Aims 1, 2 & 3
 - a. Goal – Month 36; Actual: September 2021 (Month 60)

We have begun dissemination for Aims 1, 2 & 3 (Visit 1), as mentioned above. We need additional time to complete our activities for dissemination; submitting manuscripts for review and responding to reviewer comments. We also expect to present at several additional conferences and/or grand rounds.

- **What opportunities for training and professional development has the project provided?**

Several undergraduate students have worked with our research team. Natalie Webster, a student from George Mason University has submitted a poster presentation related to her research participation.

Ellie Ballakanlou, was a medical resident at the Richmond VA. She worked with our team on the analysis of phantom limb paper and was first author of a paper that was recently accepted.

F. Clay Smither, a medical resident at the Richmond VA worked with our team on the analysis of data comparing prosthetic terminal device papers. He was first author on a conference paper.

- **How were the results disseminated to communities of interest?**

During this reporting period, we disseminated results at the following 4 conferences (3 national, 1 international):

1. American Academy of Physical Medicine and Rehabilitation (AAPM&R):
Balakhanlou, E, Webster, J, Borgia, M, Resnik, L. Frequency and severity of phantom limb pain in Veterans with major upper limb amputations: Results of a national survey. November 2019 (Abstract)
2. American Congress of Rehabilitation Medicine (ACRM):
Resnik, L., Ballakanlou, E., Phillips, S, Heckman, J. Methods and Highlights from the National Study of Veteran with Upper Limb Amputation. November 2019 (Symposium)
3. Myoelectric Controls Symposium (MEC):
Smither, F, Webster, J, Borgia, M, Phillips, S, Resnik, L. Comparative effectiveness and functional performance of multiple degree of freedom prosthetic hands in individuals with unilateral transradial or wrist disarticulation amputation. Published as part of the August 2020 Proceedings, New Brunswick, Canada (Conference Manuscript)
4. Amputee Coalition (AC):
Webster, J, Resnik, L. Upper limb amputation: New research findings from the Department of Veterans Affairs. August 2020 (Abstract)

▪ **What do you plan to do during the next reporting period to accomplish the goals?**

During the next reporting period (Year 5, NCE), we anticipate accomplishing the following activities to meet the project goals and objectives:

Project Activity	Goal Completion Date
Complete analysis for Aims 1, 2 & 3	Month 54
Complete dissemination for Aims 1, 2 & 3	Month 60
Submit 2 abstracts to national conferences	Month 60
Submit 4 publications to scientific journals	Month 60

4. IMPACT:

▪ **What was the impact on the development of the principal discipline(s) of the project?**

Many of our findings have important implications that may impact regulatory policy and clinical care.

- We reported data supporting widespread interest of Veterans in exploring osseointegration, and surgeries to restore sensation and improve motor function. This data will be useful to the FDA in reviewing risk/benefit for experimental surgeries.
- We found that a substantial proportion of Veterans did not receive amputation related care at the VA and many had never been to a VA amputation clinic, suggesting an opportunity to increase access to VA care for persons with upper limb amputation.
- We found that amputees who do not use a prosthesis report more difficulty in activities, greater overall disability, and lower physical function compared to amputees that use any type of active prosthesis. Additionally, those that do not use a prosthesis are more likely to need help with ADLs compared to those who use a body powered prosthesis. These findings demonstrated the value of active prostheses in improving quality of life and highlight the clinical imperative to encourage prosthesis use by addressing factors such as early prosthetic training to improve satisfaction with devices and reduce abandonment.
- The manuscript resulting from the in-person component of this study reported normative values for dexterity, activity performance, prosthesis satisfaction disability, HRQoL and community integration in persons with upper limb amputation by amputation level and prosthesis type. These never before published data will inform clinicians and researchers and help them create benchmarks for these standardized measures by amputation level and prosthesis types.

- **What was the impact on other disciplines?**

It is difficult to assess our impact at this time.

- **What was the impact on technology transfer?**

Nothing to report.

- **What was the impact on society beyond science and technology?**

Nothing to report.

5. **CHANGES/PROBLEMS:**

- **Changes in approach and reasons for change**

Nothing to report.

- **Actual or anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

- **Changes that had a significant impact on expenditures**

Nothing new to report regarding delays. We are using remaining funds during the no cost extension period for data analysis and dissemination activities for Aims 1 – 3.

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

- **Significant changes in use or care of human subjects**

Nothing to report.

- **Significant changes in use or care of vertebrate animals.**

Nothing to report.

- **Significant changes in use of biohazards and/or select agents**

Nothing to report.

6. **PRODUCTS:**

Publications, conference papers, and presentations

▪ **Journal publications.**

Accepted manuscripts:

1. Resnik, L, Borgia, M, Clark, MA National Survey of Prosthesis Use in Veterans with Major Upper Limb Amputation: Comparisons by Gender. PM&R 2020 Feb 27. doi: 10.1002/pmrj.12351. PubMed PMID: 32103626 [Epub ahead of print]
2. Resnik L, Borgia M, Heinemann AW, Clark MA. Prosthesis Satisfaction in a National Sample of Veterans with Upper Limb Amputation. Prosthet Orthot Int. 2020 Jan 21:309364619895201 doi: 10.1177/0309364619895201 [Epub ahead of print] PubMed PMID: 31960734
3. Resnik, L. Borgia, M, Clark M. Function and Quality of Life of Unilateral Major Upper Limb Amputees: Effect of Prosthesis Use and Type. Archives of Physical Medicine and Rehabilitation. Volume 101, Issue 8, August 2020, Pages 1396-1406. doi: 10.1016/j.apmr.2020.04.003
4. Resnik, L, Borgia, M, Biester, S, Clark, M. Longitudinal Study of Prosthesis Use in Veterans with Upper Limb Amputation. Prosthet Orthot Int. 2020 Oct 6: doi: 10.1177/0309364620957920 PubMed PMID: 33023368 [Epub ahead of print]
5. Resnik, L, Borgia, M, Cancio, J, Heckman, J, Highsmith, J, Levy, C, Phillips, S, Webster, J. Dexterity, Activity Performance, Disability, Quality of Life, and Independence in Upper Limb Veteran Prosthesis Users: A Normative Study. Disability & Rehabilitation. In Press doi: 10.1080/09638288.2020.1829106
6. Balakhanlou, E, Webster, J, Borgia, M, Resnik, L. Frequency and Severity of Phantom Limb Pain in Veterans with Major Upper Limb Amputations: Results of a National Survey. PM&R. 2020 Sep 8: doi: 10.1002/pmrj.12485 [Epub ahead of print]

Manuscripts under review:

1. Resnik, L, Borgia, M, Ekerholm, S, Highsmith, M, Randolph, B, Webster, J, Clark, J. Amputation Care Quality and Satisfaction with Prosthetic Limb Services: A Longitudinal Study of Veterans with Upper Limb Amputation. Submitted to Federal Practitioner in June 2020
2. Resnik, L, Borgia, M, Clark, M. The Prevalence and Impact of Back and Neck Pain in Veterans with Upper Limb Amputation. Submitted to Physical Medicine and Rehabilitation in July 2020
3. Resnik, L, Borgia, M, Clark, M. Contralateral Limb Pain is Prevalent, Persistent and Impacts Quality of Life of Veterans with Unilateral Upper Limb Amputation. Submitted to Rehabilitation Research and Practice in August 2020

4. Resnik, L, Borgia M, Cancio, J, Delikat, Ni, P. Psychometric Evaluation of the Southampton Hand Assessment Procedure (SHAP) in a Sample of Upper Limb Prosthesis Users. Submitted to Journal of Hand Therapy in August 2020

- **Books or other non-periodical, one-time publications.**

Nothing to report.

- **Other publications, conference papers, and presentations.**

Conference manuscript:

1. Smither, F, Webster, J, Borgia, M, Phillips, S, Resnik, L. Comparative effectiveness and functional performance of multiple degree of freedom prosthetic hands in individuals with unilateral transradial or wrist disarticulation amputation. Published as part of the MEC Symposium August 2020 Proceedings

Conference symposium:

1. Resnik, L., Ballakanlou, E., Phillips, S, Heckman, J. Methods and Highlights from the National Study of Veteran with Upper Limb Amputation ACRM November 2019

Conference abstracts:

1. Balakhanlou, E, Webster, J, Borgia, M, Resnik, L. Frequency and severity of phantom limb pain in Veterans with major upper limb amputations: Results of a national survey. AAPMR November 2019
2. Webster, J, Resnik, L. Upper limb amputation: New research findings from the Department of Veterans Affairs. Amputee Coalition August 2020

Submitted conference abstract:

1. Cancio, J, Borgia, M, Cancio, L, Dewey, W, Resnik, L. The impact of burn injury on upper extremity prosthesis users. ABA 2021 (Submitted September 2020)

Accepted conference abstract:

1. Webster, N, Webster, J, Borgia, M, Resnik, L. Frequency and severity of shoulder pain in persons with major upper limb amputation who use prostheses: Results of a national study. AAPMR November 2020

- **Website(s) or other Internet site(s)**

Nothing to report.

- **Technologies or techniques**

Nothing to report.

- **Inventions, patent applications, and/or licenses**

Nothing to report.

- **Other Products**

Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

- **What individuals have worked on the project?**

Name:	Linda Resnik
Project Role:	Principal Investigator
Researcher Identifier (e.g. ORCID ID):	
Nearest person month worked:	1.0
Contribution to Project:	Dr. Resnik has performed work in the area of overall study oversight, data quality monitoring, data analysis, manuscript preparation and oversight for the work of Ms. Biester, Mr. Borgia, Ms. Small, Mr. Davey and Ms. Underwood.
Funding Support:	n/a

Name:	Sarah Biester
Project Role:	Project Manger
Researcher Identifier (e.g. ORCID ID):	n/a

Nearest person month worked:	1.5
Contribution to Project:	Ms. Biester performed work in the area of study coordination, regulatory document preparation and submission. Ms. Biester maintained the overall study budget, prepared HR and contracting paperwork and related tasks. She also assisted with manuscript preparation. Ms. Biester left the study in Quarter 4.
Funding Support:	<i>n/a</i>

Name:	Eileen Small
Project Role:	Project Coordinator
Researcher Identifier (e.g. ORCID ID):	<i>n/a</i>
Nearest person month worked:	2.0
Contribution to Project:	Ms. Small has performed work in the area of study coordination, providing technical support to Aim 3 local site coordinators in regulatory document preparation and submission. In addition, she began maintaining the overall study budget and associated tasks when Ms. Biester departed the study. Ms. Small has also assisted with manuscript preparation.
Funding Support:	<i>n/a</i>

Name:	Matthew Borgia
Project Role:	Biostatistician/Analyst
Researcher Identifier (e.g. ORCID ID):	<i>n/a</i>
Nearest person month worked:	2.0

Contribution to Project:	Mr. Borgia has performed work to prepare study data for analysis and complete analyses for Aims 1, 2 & 3. He has assisted Dr. Resnik with preparing manuscripts for submission. He has also assisted with data analysis of the Aim 1 DoD sample.
Funding Support:	n/a

Name:	John Davey
Project Role:	Senior Research Assistant
Researcher Identifier (e.g. ORCID ID):	n/a
Nearest person month worked:	2
Contribution to Project:	Mr. Davey has performed work in the area of maintenance of study databases and preparation of study data, data cleaning, quality control reviews for Aim 3 data collection and manuscript preparation. Mr. Davey assumed Ms. Airol di's responsibilities when she left the study at the end of Quarter 1
Funding Support:	n/a

Name:	Josephine Airol di
Project Role:	Research Assistant
Researcher Identifier (e.g. ORCID ID):	n/a
Nearest person month worked:	0.5
Contribution to Project:	Ms. Airol di performed work in the area of maintenance of study databases and preparation of study data, data cleaning and quality control reviews for Aim 3 data collection. She also managed the pain map and residual limb project for Aim 3. Ms. Airol di left the study at the end of Quarter 1.
Funding Support:	

Name:	Rachel Underwood
Project Role:	Research Assistant
Researcher Identifier (e.g. ORCID ID):	n/a
Nearest person month worked:	1.0
Contribution to Project:	Ms. Underwood has performed work in the area of data cleaning and quality control reviews for Aim 3 data collection, gift card reconciliation and manuscript preparation.
Funding Support:	n/a

Name:	Jacqueline Siven
Project Role:	Research Assistant/Coordinator (Tampa)
Researcher Identifier (e.g. ORCID ID):	
Nearest person month worked:	0.5
Contribution to Project:	Ms. Siven has coordinated data collection activities for the Tampa site, including subject recruitment, travel, reimbursement, tracking, data collection and data entry. In addition, Ms. Siven has coordinated required regulatory submissions for the Tampa site and assisted with prosthetic description data dissemination planning. Ms. Siven left the study in April 2020.
Funding Support:	n/a

Name:	Meghan Rosenbrock Kern
Project Role:	Research Assistant/Coordinator (Tampa)
Researcher Identifier (e.g. ORCID ID):	

Nearest person month worked:	0.5
Contribution to Project:	Ms. Rosenbrock took over Ms. Sevin's responsibilities at the Tampa s, including coordinating required regulatory submissions.
Funding Support:	<i>n/a</i>

Name:	Matthew Jerrell
Project Role:	Research Assistant/Coordinator (Seattle)
Researcher Identifier (e.g. ORCID ID):	
Nearest person month worked:	0.5
Contribution to Project:	Mr. Jerrell has coordinated data collection activities for the Seattle site, including subject recruitment, travel, reimbursement, tracking, data collection and data entry. In addition, Mr. Jerrell has coordinated required regulatory submissions for the Seattle site.
Funding Support:	<i>n/a</i>

Name:	Mandeesh Singh
Project Role:	Research Assistant/Coordinator (Richmond)
Researcher Identifier (e.g. ORCID ID):	
Nearest person month worked:	0.5
Contribution to Project:	Ms. Singh has coordinated data collection activities for the Richmond site, including subject recruitment, travel, reimbursement, tracking, data collection and data entry. In addition, Ms. Singh has coordinated required regulatory submissions for the Richmond site.
Funding Support:	<i>n/a</i>

- **Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

There have been some changes to active support for the PI and senior/key personnel since Year 3 of our study. These changes are listed below. None of these changes have impacted level of effort on this project.

Dr. Linda Resnik - The following changes have been made to Dr. Resnik's support:

New

Title: Evaluating the impact of prosthetic device features on the experience of prosthesis use (Gracyzk PI)

Sponsor: DoD CDRMP W81XWH1910827

Role: Co-Investigator

Time Commitment: 0.0CM (VA)

Contingent Upon VA RR&D A9264-S

Period of Performance: 9/16/2019-9/15/2021

Amount Funded:

Project Goals/Specific Aims: The overall goal is to understand the critical factors associate with outcome acceptance following upper limb loss.

Title: Evaluating Medicare's New Skilled Nursing Facility Payment System (Rahman PI)

Sponsor: Warren Alpert Foundation

Role: Co-Investigator

Time Commitment: 0.5 CM (Brown)

Period of Performance: 12/1/19-11/30/21

Amount Funded:

Project Goals/Specific Aims: The overall goal is to evaluate Medicare's new skilled nursing facility payment system.

Title: LeaRRN: the Learning Health Systems Rehabilitation Research Network (Resnik PI)

Sponsor: NIH NCMRR

Role: Principal Investigator

Time Commitment: 2.0 CM (Brown)

Period of Performance: 4/1/20-3/30/25

Amount Funded:

Project Goals/Specific Aims: The overall objective of this proposal is to create a national resource network to advance stakeholder-partnered, rehabilitation learning health systems (LHS) research to improve quality of care, demonstrate value, and enhance patient and system outcomes.

Title: Peripheral Interfaces in Amputees for Sensorimotor Integration (Tyler PI)

Sponsor: VA RR&D A3355-R

Role: Role: Sub-Principal Investigator PVAMC

Time Commitment: 0.0CM (VA)

Contingent Upon VA RR&D A9264-S

Period of Performance: 8/1/20-7/31/24

Amount Funded:

Project Goals/Specific Aims: This project aims to restore the emotional and functional aspects of the hand to Veterans with upper limb loss, by implanting a system of electrodes to restore bodily sensation and naturalistic control.

Completed

Title: A Modular Multi-DOF Prosthetic Wrist and Low-Level Autonomous Control for Ease-of Use (Dollar PI)

Sponsor: DoD, W81XWH-15-C-0125, Subcontract C16J12326

Role: PI of Subcontract to Brown University

Time Commitment: 0.25 CM (Brown)

Period of Performance: 09/1/15-08/31/20 (NCE)

Amount Funded:

Project Goals/Specific Aims: This project centers on developing and evaluating a novel class of spherical prosthetic wrist that provides a range of motion equal to the unaffected human wrist while adding only two inches to the length of the residual limb. Sub to Yale University

Dr. Jill Cancio - The following changes have been made to Dr. Cancio's support:

New

Title: Comparative effectiveness of upper limb prostheses and component effects (Resnik PI)

Sponsor: (CDMRP), (OPORP), W81XWH-19-1-0800

Role: Co-Investigator / Site PI

Time Commitment: 2.4 Calendar Months

Period of Performance: 09/20/2019-09/29/2022

Award Amount Funded: (annual costs)

Project Goals/Specific Aims: The overall objective of this study is to generate evidence to guide prosthesis prescription by comparing effectiveness of upper limb prostheses and components and whether specific groups of patients are more likely to benefit from specific device types or components

Completed

Title: Development of an Engaging Training Tool to Provide Superior Muscle Computer Interfaces for Rehabilitation of Neuromusculoskeletal Injuries (Hargrove PI)

Sponsor: Clinical and Rehabilitative Medicine Research Program, W81XWH-15-2-0035

Role: Co-Investigator / Site PI

Time Commitment: 2.4 calendar months

Period of Performance: 8/15/2015-03/31/2020

Award Amount Funded:

Project Goals/Specific Aims: To increase the functional abilities of upper-extremity amputees and improve myoelectric prostheses utilization by developing a virtual reality-based, pre-prosthetic training program (Virtual Coach).

Title: Needs, Preferences, and Functional Abilities of Veterans and Service Members with Upper Limb Amputation (Resnik PI)

Sponsor: (CDMRP), (OPORP), W81XWH-16-2-0065

Role: Co-Investigator / Site PI

Time Commitment: 1.2 Calendar Months

Period of Performance: 10/01/2016-03/31/2020

Award Amount Funded: (Annual Costs)

Project Goals/Specific Aims: The proposed study will provide comprehensive cross-sectional and longitudinal data from Veterans and service members with upper limb amputation using a nationally representative sample

Dr. Melissa Clark- The following changes have been made to Dr. Clark's support:

New

Title: Neonatal Cry Acoustics and Neurobehavioral Characteristics as Early Markers of Risk for Autism Spectrum Disorder

Sponsor: W1H/NIH 1R01MH121345-01 (Sheinkopf PI)

Role: Co-Investigator

Time Commitment: 0.6 CM

Period of Performance: 09/01/2019 – 08/31/2024

Amount Funded:

Project Goals/Specific Aims: This proposed work aims to provide identification of very early indicators of risk for autism measured in the newborn period and in a setting that is feasible for future implementation. Such results would have a significant and positive impact by advancing the search for early infant indicators of risk for autism, with the potential to improve early screening and intervention.

Title: The Prenatal and Childhood Mechanisms of Health Disparities: Protocol Development and Initial Recruitment and Attention Disparities (Whitehead PI)

Sponsor: RTI/CDC

Role: Co-Investigator

Time Commitment: 1.2 CM

Period of Performance: 10/1/2019 - 07/10/2024

Amount Funded:

Project Goals/Specific Aims: The aims of this study are to investigate disparities in parents' health and behaviors during pregnancy; and mechanisms generating disparities in birth outcomes and child development during the first year of life.

Title: Implementing Statewide Emergency Department Care Pathways for Addiction Recovery after Opioid Overdose (Beaudoin PI)

Sponsor: CDC

Role: Co-Investigator

Time Commitment: 1.2 CM

Period of Performance: 09/01/2019-08/31/2022

Award Amount Funded: (sub only)

Project Goals/Specific Aims: This project will examine the current implementation and effectiveness of Rhode Island's Levels of Care (LoC) policy for treatment of opioid use disorder and opioid overdose and compare this to pre-LoC and also LoC effectiveness following an enhanced implementation strategy focused on improving uptake of patient services offered within the ED post-overdose.

Title: Comparing Glycemic Profiles in Pregnancy and Maternal and Child Health Outcomes (Werner PI)

Sponsor: WIH/NIH 1U01DK123783-01

Role: Co-Investigator

Time Commitment: 1.2 CM

Period of Performance: 9/20/19 – 7/31/2024

Award Amount Funded:

Project Goals/Specific Aims: The objective of this project is to use continual glucose monitoring (CGM) to better understand physiologic and pathologic changes in maternal glycemic profile over the course of gestation.

Title: Determinants of End-of-Life Care Experiences among Assisted Living Residents with Alzheimers Disease and Related Dementia (Belanger PI)

Sponsor: NIA R01AG066902

Role: Co-Investigator / Site PI

Time Commitment: 1.8 CM

Period of Performance: 04/01/20 – 03/31/24

Award Amount Funded:

Project Goals/Specific Aims: The overall objective of this application is to identify the determinants of better end-of-life care experiences in AL through administrative claims data, a survey of AL administrators, and interviews with the next of kin of AL decedents.

Title: LeaRRN: the Learning Health Systems Rehabilitation Research Network (Resnik PI)

Sponsor: NIH NCMRR

Role: Co-Investigator

Time Commitment: 0.48 CM (Brown)

Period of Performance: 4/1/20-3/30/25

Amount Funded:

Project Goals/Specific Aims: The overall objective of this proposal is to create a national resource network to advance stakeholder-partnered, rehabilitation learning health systems (LHS) research to improve quality of care, demonstrate value, and enhance patient and system outcomes.

Dr. Jeffrey Heckman: The following changes have been made to Dr. Heckman's support:

Completed

Title: Comparative Effectiveness of Upper Limb Prostheses and Component Effects (Resnik PI)

Role: Site Principal Investigator

Time commitments: 1.2 Calendar Months

Supporting agency: DoD, Orthotic and Prosthetics Outcomes Research Program, W81XWH-19-1-0800

Performance period: 9/30/19-9/25/20

Level of funding:

Project goals: The objective of this study is to generate evidence to guide prosthesis prescription by comparing effectiveness of upper limb prostheses and components and whether specific groups of patients are more likely to benefit from specific device types or components

Title: Criteria for Advanced Prosthetic Foot Prescription

Role: Site Principal Investigator

Time commitments: 0.6 Calendar Months

Supporting agency: DoD, Orthotic and Prosthetics Outcomes Research Program, DoD W81XWH-17-2-0014

Performance period: 8/1/2017-7/30/2020

Level of funding:

Project goals: The objective of this study is to develop a system that correlates patient goals and subjective measures with objective data to determine the most appropriate prosthetic ankle-foot category that will facilitate the greatest overall function to the user.

Title: Needs Preferences and Functional Abilities of Veterans and Service Members with Upper Limb Amputation

Role: Site Principal Investigator

Time commitments: 1.2 Calendar Months

Supporting agency: DoD, Orthotic and Prosthetics Outcomes Research Program, W81XWH-16-2-0065

Performance period: 9/30/16-03/31/2020

Level of funding:

Project goals: The objective of this study is to provide comprehensive cross-sectional and longitudinal data on function, needs, preferences, and satisfaction of Veterans and service members with major upper limb amputation.

Dr. M. Jason Highsmith - The following changes have been made to Dr. Highsmith's support:

New

Title: Prosthetic, functional, and clinical outcomes among female amputees: A scoping project to include a systematic review and 10-year retrospective record review of female Veterans with limb loss.

Supporting Agency: Center for Orthotic & Prosthetic Learning and Outcomes/Evidence-Based Practice (American Orthotic & Prosthetic Association)

Performance Period: 09/01/2020-08/31/2021

Role: Co-Investigator

Level of Funding:

Project Goals: Evaluate the quality, quantity, and consistency of existing available female amputee literature by conducting a systematic review of the literature; Analyze existing retrospective clinical hospital data (2008-2020), using a cross sectional design and analysis to produce a comparative and descriptive summary of female Veteran amputee characteristics, relative to their male counterparts, and between female subset groups (i.e. users vs nonusers, obese vs non-obese, diabetic vs non-diabetic, vascular disease vs other etiologies)

Title: Comparative Effectiveness of Upper Limb Prostheses and Component Effects

Supporting Agency: Providence VA Medical Center (prime: US Department of the Army)

Performance Period: 09/30/2019-09/29/2022

Level of funding:

Role: Co- Investigator

Project Goals: Provide comprehensive cross-sectional and longitudinal data on function, needs, preferences, and satisfaction of Veterans and service members with major upper limb amputation.

- **What other organizations were involved as partners?**

Nothing to report

8. SPECIAL REPORTING REQUIREMENTS

- **COLLABORATIVE AWARDS:**

Nothing to report, not applicable.

- **QUAD CHART:** See attached.

9. APPENDICES: Appendix A attached – Copies of 6 accepted manuscripts

Needs, Preferences and Functional Abilities of Veterans and Service Members with Upper Limb Amputation



PI: Linda Resnik, PT, PhD

Org: Providence VA Medical Center

Award Amount: \$2,497,440

Study/Product Aims

1. Describe patterns of prosthesis use; identify the impact of amputation and prosthesis use on function, activities and participation; and identify unmet prosthetic needs.
2. Conduct a one year longitudinal follow-up survey to examine changes in satisfaction with care and prosthetic services, physical performance, self-reported quality of life and physical function to assess the implementation of new clinical practice guidelines (CPGs)
3. Quantify physical function using a battery of performance based tests.

Approach

This 3-part study will provide cross-sectional and longitudinal survey and performance data. Data collection will be done through surveys and functional performance testing. Part 1 will be a cross-sectional survey. Part 2 is a one year longitudinal follow-up survey of respondents from Part 1. Part 3 is an in-person study to collect performance based measures of physical function at two time points, about one year apart.



Accomplishments: Data collection for Aim 1 (N=808 VA, N=5 DoD), Aim 2 (N=585) and Aim 3 (Visit 1 (N=127) & Visit 2 (N=64)) is complete. 9 manuscripts have been published to date and 4 manuscripts have been submitted and are under review.

Timeline and Cost

Activities - Project Year (PY)	Year 1	Year 2	Year 3	Year 4
Identify sampling frame and train interviewers	■			
Data collection – Part 1		■		
Data collection – Part 2			■	
Data collection – Part 3		■	■	■
Data analysis/dissemination			■	■
Actual Expenses YR 1-3) (*estimated YR 4)	\$404,526	\$810,622	\$679,432	\$602,860

Goals/Milestones

PY1 Goals – Study Launch – All goals met

PY2 Goals – Data collection and early analysis

- ✓ Part 2 surveys administered
- ✓ Gift cards issued Part 2
- ✓ Conduct analyses Aim 1, and preliminary analyses Aim 2

PY3 Goals – Data collection, preliminary analysis and dissemination

- ✓ Complete all data collection (Aims 1, 2 Aim 3 Visit 1)
- ✓ Analyze data Parts 1, 2 and 3 – in progress
- ✓ Submit abstracts and manuscripts – in progress

PY4 (NCE Goals) – Data, analysis and dissemination

- ✓ Complete remainder of data collection (Aim 3 Visit 2)
- Complete data analysis for Parts 1, 2 and 3
- Complete dissemination for Parts 1, 2 and 3

PY4 Budget Expenditure to Date

Projected Expenditure: \$2,497,440 (Cumulative, Y1+Y2+Y3 Projected Expenditure – now in No Cost Extension)

Actual Expenditure: \$2,270,619 as of 09/30/20120 (Cumulative, Y1+Y2+Y3 +Y4 Actual Expenditure)

APPENDIX A:

Accepted Manuscripts



A national survey of prosthesis use in Veterans with major upper limb amputation: Comparisons by gender

Journal:	<i>PM&R: The journal of injury, function and rehabilitation</i>
Manuscript ID	Draft
Wiley - Manuscript type:	Original Research
Classifications:	Amputation (including Prosthetics/Orthotics)
Keywords:	Amputations-Upper Extremity, Outcomes Research, Prosthetics, Women's health/MSK issues unique to women
Abstract:	Introduction: A better understanding of women Veterans with upper limb amputation is needed. Objective: To compare prosthetic use and outcomes of female and male Veterans with upper limb amputation. Design: Observational cohort study: Amputation characteristics, prosthesis use, and quality of life outcomes were compared by gender. Separate logistic regression models examined association of gender with prosthesis use and receipt of training to use a prosthesis. Separate linear regression models examined the relationship between gender and health related quality of life (HRQoL) outcomes. Participants: Participants were Veterans with major upper limb amputation who received care at the VA 2010-2015, identified from VA data sources. 808 individuals (755 men, 21 women) were surveyed by telephone. Main Outcome Measures: includes the QuickDASH, VR-12 PCS and VR-12 MCS, Trinity Amputation and Prosthetic Experience Scale satisfaction scale OPUS Client satisfaction with devices scale. Setting: Telephone survey of community dwelling participants. Interventions: Not applicable. Results: Survey response rate was 47.3% for men and 62.8% for women. Women were less likely to be current users (adjusted odds ratio (aOR)=0.34; CI 0.12-1.01), to have ever used a prosthesis (aOR: 0.26; CI 0.08-0.88), received training for an initial prosthesis (aOR: 0.24; CI 0.08-0.70) and to have received training for a current prosthesis (aOR: 0.15; 0.03-0.87). A greater proportion of women used cosmetic and a smaller proportion used body powered devices compared to men (P<0.05). There were no significant differences in outcome measures by gender. Conclusions: Women were less likely than men to use or have ever used prostheses, or to have received prosthetic training, more likely to use cosmetic devices, and less likely to use body powered devices. Device heaviness or fatigue was the most common reason for abandonment. Efforts to develop prostheses that are cosmetically acceptable, yet lightweight and functional are needed.

Abstract

Introduction: A better understanding of women Veterans with upper limb amputation is needed.

Objective: To compare prosthetic use and outcomes of female and male Veterans with upper limb amputation. **Design:** Observational cohort study: Amputation characteristics, prosthesis use, and quality of life outcomes were compared by gender. Separate logistic regression models examined association of gender with prosthesis use and receipt of training to use a prosthesis. Separate linear regression models examined the relationship between gender and health related quality of life (HRQoL) outcomes. **Participants:** Participants were Veterans with major upper limb amputation who received care at the VA 2010-2015, identified from VA data sources. 808 individuals (755 men, 21 women) were surveyed by telephone. **Main Outcome Measures:** includes the QuickDASH, VR-12 PCS and VR-12 MCS, Trinity Amputation and Prosthetic Experience Scale satisfaction scale OPUS Client satisfaction with devices scale. **Setting:** Telephone survey of community dwelling participants. **Interventions:** Not applicable. **Results:** Survey response rate was 47.3% for men and 62.8% for women. Women were less likely to be current users (adjusted odds ratio (aOR)=0.34; CI 0.12-1.01), to have ever used a prosthesis (aOR: 0.26; CI 0.08-0.88), received training for an initial prosthesis (aOR: 0.24; CI 0.08-0.70) and to have received training for a current prosthesis (aOR: 0.15; 0.03-0.87). A greater proportion of women used cosmetic and a smaller proportion used body powered devices compared to men ($P<0.05$). There were no significant differences in outcome measures by gender. **Conclusions:** Women were less likely than men to use or have ever used prostheses, or to have received prosthetic training, more likely to use cosmetic devices, and less likely to use body powered devices. Device heaviness or fatigue was the most common reason for abandonment. Efforts to develop prostheses that are cosmetically acceptable, yet lightweight and functional are needed.

Introduction

While the number of female Veterans from the U.S. Armed services is currently 9.4%, it is projected to increase, given that 14.6% (approximately 200,000 persons) of the current active duty force, are women. [1] Female Veterans have high rates of comorbid conditions and are 22% more likely to be diagnosed with a mental health condition as compared to male Veterans.[2] They are also more likely to have chronic pain and to develop chronic musculoskeletal pain, with rates of 19.4% vs. 15.7% for men.[3] Increasingly, women in the military are being deployed in combat or in supportive roles in combat environments and thus are being exposed to greater risks, including the risk of traumatic limb loss.

Although the Department of Veterans Affairs VA recognizes the concerns of female Veterans, including those with limb loss, female Veterans with upper limb amputation have not been well studied.[2] Studies that have been conducted with veterans with upper limb amputation have included only a handful of women with upper limb amputation.[4] Women were found to receive a greater number of prostheses than men, and to reject devices at a higher rate than men. [4] A recent study that included women reported that prosthesis rejection or abandonment rates of Veteran's with upper limb amputation were 24-30%, with rates even higher for those with transhumeral (TH) amputations or above. [5] Rejection or abandonment of prostheses is a well-documented problem in the civilian population as well, affecting approximately 20% of all upper limb amputees.[6]

Prior studies of civilians have shown mixed results with regard to prosthesis use and rejection by gender. Some studies reported higher abandonment rates among women,[7, 8] while others reported no differences by gender.[9-11] Pezzin found that men were more likely than women to be satisfied with prosthesis fit, comfort and appearance.[12]. A systematic review

concluded that gender was associated with prosthesis selection, with females using more anthropomorphic devices.[13]

It is difficult to focus services and interventions to best serve the needs of female Veterans with amputation without having a better understanding of this population. Therefore, the purpose of this study was to compare prosthetic use and outcomes of female and male Veterans with upper limb amputation. Specifically, we aimed to conduct comparisons by gender of: a) demographic and amputation-related characteristics, b) patterns of prosthesis use, training and abandonment, and hours of prosthesis use, and c) prosthetic satisfaction, health related quality of life (HRQoL), and disability.

Methods

Recruitment

We identified individuals with major upper-limb amputation who had been treated at the VA between 2011 and 2015 using VA Corporate Data Warehouse (CDW) sources (including Inpatient, Outpatient, and Fee domains; the main source for information regarding VHA Benefit compensation and pension benefits paid to veterans and their beneficiaries; and Veteran’s Benefits Administration (VBA) disability ratings). We defined major upper limb amputation using diagnosis codes for amputation at the forequarter, shoulder disarticulation, TH, elbow disarticulation, transradial (TR), or wrist disarticulation level (Appendix A).

Data Collection

Participants provided oral informed consent to participate in a comprehensive 45 minute, telephone survey.[14] The survey was developed through cognitive (N=10) and pilot testing

(N=10) to ensure that items were comprehensible and clear. The survey development process is described elsewhere.[14] This manuscript reports on selected portions of the survey as described below.

The survey's demographics section included items on gender, age, race/ethnicity, and employment. In cases where the gender item was not answered at the time of interview, we utilized the gender variable from VA Corporate Data Warehouse (CDW). The amputation section included items asking about: the side and level of amputation; date, etiology, and surgical history related to the amputation; and prior hand dominance. For our analyses, we collapsed the original categories of amputation level into the following three categories: shoulder (forequarter and shoulder disarticulation), TH (transhumeral and elbow disarticulation) and TR (transradial and wrist disarticulation). The prosthesis use section included items on current device use, types of device and terminal device used, suspension methods, frequency and hours of use, receipt of prosthetic training, as well as history of prior prosthesis use and abandonment.

The survey included two standardized measures of prosthetic satisfaction: the Trinity Amputation and Prosthetic Experience Scale (TAPES) satisfaction scale[15] and OPUS (Orthotics and Prosthetics User's Survey) Client satisfaction with devices (CSD) scale. The TAPES satisfaction scale consists of 10 items addressing color, shape, noise, appearance, weight, usefulness, reliability, fit, comfort and overall satisfaction each rated on a 5-point scale (1=very dissatisfied, 5= very satisfied), with scores summed and averaged for a total score. The CSD consists of 11 items rated on a 4-point scale that address prosthesis weight, ease of donning, durability, fit, appearance, comfort, wear and tear from clothes, pain of wearing, skin abrasions, cost of maintenance and cost of repair. The cost-related items are scored separately, while the other 9 items are used to calculate the final score, which is the sum of item scores (all items

without missing values) cross-walked to the norm-based values shown on the OPUS Scoring Guide.[16] The survey also included investigator-generated items asking about desire to change devices, inability to wear the prosthesis because of poor socket fit, satisfaction with the way the prostheses and terminal device moves, and unintended movement of the prosthesis..

The survey included measures of health-related quality of life (HRQoL) and disability. HRQoL was measured using the Veteran version of the SF-12 Health Survey (VR-12). The VR-12 produces the Physical Component Summary (PCS) and the Mental Component Summary (MCS) scores.[17, 18] Disability was measured using the 11-item QuickDASH (Disabilities of the Arm, Shoulder and Hand) score, which has been validated in upper limb amputees.[19] QuickDASH items assess difficulty performing activities, amount of limitation, or the extent of interference with activities as well as extent of arm, shoulder and hand pain and tingling.[20, 21] The survey also asked several investigator-generated items including whether or not respondents needed help from another person to perform daily activities, and if so, the number of hours of help required in a typical day. For additional details about the survey, see Resnik et al. [22]

Statistical Methods

We calculated response rates separately for females and males using the American Association for Public Opinion Research guidelines.[23] We examined statistics by gender to characterize respondents, their patterns of prosthesis use and abandonment, the prostheses and componentry used, and the receipt of prosthetic training. We conducted bivariate analyses to understand differences by gender in select characteristics including prosthesis use, type and number of prostheses/terminal devices used, device abandonment and reasons for abandonment.

We compared prevalence of phantom limb, residual limb, neck and low back pain, and sound-side musculoskeletal conditions including carpal tunnel syndrome, tendonitis of the wrist, tendonitis of the elbow, tendonitis of the finger, tendonitis of the thumb, ganglion cyst, rotator cuff tendinitis, osteoarthritis, nerve damage or other problem by gender. We also compared hours of prosthetic use by gender. Chi-square and Fisher's exact tests were used as appropriate. We performed multiple comparison tests using the COMPROP macro, a Tukey-type method [24] in SAS to examine differences between sub-groups. We also conducted bivariate comparisons of scores for QuickDASH, VR-12 PCS and MCS scores, prosthetic satisfaction (TAPES, CSD), and investigator-generated satisfaction items by gender using non-parametric Wilcoxon Signed-Rank (WSR) tests.

Given that women had more recent amputation and that standards of prosthetic rehabilitation have changed over time, [25 , 26] we computed separate logistic regression models to assess the relationship between gender and a) ever having used a prosthesis, b) receipt of training to use initial prosthesis, c) current prosthesis use (among those who had ever used a prosthesis), and d) receipt of training to use current prosthesis. These models controlled for year of amputation (prior to 2000, 2001-2009, 2010-2016), age, amputation level and prosthesis type. The model for training to use current prosthesis also included a variable indicating whether there had been a change in prosthesis type from the initial prosthesis received to the type currently reported. Using linear regression models, we examined the relationship of gender with QuickDASH, VR-12 PCS and VR-12 MCS scores, while controlling for age, years as amputee, amputation level, and current prosthesis type. Unknown data were treated as missing for prosthesis use, training and years of amputation in all regression analyses.

Results

Sampling Frame and Response Rate

Our initial sampling frame consisted of 5501 men and 138 women. We excluded 2080 persons (2036 men and 44 women), 1479 (1462 men and 17 women) who were deceased, and 601 (564 men and 27 women) who were missing valid contact information. Recruitment materials with opt out cards were sent to the remaining 3522 men and 94 women. Up to 10 phone call attempts were made to contact those who did not opt-out of participation or inform us that they did not meet eligibility criteria. The 1893 Veterans who were reached by phone (63 women and 1830 men) were screened for eligibility. Of these, an additional 195 men and 13 women were determined not to meet study eligibility criteria, 405 men and three women declined participation, and 1035 men and 15 women could not be reached for screening.

In total, 945 men and 25 women were found eligible. Seven hundred and eighty-seven (83%) of the men eligible after screening were recruited into the study, and 21 (84%) of the women were recruited. The final response rate (RR) and cooperation rate (CR) for the men was 47.3% and 62.8%, respectively [23]. Among women, the RR was 66.8% and the CR was 87.5%. Figures 1 and 2 show the flow diagrams of participants by gender.

Sample characteristics

Seven hundred eighty-eight individuals completed the survey in its entirety, while 20 completed at least part of the survey. The sample consisted of 776 unilateral amputees and 32 bilateral amputees. Because there were no female respondents with bilateral amputation, we

excluded men with bilateral amputation from the analyses for this manuscript to enhance validity of our comparisons. Demographic and detailed amputation characteristics are shown in Table 1.

Briefly, 57.1% of women identified themselves as white and 4.8% as Hispanic or Latino. Seventy-six percent of the men were white, and 8.1% Hispanic or Latino. Average age was 54.5 years (sd 9.6) for women and 63.5 years (sd 14.1) for men. Women had been amputees for an average of 18.1 (sd 12.1) years, and men an average of 31.7 (sd 18.4) years.

Nineteen percent of women and 13% of men were working full- or part- time, while 48% and 69% (respectively) were retired. Amputation level for women and men, respectively, was 9.5% and 12.2% shoulder/forequarter, 47.6% and 35.2% transhumeral/at the elbow, and 42.9% and 52% transradial/at the wrist joint. The two most common etiologies of amputation (respondents indicated all etiologies that applied) were accident (66.7% of women, 62.0% of men), “other” (57.1% of women, 53% of men), followed by infection for women (19.1%) and combat injury for men (36.1%).

Prosthesis Use, Abandonment and Training

A smaller proportion of female respondents were prosthesis users; 47.1% versus 64.7% of male amputees (Table 2), although the difference was not statistically significant ($p=0.23$). There was a greater proportion of women (19.1%) compared to men (6.4%) who had never used a prosthesis ($p=0.08$). A larger proportion of women used two or more prostheses as compared to men; 87.5% v. 36.0%, ($p=0.005$). Among those who used a prosthesis, 75% of women and 42.6% of men received their most recent prosthesis within the prior 2 years ($p=0.0018$).

Myoelectric/hybrid devices were used by about the same proportion of women and men. However, compared to men, women were less likely to use body-powered devices (37.5% vs.

71.3%) and more likely to use cosmetic devices (37.5% vs. 4.2%). Comparison of all prosthesis types by gender was significant at $p=0.0063$. Post-hoc comparisons found significant differences between only body-powered and cosmetic device use. Descriptively, differences were also noted in prosthetic suspension types used. The most common suspension for females was gel or silicone liner (75.0%), while harnessing was the most commonly used type of suspension for males (75.3%). The most commonly used terminal device was a hook (women 62.5%, men 60.9%). However, a greater proportion of women used a multifunctional terminal device (37.5% vs. 10.2%).

A smaller proportion of women had received training to utilize their first prosthesis (58.8% vs 76.4%) although this difference was not statistically significant in bivariate analyses ($p=0.23$). Similarly, a smaller proportion of women had received training to use their current prosthesis (37.5% vs 65.8%; $p=0.23$).

Table 3 shows that a greater proportion of women had abandoned a prosthesis (76.5% women vs. 52.3% men %; $p=0.02$), and the majority of devices abandoned were body-powered. The most common reason for abandonment of body-powered devices was that it did not fit or was uncomfortable (87.5% women, 73.5% men); while the most common reason for abandoning a myoelectric device was heaviness or fatigue (83.3%) for women and poor fit/comfort (69.8%) for men.

The reasons reported for abandoning any type of device are shown in Figure 3. The most common overall reason was uncomfortable fit for men; uncomfortable fit and ‘other’ reasons were most common among women. For both men and women, the least common reason was that the device was not cosmetic.

In the logistic regression models (Table 4), women were less likely to have ever used a prosthesis (aOR: 0.26, $p=0.04$), to have received training for an initial prosthesis (aOR: 0.24, $p=0.01$), to be current prosthesis users (adjusted odds ratio aOR=0.34, $p=0.05$); and to have received training for a current prosthesis (aOR: 0.15, $p=0.04$).

Older amputees (OR=0.98, $p=0.05$), more recent amputees, and for those with TH (OR=0.18, $p<0.0001$) and SH (OR=0.13, $p<0.0001$) amputation were less likely to have ever used a prosthesis (Table 4, column 2). The odds of ever using a prosthesis were lower for those with amputations in 2001-2009 (OR=0.35, $p=0.01$) and 2010-2016 (OR=0.27, $p=0.002$) compared to those with amputations before 2000. Older age (OR=0.97, $p=0.0005$) and initial prosthesis use with cosmetic (rather than body-powered) devices (OR=0.31, $p=0.03$) was significantly associated with lower odds of training with the initial prosthesis among those who had ever used a prosthesis (Table 4, column 3). Compared to persons with TR amputation, persons with TH and SH amputation had 0.22 ($p<0.0001$) and 0.14 ($p<0.0001$) times the odds of currently use a prosthesis, respectively (Table 4, column 4). Among those currently using a prosthesis, cosmetic users (OR=0.20, $p=0.004$) were less likely to have received training on that device than body-powered users. Older age (OR=0.97, $p=0.02$) was also associated with lower odds of training on the current device (table 4, column 5).

Bivariate outcome comparisons by gender are shown in Table 5. There were no statistically significant differences in QuickDASH, or PCS scores by gender. However, women had lower MCS scores (mean 43.9, sd 13.6) compared to men (mean 49.7, sd 13.4) ($p=0.05$). There were no differences in the percent of participants with any pain, or with musculoskeletal conditions by gender. TAPES and CSD item or summary scores also did not differ by gender (item scores not shown) among prosthesis users. Women rated satisfaction with

prosthesis/terminal device movement more favourably compared to men ($p=0.01$). There were no differences in hours of prosthesis use by gender.

Linear regression models of QuickDASH ($R^2=0.07$), VR-12 PCS ($R^2=0.05$) and VR-12 MCS ($R^2=0.06$) scores (Table 6) showed no significant association with gender. QuickDASH disability scores were on average 0.20 points lower (better) for each additional year of being an amputee ($P=0.0011$), 9.5 points higher for users of cosmetic prostheses ($P=0.0454$) and 8.8 points higher for nonusers ($P<0.0001$) compared to users of body-powered prostheses (Table 6, column 2). VR-12 PCS scores were 0.13 points lower (worse) on average for each additional year of age ($P<0.0001$), 0.06 points higher with each additional year as an amputee ($P=0.0176$), and 2.8 points lower (worse) for nonusers compared to users of body-powered prostheses (Table 6, column 3). VR-12 MCS scores were also 0.14 higher (better) for those for each additional year as an amputee ($P=0.0004$); amputation level was not significantly associated with any of the outcome measures.

Discussion

We conducted the first of its kind, national study of Veterans with upper limb amputation and compared prosthesis use and abandonment, receipt of training and important outcomes by gender. We found that women were less likely to have ever used a prosthesis compared to men. These findings are consistent with earlier reports that women with upper limb amputation were more likely to reject devices outright, and never use them.[8, 27] Women in prior studies have expressed preferences for, and challenges in obtaining, appropriately gendered prostheses that are smaller sized and look more feminine.[28-30]

We also found that time since amputation was independently associated with ever having used a prosthesis, with the likelihood of ever having used a prosthesis increasing with time. This suggests that with greater opportunities for exposure through more years as an amputee, Veterans are more likely to try a prosthesis.

Multivariable models did not show a statistically significant association between gender and current prosthesis use after controlling for age, year of amputation, and amputation level. The lack of statistical significance in the multivariable model is likely a consequence of the small female sample size.

We found that male and female Veterans who used prostheses were similarly satisfied with them according to TAPES and OPUS CSD scores. However, women used more and different types of devices as compared male. Women who did use a prosthesis were more than twice as likely as men to use two or more types of devices. Women were more likely than men to use cosmetic devices and less likely to use body powered devices. Furthermore, a higher proportion of women used multifunctional terminal devices; in fact, all women who were using myoelectric devices also had multi-functional terminal devices. These findings suggest that women may be more sensitive to prosthesis appearance, preferring more natural looking and anthropomorphic devices, findings that have been widely reported by prior researchers. [27] [28] Our findings suggest that women may prefer the option of switching between several types of devices, depending upon need and lifestyle, a finding supported by our earlier work. [30] The higher prevalence of use of anthropomorphic terminal devices among the female suggests a desire to have a less conspicuous, more natural looking device.[31]

The most common reasons for prosthesis abandonment for women were poor fit/discomfort, other reasons, and heaviness or fatigue. We examined the text descriptions of

“other reasons” for abandonment, but found no clear patterns. A greater proportion of women as compared to men had abandoned using a body powered device, which is consistent with prior reports.[7, 8]

Although the role of prosthesis training in abandonment is not clear, it is generally believed that training will lead to better functional outcomes. [9] While there are no specific guidelines regarding training with a cosmetic prosthesis, the VA/DoD guidelines on upper limb amputation rehabilitation state the importance of early prosthetic training. [26] Many aspects of training, including care of prosthesis, acclimating to wear time, and inspection of the residual limb are certainly applicable regardless of type of device used. We found that women had lower odds than men to have received training for their initial and current prostheses, even after controlling for device type. Taken together, our findings suggest differences in access to prosthesis training, or in attitudes towards training either by women or their healthcare providers. Further research is needed to understand why women with upper limb amputation are less likely to receive prosthetic training.

Our finding in bivariate analyses that women had lower MCS scores as compared to men is consistent with the literature that reports that female Veterans are more likely than males to be diagnosed with a mental health condition.[2] However, the relationship between gender and MCS scores was not statistically significant after controlling for age, years as an amputee, amputation level and prosthesis type/use. Given the consistent effect of gender seen in both the bivariate and linear regression analyses, we expect that this relationship would be significant if examined in a larger sample.

Our findings are generalizable to male and female Veterans with upper limb amputation who receive care at the VA, but there are limits to generalizability outside of this sample. We

compared the respondents to eligible individuals who did not respond to the survey and found that on average, respondents were 1.8 years younger, more often female, and had a more recent year of service utilization at the VA. [14] We do not know whether male and female Veterans are equally likely to come to the VA for care. If females are less likely to come to the VA for care, then our findings may underrepresent female Veterans with upper limb amputation. Furthermore, given that only about 40% of female Veterans are currently using services in the Department of Veterans Affairs (VHA) [32], the findings from this study are useful for care providers both within and outside of the VHA.

Conclusion

This national study of Veterans with upper limb amputation found that women were less likely than men to use or have ever used prostheses, or to have received prosthetic training. Women were more likely than men to use cosmetic devices and multifunctional terminal devices and less likely to use body powered devices. Device heaviness or fatigue was the most common reason for women to have abandoned a prosthesis. Efforts to develop prostheses that are cosmetically acceptable, yet lightweight and functional are needed.

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397 **Table 1. Demographics characteristics by gender**

	Male N=755	Female N=21	All N=776
	Mean (sd)	Mean (sd)	Mean (sd)
Age (Years)	63.5 (14.1)	54.5 (9.6)	63.2 (14.1)
Missing (n)	23	1	24
Years since initial amputation	31.7 (18.4)	18.1 (12.1)	31.3 (18.4)
Missing (n)	21	0	21
	N (%)	N (%)	N (%)
Year of initial amputation			
1940-1979	344 (45.6)	0 (0.0)	344 (44.3)
1980-2000	155 (20.5)	10 (47.6)	165 (21.3)
2001-2009	131 (17.4)	4 (19.1)	135 (17.4)
2010-2016	104 (13.8)	7 (33.3)	111 (14.3)
Unknown	21 (2.8)	0 (0.0)	21 (2.7)
Race			
White	571 (75.6)	12 (57.1)	583 (75.1)
Black	82 (10.9)	4 (19.1)	86 (11.1)
Other (including mixed race)	34 (4.5)	1 (4.8)	35 (4.5)
Unknown	68 (9.0)	4 (19.1)	72 (9.3)
Hispanic or Latino			
Yes	61 (8.1)	1 (4.8)	62 (8.0)
No	659 (87.3)	19 (90.5)	678 (87.4)
Unknown	35 (4.6)	1 (4.8)	36 (4.6)
Employment			
Employed full-time	69 (9.1)	4 (19.1)	73 (9.4)
Employed part-time	31 (4.1)	0 (0.0)	31 (4.0)
Student	20 (2.7)	0 (0.0)	20 (2.6)
Retired, but employed after amputation	369 (49.9)	4 (19.1)	373 (48.1)
Retired, but not employed after amputation	146 (19.3)	6 (28.6)	152 (19.6)
On medical leave	8 (1.1)	1 (4.8)	9 (1.2)
Other	88 (11.7)	5 (23.8)	93 (12.0)
Unknown	24 (3.2)	1 (0.0)	24 (3.2)
Amputation Level			
Forequarter	23 (3.1)	0 (0.0)	23 (3.0)
At the shoulder joint	69 (9.1)	2 (9.5)	71 (9.2)
Above the elbow	226 (29.9)	10 (47.6)	236 (30.4)
At the elbow	40 (5.3)	0 (0.0)	40 (5.2)
Below the elbow	272 (36.0)	8 (38.1)	280 (36.1)
At the wrist joint	125 (16.6)	1 (4.8)	126 (16.2)

Etiology of amputation[^]			
Combat injury	272 (36.1)	3 (14.3)	275 (35.5)
Accident	467 (62.0)	14 (66.7)	481 (62.1)
Burn	79 (10.5)	2 (9.5)	81 (10.5)
Cancer	30 (4.0)	0 (0.0)	30 (3.9)
Diabetes	10 (1.3)	1 (4.8)	11 (1.4)
Infection	82 (10.9)	4 (19.1)	86 (11.1)
Other	405 (53.9)	12 (57.1)	417 (54.0)
Amputation of Lower Limb			
Yes	93 (12.3)	1 (4.8)	94 (12.1)
No	662 (87.7)	20 (95.2)	682 (87.9)
Those with Amputation of Lower Limb	N=93	N=1	N=94
Amputation of Lower Limb			
Right Side	38 (40.9)	1 (100.0)	39 (41.5)
Left Side	23 (24.7)	0 (0.0)	23 (24.5)
Both Sides	32 (34.4)	0 (0.0)	32 (34.0)

[^] may indicate more than one etiology

Table 2. Type of prostheses, suspension methods, terminal devices and prosthetic training: comparison of female and male unilateral upper limb amputees

	Male N=755	Female N=21
	N (%)	N (%)
Ever used a prosthesis		
Yes	700 (92.7)	17 (81.0)
No	48 (6.4)	4 (19.1)
Unknown	7 (0.9)	0 (0.0)
Prosthesis users (ever)	Male N=700	Female N=17
Initial type of prosthesis used		
Body powered	554 (79.1)	11 (64.7)
Myoelectric/ Hybrid	102 (14.6)	5 (29.4)
Cosmetic	19 (2.7)	1 (5.9)
Sports/Recreation/Unknown	25 (3.6)	0 (00)
Received training to use first prosthesis		
Yes	535 (76.4)	10 (58.8)
No	158 (22.6)	7 (41.1)
Unknown	7 (1.0)	0 (0.0)
Currently use a prosthesis		
Yes	453 (64.7)	8 (47.1)
No	245 (35.0)	9 (52.9)
Unknown	2 (0.3)	0 (0.0)
Current prosthesis users	Male N=453	Female N=8
Received training to use current prosthesis		
Yes	298 (65.8)	3 (37.5)
No	148 (32.7)	5 (62.5)
Unknown	7 (1.6)	0 (0.0)
Prosthesis users: most recent prosthesis received		
<2 years ago	193 (42.6)	6 (75.0)
2 + years ago	259 (57.2)	1 (12.5)
Unknown	1 (0.2)	1 (12.5)
Number of prostheses used		
One	290 (64.0)	1 (12.5)
Two or more	163 (36.0)	7 (87.5)
Number of terminal devices used		
One	256 (56.5)	3 (37.5)
Two or more	190 (42.9)	5 (62.5)
Unknown	7 (1.6)	0 (0.0)
Primary type of prosthesis used		

Body powered	323 (71.3)	3 (37.5)
Myoelectric/ Hybrid	100 (22.1)	2 (25.0)
Cosmetic	19 (4.2)	3 (37.5)
Sports/Recreation/Unknown	11 (2.4)	0 (0.0)
Initial to current prosthesis type		
Same	339 (74.8)	3 (37.5)
Changed	105 (23.2)	5 (62.5)
Unknown	9 (2.0)	0 (0.0)
Suspension type for primary prosthesis		
Suction	152 (33.6)	4 (50.0)
Gel or silicone liner with pin	85 (18.8)	6 (75.0)
Vacuum	50 (11.0)	1 (12.5)
Self-suspending because of the socket shape	168 (37.1)	4 (50.0)
Harnessing	341 (75.3)	4 (50.0)
External Suspension	61 (13.5)	1 (12.5)
Unsure	3 (0.4)	0 (0.0)
Primary type of terminal device used		
Voluntary opening/closing hook	276 (60.9)	5 (62.5)
Greiffer	6 (1.3)	0 (0.0)
Power hook (ETD)	17 (3.8)	0 (0.0)
Sensor Speed Hand	11 (2.4)	0 (0.0)
I-Limb/ Michaelangelo hand / Bebionic hand	46 (10.2)	3 (37.5)
Unknown	97 (21.4)	0 (0.0)
Prosthetic users with two or more prostheses		Male N=163
Secondary type of prosthesis used		Female N=7
Body powered	72 (44.2)	2 (28.6)
Myoelectric/ Hybrid	64 (39.5)	2 (28.6)
Cosmetic	5 (3.1)	0 (0.0)
Sports/Recreation/ Unknown	21 (10.5)	3 (42.9)

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Table 3. Prosthesis Abandonment by Gender	Male N=700	Female N=17
Have you ever stopped using a prosthesis?		
Yes	366 (52.3)	13 (76.5)
No	324 (46.3)	3 (17.7)
Unknown	10 (1.4)	1 (5.9)
Those who stopped using a prosthesis	Male N=366	Female N=13
Were any of the prostheses that you stopped using?		
Body powered	268 (73.2)	8 (61.5)
Myoelectric	129 (35.3)	6 (46.2)
Hybrid	26 (7.1)	0 (0.0)
Other	20 (5.5)	1 (7.7)
If ever stopped using body-powered device:	Male N=268	Female N=8
Major reasons for stopping device use were:		
It was too heavy or fatiguing to wear	141 (52.6)	4 (50.0)
It didn't fit or was uncomfortable	197 (73.5)	7 (87.5)
It was not functional enough	172 (64.2)	5 (62.5)
It was too much fuss	154 (57.5)	6 (75.0)
It broke or was unreliable	81 (30.2)	2 (25.0)
It was not cosmetic	54 (20.2)	1 (12.5)
It was not intuitive to use	111 (41.4)	3 (37.5)
Some other reason	161 (60.1)	8 (100.0)
If ever stopped using myoelectric device	Male N=129	Female N=6
Major reasons for stopping device use were:		
It was too heavy or fatiguing to wear	79 (61.2)	5 (83.3)
It didn't fit or was uncomfortable	90 (69.8)	4 (66.7)
It was not functional enough	89 (69.0)	5 (83.3)
It was too much fuss	86 (66.7)	4 (66.7)
It broke or was unreliable	64 (49.6)	3 (50.0)
It was not cosmetic	23 (17.8)	1 (16.7)
It was not intuitive to use	46 (35.7)	2 (33.3)
Some other reason	77 (59.7)	3 (50.0)
If ever stopped using hybrid device	Male N=26	Female N=0
Major reasons for stopping device use were:		
It was too heavy or fatiguing to wear	18 (69.2)	0 (0.0)
It didn't fit or was uncomfortable	19 (73.1)	0 (0.0)
It was not functional enough	20 (76.9)	0 (0.0)
It was too much fuss	19 (73.1)	0 (0.0)

It broke or was unreliable	10 (38.5)	0 (0.0)
It was not cosmetic	4 (15.4)	0 (0.0)
It was not intuitive to use	12 (46.2)	0 (0.0)
Some other reason	14 (53.9)	0 (0.0)

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Table 4. Results of separate logistic regressions estimating the impact of year of amputation and gender on prosthesis use and training

	Ever used a prosthesis (N=732)		Training to use initial prosthesis (N=676)		Currently use a prosthesis (N=681)		Training to use current prosthesis (N=434)	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Gender								
Male (ref)								
Female	0.26	0.08-0.88	0.24	0.08-0.70	0.34	0.12-1.01	0.15	0.03-0.87
Age	0.98	0.95-1.00	0.97	0.95-0.99	0.99	0.97-1.00	0.97	0.95-1.00
Year of amputation								
1940-2000 (ref)								
2001-2009	0.35	0.16-0.77	0.61	0.33-1.13	0.74	0.43-1.24	0.68	0.33-1.41
2010-2016	0.27	0.12-0.61	0.75	0.39-1.44	0.72	0.40-1.27	1.07	0.47-2.44
Amputation level								
Transradial (ref)								
Transhumeral	0.18	0.08-0.41	1.10	0.71-1.70	0.22	0.16-0.32	1.17	0.72-1.90
Shoulder/forequarter	0.13	0.05-0.32	0.87	0.47-1.63	0.14	0.08-0.24	1.09	0.43-2.72
Initial prosthesis								
Body-powered (ref)								
Myo-hybrid			3.05	1.38-6.75				
Cosmetic			0.31	0.11-0.86				
Other/Unknown			3.22	0.66-15.75				
Primary prosthesis Current								
Body-powered (ref)								
Myo-hybrid							1.22	0.60-2.49
Cosmetic							0.20	0.07-0.60
Other/Unknown							0.16	0.03-0.94
Initial to current prosthesis type								
Same (ref)								
Changed							1.37	0.67-2.81

Unknown							9.33	0.65-134.7
Model Fit								
Bold font in OR and CI indicates statistically significant values at P<0.05								

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Table 5. Prosthesis Satisfaction, Disability and quality of life: comparison of female and male upper limb amputees

Full sample	Male N=755		Female N=21		
	N	Mn (sd)	N	Mn (sd)	WSR p
QuickDASH	724	36.8 (27.1)	19	40.2 (19.1)	0.24
VR-12 PCS	708	45.1 (8.6)	19	43.8 (10.5)	0.44
VR-12 MCS	708	49.7 (13.4)	19	43.9 (13.6)	0.05
	N	N (%)	N	N (%)	Fisher's Exact p
Phantom limb pain (yes/no)	740	534 (72.2)	20	17 (85.0)	0.3093
Residual limb pain (yes/no)	740	441 (59.6)	20	16 (80.0)	0.1027
Neck pain (yes/no)	740	538 (73.1)	20	17 (85.0)	0.3096
Low back pain (yes/no)	740	418 (64.8)	20	14 (77.8)	0.3215
musculoskeletal conditions of sound side	N	N (%)	N	N (%)	Fisher's Exact p
Carpal tunnel	746	173 (23.2)	21	5 (23.8)	1.0000
Tendonitis wrist	746	122 (16.4)	21	1 (4.8)	0.2280
Tendonitis elbow	746	144 (19.3)	21	2 (9.5)	0.3980
tendonitis finger	742	88 (11.9)	21	0 (0.0)	0.1567
Tendonitis thumb	741	78 (10.5)	21	0 (0.0)	0.1544
Ganglion cyst	731	39 (5.3)	21	1 (4.8)	1.0000
Rotator cuff tendinitis	743	199 (26.8)	21	3 (14.3)	0.3140
Osteoarthritis	741	163 (22.0)	21	5 (25.0)	0.7847
Nerve damage	747	170 (22.8)	21	5 (23.8)	1.0000
Other problem	747	182 (24.4)	21	5 (23.8)	1.0000
Prosthetic Users	Male N=453		Female N=8		
	N	Mn (sd)	N	Mn (sd)	WSR p
TAPES	446	4.0 (0.9)	7	4.3 (0.5)	0.35
OPUS CSD	342	25.0 (5.1)	5	26.0 (7.6)	0.98
Additional satisfaction related items					
My terminal device is appropriately sized for me	311	1.8 (0.6)	7	1.7 (1.0)	0.62
Overall, my prosthetic device is appropriately sized	311	1.8 (0.6)	7	1.7 (1.1)	0.34
I am self-conscious about wearing my prosthesis	440	2.9 (0.9)	7	2.4 (1.0)	0.15
Desire to change devices	422	2.7 (0.9)	7	2.3 (1.0)	0.29
Inability to wear the prosthesis due to fit	433	3.1 (0.8)	7	3.1 (0.9)	0.92

Satisfaction with prosthesis/terminal device movement	436	1.8 (0.8)	7	2.4 (0.8)	0.01
Unintended movement	434	2.5 (0.9)	6	2.2 (0.4)	0.27
Prosthetic Users	Male N=453		Female N=8		
	N (%)		N (%)		Fisher's Exact p
Hours of prosthesis use/day					0.69
Less than 2 hours	86 (19.0)		2 (25.0)		
2 to less than 4 hours	41 (9.1)		1 (12.5)		
4 to less than 8 hours	83 (18.3)		2 (25.0)		
8 to less than 12 hours	86 (19.0)		2 (25.0)		
12 hours or more a day	151 (33.3)		1 (12.5)		
Unknown	6 (1.3)		0 (0.0)		
Hours of prosthesis use/day					0.48
Less than 8 hours	210 (47.0)		5 (62.5)		
8 or more a day	237 (53.0)		3 (37.6)		

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Table 6. Linear regression of outcome measures

	QuickDASH (N=669)		VR-12 PCS (N=662)		VR-12 MCS (N=662)	
	β	p	β	p	β	p
Gender						
Male (ref)						
Female	3.69	0.4793	0.02	0.9926	-6.08	0.0813
Age	0.09	0.2382	-0.13	<0.0001	-0.02	0.7545
Years as Amputee	-0.20	0.0011	0.06	0.0175	0.14	0.0004
Amputation level						
Transradial (ref)						
Transhumeral	5.19	0.0543	-0.56	0.6194	1.11	0.5270
Shoulder/forequarter	2.25	0.2119	0.57	0.4452	0.02	0.9840
Current prosthesis type						
Body-powered (ref)						
Myo-hybrid	-0.17	0.9456	0.66	0.5222	1.31	0.4170
Cosmetic	9.45	0.0454	1.08	0.5907	-4.41	0.1596
Other/Unknown	9.09	0.1708	3.55	0.1964	0.73	0.8655
Nonuser	8.80	<0.0001	-2.86	0.0003	-1.29	0.2929

419 **Figure legends**

420 Figure 1. Male flow diagram

421 Figure 2. Female flow diagram

422 Figure 3. Reasons for abandonment over all device types.

Table 1. Demographics characteristics by gender

	Male N=755	Female N=21	All N= 776
	Mean (sd)	Mean (sd)	Mean (sd)
Age (Years)	63.5 (14.1)	54.5 (9.6)	63.2 (14.1)
Missing (n)	23	1	24
Years since initial amputation	31.7 (18.4)	18.1 (12.1)	31.3 (18.4)
Missing (n)	21	0	21
	N (%)	N (%)	N (%)
Year of initial amputation			
1940-1979	344 (45.6)	0 (0.0)	344 (44.3)
1980-2000	155 (20.5)	10 (47.6)	165 (21.3)
2001-2009	131 (17.4)	4 (19.1)	135 (17.4)
2010-2016	104 (13.8)	7 (33.3)	111 (14.3)
Unknown	21 (2.8)	0 (0.0)	21 (2.7)
Race			
White	571 (75.6)	12 (57.1)	583 (75.1)
Black	82 (10.9)	4 (19.1)	86 (11.1)
Other (including mixed race)	34 (4.5)	1 (4.8)	35 (4.5)
Unknown	68 (9.0)	4 (19.1)	72 (9.3)
Hispanic or Latino			
Yes	61 (8.1)	1 (4.8)	62 (8.0)
No	659 (87.3)	19 (90.5)	678 (87.4)
Unknown	35 (4.6)	1 (4.8)	36 (4.6)
Employment			
Employed full-time	69 (9.1)	4 (19.1)	73 (9.4)
Employed part-time	31 (4.1)	0 (0.0)	31 (4.0)
Student	20 (2.7)	0 (0.0)	20 (2.6)
Retired, but employed after amputation	369 (49.9)	4 (19.1)	373 (48.1)
Retired, but not employed after amputation	146 (19.3)	6 (28.6)	152 (19.6)
On medical leave	8 (1.1)	1 (4.8)	9 (1.2)
Other	88 (11.7)	5 (23.8)	93 (12.0)
Unknown	24 (3.2)	1 (0.0)	24 (3.2)
Amputation Level			
Forequarter	23 (3.1)	0 (0.0)	23 (3.0)
At the shoulder joint	69 (9.1)	2 (9.5)	71 (9.2)
Above the elbow	226 (29.9)	10 (47.6)	236 (30.4)
At the elbow	40 (5.3)	0 (0.0)	40 (5.2)
Below the elbow	272 (36.0)	8 (38.1)	280 (36.1)
At the wrist joint	125 (16.6)	1 (4.8)	126 (16.2)
Etiology of amputation[^]			

Combat injury	272 (36.1)	3 (14.3)	275 (35.5)
Accident	467 (62.0)	14 (66.7)	481 (62.1)
Burn	79 (10.5)	2 (9.5)	81 (10.5)
Cancer	30 (4.0)	0 (0.0)	30 (3.9)
Diabetes	10 (1.3)	1 (4.8)	11 (1.4)
Infection	82 (10.9)	4 (19.1)	86 (11.1)
Other	405 (53.9)	12 (57.1)	417 (54.0)
Amputation of Lower Limb			
Yes	93 (12.3)	1 (4.8)	94 (12.1)
No	662 (87.7)	20 (95.2)	682 (87.9)
Those with Amputation of Lower Limb	N=93	N=1	N=94
Amputation of Lower Limb			
Right Side	38 (40.9)	1 (100.0)	39 (41.5)
Left Side	23 (24.7)	0 (0.0)	23 (24.5)
Both Sides	32 (34.4)	0 (0.0)	32 (34.0)

^ may indicate more than one etiology

Table 2. Type of prostheses, suspension methods, terminal devices and prosthetic training: comparison of female and male unilateral upper limb amputees

	Male N=755	Female N=21
	N (%)	N (%)
Ever used a prosthesis		
Yes	700 (92.7)	17 (81.0)
No	48 (6.4)	4 (19.1)
Unknown	7 (0.9)	0 (0.0)
Prosthesis users (ever)	Male N=700	Female N=17
Initial type of prosthesis used		
Body powered	554 (79.1)	11 (64.7)
Myoelectric/ Hybrid	102 (14.6)	5 (29.4)
Cosmetic	19 (2.7)	1 (5.9)
Sports/Recreation/Unknown	25 (3.6)	0 (00)
Received training to use first prosthesis		
Yes	535 (76.4)	10 (58.8)
No	158 (22.6)	7 (41.1)
Unknown	7 (1.0)	0 (0.0)
Currently use a prosthesis		
Yes	453 (64.7)	8 (47.1)
No	245 (35.0)	9 (52.9)
Unknown	2 (0.3)	0 (0.0)
Current prosthesis users	Male N=453	Female N=8
Received training to use current prosthesis		
Yes	298 (65.8)	3 (37.5)
No	148 (32.7)	5 (62.5)
Unknown	7 (1.6)	0 (0.0)
Prosthesis users: most recent prosthesis received		
<2 years ago	193 (42.6)	6 (75.0)
2 + years ago	259 (57.2)	1 (12.5)
Unknown	1 (0.2)	1 (12.5)
Number of prostheses used		
One	290 (64.0)	1 (12.5)
Two or more	163 (36.0)	7 (87.5)
Number of terminal devices used		
One	256 (56.5)	3 (37.5)
Two or more	190 (42.9)	5 (62.5)
Unknown	7 (1.6)	0 (0.0)
Primary type of prosthesis used		

Body powered	323 (71.3)	3 (37.5)
Myoelectric/ Hybrid	100 (22.1)	2 (25.0)
Cosmetic	19 (4.2)	3 (37.5)
Sports/Recreation/Unknown	11 (2.4)	0 (0.0)
Initial to current prosthesis type		
Same	339 (74.8)	3 (37.5)
Changed	105 (23.2)	5 (62.5)
Unknown	9 (2.0)	0 (0.0)
Suspension type for primary prosthesis		
Suction	152 (33.6)	4 (50.0)
Gel or silicone liner with pin	85 (18.8)	6 (75.0)
Vacuum	50 (11.0)	1 (12.5)
Self-suspending because of the socket shape	168 (37.1)	4 (50.0)
Harnessing	341 (75.3)	4 (50.0)
External Suspension	61 (13.5)	1 (12.5)
Unsure	3 (0.4)	0 (0.0)
Primary type of terminal device used		
Voluntary opening/closing hook	276 (60.9)	5 (62.5)
Greiffer	6 (1.3)	0 (0.0)
Power hook (ETD)	17 (3.8)	0 (0.0)
Sensor Speed Hand	11 (2.4)	0 (0.0)
I-Limb/ Michaelangelo hand / Bebionic hand	46 (10.2)	3 (37.5)
Unknown	97 (21.4)	0 (0.0)
Prosthetic users with two or more prostheses		Male N=163
Secondary type of prosthesis used		Female N=7
Body powered	72 (44.2)	2 (28.6)
Myoelectric/ Hybrid	64 (39.5)	2 (28.6)
Cosmetic	5 (3.1)	0 (0.0)
Sports/Recreation/ Unknown	21 (10.5)	3 (42.9)

Table 3. Prosthesis Abandonment by Gender	Male N=700	Female N=17
Have you ever stopped using a prosthesis?		
Yes	366 (52.3)	13 (76.5)
No	324 (46.3)	3 (17.7)
Unknown	10 (1.4)	1 (5.9)
Those who stopped using a prosthesis	Male N=366	Female N=13
Were any of the prostheses that you stopped using?		
Body powered	268 (73.2)	8 (61.5)
Myoelectric	129 (35.3)	6 (46.2)
Hybrid	26 (7.1)	0 (0.0)
Other	20 (5.5)	1 (7.7)
If ever stopped using body-powered device:	Male N=268	Female N=8
Major reasons for stopping device use were:		
It was too heavy or fatiguing to wear	141 (52.6)	4 (50.0)
It didn't fit or was uncomfortable	197 (73.5)	7 (87.5)
It was not functional enough	172 (64.2)	5 (62.5)
It was too much fuss	154 (57.5)	6 (75.0)
It broke or was unreliable	81 (30.2)	2 (25.0)
It was not cosmetic	54 (20.2)	1 (12.5)
It was not intuitive to use	111 (41.4)	3 (37.5)
Some other reason	161 (60.1)	8 (100.0)
If ever stopped using myoelectric device	Male N=129	Female N=6
Major reasons for stopping device use were:		
It was too heavy or fatiguing to wear	79 (61.2)	5 (83.3)
It didn't fit or was uncomfortable	90 (69.8)	4 (66.7)
It was not functional enough	89 (69.0)	5 (83.3)
It was too much fuss	86 (66.7)	4 (66.7)
It broke or was unreliable	64 (49.6)	3 (50.0)
It was not cosmetic	23 (17.8)	1 (16.7)
It was not intuitive to use	46 (35.7)	2 (33.3)
Some other reason	77 (59.7)	3 (50.0)
If ever stopped using hybrid device	Male N=26	Female N=0
Major reasons for stopping device use were:		
It was too heavy or fatiguing to wear	18 (69.2)	0 (0.0)
It didn't fit or was uncomfortable	19 (73.1)	0 (0.0)
It was not functional enough	20 (76.9)	0 (0.0)
It was too much fuss	19 (73.1)	0 (0.0)

It broke or was unreliable	10 (38.5)	0 (0.0)
It was not cosmetic	4 (15.4)	0 (0.0)
It was not intuitive to use	12 (46.2)	0 (0.0)
Some other reason	14 (53.9)	0 (0.0)

	Ever used a prosthesis (N=732)		Training to use initial prosthesis (N=676)		Currently use a prosthesis (N=681)		Training to use current prosthesis (N=434)	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Gender								
Male (ref)								
Female	0.26	0.08-0.88	0.24	0.08-0.70	0.34	0.12-1.01	0.15	0.03-0.87
Age	0.98	0.95-1.00	0.97	0.95-0.99	0.99	0.97-1.00	0.97	0.95-1.00
Year of amputation								
1940-2000 (ref)								
2001-2009	0.35	0.16-0.77	0.61	0.33-1.13	0.74	0.43-1.24	0.68	0.33-1.41
2010-2016	0.27	0.12-0.61	0.75	0.39-1.44	0.72	0.40-1.27	1.07	0.47-2.44
Amputation level								
Transradial (ref)								
Transhumeral	0.18	0.08-0.41	1.10	0.71-1.70	0.22	0.16-0.32	1.17	0.72-1.90
Shoulder/forequarter	0.13	0.05-0.32	0.87	0.47-1.63	0.14	0.08-0.24	1.09	0.43-2.72
Initial prosthesis								
Body-powered (ref)								
Myo-hybrid			3.05	1.38-6.75				
Cosmetic			0.31	0.11-0.86				
Other/Unknown			3.22	0.66-15.75				
Primary prosthesis Current								
Body-powered (ref)								
Myo-hybrid							1.22	0.60-2.49
Cosmetic							0.20	0.07-0.60
Other/Unknown							0.16	0.03-0.94
Initial to current prosthesis type								
Same (ref)								
Changed							1.37	0.67-2.81
Unknown							9.33	0.65-134.7

Bold font in OR and CI indicates statistically significant values at $P<0.05$

Table 5. Prosthesis Satisfaction, Disability and quality of life: comparison of female and male upper limb amputees

Full sample	Male N=755		Female N=21		
	N	Mn (sd)	N	Mn (sd)	WSR p
QuickDASH	724	36.8 (27.1)	19	40.2 (19.1)	0.24
VR-12 PCS	708	45.1 (8.6)	19	43.8 (10.5)	0.44
VR-12 MCS	708	49.7 (13.4)	19	43.9 (13.6)	0.05
	N	N (%)	N	N (%)	Fisher's Exact p
Phantom limb pain (yes/no)	740	534 (72.2)	20	17 (85.0)	0.3093
Residual limb pain (yes/no)	740	441 (59.6)	20	16 (80.0)	0.1027
Neck pain (yes/no)	740	538 (73.1)	20	17 (85.0)	0.3096
Low back pain (yes/no)	740	418 (64.8)	20	14 (77.8)	0.3215
musculoskeletal conditions of sound side	N	N (%)	N	N (%)	Fisher's Exact p
Carpal tunnel	746	173 (23.2)	21	5 (23.8)	1.0000
Tendonitis wrist	746	122 (16.4)	21	1 (4.8)	0.2280
Tendonitis elbow	746	144 (19.3)	21	2 (9.5)	0.3980
tendonitis finger	742	88 (11.9)	21	0 (0.0)	0.1567
Tendonitis thumb	741	78 (10.5)	21	0 (0.0)	0.1544
Ganglion cyst	731	39 (5.3)	21	1 (4.8)	1.0000
Rotator cuff tendinitis	743	199 (26.8)	21	3 (14.3)	0.3140
Osteoarthritis	741	163 (22.0)	21	5 (25.0)	0.7847
Nerve damage	747	170 (22.8)	21	5 (23.8)	1.0000
Other problem	747	182 (24.4)	21	5 (23.8)	1.0000
Prosthetic Users	Male N=453		Female N=8		
	N	Mn (sd)	N	Mn (sd)	WSR p
TAPES	446	4.0 (0.9)	7	4.3 (0.5)	0.35
OPUS CSD	342	25.0 (5.1)	5	26.0 (7.6)	0.98
Additional satisfaction related items					
My terminal device is appropriately sized for me	311	1.8 (0.6)	7	1.7 (1.0)	0.62
Overall, my prosthetic device is appropriately sized	311	1.8 (0.6)	7	1.7 (1.1)	0.34
I am self-conscious about wearing my prosthesis	440	2.9 (0.9)	7	2.4 (1.0)	0.15
Desire to change devices	422	2.7 (0.9)	7	2.3 (1.0)	0.29
Inability to wear the prosthesis due to fit	433	3.1 (0.8)	7	3.1 (0.9)	0.92

Satisfaction with prosthesis/terminal device movement	436	1.8 (0.8)	7	2.4 (0.8)	0.01
Unintended movement	434	2.5 (0.9)	6	2.2 (0.4)	0.27
Prosthetic Users	Male N=453		Female N=8		
	N (%)		N (%)		Fisher's Exact p
Hours of prosthesis use/day					0.69
Less than 2 hours	86 (19.0)		2 (25.0)		
2 to less than 4 hours	41 (9.1)		1 (12.5)		
4 to less than 8 hours	83 (18.3)		2 (25.0)		
8 to less than 12 hours	86 (19.0)		2 (25.0)		
12 hours or more a day	151 (33.3)		1 (12.5)		
Unknown	6 (1.3)		0 (0.0)		
Hours of prosthesis use/day					0.48
Less than 8 hours	210 (47.0)		5 (62.5)		
8 or more a day	237 (53.0)		3 (37.6)		

Table 6. Linear regression of outcome measures

	QuickDASH (N=669)		VR-12 PCS (N=662)		VR-12 MCS (N=662)	
	β	p	β	p	β	p
Gender						
Male (ref)						
Female	3.69	0.4793	0.02	0.9926	-6.08	0.0813
Age	0.09	0.2382	-0.13	<0.0001	-0.02	0.7545
Years as Amputee	-0.20	0.0011	0.06	0.0175	0.14	0.0004
Amputation level						
Transradial (ref)						
Transhumeral	5.19	0.0543	-0.56	0.6194	1.11	0.5270
Shoulder/forequarter	2.25	0.2119	0.57	0.4452	0.02	0.9840
Current prosthesis type						
Body-powered (ref)						
Myo-hybrid	-0.17	0.9456	0.66	0.5222	1.31	0.4170
Cosmetic	9.45	0.0454	1.08	0.5907	-4.41	0.1596
Other/Unknown	9.09	0.1708	3.55	0.1964	0.73	0.8655
Nonuser	8.80	<0.0001	-2.86	0.0003	-1.29	0.2929

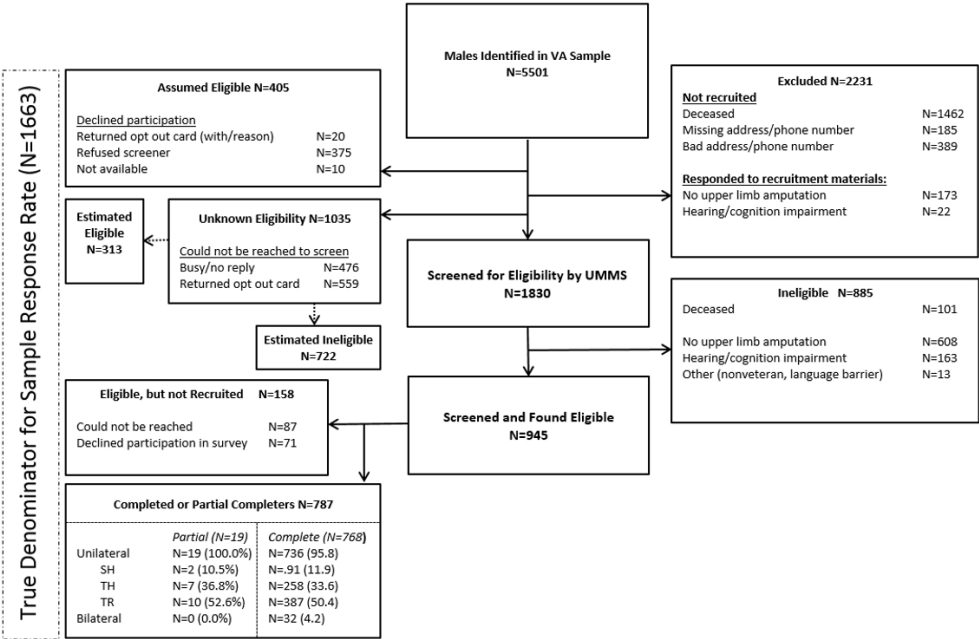
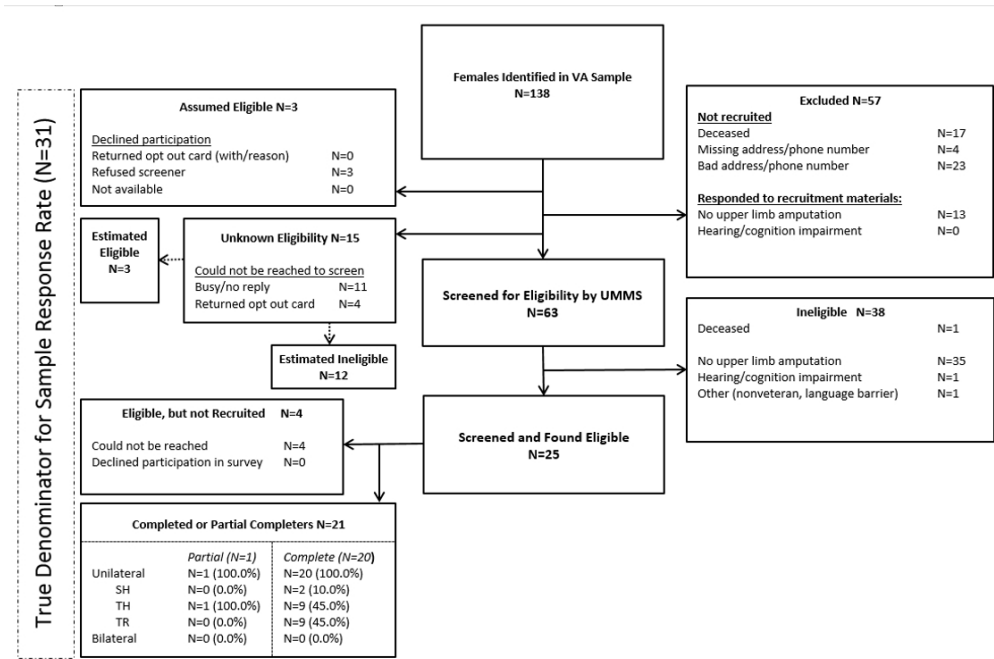
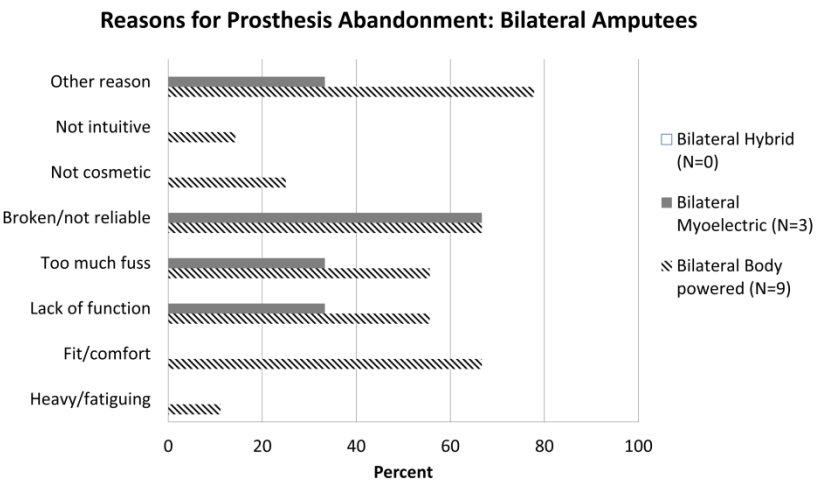


Figure 1

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94x63mm (300 x 300 DPI)



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Prosthesis satisfaction in a national sample of Veterans with upper limb amputation

Linda Resnik¹ , Matthew Borgia¹,
Allen W Heinemann²  and Melissa A Clark³

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Abstract

Background: Many persons with upper limb amputation reject prostheses, and many are not satisfied with their devices. Research is needed to understand modifiable factors related to device satisfaction. Myoelectric devices with multiple degrees of freedom are now available; however, no studies have examined whether they lead to greater device satisfaction. Prosthetic training contributes to more skillful prosthesis use and greater likelihood of long-term use; however, the relationship between training and device satisfaction is unclear.

Objectives: (1) To describe and compare satisfaction by prosthesis and terminal device type and (2) to identify factors associated with satisfaction.

Study design: Cross-sectional survey.

Methods: Participants were 449 persons with unilateral upper limb amputation who used a prosthesis. Participants described their prostheses, prosthetic training, device repairs, visits to a prosthetist, and rated device satisfaction using two standardized measures (Trinity Amputation and Prosthetic Experience Satisfaction Scale and OPUS Client Satisfaction with Devices scale). Multivariate generalized linear regression models examined the relationship between prosthesis and terminal device type and satisfaction, controlling for covariates that were meaningful in bivariate analyses.

Results: There were no differences in satisfaction by prosthesis type or terminal device degrees of freedom. Satisfaction was associated with receipt of training to use the initial prosthesis, amputation level, age, and race.

Conclusion: No differences in satisfaction by device or terminal device type were observed. Worse satisfaction was associated with more proximal amputation level, younger age, and black race. The association between receipt of initial prosthetic training and device satisfaction points to the critical role of occupational or physical therapy in the early stages of prosthetic care.

Clinical relevance

Prosthetic satisfaction did not vary by device or terminal device degrees of freedom (DOF). Proximal amputation level, younger age, and black race were associated with lower prosthetic satisfaction. Receipt of initial prosthetic training was associated with greater device satisfaction, pointing to the critical role and lasting impact of early training.

Keywords

upper limb, amputation, survey, satisfaction, Veterans

Date received: 29 July 2019; accepted: 17 November 2019

Background

Many persons with upper limb amputation abandon or reject their prostheses, and a substantial proportion of prosthesis users are not satisfied with their devices.¹⁻⁵ Surveys have identified factors associated with dissatisfaction such as problems with function, comfort, fit, and device weight.^{1,5-7} Many wish their prostheses had features such as powered wrist movement and multiple grip patterns.^{8,9} Limited powered wrist movement is available

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through some myoelectric/hybrid devices, and myoelectric devices with multiple degrees of freedom (multi-DOF) have become commercially available. However, no studies have examined whether greater functionality offered by new technologies is associated with greater device satisfaction.

Some data suggest that individuals using prostheses with advanced technologies are not more satisfied with their prostheses than individuals using older technologies. For example, Veterans who lost their limbs in combat in Operation Enduring Freedom and Operation Iraqi Freedom, a group with greater access to prostheses with more advanced technologies, are not more satisfied with their prostheses than Vietnam era combat Veterans with amputations.¹⁰ Additional research is needed to understand influences on device satisfaction, particularly factors that might be modified to improve patient experience and enhance device adoption. Prosthetic training is an essential aspect of rehabilitative care¹¹ and contributes to more skillful prosthesis use¹² and greater likelihood of long-term use.^{13,14} However, the relationship between training and device satisfaction has not been studied.

A recent study of Veterans with upper limb amputation collected detailed data on prosthesis satisfaction. Results about satisfaction with prostheses, comparing satisfaction ratings of persons with unilateral and bilateral amputation,¹⁵ and device satisfaction by gender¹⁶ have been reported. However, these studies have not compared satisfaction by prosthesis configuration or examined the relationship between initial prosthesis training and device satisfaction. Thus, the objectives of this study were to (1) describe and compare device satisfaction by device type in a national sample of Veterans with upper limb amputation and (2) identify factors that are associated with device satisfaction. We hypothesized that prosthesis satisfaction would be associated with primary device type, terminal device DOF, and receipt of training to use the device.

Methods

Study design

The study, approved by XXXXXX, was a telephone administered survey, described in detail elsewhere.¹⁵ [AQ: 2] Participants, identified from the VA's CDW sources, were Veterans with major upper limb amputation who received any type of medical or clinical care in the VA between 2010 and 2015.¹⁵ Eligible participants were alive, with valid telephone numbers and addresses with no significant cognitive or hearing deficits preventing participation by telephone. Participants gave verbal informed consent before participating in the survey. Results reported here are for the subset of respondents with unilateral amputation using a body-powered, myoelectric, hybrid, or cosmetic prosthesis.

Measures

Dependent variables

We used two measures of prosthesis satisfaction: the Trinity Amputation and Prosthetic Experience Satisfaction Scale (TAPES)¹⁷ and the OPUS Client Satisfaction with Devices scale (CSD).¹⁸ The 10-item TAPES addresses color, shape, noise, appearance, weight, usefulness, reliability, fit, comfort, and overall satisfaction.¹⁷ Respondents rate items on a 5-point scale (1 = very dissatisfied, 5 = very satisfied). The TAPES' content and scoring were developed for persons with lower limb amputations; however, its structural validity was examined and scoring modified for persons with upper limb amputation.¹⁷ The TAPES summary score is the average of item ratings.

A variety of studies have evaluated the measurement properties of non-English (translated) versions of the 11-item OPUS CSD,^{19–25} with some recommending removal of several items.²² Additional research on the structural validity of the CSD is needed. We administered the original OPUS CSD in the survey, but decided to use a modified version after conducting Rasch analysis (using Winsteps version 4.4.2) of the original version. We removed two items (affordability of purchase and repair costs) due to dimensionality issues. We also dropped an item addressing wear and tear on clothing because of item misfit (Mms outfit > 2.0). The eight items in the modified scale address satisfaction with: fit, weight, comfort, donning ease, appearance, durability, skin irritation, and pain. Respondents use a 4-point scale (1 = strongly agree, 4 = strongly disagree) with higher CSS scores indicating less satisfaction. [AQ: 3] The 8-item CSD Rasch measure had a person separation of 0.82 and 10.7% of unexplained variance in the first residual factor from a principal component analysis (PCA). The Rasch score can be calculated from the total score using the complete score-to-measure table shown in the Supplemental Appendix Table 1. We evaluated the three items dropped from the 8-item summary scale separately.

We also administered seven new items, which we believed were important elements of prosthesis satisfaction not addressed in the TAPES or CSD. These items addressed satisfaction with terminal device size, prosthesis size, self-consciousness wearing the prosthesis, desire to change to another prosthesis type, inability to wear the prosthesis because of fit, satisfaction with device movement, and unintended movement. Respondents used a 4-point scale (1 = strongly agree, 4 = strongly disagree).

Independent variables: prosthesis type, characteristics, and training

Primary prosthesis type was categorized as body-powered, myoelectric/hybrid, or cosmetic based on responses to items about primary prosthesis and terminal device type.

Respondents also answered questions about number of devices and terminal devices used, when the most recent device was received, and whether they received training with the initial and/or current device (yes/no).

Frequency of prosthesis use was classified as daily, weekly, monthly, every few months, and 1–2 times/year. Intensity of prosthesis use was categorized as <2 h, 2 to <4 h, 4 to <8 h, 8 to <12 h, and >12 h. The most recent date a prosthesis was received was categorized as <2 years, ≥2 years, and unknown. Number of prostheses and terminal devices used was categorized as 1, 2 or more, or unknown.

Respondents indicated whether their primary terminal device was a body-powered hook, Greifer, powered hook, sensor speed hand, I-Limb/Michaelangelo or Bebionic hand, Cosmetic hand, or unknown. Because of small sample sizes, we collapsed terminal device categories based on device DOF. Cosmetic devices were classified as 0 DOF, while hooks, electronic terminal devices (ETDs), Greifers and sensor speed hands, and unknown myoelectric terminal devices types were categorized as 1 DOF, and I-Limb/Michaelangelo or Bebionic hand were categorized as Multi-DOF. Secondary type of prosthesis was classified as body-powered, myoelectric, hybrid, cosmetic, sports/recreation, or unknown.

Receipt of training for initial and for current prosthesis were classified as yes, no, or unknown. The number of times the prosthesis was repaired and number of visits to a prosthetist for socket adjustment in the prior 12 months were classified as 0, 1, 2–3, ≥4, and unknown.

Participant characteristics

Participant age was evaluated as a continuous variable and categorized as: 18 to <45, 45 to <65, 65 to <75, and ≥75 years. Gender was self-reported as male or female. Race was classified as white, black, other (which included >1 race), and unknown. Hispanic ethnicity was classified as yes, no, and unknown. Employment was self-reported as: employed full-time, employed part-time, student, retired but employed after amputation, retired but not employed after amputation, on medical leave, other, or unknown. Marital status was self-reported as married/living together, divorced/separated, widowed, never married, or unknown.

Amputation level was collapsed into a three-category variable for analysis: (1) shoulder (forequarter or shoulder disarticulation), (2) TH (TH or ED), and (3) TR (TR and WD). [AQ: 4] Participants indicated the etiology of their amputation using seven yes/no variables: combat injury, accident, burn, cancer, diabetes, infection, and other. The majority (94%) of 244 respondents who indicated “other” etiology provided a description of the etiology. We examined these descriptions among respondents who did not endorse any of the seven provided etiologies and were able to classify etiology in all but two cases. Therefore, we

dropped “other” etiology from comparative analyses. Amputation of one or both lower limbs was categorized as yes or no. Participants reported time since initial amputation in years.

Statistical analyses

We described the participant characteristics and prosthesis use characteristics for the overall analytic sample and by type of primary prosthesis used. Descriptive analyses examined the proportion of missing/unknown responses; however, these responses were excluded from subsequent analyses, with the exception of race (which had a high proportion of missing values) and terminal device DOF (classification described above).

Number of repairs and visits to a prosthetist for socket adjustment by primary device type were compared using Kruskal–Wallis tests. TAPES and CSD scores were compared across prosthesis types using one-way analyses of variance (ANOVAs), and Kruskal–Wallis tests were used to compare ordinal ratings of individual items. Tukey’s method was used as a post hoc comparison of any differences in summary scores. Simple general linear regression models (GLM) for TAPES and the CSD were used to examine bivariate relationships with the following participant and prosthesis characteristics: age, gender, race, marital status, amputation etiology, amputation of lower limb, amputation of dominant side, recency of prosthesis receipt, number of prostheses and terminal devices, DOF of primary device, training with initial and current prosthesis, number of prosthesis repairs and adjustment visits in prior year, and frequency and intensity of prosthesis use.

We then constructed multivariate GLM models of (1) TAPES and (2) the CSD score including prosthesis type, and simultaneously controlling for all variables with bivariate association at $p < 0.20$ with either satisfaction score. We did not include frequency and intensity of prosthesis use because we believed that they were strong consequences of prosthesis satisfaction. Persons who used cosmetic prostheses were excluded from the multivariate analysis due to the small subgroup size ($N=22$). We examined assumptions of GLM. Residual plots supported homoscedasticity, SPEC tests did not reject the assumption of identical and independent error terms, and Durbin–Watson’s statistics also supported the independence assumption. [AQ: 5] Examination of Q-Q plots supported normality of residuals. Pearson correlations between IVs were all below 0.4 and the variance inflation factors were below 5. [AQ: 6]

Results

Sample

Eighty-three percent ($N=808$) of those screened eligible were recruited into the main study (Figure 1). The survey

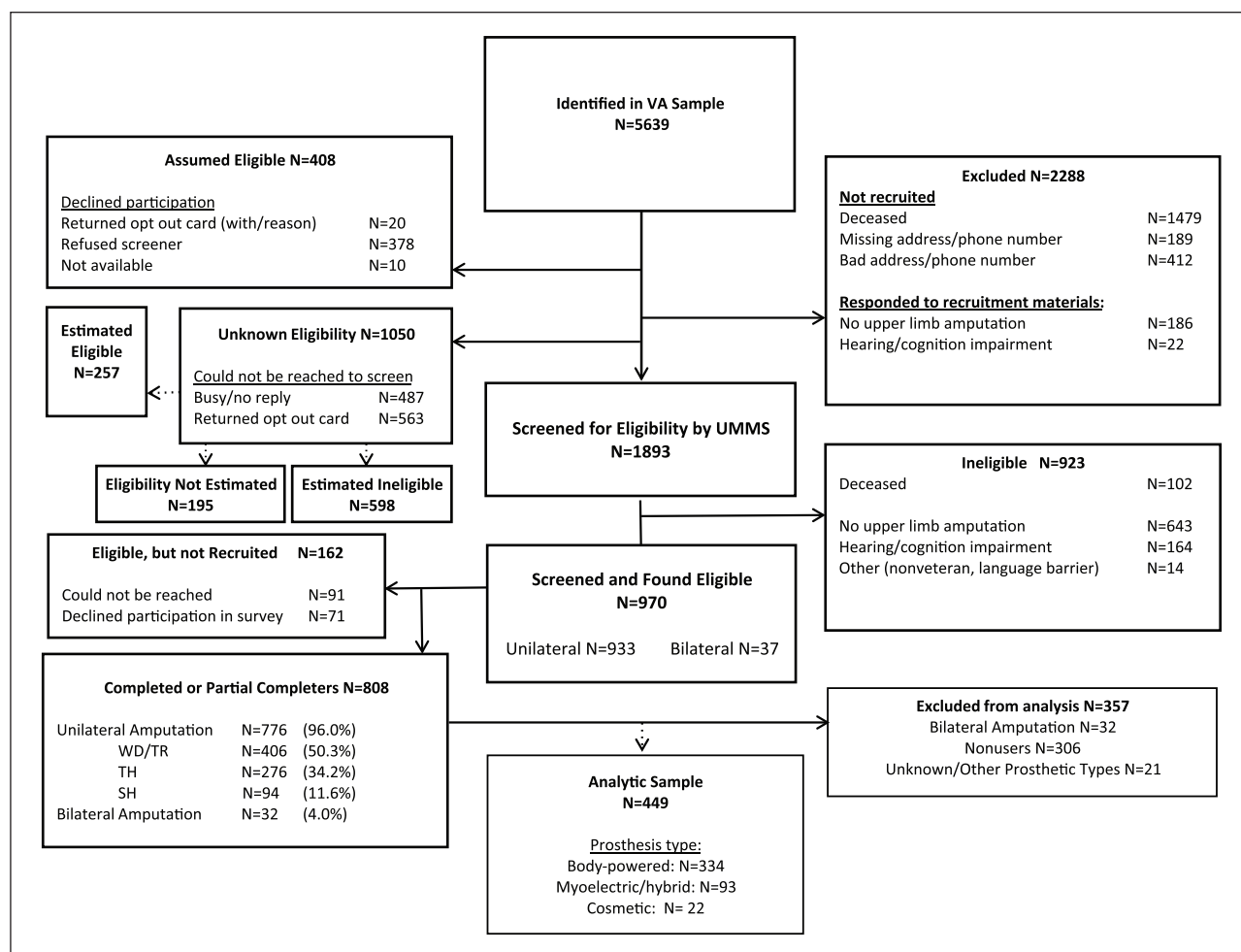


Figure 1. Flow diagram.

response rate and cooperation rate were 47.7% and 63.3%, respectively, as calculated using the American Association for Public Opinion Research methodology.²⁶ The analytic sample for this report was 449 persons. We excluded 20 participants for whom we had incomplete information on prosthesis use or type of prosthesis, and one participant with conflicting data on type of device used. Nine participants who self-identified as myoelectric or hybrid prosthesis users but specified that they used a body-powered hook as their terminal device were reclassified as users of a body-powered prosthesis type.

The final analytic sample of 429 included 334 (74.4%) body-powered, 88 myoelectric (19.6%), 5 (1.1%) hybrid, and 22 (5%) cosmetic users.

Demographic characteristics

Participants were on average 63.4 years (standard deviation (SD), 13.8) of age, with myoelectric users being the youngest group (mean=55.6, SD=15.7) (Table 1). Participants reported an average of 33.5 (SD=18.2) years since amputation, with myoelectric users having more

recent amputations (mean=23.7 years, SD=17.5). The sample was 98% male. A greater proportion of females were in the cosmetic prosthesis group (13.6%), compared to 1%–2% of females in other groups. The sample was 75% white. A greater proportion of black participants were in the cosmetic group (36.4%) compared to 10% in other groups. Almost 17% of respondents in the myoelectric group were employed full-time versus 10.2% and 9.1% for body-powered and cosmetic users, respectively. Most participants were married or cohabitating (66.4%).

Amputation level of respondents was 46.3% transradial, 22.1% transhumeral, 21.4% wrist joint, 4.2% elbow disarticulation, 3.6% shoulder, and 3.5% forequarter amputation. A greater proportion with amputation at the forequarter or shoulder level were cosmetic users. The most common amputation etiology was “accident” (62.6%) followed by “combat injury” (44.1%).

Forty percent of body-powered users, 57.0% of myoelectric users, and 27.3% of cosmetic users received their device within the prior 2 years (Table 2). A greater portion of myoelectric users reported use of two or more prostheses (55.9%) or terminal devices (64.5%). Among

Table 1. Demographics and amputation-related characteristics by primary device type.

	Prosthesis type			
	Body-powered N=334	Myoelectric/hybrid N=93	Cosmetic N=22	All N=449
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	65.5 (12.7)	55.7 (15.4)	63.9 (10.4)	63.4 (13.8)
Missing (n)	10	3	1	14
Years since initial amputation	36.3 (17.6)	23.5 (17.1)	32.8 (17.8)	33.5 (18.2)
Missing (n)	6	3	1	10
	N (%)	N (%)	N (%)	N (%)
Gender				
Male	331 (99.1)	91 (97.9)	19 (86.4)	441 (98.2)
Female	3 (0.9)	2 (2.2)	3 (13.6)	8 (1.8)
Age				
18–45	30 (9.3)	25 (27.8)	1 (4.8)	56 (12.9)
45–65	73 (22.5)	31 (34.4)	7 (33.3)	111 (25.5)
65–75	172 (53.1)	27 (30.0)	12 (57.1)	211 (48.5)
75+	49 (15.1)	7 (7.8)	1 (4.8)	57 (13.1)
Race				
White	260 (77.8)	68 (73.1)	10 (45.5)	338 (75.3)
Black	33 (9.9)	9 (9.7)	8 (36.4)	50 (11.1)
Other (including mixed race)	16 (4.8)	3 (3.2)	2 (9.1)	21 (4.7)
Unknown	25 (7.5)	13 (14.0)	2 (9.1)	40 (8.9)
Hispanic or Latino				
Yes	23 (6.9)	12 (12.9)	1 (4.6)	36 (8.0)
No	296 (88.6)	77 (82.9)	20 (90.9)	393 (87.5)
Unknown	15 (4.5)	4 (4.3)	1 (4.6)	20 (4.5)
Employment				
Employed full-time	34 (10.2)	15 (16.1)	2 (9.1)	51 (11.4)
Employed part-time	15 (4.5)	3 (3.2)	1 (4.6)	19 (4.2)
Student	2 (0.6)	4 (4.3)	1 (4.6)	7 (1.6)
Retired, but employed after amputation	191 (57.1)	38 (40.9)	9 (40.9)	238 (53.0)
Retired, but not employed after amputation	54 (15.3)	19 (20.4)	6 (27.3)	76 (16.9)
On medical leave	3 (0.9)	0 (0.0)	0 (0.0)	3 (0.7)
Other	27 (8.1)	11 (11.8)	2 (9.1)	40 (8.9)
Unknown	11 (3.3)	3 (3.2)	1 (4.6)	15 (3.3)
Marital status				
Married or living together	2124 (67.0)	62 (66.7)	12 (54.6)	298 (66.4)
Divorced or separated	64 (19.2)	22 (23.7)	2 (9.1)	88 (19.6)
Widowed	20 (6.0)	2 (2.2)	2 (9.1)	24 (5.4)
Never married	16 (4.8)	4 (4.3)	5 (22.7)	25 (5.6)
Unknown	10 (3.0)	3 (3.2)	1 (4.6)	14 (3.1)
Amputation level				
Forequarter	5 (1.5)	3 (3.2)	3 (13.6)	11 (3.5)
At the shoulder joint	9 (2.7)	6 (6.5)	1 (4.5)	16 (3.6)
Above the elbow	79 (23.7)	16 (17.2)	4 (18.2)	99 (22.1)
At the elbow	17 (5.1)	2 (2.2)	0 (0.0)	19 (4.2)
Below the elbow	153 (45.8)	44 (47.3)	11 (50.0)	208 (46.3)
At the wrist joint	71 (21.3)	22 (23.7)	3 (13.6)	96 (21.4)
Etiology of amputation (may be more than one)				
Combat injury	149 (44.6)	41 (44.1)	8 (36.4)	198 (44.1)
Accident	208 (62.3)	60 (64.5)	13 (59.1)	281 (62.6)

(Continued)

Table 1. (Continued)

	N (%)	N (%)	N (%)	N (%)
Burn	35 (10.5)	10 (10.8)	2 (9.1)	47 (10.5)
Cancer	4 (1.2)	3 (3.2)	2 (9.1)	9 (2.0)
Diabetes	3 (0.9)	0 (0.0)	0 (0.0)	3 (1.0)
Infection	35 (10.5)	6 (6.5)	2 (9.1)	43 (9.6)
Amputation of lower limb				
Yes	39 (11.7)	12 (12.9)	6 (27.3)	57 (12.7)
No	295 (88.3)	81 (87.1)	16 (72.7)	392 (87.3)
Amputation of dominant side				
Yes	179 (53.6)	48 (51.6)	9 (40.9)	346 (52.6)
No	153 (45.8)	45 (48.4)	13 (59.1)	211 (47.0)
Unknown	2 (0.6)	0 (0.0)	0 (0.0)	2 (0.5)

SD: standard deviation.

Table 2. Prosthesis use characteristics.

	Body-powered N=334	Myoelectric/hybrid N=93	Cosmetic N=22
Frequency of prosthesis use			
Daily	257 (78.1)	72 (78.3)	14 (63.6)
Weekly	43 (13.1)	8 (8.7)	5 (22.7)
Monthly	14 (4.3)	5 (5.4)	0 (0.0)
Every few months	11 (3.3)	2 (2.2)	1 (4.6)
1 to 2 times per year	4 (1.2)	5 (5.4)	2 (9.1)
Intensity of prosthesis use (h) ^a			
<2	68 (20.6)	12 (13.0)	4 (18.2)
2 to <4	29 (8.8)	11 (12.0)	2 (9.1)
4 to <8	58 (17.6)	20 (21.7)	5 (22.7)
8 to <12	64 (19.4)	18 (19.6)	3 (13.6)
≥12	111 (33.6)	31 (33.7)	8 (36.4)
Most recent prosthesis received			
<2 years ago	135 (40.4)	53 (57.0)	6 (27.3)
2+ years ago	198 (59.3)	39 (41.9)	16 (72.7)
Unknown	1 (0.3)	1 (1.1)	0 (0.0)
Number of prostheses used			
One	229 (68.6)	41 (41.1)	14 (63.6)
Two or more	105 (31.4)	52 (55.9)	8 (36.4)
Number of terminal devices used			
One	209 (62.6)	30 (32.3)	17 (77.3)
Two or more	123 (36.8)	60 (64.5)	4 (18.2)
Unknown	2 (0.6)	3 (2.9)	1 (4.7)
Primary type of terminal device used			
Body-powered hook	334 (100.0)	0 (0.0)	0 (0.0)
Greifer	0 (0.0)	6 (6.5)	0 (0.0)
Power hook (—ETD)	0 (0.0)	15 (16.1)	0 (0.0)
Sensor speed hand	0 (0.0)	9 (9.7)	0 (0.0)
I-Limb/Michaelangelo hand/Bebionic hand	0 (0.0)	40 (43.0)	0 (0.0)
Cosmetic	0 (0.0)	0 (0.0)	22 (100.0)
Unknown	0 (0.0)	23 (24.7)	0 (0.0)
DOF of primary terminal device			
No DOF (cosmetic)	0 (0.0)	0 (0.0)	22 (100.0)
Single DOF	334 (100.0)	30 (32.3)	0 (0.0)

(Continued)

Table 2. (Continued)

	Body-powered N=334	Myoelectric/hybrid N=93	Cosmetic N=22
Multi-DOF	0 (0.0)	40 (43.0)	0 (0.0)
Unknown	0 (0.0)	23 (24.7)	0 (0.0)
Received training to use initial prosthesis			
Yes	254 (76.1)	75 (80.7)	11 (50.0)
No	77 (23.1)	18 (19.4)	10 (45.5)
Unknown	3 (0.9)	0 (0.0)	1 (4.9)
Received training to use current prosthesis			
Yes	216 (64.7)	75 (76.3)	7 (31.8)
No	113 (33.8)	21 (22.6)	15 (68.2)
Unknown	5 (1.5)	1 (1.1)	0 (0.0)
How many times was your prosthesis repaired in the past 12 months?			
0	138 (42.6)	37 (40.2)	12 (57.1)
1	85 (26.2)	14 (15.2)	6 (28.6)
2–3	68 (21.0)	22 (23.9)	3 (14.3)
≥4	33 (10.2)	19 (20.7)	0 (0.0)
How many times did you visit a prosthetist for adjustment to your socket in the past 12 months?			
0	217 (66.4)	49 (53.3)	12 (60.0)
1	42 (12.8)	16 (17.4)	4 (20.0)
2–3	46 (14.1)	19 (20.7)	1 (5.0)
≥4	22 (6.7)	8 (8.7)	3 (15.0)
Prosthetic users with two or more prostheses	Body-powered N=98	Myoelectric/hybrid N=59	Cosmetic N=8
Secondary type of prosthesis used			
Body-powered	43 (41.0)	28 (53.9)	1 (12.5)
Myoelectric/hybrid	50 (47.6)	12 (23.1)	3 (37.5)
Cosmetic	1 (1.0)	1 (1.9)	3 (37.5)
Sports/recreation	8 (7.6)	9 (17.3)	1 (12.5)
Unknown	3 (2.9)	2 (3.9)	0 (0.0)
Frequency of secondary prosthesis use			
Daily	23 (21.9)	16 (30.8)	4 (50.0)
Weekly	45 (42.9)	22 (42.3)	1 (12.5)
Monthly	11 (10.5)	5 (9.6)	1 (12.5)
Every few months	12 (11.4)	3 (5.8)	0 (0.0)
1 to 2 times per year	14 (13.3)	4 (7.7)	2 (25.0)
Unknown	0 (0.0)	2 (3.9)	0 (0.0)

ETD: electronic terminal devices; DOF: degrees of freedom.

IAQ: 71

myoelectric users, 32.3% reported a single DOF terminal device, 43.0% a multi-DOF terminal device, and for 24.7% the terminal DOF was unknown.

Eighty-one percent of myoelectric users reported receiving initial prosthetic training and 76.3% received current device training. In contrast, 76.1% of body-powered users received initial training and 64.7% current training, while among cosmetic users 50.0% received initial training and 31.8% current training.

Myoelectric users were more likely to report two or more repairs in the past 12 months as compared to other device type users, and cosmetic users reported the fewest.

There was no meaningful association between prosthesis type and visits for socket adjustments. Among respondents using two or more prostheses ($N=165$), the most common secondary devices for body-powered users were myoelectric prostheses (48%), while the most common secondary devices for myoelectric users were body-powered prostheses (54%). Secondary devices of cosmetic users were distributed between myoelectric and additional cosmetic prostheses (37.5% each). There was no significant difference in prosthesis use intensity or frequency by primary prosthesis type, with 63.6%–78.3% reporting daily device use (Supplemental Appendix Table A.2).

Satisfaction outcomes

Results of bivariate analyses show that TAPES summary scores (Supplemental Appendix Table A.3) varied by prosthesis type ($DF=2$, $F=3.42$, $p=0.03$) though post hoc analysis revealed no significant group differences. Ratings of color, noise, appearance, weight, reliability, and overall satisfaction items also varied by prosthesis type; body-powered users reported the highest satisfaction. Ratings were lowest among myoelectric users for items assessing weight, reliability, and overall satisfaction. Satisfaction ratings for color and noise were lowest among cosmetic users.

The CSD summary scores did not differ by prosthesis type in bivariate analyses; however, there were differences in two items. Cosmetic users disagreed more with “my prosthesis looks good,” while users of body-powered devices agreed most with “my prosthesis is durable.” Body-powered users disagreed most with the original CSD item, “my clothes are free of wear and tear.” Cosmetic users disagreed most with “I am self-conscious about wearing my prosthesis,” and with “I am satisfied with the way my primary prosthesis and terminal device moves.” Myoelectric users agreed most with, “my primary prosthesis sometimes moves in a way that I do not intend it to.”

Bivariate analyses identified the following variables as associated ($p < 0.20$) with either the TAPES or CSD scores: amputation level, type of prosthesis, age, race, marital status, etiology of amputation (burn, cancer, and diabetes), amputation of lower limb, training with initial prosthesis, number of prosthesis repairs, number of visits to a prosthetist for socket adjustment, frequency of prosthesis use, and intensity of prosthetic use. Terminal device DOF was not associated with either the TAPES or CSD scores in the full sample (Supplemental Appendix Table A.4) or in the subsample of myoelectric device users.

Multivariate GLMs of outcome measures (Table 3) show that, after controlling for other covariates, there were no differences in summary satisfaction scores for body-powered versus myoelectric device users. [AQ: 8] TAPES scores were lower (worse) for those with SH and TH level amputation compared to those with TR. TAPES scores were higher for older respondents and those who received training with their initial prosthesis. CSD scores were higher (worse) for those with SH level amputation compared to those with TR level amputation, and for those who identified as black compared to white, and lower (better) for older versus younger respondents.

Discussion

We analyzed data from 449 unilateral upper limb prosthesis users to assess satisfaction by prosthesis type and identify factors associated with satisfaction. Our study used

two primary measures of satisfaction, the TAPES and an adapted version of the CSD. Results contribute new knowledge on prosthesis satisfaction as well as a new version of a prosthesis satisfaction measure for use with persons with upper limb amputation.

When controlling for multiple covariates in regression models, prosthesis type was not associated with device satisfaction as measured by TAPES or CSD. Bivariate comparisons of individual satisfaction items across prosthesis types largely mirrored results of systematic reviews comparing body-powered and myoelectric devices.^{27,28} Body-powered users were more satisfied with reliability, durability, and lower weight, but not with wear and tear on clothes. Myoelectric users were less satisfied with weight and unintended movement. Cosmetic users were least satisfied with device color and noise, but reported lower levels of self-consciousness.

We had expected to see greater satisfaction for persons using multi-DOF terminal device, a newer technology that promises greater functionality and which is more anthropomorphic. Over 43% of the 93 myoelectric users reported using a multi-DOF terminal device, a prevalence that is likely higher in the VA than in the civilian sector, given the high costs for these devices and the limitations on prosthetic coverage outside of the VA. Bivariate analyses found no differences in device satisfaction for myoelectric device users of multi-DOF versus single-DOF terminal devices, and thus we did not add terminal device DOF to the multivariate models. Further research is needed on consumer satisfaction with multi-DOF terminal devices.

We found that receipt of training to use the initial prosthesis, amputation level, age, and race were independently associated with device satisfaction. Current device training was not added to the multivariate models because it was not associated with device satisfaction in bivariate analyses. These findings point to the importance of providing initial training and its role in promoting device use, consistent with earlier reports on the association between device abandonment and prosthesis training.^{13,14}

Differences observed in prosthesis satisfaction by amputation level are consistent with the literature reporting greater dissatisfaction and abandonment in persons with proximal amputations.^{7,13,29} Persons with TR amputation had the lowest rate of rejection (6%), followed by TH (57%) and SD (60%).² These findings highlight the need for continued research to improve prosthetic options and care for persons with proximal amputations.

We also found that older persons were more satisfied with their prostheses, perhaps because, on average, they had been prosthesis users for the longest period of time and perhaps had come to value their devices. Finally, our models found that black respondents were less satisfied with their devices than were white respondents, a finding which needs further exploration to understand the root causes.

Table 3. Multivariate linear regression models predicting device satisfaction ($N=379$) **TAQ: 9]**

	TAPES		CSD ^b	
	N = 408		N = 384	
	Beta ^a	p	Beta ^a	p
Amputation level				
SH/FQ	−0.35	0.0141	8.63	0.0265
TH/ED	−0.25	0.0006	4.34	0.0366
TR/Wrist (ref)				
Type of prosthesis				
Body-powered (ref)				
Myoelectric/hybrid	−0.08	0.3368	1.19	0.5893
Age (years)	0.01	0.0007	−0.20	0.0043
Race				
White (ref)				
Black	−0.19	0.0730	5.84	0.0434
Other	−0.05	0.7267	−1.74	0.6762
Unknown	−0.09	0.4900	6.04	0.1262
Marital status				
Married or living together (ref)				
Divorced or separated	0.03	0.7057	1.80	0.4072
Widowed	0.04	0.7900	−4.30	0.3002
Never married	−0.17	0.2498	2.36	0.5507
Etiology				
Burn	0.10	0.3642	1.47	0.6127
Cancer	0.38	0.1164	−9.85	0.1331
Diabetes	0.58	0.1996	−3.81	0.7532
Amputation of lower limb				
Yes	0.13	0.1717	−5.02	0.0625
No (ref)				
Received training to use initial prosthesis				
Yes	0.27	0.0005	−3.03	0.1524
No (ref)				
How many times was your prosthesis repaired in the past 12 months?				
0 (ref)				
1	0.08	0.3220	−0.84	0.7221
2–3	0.10	0.2661	−2.17	0.3988
4 or more	−0.05	0.6884	−1.53	0.6401
How many times did you visit a prosthetist for adjustment to your socket in the past 12 months?				
0 (ref)				
1	0.00	0.9870	2.83	0.3096
2–3	0.01	0.9132	0.13	0.9636
4 or more	−0.16	0.2466	6.41	0.0863
Model R ²	0.15		0.12	

TAPES: Trinity Amputation and Prosthetic Experience Satisfaction Scale; CSD: Client Satisfaction with Devices scale.

^aUnstandardized regression coefficient.^bRasch scores of 8-item CSD.

Limitations

The sample included Veterans who had received care at the VA between 2010 and 2015; nearly 62% was 65 years or older, with a minority under age 45 years, reflecting the age distribution of the US Veteran population. Thus, findings may not be generalizable to the larger Veteran

population, to non-Veterans with upper limb amputations who have limited access to prosthetic care, or to younger persons with upper limb amputations. Although the study had a high response rate, there were few women and cosmetic devices users, limiting our ability to compare these prosthesis users. That said, this sample is one of the largest

reporting device satisfaction and provides strong evidence about device satisfaction in older individuals with good access to prosthetic care.

The sample included current prosthesis users, so it is likely that persons who were most dissatisfied with prostheses were excluded. Thus, conclusions are limited to prostheses users only.

Although we used two measures of prosthesis satisfaction, we acknowledge that they address limited facets of prosthesis use. Both measures focus on device attributes and neither addresses satisfaction with prosthesis function. Only one item in the TAPES addresses usefulness which may be related to function, while no items in the 8-item CSD address function. Studies that use other satisfaction measures or that compare satisfaction with device function are needed.

Conclusion

We evaluated satisfaction with upper limb prostheses using data from a national survey of Veterans. Users of body-powered, myoelectric, and cosmetic prostheses were equally satisfied with their devices. We did not observe meaningful differences in overall device satisfaction between users of multi-DOF terminal devices and users of single-DOF terminal devices. Lower device satisfaction was observed among individuals with more proximal amputations (TH and SH), younger age, and black race. Receipt of initial prosthetic training was associated with greater device satisfaction, pointing to the critical role of occupational or physical therapy in the early stages of prosthetic care.

Author contributions

L.R. obtained funding, designed the study, led data analyses, and wrote the manuscript. M.B. assisted in study design, performed data analyses, and wrote portions of the manuscript. A.W.H. assisted in design of analyses of the OPUS CSD data, participated in reviewing analytical results, and participated in manuscript writing. M.A.C. participated in study design, supervised data collection, and participated in data analyses and manuscript writing.

Declaration of conflicting interests

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Supplemental material

Supplemental material for this article is available online.

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ORIGINAL RESEARCH

Function and Quality of Life of Unilateral Major Upper Limb Amputees: Effect of Prosthesis Use and Type



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Abstract

Objective: To compare patient-reported outcomes of disability, activity difficulty, and health-related quality of life (HRQOL) by prosthetic device use and configuration and to identify factors associated with these outcomes.

Design: Telephone survey.

Setting: General community.

Participants: Population-based sample of veterans (N=755) with unilateral upper limb amputation recruited from a national sample of veterans with upper limb amputation who received care at the Veterans Affairs clinic from 2010-2015.

Interventions: Not applicable.

Main Outcome Measures: Upper limb-related disability was measured using Disabilities of the Arm, Shoulder, and Hand score (QuickDASH). HRQOL was measured using the Veterans RAND 12-item Health Survey Mental and Physical Component scores. Activity difficulty was assessed for 1-handed and 2-handed tasks and by questions about the need for help with activities of daily living (ADLs).

Results: Patients who did not use a prosthesis had more difficulty performing 1-handed tasks using the residual limb as compared with those who used body-powered prostheses. Cosmetic device users had more task difficulty than body-powered or myoelectric users. Linear regression models did not show an association between type of prosthesis used and HRQOL scores, but did show that those who did not use a prosthesis (non-users) had worse QuickDASH scores ($\beta=9.4$; $P=.0004$) compared to body-powered users. In logistic regression modeling, the odds of needing help with ADLs were 1.84 times higher (95% confidence interval, 1.16-2.92) for non-users compared with body-powered users.

Conclusions: Amputees who did not use a prosthesis or used a cosmetic prosthesis reported more difficulty in activities and greater disability as compared with those who use body-powered and myoelectric devices. Non-users were more likely to need help with ADLs as compared with those who used a body-powered prosthesis. Our findings highlight the clinical importance of encouraging prosthesis use. Further research is needed to compare physical performance by prosthesis configuration.

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A wide variety of upper limb prostheses and components are available to upper limb amputees; however, it is unclear which devices are best, and clinicians have little evidence to guide decision-making around specific prosthetic components and device types. The inconclusive results of recent systematic reviews comparing body-powered prostheses to myoelectric prostheses^{1,2}

underscore the need for studies that address the comparative effectiveness of upper limb prosthetic devices and components.

In the past decade, multi-degrees of freedom (DOF) prosthetic terminal devices that enable multiple grip patterns have become commercially available. Although surveys of upper limb amputees have identified a desire for terminal devices with additional grip patterns,^{3,4} few studies compare single- vs multi-DOF terminal devices.⁵ Several small studies that measured dexterity of single- vs multi-DOF terminal devices showed no clear pattern of superiority of one type of device over another.⁶⁻⁹ Without a body of evidence quantifying the relative benefits of specific devices and components, clinicians have to rely only on expert opinion,

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experience, manufacturers' claims, limited clinical practice guidelines, and small studies when prescribing prostheses.

This study was a first step in addressing this knowledge gap. We conducted a national survey of veterans with upper limb amputation and examined the associations between prosthesis configuration and outcomes. Our purposes were to (1) compare outcomes of disability, activity difficulty, and health-related quality of life (HRQOL) by device configuration and (2) identify other potentially modifiable factors associated with disability, activity difficulty, and HRQOL among upper limb amputees.

Methods

Survey, participants, and recruitment

The study, with a waiver of written informed consent, was approved by the central institutional review board of the Department of Veterans Affairs (VA). The sampling frame consisted of all veterans with a diagnosis of major upper limb amputation who received care in the VA between 2010-2015, identified using VA Corporate Data Warehouse sources, including the inpatient, outpatient, and fee files. We sent recruitment packages to all nondeceased veterans with current addresses and phone numbers. Veterans who did not opt out of participation or inform us that they did not meet study eligibility criteria were contacted by the study interviewers to obtain oral informed consent. Eight hundred and eight veterans were interviewed. After excluding 32 participants with bilateral amputation and 21 with unknown or other prosthesis type, the analytical sample included 755 individuals with unilateral amputation.

Survey development and content

The development and pilot testing of the survey instrument with 10 cognitive interviews and 13 pretest subjects was reported previously.¹⁰ The survey contained existing survey items and standardized metrics, and new or modified items designed for this study. The survey asked questions about demographic, amputation, and prosthesis characteristics. The current paper focuses on the sections of the survey pertaining to prosthesis use and type, function, and HRQOL.

Key variables

Outcome variables

disability and quality of life

The survey included the Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score which measures perceived disability by assessing difficulty performing activities, amount of limitation,

extent of interference with activities, and extent of arm, shoulder, and hand pain and tingling.¹¹⁻¹³ The Physical Component Summary (PCS) score and the Mental Component Summary (MCS) score of the Veterans RAND 12-item Health Survey (VR-12) measured HRQOL.^{14,15} The survey asked about the need for help with daily activities (ADLs) and hours of help needed. New items asked about difficulty in unilateral and bilateral task performance to quantify any additive benefit of using a prosthesis vs using the residual limb only and to compare prosthesis configuration. Respondents who were prosthesis users rated difficulty performing the activities first with and then without the device.

Primary independent variable

The primary independent variable, prosthesis configuration, was defined as the combination of primary prosthesis and terminal device type used. We categorized terminal device based on the DOF of the device. Cosmetic devices were classified as having no DOF, while hooks, electronic terminal devices, Greifers and sensor speed hands were categorized as 1 DOF, and I-Limb/Michelangelo or Bebionic hand were categorized as multi-DOF. We used information on prosthesis and terminal device type to create the 5-category prosthesis configuration variable: (1) no prosthesis, (2) body-powered, (3) myoelectric single-DOF terminal devices, (4) myoelectric multi-DOF terminal device, and (5) cosmetic. When terminal device type was unknown and the device type was either body-powered or myoelectric, we classified the prosthesis type as myoelectric single DOF given that this is the most common type of device. We also expected that recipients of multi-DOF terminal devices, who are typically very involved in the device selection, would be able to name the brand correctly.

Statistical analyses

We described demographic and amputation characteristics by prosthesis configuration; missing data were presented in descriptives of categorical variables but treated as missing in subsequent analysis. SAS,^a version 9.4, was used for statistical analyses. We compared characteristics across prosthesis configuration groups using chi-square and Fisher exact tests. We compared difficulty in task performance by prosthesis configuration for tasks done without a prosthesis, with a prosthesis, and with the residual limb using Kruskal-Wallis tests, and conducted Dunn post-hoc analyses to determine which groups significantly differed. We also compared difficulty in task performance without a prosthesis, with the primary prosthesis, and with the residual limb (unilateral tasks only) using Wilcoxon signed-rank tests. These analyses were conducted separately for each prosthesis configuration.

Spearman correlations were estimated between task difficulty and hours of ADL help. We compared QuickDASH; VR-12 MCS and PCS scores; likelihood of needing any help; and hours of help needed across prosthesis configuration using analysis of variance, chi-square, and Kruskal-Wallis tests as appropriate. We also conducted Tukey, Tukey-style,¹⁶ and Dunn post-hoc analyses, respectively, to identify differences between groups. Bivariate linear regression models examined associations between potential confounders and outcomes. We included variables with associations at $P < .10$ in subsequent multivariate models. Separate multivariable linear regression models examined the association between prosthesis configuration and the VR-12 MCS, PCS, and QuickDASH. A multivariable logistic regression model examined the association between primary prosthesis configuration and

List of abbreviations:

ADL	activity of daily living
DOF	degrees of freedom
HRQOL	health-related quality of life
MCS	Mental Component Summary
PCS	Physical Component Summary
QuickDASH	Disabilities of the Arm
Shoulder	and Hand score
VA	Veterans Affairs
VR-12	Veterans RAND 12-item Health Survey

likelihood of needing any ADL help. Regression models controlled for age, years since amputation, race, marital status, amputation level, ever having used a prosthesis, lower limb amputation, amputation of dominant side, amputation etiology, initial and current prosthesis training, year of prosthesis receipt, and number of prostheses. We conducted sensitivity analyses to determine whether there was detectable bias introduced by excluding the group with unknown terminal device type.

Results

Sample

Eighty-three percent (N=808) of those screened to be eligible were recruited into the main study (Fig 1). The survey response rate and cooperation rate were 47.7% and 63.3%, respectively, as calculated using the American Association for Public Opinion Research methodology. The analysis reported here included only participants with unilateral amputation. We excluded 21 participants who had incomplete or conflicting data on prosthesis use: 9 of these due to missing information about prosthesis use, 11 due to missing information on type of prosthesis or reports that the primary prosthesis was a sports device, and 1 because of a mismatch between prosthesis and terminal device type. The final analytic sample (N=755) included 306 (39.4%) patients with no prosthesis, 325 (43.1%) patients with body-powered devices,

62 (8.2%) patients with a myoelectric or hybrid single-DOF terminal device, 40 (5.3%) patients with a myoelectric multi-DOF terminal device, and 22 (2.8%) patients with cosmetic devices.

Demographic characteristics

Table 1 shows the characteristics of respondents. Participants were on average (mean $\pm$ SD) aged 63.5 ± 13.9 . On average, it had been 31.4 ± 18.3 years since amputation. The sample was 97.2% male and 75.8% white. Most participants were married or cohabitating (62.4%). Overall, 35.8% had below elbow amputation, 30.9% above elbow, 16.4% wrist disarticulation, 9.1% shoulder disarticulation, 4.9% elbow disarticulation, and 2.9% forequarter amputation. The most common amputation etiology of limb loss was classified as "accident" (63.7%) followed by "combat injury" (35.1%). Most respondents received training for their initial and current prostheses (75.7% and 65.5%, respectively) and had only 1 prosthesis (63.3%).

Difficulty in activity performance

There were no meaningful differences in self-reported difficulty of performing two-handed tasks without a prosthesis by prosthesis configuration (table 2). Difficulty of performing 2-handed tasks with a prosthesis differed significantly by prosthesis type ($P < .01$). Cosmetic device users rated tasks as the most difficult, followed by myoelectric multi-DOF and single-DOF users. Post-hoc

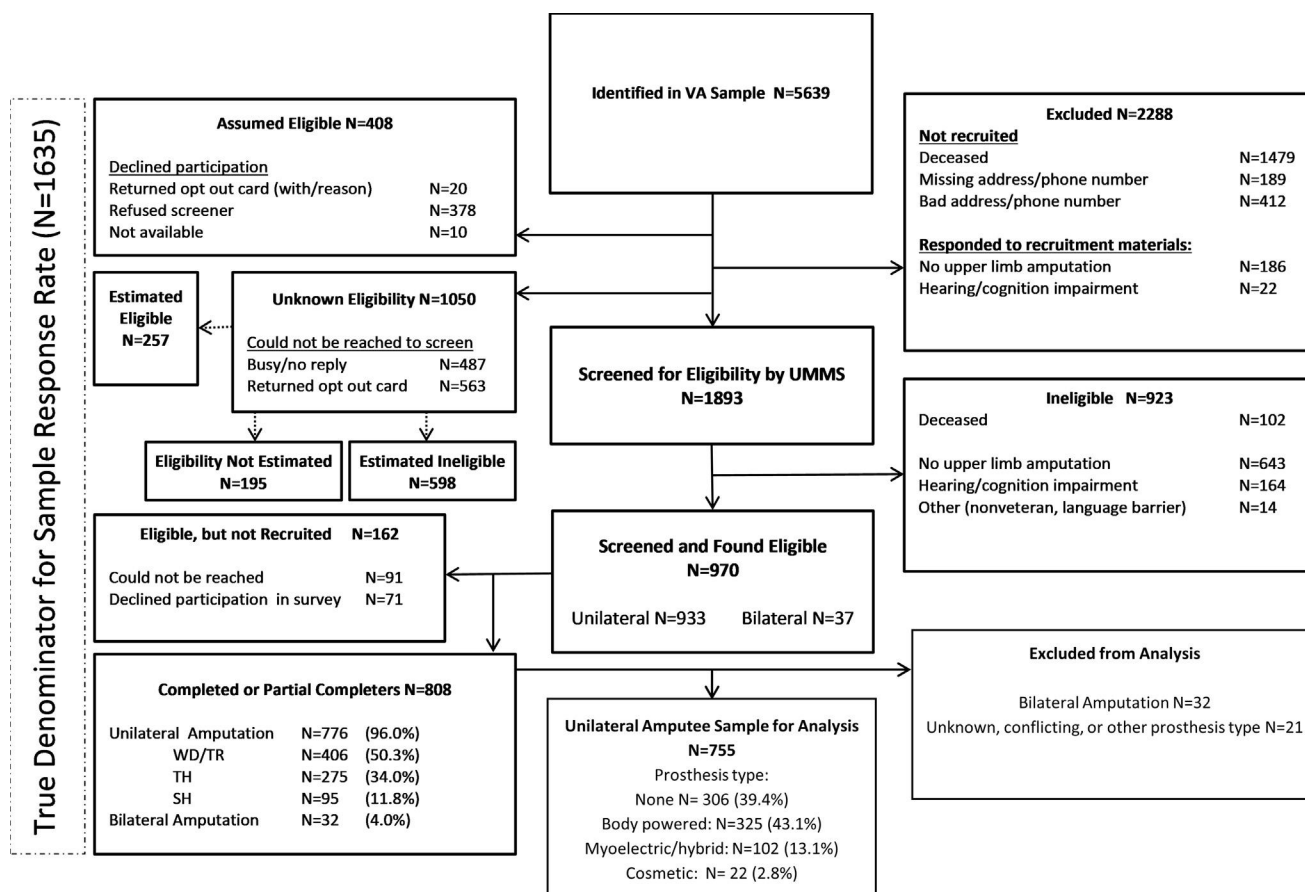


Fig 1 Flow diagram.

Table 1 Demographics and amputation related characteristics by primary device type

Variables	Prosthesis Configuration					
	Body-Powered n = 325	Myoelectric Single/Unknown DOF n = 62	Myoelectric Multi-DOF n = 40	Cosmetic n = 22	Non-Users n = 306	All N = 755
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Age, y	65.8 $\pm$ 12.4	58.7 $\pm$ 15.9	63.9 $\pm$ 10.4	63.9 $\pm$ 10.4	63.6 $\pm$ 14.1	63.5 $\pm$ 13.9
Missing, n	10	2	1	1	4	18
Time since initial amputation, y	36.6 $\pm$ 17.4	25.7 $\pm$ 18.4	32.8 $\pm$ 17.8	32.8 $\pm$ 17.8	28.3 $\pm$ 18.0	31.4 $\pm$ 18.3
Missing, n	6	2	1	1	8	18
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Age, y						
18-45	26 (8.3)	15 (25.0)	14 (35.9)	1 (4.8)	37 (12.3)	93 (12.6)
45-65	72 (22.9)	18 (30.0)	14 (35.9)	7 (33.3)	92 (30.5)	203 (27.5)
65-75	170 (54.0)	18 (30.0)	11 (28.2)	12 (57.1)	124 (41.1)	335 (45.5)
75+	47 (14.9)	9 (15.0)	0 (0.0)	1 (4.8)	49 (16.2)	105 (14.4)
Time since initial amputation, y						
0-20	77 (24.1)	31 (51.7)	23 (59.0)	6 (28.6)	119 (39.9)	256 (34.7)
20-50	181 (56.7)	24 (40.0)	15 (38.5)	13 (61.9)	149 (50.0)	382 (51.8)
50+	61 (19.1)	5 (8.3)	1 (2.6)	2 (9.5)	30 (10.1)	99 (13.4)
Sex						
Male	322 (99.1)	62 (100.0)	38 (95.0)	19 (86.4)	293 (95.8)	734 (97.2)
Female	3 (0.9)	0 (0.0)	2 (5.0)	3 (13.6)	13 (4.3)	21 (2.8)
Race						
White	254 (78.2)	51 (82.3)	23 (57.5)	10 (45.5)	234 (76.5)	572 (75.8)
Black	30 (9.2)	5 (8.1)	7 (17.5)	8 (36.4)	36 (11.8)	86 (11.4)
Other (including mixed race)	16 (4.9)	2 (3.2)	1 (2.5)	2 (9.1)	13 (4.3)	34 (4.5)
Missing	25 (7.7)	4 (6.5)	9 (22.5)	2 (9.1)	23 (7.5)	63 (8.3)
Hispanic or Latino ethnicity						
Yes	22 (6.8)	6 (9.7)	7 (17.5)	1 (4.6)	23 (7.5)	59 (7.8)
No	288 (88.6)	54 (87.1)	31 (77.5)	20 (90.9)	273 (89.2)	666 (88.2)
Missing	15 (4.6)	2 (3.2)	2 (5.0)	1 (4.6)	10 (3.3)	30 (4.0)
Employment						
Employed full-time	32 (9.9)	9 (14.5)	8 (20.0)	2 (9.1)	20 (6.5)	71 (9.4)
Employed part-time	15 (4.6)	2 (3.2)	1 (2.5)	1 (4.6)	11 (3.6)	30 (4.0)
Student	2 (0.6)	2 (3.2)	2 (5.0)	1 (4.6)	10 (3.3)	17 (2.3)
Retired, but employed after amputation	187 (57.5)	31 (50.0)	11 (27.35)	9 (40.9)	139 (42.5)	368 (48.7)
Retired, but not employed after amputation	49 (15.1)	13 (21.0)	8 (20.0)	6 (27.3)	74 (24.2)	150 (19.9)
On medical leave	3 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)	6 (2.0)	9 (1.2)
Other	26 (8.0)	3 (4.8)	9 (22.5)	2 (9.1)	51 (16.7)	91 (12.1)
Missing	11 (3.4)	2 (3.2)	1 (2.5)	1 (4.6)	4 (1.3)	19 (2.5)
Marital status						
Married or living together	219 (67.4)	40 (64.5)	27 (67.5)	12 (54.6)	173 (56.5)	471 (62.4)
Divorced or separated	61 (18.8)	14 (22.6)	11 (27.5)	2 (9.1)	78 (25.5)	166 (22.0)

(continued on next page)

Table 1 (*continued*)

Widowed	19 (5.9)	3 (4.8)	0 (0.0)	2 (9.1)	20 (6.5)	44 (5.8)
Never married	16 (4.9)	3 (4.8)	1 (2.5)	5 (22.7)	30 (9.8)	55 (7.3)
Missing	10 (3.1)	2 (3.2)	1 (2.5)	1 (4.6)	5 (1.6)	19 (2.5)
Amputation level						
Forequarter	5 (1.5)	2 (3.2)	1 (2.5)	3 (13.6)	11 (3.6)	22 (2.9)
At the shoulder joint	9 (2.8)	2 (3.2)	4 (10.0)	1 (4.5)	53 (17.3)	69 (9.1)
Above the elbow	79 (24.3)	8 (12.9)	8 (20.0)	4 (18.2)	134 (43.8)	233 (30.9)
At the elbow	16 (4.9)	2 (3.2)	1 (2.5)	0 (0.0)	18 (5.9)	37 (4.9)
Below the elbow	148 (45.5)	32 (51.6)	17 (42.5)	11 (50.0)	62 (20.3)	270 (35.8)
At the wrist joint	68 (20.9)	16 (25.8)	9 (22.5)	3 (13.6)	28 (9.2)	124 (16.4)
Amputation of lower limb						
Yes	38 (11.7)	10 (16.1)	3 (7.5)	6 (27.3)	34 (11.1)	91 (12.1)
No	287 (88.3)	52 (83.9)	37 (92.5)	16 (72.7)	272 (88.9)	664 (88.0)
Amputation of dominant side						
Yes	174 (53.5)	28 (45.2)	25 (62.5)	9 (40.9)	152 (49.7)	388 (51.4)
No	149 (45.9)	34 (54.8)	15 (37.5)	13 (59.1)	154 (50.3)	365 (48.3)
Missing	2 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.3)
Etiology of amputation (may be more than one)						
Combat injury	145 (44.6)	26 (41.9)	19 (47.5)	8 (36.4)	67 (21.9)	265 (35.1)
Accident	202 (62.2)	41 (66.1)	25 (62.5)	13 (59.1)	200 (65.4)	481 (63.7)
Burn	35 (10.8)	6 (9.7)	4 (10.0)	2 (9.1)	30 (9.8)	77 (10.2)
Cancer	4 (1.2)	1 (1.6)	2 (5.0)	2 (9.1)	21 (6.9)	30 (4.0)
Diabetes	3 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)	7 (2.3)	10 (1.3)
Infection	34 (10.5)	6 (9.7)	1 (2.5)	2 (9.1)	44 (14.4)	87 (11.5)
Ever used prosthesis						
Yes	235 (100.0)	62 (100.0)	40 (100.0)	22 (100.0)	254 (83.0)	703 (93.1)
No	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	52 (17.0)	52 (6.9)
Prosthesis users (ever) only	n = 325	n = 62	n = 40	n = 22	n = 254	n = 703
Initial prosthesis training						
Yes	245 (75.4)	53 (85.5)	31 (77.5)	11 (50.0)	192 (75.6)	532 (75.7)
No	77 (23.7)	9 (14.5)	9 (22.5)	10 (45.5)	59 (23.2)	164 (23.3)
Missing	3 (0.9)	0 (0.0)	0 (0.0)	1 (4.6)	3 (1.2)	7 (1.0)
Prosthesis users (current) only	n = 325	n = 62	n = 40	n = 22	n = 0	n = 449
Current prosthesis training						
Yes	208 (64.0)	46 (74.2)	33 (82.5)	7 (31.8)		294 (65.5)
No	112 (34.5)	15 (24.2)	7 (31.8)	15 (68.2)		149 (33.2)
Missing	5 (1.5)	1 (1.6)	0 (0.0)	0 (0.0)		6 (1.3)
Most recent prosthesis received						
<1 year ago	76 (23.4)	19 (30.7)	9 (22.5)	3 (13.5)		107 (23.8)
1 to < 4 years ago	128 (39.4)	29 (46.8)	27 (67.5)	9 (40.9)		193 (43.0)
4 years ago +	120 (36.9)	14 (22.6)	3 (7.5)	10 (45.5)		147 (32.7)
Missing	1 (0.3)	0 (0.0)	1 (2.5)	0 (0.0)		2 (0.5)
Number of prostheses						
1	227 (69.9)	24 (38.7)	19 (47.5)	14 (63.6)		284 (63.3)
2 +	98 (30.2)	38 (61.3)	21 (52.5)	8 (36.4)		165 (36.8)

Table 2 Difficulty of activity performance under 4 conditions between primary device configuration (n=741)

Conditions	Body-Powered n = 325	Myoelectric Single/Missing DOF n = 62	Myoelectric Multi-DOF n = 40	Cosmetic n = 22	Non-Users n = 306	Kruskal-Wallis P Value
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
Without a prosthesis: two-handed tasks						
Lift and carry bulky objects like grocery bags or crates that weigh more than 15 lb?	2.7 $\pm$ 1.1	2.8 $\pm$ 1.0	2.7 $\pm$ 1.1	3.0 $\pm$ 1.2	2.9 $\pm$ 1.1	.2471
Spread peanut butter on fresh bread?	3.0 $\pm$ 1.0	3.2 $\pm$ 1.1	3.3 $\pm$ 1.2	3.1 $\pm$ 1.2	3.1 $\pm$ 1.1	.3524
Do housework such as carrying a laundry basket?	2.6 $\pm$ 1.0	2.7 $\pm$ 1.0	2.8 $\pm$ 1.2	3.1 $\pm$ 1.6	2.9 $\pm$ 1.2	.1552
With primary prosthesis: two-handed tasks						
Lift and carry bulky objects like grocery bags or crates that weigh more than 15 lb?	2.4 $\pm$ 1.1	2.5 $\pm$ 1.1	2.8 $\pm$ 1.3	3.6 $\pm$ 1.4	NA	.0006
Spread peanut butter on fresh bread?	2.9 $\pm$ 1.3	2.9 $\pm$ 1.2	3.1 $\pm$ 1.4	3.9 $\pm$ 1.3	NA	.0056
Do housework such as carrying a laundry basket?	2.3 $\pm$ 1.0	2.4 $\pm$ 1.0	2.5 $\pm$ 1.1	3.5 $\pm$ 1.5	NA	.0003
With primary prosthesis: one-handed tasks						
Pick up small objects such as coins and paper clips using your amputated side?	3.2 $\pm$ 1.2	3.4 $\pm$ 1.2	3.5 $\pm$ 1.1	4.2 $\pm$ 1.2	NA	.0028
Grasp rounded objects, such as cans, using your amputated side?	2.7 $\pm$ 1.2	2.5 $\pm$ 1.0	2.6 $\pm$ 1.2	4.1 $\pm$ 1.2	NA	<.0001
Residual limb without prosthesis: one-handed tasks						
Pick up small objects such as coins and paper clips using your amputated side?	4.4 $\pm$ 1.0	4.4 $\pm$ 1.1	4.5 $\pm$ 1.1	4.6 $\pm$ 0.9	4.6 $\pm$ 0.9	.0899
Grasp rounded objects, such as cans, using your amputated side?	4.0 $\pm$ 1.3	4.0 $\pm$ 1.3	4.1 $\pm$ 1.2	4.5 $\pm$ 0.9	4.4 $\pm$ 1.1	.0002

NOTE. Response categories: 1=very easy; 2=easy; 3=difficult; 4=very difficult; 5=cannot do at all. Abbreviation: NA, not available.

comparisons showed that cosmetic device users had significantly ($\alpha=.05$) more difficulty in all three 2-handed tasks with a prosthesis as compared with body-powered users and more difficulty than myoelectric single-DOF users with lifting bulky objects and spreading peanut butter. Difficulty with 1-handed task performance using a prosthesis was also significantly different by prosthesis type ($P<.005$). Post-hoc analyses showed that cosmetic users had significantly more difficulty ($\alpha=.05$) than body-powered users in picking up small items, and more difficulty than all other groups in grasping rounded objects. The 1-handed task of grasping rounded objects with the residual limb was significantly different by prosthesis type ($P=.0002$); in the post-hoc analysis, non-users had significantly more difficulty than body-powered users.

Table 3 shows task difficulty with and without a prosthesis, stratified by device type. Lifting bulky objects and doing housework was rated as easier when done with a prosthesis only by body-powered users ($P<.0001$). Spreading peanut butter on fresh bread was rated as easier without using a prosthesis by cosmetic users. Picking up small objects and grasping rounded objects were rated as easier when done with a prosthesis as compared to

without (with residual limb) by all but the cosmetic users ($P<.001$).

There were statistically significant weak to moderate correlations ($r: 0.12$ - 0.33 ; $P<.05$) between the hours of help needed per day and self-rated difficulty in performing 1- and 2-handed tasks with and without the prosthesis (supplemental table S1, available online only at <http://www.archives-pmr.org/>).

Performance and satisfaction outcomes

Bivariate linear regression results are shown in supplemental table S2 (available online only at <http://www.archives-pmr.org/>). After controlling for potential confounders in multivariable models, there were no meaningful differences in MCS or PCS scores by prosthesis configuration (table 4). MCS scores were better for respondents with longer amputation histories and those who received training with their initial prosthesis but lower for those who were black or unknown race as compared to white. PCS scores were better for those who were younger, had longer amputation histories, those who received training to use their current prosthesis, and those who had 2 or more prostheses. PCS

Table 3 Difficulty of activity performance under 3 conditions by primary device type

Task Type	Without a Prosthesis Mean $\pm$ SD	Primary Prosthesis Mean $\pm$ SD	Residual Limb Without Prosthesis Mean $\pm$ SD	Wilcoxon Signed-Ranks P Value
Two-handed tasks	Body-powered (n = 312)			
Lift and carry bulky objects like grocery bags or crates that weigh more than 15 lb?	2.7 $\pm$ 1.1	2.4 $\pm$ 1.1	NA	<.0001
Spread peanut butter on fresh bread?	3.2 $\pm$ 1.0	2.9 $\pm$ 1.3	NA	.1516
Do housework such as carrying a laundry basket?	2.6 $\pm$ 1.0	2.3 $\pm$ 1.0	NA	<.0001
One-handed tasks				
Pick up small objects such as coins and paper clips using your amputated side?	NA	3.2 $\pm$ 1.2	4.4 $\pm$ 1.0	<.0001
Grasp rounded objects, such as cans, using your amputated side?	NA	2.6 $\pm$ 1.2	4.0 $\pm$ 1.3	<.0001
Two-handed tasks	Myoelectric/Hybrid: Single/Unknown DOF (n = 59)			
Lift and carry bulky objects like grocery bags or crates that weigh more than 15 lb?	2.8 $\pm$ 1.0	2.5 $\pm$ 1.1	NA	.1064
Spread peanut butter on fresh bread?	3.2 $\pm$ 1.2	2.9 $\pm$ 1.2	NA	.2211
Do housework such as carrying a laundry basket?	2.7 $\pm$ 1.0	2.4 $\pm$ 1.0	NA	.1119
One-handed tasks				
Pick up small objects such as coins and paper clips using your amputated side?	NA	3.4 $\pm$ 1.2	4.4 $\pm$ 1.1	<.0001
Grasp rounded objects, such as cans, using your amputated side?	NA	2.5 $\pm$ 1.0	4.0 $\pm$ 1.3	<.0001
Two-handed tasks	Myoelectric/Hybrid: Multi-DOF (n = 40)			
Lift and carry bulky objects like grocery bags or crates that weigh more than 15 lb?	2.7 $\pm$ 1.1	2.8 $\pm$ 1.3	NA	.6749
Spread peanut butter on fresh bread?	3.3 $\pm$ 1.3	3.1 $\pm$ 1.4	NA	.5978
Do housework such as carrying a laundry basket?	2.8 $\pm$ 1.2	2.5 $\pm$ 1.1	NA	.1155
One-handed tasks				
Pick up small objects such as coins and paper clips using your amputated side?	NA	3.5 $\pm$ 1.1	4.5 $\pm$ 1.1	.0008
Grasp rounded objects, such as cans, using your amputated side?	NA	2.6 $\pm$ 1.2	4.1 $\pm$ 1.2	<.0001
Two-handed tasks	Cosmetic (n = 21)			
Lift and carry bulky objects like grocery bags or crates that weigh more than 15 lb?	3.0 $\pm$ 1.2	3.6 $\pm$ 1.4	NA	.1172
Spread peanut butter on fresh bread?	3.2 $\pm$ 1.2	3.9 $\pm$ 1.3	NA	.0215
Do housework such as carrying a laundry basket?	3.1 $\pm$ 1.5	3.5 $\pm$ 1.5	NA	.2334
One-handed tasks				
Pick up small objects such as coins and paper clips using your amputated side?	NA	4.2 $\pm$ 1.2	4.6 $\pm$ 0.9	.1250
Grasp rounded objects, such as cans, using your amputated side?	NA	4.1 $\pm$ 1.2	4.5 $\pm$ 0.9	.2500

NOTE. Response categories: 1 = very easy; 2 = easy; 3 = difficult; 4 = very difficult; 5 = cannot do at all. Abbreviation: NA, not available.

scores were worse for participants who had never used a prosthesis compared with those who had ever used a prosthesis.

In multivariate analyses, respondents who did not use a prosthesis had significantly higher (worse) QuickDASH scores ($\beta=8.18$; $P=.002$) as compared with body-powered users. QuickDASH scores were also higher for participants who had shorter amputation histories and were black, other race, or unknown race, as compared to white.

Chi-squared analysis found that need for ADL help differed ($P=.01$) by prosthesis configuration (not shown). Post-hoc analyses showed that the only statistically significant difference in needing help was between non-users and body-powered users. Bivariate linear regression results are shown in [supplemental table S3](#) (available online only at <http://www.archives-pmr.org/>). Multivariate logistic regression models showed that the odds of

needing ADL help were 1.84 times higher for respondents who did not use a prosthesis, as compared to body-powered users ([table 5](#)). Amputation level was not associated with need for ADL help. Black participants had 3.44 times the odds of white participants of needing ADL help. Participants had lower odds of needing ADL help if they were divorced or separated ($\beta=0.51$) or never married ($\beta=0.26$) compared to those married or living as married.

Discussion

This study compared disability, HRQOL, and ADL assistance for persons with major upper limb amputation who did not use a prosthesis, and those who used body-powered, myoelectric single-

Table 4 Multivariate linear regression modeling outcomes: results of separate models

Variables	HRQOL				Disability	
	VR-12 MCS		VR-12 PCS		QuickDASH	
	Beta (95% CI)	P Value	Beta (95% CI)	P Value	Beta (95% CI)	P Value
Age, y	0.00 (−0.11 to 0.10)	.9363	−0.12 (−0.19 to −0.06)	.0004	0.08 (−0.09 to 0.25)	.3451
Years since amputation	0.11 (0.03–0.20)	.0088	0.06 (0.01–0.12)	.0213	−0.17 (−0.30 to −0.05)	.0078
Race						
White (ref)						
Black	−5.16 (−8.27 to −2.06)	.0012	−1.85 (−3.83 to 0.13)	.0677	11.66 (6.82–16.50)	<.0001
Other	−1.20 (−5.93 to 3.54)	.6202	0.73 (−2.30 to 3.75)	.6363	8.17 (0.85–15.48)	.0287
Missing	−5.91 (−10.10 to −1.72)	.0057	−0.20 (−2.87 to 2.48)	.8847	9.27 (2.80–15.74)	.0050
Marital status						
Married or living together (ref)						
Divorced or separated	−1.96 (−4.40 to 0.49)	.1161	−0.92 (−2.48 to 0.64)	.2493	−0.17 (−3.93 to 3.60)	.9297
Widowed	2.90 (−1.35 to 7.14)	.1808	−0.36 (−3.07 to 2.35)	.7947	−3.03 (−9.58 to 3.51)	.3631
Never married	−1.55 (−5.54 to 2.43)	.4452	0.08 (−2.47 to 2.63)	.9511	3.73 (−2.17 to 9.63)	.2152
Amputation level						
SH/FQ	1.39 (−1.89 to 4.68)	.4056	0.61 (−1.49 to 2.71)	.5664	2.74 (−2.27 to 7.75)	.2838
TH/ED	0.59 (−1.70 to 2.89)	.6111	0.96 (−0.50 to 2.43)	.1980	0.20 (−3.32 to −3.73)	.9100
TR/wrist (ref)						
Etiology						
Combat injury	−0.03 (−3.21 to 3.15)	.9874	1.26 (−0.77 to 3.29)	.2246	−1.18 (−6.12 to 3.77)	.6409
Accident	−1.15 (−4.03 to 1.74)	.4359	1.08 (−0.76 to 2.92)	.2503	−1.20 (−5.66 to 3.26)	.5984
Infection	1.27 (−1.94 to 4.47)	.4383	−1.10 (−3.15 to 0.94)	.2898	−0.27 (−5.17 to 4.63)	.9136
Ever used prosthesis						
Yes (ref)						
No	2.87 (−1.95 to 7.70)	.2428	−3.33 (−6.41 to −0.23)	.0344	−4.54 (−11.77 to 2.69)	.2176
Prosthesis configuration						
Body (ref)						
Myoelectric/hybrid	2.07 (−1.73 to 5.87)	.2855	0.17 (−2.26 to 2.59)	.8921	−1.72 (−7.58 to 4.14)	.5640
Single/missing DOF						
Myoelectric/hybrid multi-DOF	2.59 (−2.14 to 7.32)	.2825	−0.97 (−3.99 to 2.05)	.5295	1.24 (−5.88 to 8.36)	.7326
Cosmetic	−3.65 (−10.04 to 2.75)	.2634	1.40 (−2.69 to 5.48)	.5022	4.60 (−5.03 to 14.22)	.3488
Non-users	−2.23 (−5.49 to 1.03)	.1796	−0.41 (−2.49 to 1.67)	.6977	8.18 (3.16–13.20)	.0015
Initial prosthesis training						
Yes	3.32 (0.46–6.17)	.0229	−1.47 (−3.30 to 0.35)	.1130	−1.40 (−5.79 to 3.00)	.5323
No (ref)						
Current prosthesis training						
Yes	0.08 (−3.04 to 3.21)	.9577	2.66 (0.67–4.66)	.0090	−2.43 (−7.22 to 2.36)	.3192
No (ref)						
Number of prostheses						
1 (ref)						
2+	−2.75 (−5.55 to 0.05)	.0543	2.38 (0.59–4.17)	.0092	0.69 (−3.62 to 4.99)	.7546
Model n, R ²	688, 0.10		668, 0.12		698, 0.14	

Abbreviations: CI, confidence interval; ED, elbow disarticulation; FQ, forequarter amputation; ref, reference; SH, amputation at the forequarter or shoulder disarticulation level; TH, transhumeral amputation; TR, transradial amputation.

DOF, myoelectric multi-DOF, and cosmetic devices. We found that amputees who do not use a prosthesis report more difficulty in activities, greater overall disability, and lower physical function compared with amputees who use any type of active prosthesis. Furthermore, those who do not use a prosthesis are more likely to need help with ADLs compared with those who use a body-powered prosthesis. These findings demonstrate the value of active prostheses in improving HRQOL and highlight the clinical imperative to encourage prosthesis use by addressing factors such

as early prosthetic training to improve satisfaction with devices and reduce abandonment.^{17,18}

Our analyses of task difficulty ratings with and without a prosthesis demonstrate the value of active prostheses in unilateral tasks involving fine motor activities, and to a lesser extent in bilateral activities. While cosmetic devices, a preference of many female amputees,¹⁹ may enhance body image and psychosocial adjustment,^{20,21} they are not suitable for specific activities (ie, spreading peanut butter, grasping rounded objects). Users of

Table 5 Multivariate logistic model of ADL help needed

Variables	ADL Help Needed	
	OR (95% CI)	P Value
Age, y		
18-45	1.18 (0.64-2.17)	.5947
45-65 (ref)		
65-75	0.92 (0.57-1.47)	.7190
75+	0.49 (0.23-1.03)	.0593
Years since initial amputation		
0-20 (ref)		
20-50	0.57 (0.36-0.91)	.0185
50+	0.93 (0.46-1.87)	.8364
Race		
White (ref)		
Black	3.44 (2.05-5.79)	<.0001
Other	0.97 (0.39-2.42)	.9475
Missing	1.79 (0.89-3.62)	.1037
Marital Status		
Married or living together (ref)		
Divorced or separated	0.51 (0.32-0.81)	.0042
Widowed	0.90 (0.39-2.09)	.8142
Never married	0.26 (0.11-0.62)	.0025
Amputation Level		
SH/FQ	0.89 (0.50-1.61)	.7095
TH/ED	1.00 (0.66-1.52)	.9927
TR/wrist (ref)		
Prosthesis Configuration		
Body (ref)		
Myoelectric/hybrid	0.55 (0.24-1.23)	.1435
single/missing DOF		
Myoelectric/hybrid multi-DOF	1.75 (0.81-3.79)	.1557
Cosmetic	0.44 (0.11-1.72)	.2395
Non-users	1.84 (1.16-2.92)	.0094
Protheses used, n		
1 (ref)		
2+	1.31 (0.78-2.21)	.3133

Abbreviations: CI, confidence interval; ED, elbow disarticulation; FQ, forequarter amputation; OR, odds ratio, ref, reference; SH, amputation at the forequarter or shoulder disarticulation level; TH, transhumeral amputation; TR, transradial amputation.

cosmetic prostheses also report the most difficulty in general task performance such as housework. These findings are not surprising given that cosmetic devices have no ability for active grasp and can only be used as stabilizers.²²

Despite the promise of multi-DOF terminal devices, in our sample, myoelectric multi-DOF users generally had greater disability (QuickDASH) as compared with body-powered and single-DOF myoelectric device users. However, we did not observe any differences in those tasks that require grasp of small and rounded objects. It is possible that our measure of task difficulty was not sufficiently sensitive to detect differences in device type, or that these data were confounded by other factors. For example, multi-DOF terminal devices may be more likely to be prescribed to persons with greater disability in the hopes of improving their function. Further study is needed to compare fine motor and activity performance of users of single- vs multi-DOF terminal devices.

Our multivariable models, which controlled for factors potentially associated with disability and quality of life outcomes, did

not detect any differences in these outcomes by device configuration. However, we did identify other factors associated with these outcomes. Interestingly, persons who reported that they used 2 or more types of prostheses had better PCS scores, suggesting that having multiple devices provides greater functionality; perhaps this is because the amputee can select the device that best matches his or her needs for activity on any given day. Other research highlights the value of having multiple prostheses, and indicates that amputees may utilize their devices selectively, best matching the device for particular functions or activities.^{23,24}

We found that PCS scores were better for those who had training to use their current prosthesis, an important finding that supports the best practice recommendations of clinical experts.²⁵⁻²⁸ Receipt of initial prosthetic training was associated with better MCS scores, which may suggest that early quality of amputation care has long-lasting effects on mental health.

Years since amputation was independently associated with better physical function and lower disability, and less likelihood of needing any ADL help. These findings clearly demonstrate that amputees adapt and gain skills and function as they accommodate to their amputation regardless of whether they utilize a prosthesis or not.

We found significant differences in outcomes for black veterans, who reported lower mental function, greater disability, and higher likelihood of needing help with ADLs as compared to white veterans. This finding is consistent with the literature on racial and ethnic disparities in rehabilitation outcomes for persons with stroke,²⁹ where racial or ethnic minorities have been reported to be less likely to achieve equivalent health outcomes as compared with non-minorities.²⁹ It is possible that differences in outcomes are explained by a greater prevalence of adverse psychosocial factors such as depression, self-efficacy, and health literacy in combination with lower socioeconomic status among black veterans. Additionally, some studies show that patients who are black have greater pain intensity and pain-related disability as compared to white patients.³⁰ Further study is needed to understand the sources of racial disparities among veterans with upper limb amputation that we observed.

Study limitations

Results of our comparisons between prosthesis configurations should be interpreted cautiously given the limitations of our study design. Our study was cross-sectional and observational. There are limits to generalizability of results beyond the veteran and male population, and those not served by VA care. Participants were not randomly assigned to prosthesis configurations, and prosthesis users had varying amounts of training and experience, 2 factors that may affect skillfulness of prosthesis use. It is possible that differences between multi- and single-DOF terminal devices were not detected because of confounding by indication. This may have occurred if amputees with greater disability and need are more likely to be prescribed multi-DOF devices. Given the cross-sectional nature of our study, we have no way to examine outcomes before and after prescription of a multi-DOF device. Prospective, longitudinal studies would be helpful in assessing whether there are differences associated with prosthesis configuration.

Another limitation is that this study relied on self-reported survey data which may not fully reflect physical performance. Additional studies that utilize performance metrics to compare outcomes by prosthesis configuration are needed. While our study

was very large for a study of upper limb amputees, it may have been underpowered to detect differences by certain prosthesis configuration subgroups due to their relatively small size. It is also possible that our study was affected by missing or incomplete data on terminal device type and by our decision to categorize unknown terminal device type as single DOF. In sensitivity analyses for unknown terminal device type classification, we found that 2-handed tasks were significantly harder without a prosthesis for those in the myoelectric single-DOF group, only when those with unknown DOF were excluded. There were no changes in any findings on the association of prosthesis type with disability, HRQOL, or help with ADLs.

Conclusions

This large survey of veterans with upper limb amputation found that those who did not use a prosthesis reported more difficulty in activities, greater disability, and lower HRQOL as compared with those who used any type of active prosthesis. Those who do not use a prosthesis are more likely to need help with ADLs as compared with those who use a body-powered prosthesis. Users of cosmetic prostheses report greater difficulty in task performance compared with users of active prostheses. However, no differences were observed between body-powered, myoelectric single-DOF, and myoelectric multi-DOF devices in perceived activity difficulty, likelihood of needing assistance with ADLs, self-reported disability, or HRQOL. Further study is needed to compare fine motor and activity performance of users of different types of prostheses to assess if and how specific device configurations contribute to performance.

Supplier

a. SAS version 9.4; SAS Institute.

Keywords

Amputation; Quality of life; Rehabilitation; Survey; Upper limb; Veterans

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Longitudinal study of prosthesis use in veterans with upper limb amputation

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Abstract

Background: Little is known about the patterns of prosthesis use and satisfaction of those who cease use or begin to use prostheses.

Objectives: Among a longitudinal sample of Veterans with upper limb amputation, to (1) describe changes in prosthesis use over 1 year, (2) examine rates of receipt of new prostheses, and (3) compare prosthesis satisfaction in respondents who received a new prosthesis to those who did not.

Study Design: Longitudinal survey.

Methods: Structured telephone interviews were conducted with 585 Veterans who had participated in a baseline interview 1 year earlier.

Results: A total of 562 persons with unilateral and 23 with bilateral amputation participated (Response rate = 72.4% and 85.2%, respectively). Prosthesis use, frequency and intensity of use, and types of prostheses used were stable over 1 year. About 24% reported using a different primary terminal device type at follow-up than baseline. Prosthesis use was less frequent/intense at baseline among those who discontinued use compared with those who did not ($P < 0.05$), and less frequent/intense for those who started using a prosthesis compared with those who continued ($P < 0.0001$). Rates of prosthetic training were higher among those who received a different prosthesis type compared with the same type ($P = 0.06$). Satisfaction scores were higher ($P < 0.01$) for new prosthesis recipients, and lower at baseline for prosthesis abandoners compared with continued users ($P = 0.03$).

Conclusion: Prosthesis abandonment is predicated on dissatisfaction with the device, as well less frequent/intense prosthesis use. These findings can be used to identify those at risk for prosthesis abandonment to improve their prosthesis experience.

Keywords

Upper limb, amputation, survey, epidemiology, veterans, longitudinal, prosthesis, longitudinal study [AQ: 2]

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Background

Many cross-sectional studies have examined use and abandonment of upper limb prostheses,¹⁻⁶ reporting prevalent dissatisfaction, and abandonment in about 26% of the population.⁷ A 2018 survey of Veterans with upper limb amputation found that 60% with unilateral amputation were using prostheses, a rate of use below that reported in prior systematic reviews and studies of Vietnam and recent combat Veterans.⁸ While prevalence rates of rejection for myoelectric and body-powered prostheses have been reported as roughly equivalent,⁷ rates of terminal devices rejection may vary. Rejection rates for myoelectric hands, body-powered hooks, and passive hands have been reported to be 39%, 50%, and 53%, respectively.⁹

Our survey of Veterans found 50% with unilateral amputation had discontinued using a prosthesis in the past, with 36% of Veterans abandoning body-powered and 18% abandoning myoelectric prostheses.⁸ However, to date,

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there have been no data to determine how often Veterans change prosthesis types. Cross-sectional studies provide a snapshot of prosthesis use, but do not provide information about use over time. It is likely that in any given year, some will stop using prostheses, others will resume or initiate using a device, and some will switch to a new prosthesis type.

Prior research reported that between 2000 and 2010, Veterans received a new upper limb prosthesis every 3.5 years.¹⁰ However, this research did not evaluate whether new prostheses received were of the same type. The relationship between prosthesis satisfaction and switching to or obtaining a new prosthesis has also not been previously examined. In addition, little is known about the patterns of prosthesis use among those who stop using prostheses or those who begin using new ones. Finally, no studies to date have examined the 1-year incidence rates of prosthesis abandonment or uptake or the factors associated with these events.

Prevalent dissatisfaction with upper limb prostheses among Veterans has been previously recognized. An Office of the Inspector General (OIG) report called for additional research to evaluate the needs of Veterans with upper limb amputations.¹¹ To meet this need, we conducted the aforementioned survey of Veterans with upper limb amputation.⁸ We followed this cohort over 1 year to examine stability and change in prosthesis use and satisfaction over time. This article presents summary findings from this longitudinal study. The purposes were to (1) describe 1 year changes in prosthesis use; (2) examine the rate of receipt of new prostheses and terminal devices; and (3) compare prosthesis satisfaction among prosthesis users who received a new prosthesis to those who did not.

Methods

The structured baseline interview included a representative sample of Veterans with major upper limb amputation who received care in the Veterans Administration (VA) between 2010 and 2015. The VA is a comprehensive, integrated health care system that serves more than 8.9 million U.S. Veterans annually. VA providers prescribe prostheses and amputation rehabilitation services based upon a Veteran's clinical needs. The VA furnishes authorized items to eligible Veterans through internal VA resources or through an authorized VA vendor or contractor based in the community.

The sampling frame, described in a prior publication, was identified using amputation diagnosis and procedure codes from VA Corporate Data Warehouse (CDW) sources.⁸ Those with valid addresses and telephone numbers were contacted by letter and provided an opportunity to opt-out of study participation. Those who did not opt-out were contacted by telephone. Participants provided oral informed consent by telephone prior to participating in the interview. A waiver of documentation of informed

consent was obtained from the VA Central IRB. Forty-five-minute structured telephone interviews were conducted at baseline and follow-up by professional interviewers from an academic survey center who were trained by the study PI. Respondents who agreed to participate in future activities were re-contacted 1 year after the baseline interview. Response (RR) and cooperation (CR) rates were calculated using American Association of Public Opinion Research guidelines (AAPOR RR4 and CR4).¹² To assess for potential nonresponse bias, we compared baseline and follow-up respondents to Veterans with upper limb amputation diagnoses identified in the original full sampling frame on data available in CDW (age, sex, and year of most recent encounter at the VA).

Data collection

The content of the interview has been described in detail elsewhere.⁸ Items relevant to the analyses presented in this article are described below and provided in the supplemental appendix. The baseline and longitudinal interview contained a demographics section that asked about characteristics including age, sex, marital status, number of children, race/ethnicity, and employment; and a section on amputation that included items on side of limb loss, amputation level, date, and etiology.

In our analyses, we collapsed amputation levels into three groups: (1) TR, which included those with transradial and wrist disarticulation amputation, (2) TH, which included those with transhumeral and elbow disarticulation, and (3) SH, which included those with shoulder disarticulation and forequarter amputation. The interview contained some items specific to prosthesis users. Specifically, those who used a prosthesis were asked to identify type of prosthesis and terminal devices that they used, as well as the suspension method. In addition, those who indicated that they used more than one type of device were asked to identify the primary device and the device that they considered their secondary device. They were then asked how these prostheses were suspended on their body.

Respondents who were current prosthesis users were asked if they had received prosthetic training (yes or no). They were also asked to report frequency of prosthesis use, and average hours per day of use. Prosthesis satisfaction was assessed using two measures: the Trinity Amputation and Prosthetic Experience Scale (TAPES) satisfaction scale, and the modified 8-item Orthotics and Prosthetics Users Survey (OPUS) Client Satisfaction with Device (CSD) scale.^{13–15}

Statistical analyses

We conducted descriptive analyses to characterize prosthesis use and changes in use between baseline and follow-up and identified respondents who had ceased using,

starting using, or continued using a prosthesis. Chi-square analyses were used to compare the proportions of unilateral vs bilateral prosthesis users who used two or more prostheses or two or more terminal devices. We examined differences between these groups in days and hours of use with Wilcoxon Mann–Whitney tests. For those who reported using a prosthesis at both baseline and follow-up, we compared days and hours of use at each time point with Wilcoxon signed-ranks tests. For prosthesis users with bilateral amputation, prosthesis use of the dominant side was used for analysis. We calculated the proportion of respondents who reported using a different type of primary prosthesis or terminal device in the follow-up and baseline interviews. In these analyses, we utilized the prosthesis and terminal device type of the dominant side for bilateral prosthesis users.

We examined the rates of receipt of a new prosthesis in the year prior to the baseline and follow-up. We also identified respondents who received a type of prosthesis at follow-up that was not reported at baseline. For those who received a new prosthesis between baseline and follow-up, we used a chi-square test to compare rates of receipt of any prosthetic training between those who received a different prosthesis type and those who received a similar prosthesis type. To determine whether there were differences in rates of switching prosthesis types for persons who used body-powered and myoelectric prostheses (the two largest groups), we performed a McNemar's comparison.

We compared CSD and TAPES satisfaction scores at baseline and follow-up for respondents who were using the same primary prosthesis type and for those who received a new device. Because normality tests of the satisfaction measures all rejected the assumption of normality in this sample, Wilcoxon signed-rank tests were used. We used nonparametric Wilcoxon Mann–Whitney tests to determine whether poorer baseline prosthesis satisfaction predicted prosthesis abandonment 1 year later. We also compared baseline satisfaction scores between respondents who had stopped using a prosthesis in the subsequent year to those who continued prosthesis use. A critical alpha of 0.05 was used for all analyses.

Results

Sampling frame and response rate

Eight-hundred eight persons were interviewed at baseline and 585 at follow-up. Figure 1 shows the reasons for loss to follow-up. The response rate and cooperation rate at follow-up among those who completed the baseline survey was 72.4% and 85.2%, respectively. Table 1 shows the characteristics of follow-up respondents, baseline completers, and those identified as eligible or of unknown eligibility in the initial sampling frame.

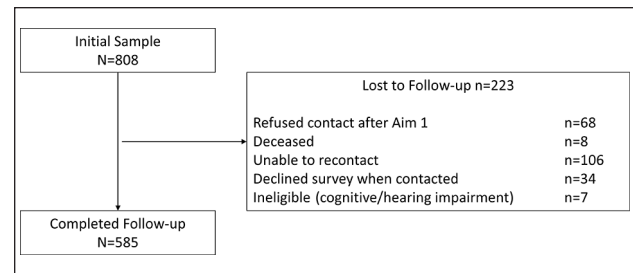


Figure 1. Flow diagram of study participation.

Sample characteristics and prosthesis use

Table 2 compares characteristics of those with unilateral ($n = 562$) and bilateral ($n = 23$) amputation in the longitudinal sample. Fifty-two percent ($n = 293$) of persons with unilateral amputation were classified in the TR group, 37% in the TH group ($n = 206$) and 11% in the SH group ($n = 11$). In the group with bilateral amputation, 15 (65%) had TR amputation on both sides, 3 (13%) had TH amputation on both sides, 2 (9%) had TR on one side and TH on the other side, 2 (9%) had TR amputation on one side and shoulder level amputation on the other, while 1 (4%) had shoulder amputation on one side and TH on the other.

There were no changes in amputation level from baseline to follow-up. Prosthesis use was stable over the 1-year period. Among individuals with unilateral amputation, 59.9% and 61.7% used a prosthesis at baseline and follow-up, respectively (Table 3). Ninety-five percent of individuals with bilateral amputation used a prosthesis (on at least one side) at baseline and at follow-up. Six percent of those with unilateral amputation had never used a prosthesis at either baseline or follow-up. Prevalence of prosthesis types at baseline and follow-up are shown in Table 3. Body-powered devices were used by 73% of persons with unilateral amputation and 75% of persons with bilateral amputation (on at least one side) at baseline and 69% of persons with unilateral amputation and 85% of persons with bilateral amputation at follow-up. Figure 2 shows data for persons with bilateral amputation, showing levels of amputation and the prostheses combinations used. Sixty percent of persons with bilateral transradial amputation used a body-powered device on both sides.

The proportion reporting use of multiple prostheses was stable over the 1-year period. Thirty percent of prosthesis users with unilateral amputation used two or more prostheses at follow-up (as compared with 36.0% at baseline), and 22.7% of prosthesis users with bilateral amputation used two or more prostheses on at least one side at follow-up (compared with 27.3% at baseline). Rate of receipt of new prostheses within the past year was stable from baseline to follow-up for those with unilateral (23% and 20%) and bilateral (50% and 50%) amputation. There were no

Table 1. Characteristics of Veterans assumed eligible and those who completed baseline and follow-up interviews.

	Eligible or unknown eligibility (n = 2428)	Completed baseline interview (n = 808)	Completed 1-year follow- up interview (n = 585)
	M (SD)	M (SD)	M (SD)
Age (years)	64.4 (15.4)	63.2 (14.2)	67.2 (14.9)
	n (%)	n (%)	n (%)
Sex			
Female	45 (1.9)	21 (2.6)	3 (0.5)
Male	2383 (98.2)	787 (97.4)	581 (99.5)
Race			
White	1663 (68.5)	558 (69.1)	400 (68.5)
Black	284 (11.7)	82 (10.2)	82 (14.0)
Other/mixed	93 (3.8)	30 (3.7)	24 (4.1)
Unknown	388 (16.0)	138 (17.1)	78 (13.4)
Date of last VA encounter ^a			
2010	6 (0.3)	1 (0.1)	1 (0.2)
2011	20 (0.8)	5 (0.6)	6 (1.0)
2012	21 (0.9)	2 (0.3)	7 (1.2)
2013	43 (1.8)	7 (0.9)	10 (1.7)
2014	44 (1.8)	14 (1.7)	7 (1.2)
2015	83 (3.4)	20 (2.5)	27 (4.6)
2016	2211 (91.1)	759 (93.9)	527 (90.1)

^aPrior to 1 January 2017.**Table 2.** Longitudinal sample: demographic characteristics.

	Unilateral (n = 562)	Bilateral (n = 23)	All (n = 585)
	M (SD)	M (SD)	M (SD)
Age (years)	63.2 (14.1)	63.6 (15.3)	63.7 (13.6)
Years since initial amputation	31.3 (18.4)	32.8 (18.1)	31.7 (18.0)
Unknown 	14 (X%)	0 (X%)	14 (X%)
	n (%)	n (%)	n (%)
Sex			
Male	552 (98.2)	23 (100.0)	575 (98.3)
Female	10 (1.8)	0 (0.0)	10 (1.7)
Race			
White	441 (78.5)	18 (78.3)	459 (78.5)
Black	59 (10.5)	1 (4.4)	60 (10.3)
Native American	5 (0.9)	0 (0.0)	5 (0.9)
Other (including mixed race)	25 (4.5)	2 (8.7)	27 (4.6)
Unknown	32 (5.7)	2 (8.7)	34 (5.8)
Hispanic or Latino			
Yes	42 (7.5)	4 (17.4)	46 (7.9)
No	513 (91.3)	19 (82.6)	532 (90.9)
Unknown	7 (1.3)	0 (0.0)	7 (1.2)
Employment			
Employed full-time	54 (9.6)	1 (4.4)	55 (9.4)
Employed part-time	24 (4.3)	0 (0.0)	24 (4.1)
Student	15 (2.7)	0 (0.0)	15 (2.6)

(Continued)

Table 2. (Continued)

	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
Retired, but was employed after amputation	290 (51.6)	10 (43.5)	300 (51.3)
Retired, but was not employed after amputation	110 (19.6)	7 (30.4)	117 (20.0)
On medical leave	5 (0.9)	0 (0.0)	5 (0.9)
Other	63 (11.2)	5 (21.7)	68 (11.6)
Unknown	1 (0.2)	0 (0.0)	1 (0.2)
Laterality of amputation			
Unilateral right	273 (48.6)	0 (0.0)	273 (46.7)
Unilateral left	289 (51.4)	0 (0.0)	289 (49.4)
Bilateral	0 (0.0)	23 (100.0)	23 (3.9)
Amputation of dominant arm			
Yes	286 (50.9)	23 (100.0)	309 (52.8)
No	274 (48.8)	0 (0.0)	274 (46.8)
Unknown	2 (0.4)	0 (0.0)	2 (0.3)
Amputation of lower limb			
Yes	67 (11.9)	6 (26.1)	73 (12.5)
No	495 (88.1)	17 (73.9)	512 (87.5)
Side of lower limb amputation			
Right side	30 (44.8)	1 (16.7)	31 (42.5)
Left side	15 (22.4)	1 (16.7)	16 (21.9)
Both sides	22 (32.8)	4 (66.7)	26 (35.6)
		Left	Right
Amputation level			
Forequarter	18 (3.2)	1 (4.4)	0 (0.0)
At the shoulder joint	45 (8.0)	1 (4.4)	1 (4.4)
Above the elbow	175 (31.1)	5 (21.7)	4 (17.4)
At the elbow	31 (5.5)	0 (0.0)	0 (0.0)
Below the elbow	198 (35.2)	8 (34.8)	14 (60.9)
At the wrist joint	95 (16.9)	7 (30.4)	4 (17.4)
Through the hand	0 (0.0)	1 (4.4)	0 (0.0)
Etiology of amputation (more than one may apply)			
Combat injury	194 (34.5)	6 (26.1)	6 (26.1)
Accident	366 (65.1)	14 (60.9)	14 (60.9)
Burn	60 (10.7)	9 (39.1)	9 (39.1)
Cancer	20 (3.6)	0 (0.0)	0 (0.0)
Diabetes	4 (0.7)	0 (0.0)	0 (0.0)
Infection	63 (11.2)	7 (30.4)	6 (26.1)

Table 3. Prostheses use and description for persons with unilateral and bilateral amputation at baseline and follow-up.

	Baseline			Follow-up		
	Unilateral (<i>n</i> = 562)	Bilateral (<i>n</i> = 23)		Unilateral (<i>n</i> = 562)	Bilateral (<i>n</i> = 23)	
	<i>n</i> (%)	Left <i>n</i> (%)	Right <i>n</i> (%)	<i>n</i> (%)	Left <i>n</i> (%)	Right <i>n</i> (%)
Currently use a prosthesis						
Yes	336 (59.9)	19 (82.6)	20 (87.0)	347 (61.7)	18 (78.3)	20 (87.0)
No	190 (33.9)	4 (17.4)	3 (13.0)	182 (32.4)	5 (21.7)	3 (13.0)
*Never Used Prosthesis	33 (5.9)	0 (0.0)	0 (0.0)	32 (5.7)	0 (0.0)	0 (0.0)
Unknown	2 (0.4)	0 (0.0)	0 (0.0)	1 (0.2)	0 (0.0)	0 (0.0)
Missing (<i>n</i>)	1	0	0	0	0	0

(Continued)

Table 3. (Continued)

Prosthesis users only	n = 336	n = 19	n = 20	n = 347	n = 18	n = 20
Type of primary prosthesis						
Body powered	245 (72.9)	14 (73.7)	15 (75.0)	240 (69.2)	15 (83.3)	17 (85.0)
Myoelectric	68 (20.2)	2 (10.5)	3 (15.0)	83 (23.9)	2 (11.1)	3 (15.0)
Hybrid	4 (1.2)	0 (0.0)	0 (0.0)	5 (1.4)	0 (0.0)	0 (0.0)
Cosmetic	12 (3.6)	3 (15.8)	2 (10.0)	12 (3.5)	1 (5.6)	0 (0.0)
Sport/recreation	4 (1.2)	0 (0.0)	0 (0.0)	7 (2.0)	0 (0.0)	0 (0.0)
Unknown	3 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Number of prostheses used						
One	215 (64.0)	17 (89.5)	14 (70.0)	244 (70.3)	14 (77.8)	15 (75.0)
Two or more	121 (36.0)	2 (10.5)	6 (30.0)	103 (29.7)	4 (22.2)	5 (25.0)
Most recent prosthesis received						
< 1 year ago	76 (22.6)	7 (36.8)	8 (40.0)	68 (19.6)	10 (55.6)	10 (50.0)
1 year or more ago	259 (77.1)	12 (63.2)	12 (60.0)	279 (80.4)	8 (44.4)	10 (50.0)
Unknown	1 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Suspension type for primary prosthesis						
Suction	109 (32.4)	4 (21.1)	5 (25.0)	108 (31.1)	1 (5.6)	3 (15.0)
Gel or silicone liner with pin	66 (19.6)	2 (10.5)	2 (10.0)	63 (18.2)	2 (11.1)	3 (15.0)
Vacuum	38 (11.3)	2 (10.5)	3 (15.0)	41 (11.8)	0 (0.0)	1 (5.0)
Self-suspending due to socket shape	131 (39.0)	8 (42.1)	7 (35.0)	111 (32.0)	4 (22.2)	7 (35.0)
Harnessing	253 (75.3)	16 (84.2)	16 (80.0)	256 (73.8)	15 (83.3)	17 (85.0)
External strap	40 (11.9)	3 (15.8)	2 (10.0)	46 (13.3)	2 (11.1)	1 (5.0)
Number of terminal devices used						
One	199 (59.2)	19 (100.0)	17 (85.0)	219 (63.1)	14 (77.8)	14 (70.0)
Two or more	135 (40.2)	0 (0.0)	3 (15.0)	126 (36.3)	4 (22.2)	6 (30.0)
Unknown	2 (0.6)	0 (0.0)	0 (0.0)	2 (0.6)	0 (0.0)	0 (0.0)
Users of one or more terminal devices	n = 334	n = 19	n = 20	n = 345	n = 18	n = 20
Primary type of terminal device used						
Body-powered hook	216 (64.7)	14 (73.7)	15 (75.0)	218 (63.2)	13 (72.2)	15 (75.0)
Greifer	6 (1.8)	0 (0.0)	0 (0.0)	8 (2.3)	0 (0.0)	0 (0.0)
Power hook (ETD)	11 (3.3)	0 (0.0)	3 (15.0)	16 (4.6)	0 (0.0)	1 (5.0)
Sensor speed hand	10 (3.0)	1 (5.3)	0 (0.0)	10 (2.9)	1 (5.6)	0 (0.0)
I-Limb	9 (2.7)	0 (0.0)	0 (0.0)	6 (1.7)	0 (0.0)	0 (0.0)
Michaelangelo hand	6 (1.8)	0 (0.0)	0 (0.0)	5 (1.5)	0 (0.0)	0 (0.0)
Bebionic hand	19 (5.7)	0 (0.0)	0 (0.0)	15 (4.4)	0 (0.0)	1 (5.0)
Other	51 (15.3)	4 (21.1)	2 (10.0)	65 (18.8)	4 (22.2)	3 (15.0)
Unknown	6 (1.8)	0 (0.0)	0 (0.0)	2 (0.6)	0 (0.0)	0 (0.0)
Missing (n)	2	0	0	2	0	0
Users of two or more prostheses	n = 121	n = 2	n = 6	n = 103	n = 4	n = 5
Secondary type of prosthesis used						
Body powered	56 (46.3)	0 (0.0)	2 (33.3)	44 (42.7)	1 (25.0)	1 (20.0)
Myoelectric	47 (38.8)	2 (100.0)	3 (50.0)	38 (36.9)	2 (50.0)	3 (60.0)
Hybrid	2 (1.7)	0 (0.0)	0 (0.0)	2 (1.9)	1 (25.0)	1 (20.0)
Cosmetic	2 (1.7)	0 (0.0)	1 (16.7)	4 (3.9)	0 (0.0)	0 (0.0)
Sports/recreation	10 (8.3)	0 (0.0)	0 (0.0)	15 (14.6)	0 (0.0)	0 (0.0)

significant differences in the proportion of respondents with unilateral vs bilateral amputation who used two or more prostheses at either baseline ($\chi^2=0.48$, $P=0.49$) or at follow-up ($\chi^2=0.77$, $P=0.38$).

About the same proportion of respondents used multiple terminal devices across the 1-year period. Thirty-six

percent of prosthesis users with unilateral amputation used two or more types of terminal devices at follow-up (40% at baseline). In contrast, 27% of prosthesis users with bilateral amputation used two or more terminal devices on at least one side at follow-up (14% at baseline). The proportions of those using two or more

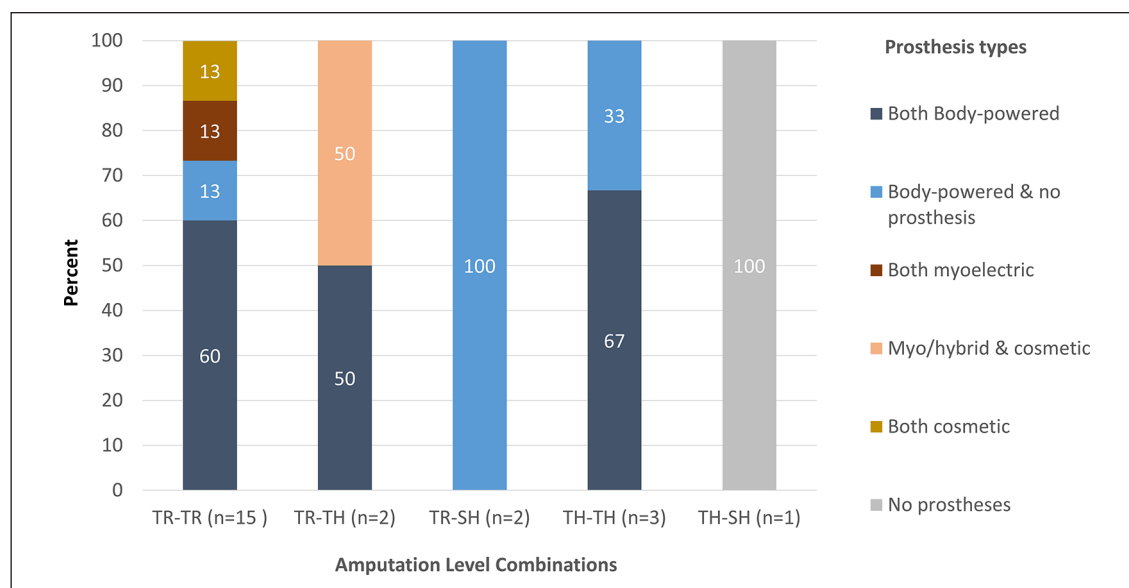


Figure 2. Amputation level and primary prostheses types used for persons with bilateral amputation ($n=23$).

Table 4. Comparison of frequency/intensity of prosthesis use at baseline and follow-up for respondents who (1) abandoned a prosthesis, (2) continued using a prosthesis, and (3) started using a prosthesis.

	Baseline				Follow-up			
	Abandoned a prosthesis ($n=21$)	Continued prosthesis use ($n=337$)	Wilcoxon Mann-Whitney		Continued prosthesis use ($n=337$)	Started using a prosthesis ($n=30$)	Wilcoxon Mann-Whitney	
	n (%)	n (%)	W	P value	n (%)	n (%)	W	P value
Frequency of prosthesis use			4550	0.0096			7507	<0.0001
Daily	13 (61.9)	270 (81.1)			263 (78.3)	12 (40.0)		
Weekly	1 (4.8)	40 (12.0)			45 (14.4)	10 (33.3)		
Monthly	2 (9.5)	11 (3.3)			15 (4.5)	2 (6.7)		
Every few months	2 (9.5)	8 (2.4)			9 (2.7)	4 (13.3)		
1 to 2 times per year	3 (14.3)	4 (1.2)			4 (1.2)	2 (6.7)		
Intensity of prosthesis use			2664	0.0393			2984	<0.0001
<2 hours	8 (40.0)	57 (17.1)			43 (12.8)	10 (33.3)		
2 to <4 hours	1 (5.0)	26 (7.8)			47 (14.0)	11 (36.7)		
4 to <8 hours	3 (15.0)	62 (18.6)			59 (17.6)	4 (13.3)		
8 to <12 hours	4 (20.0)	69 (20.7)			65 (19.4)	3 (10.0)		
≥12 hours	4 (20.0)	120 (35.9)			122 (36.3)	2 (6.7)		

terminal devices was significantly different between those with unilateral vs bilateral amputation only at baseline ($\chi^2=6.23$, $P=0.01$).

Terminal device type and suspension method at follow-up were similar to those at baseline. At follow-up, the most common types of primary terminal devices were body-powered hooks (unilateral: 63%, bilateral: 72% left, 75% right). Multi-degree of freedom terminal devices (including the I-limb,¹³ Michaelangelo Hand,¹⁴ and Bebionic)¹⁵ were used by 8% and 4.5% of those with unilateral and bilateral amputation, respectively.

Changes in prosthesis use in prior year

Table 4 shows the comparisons of prosthesis use frequency and intensity for the separate sub-groups who (1) ceased using a prosthesis; (2) continued using a prosthesis; and (3) started using a prosthesis between baseline and follow-up. Prosthesis use as reported at baseline was less frequent and less intense among the 6% of prosthesis users who abandoned a prosthesis during the subsequent year as compared with those who did not ($P=0.01$). At follow-up, respondents who started using a prosthesis reported significantly less frequent prosthesis use, and fewer hours of

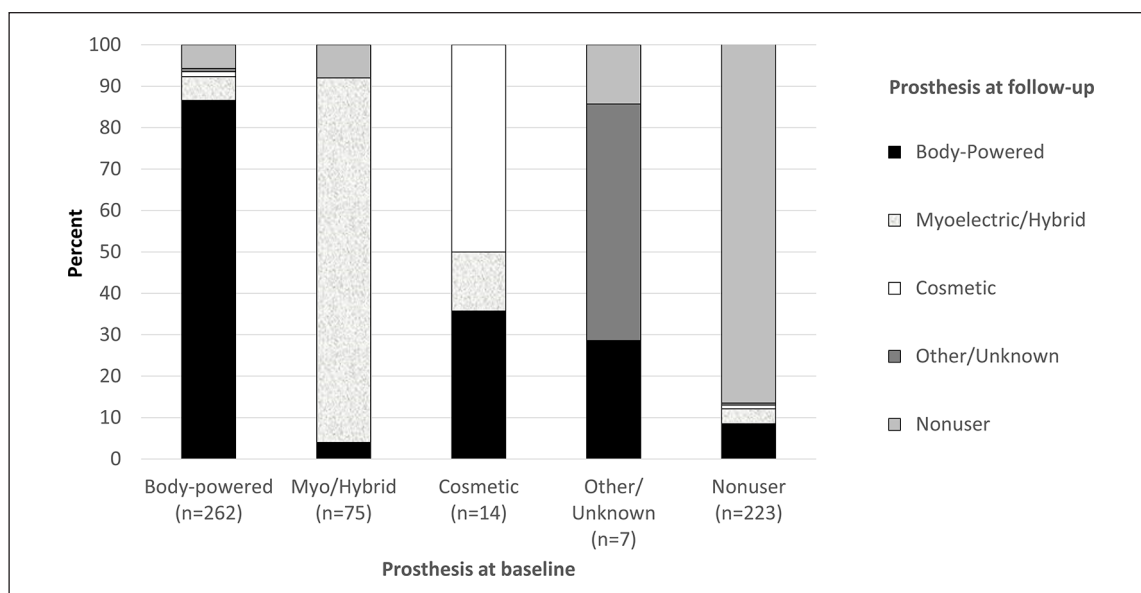


Figure 3. Primary prosthesis type at baseline and follow-up: respondents with unilateral or bilateral amputation ($n = 581$).

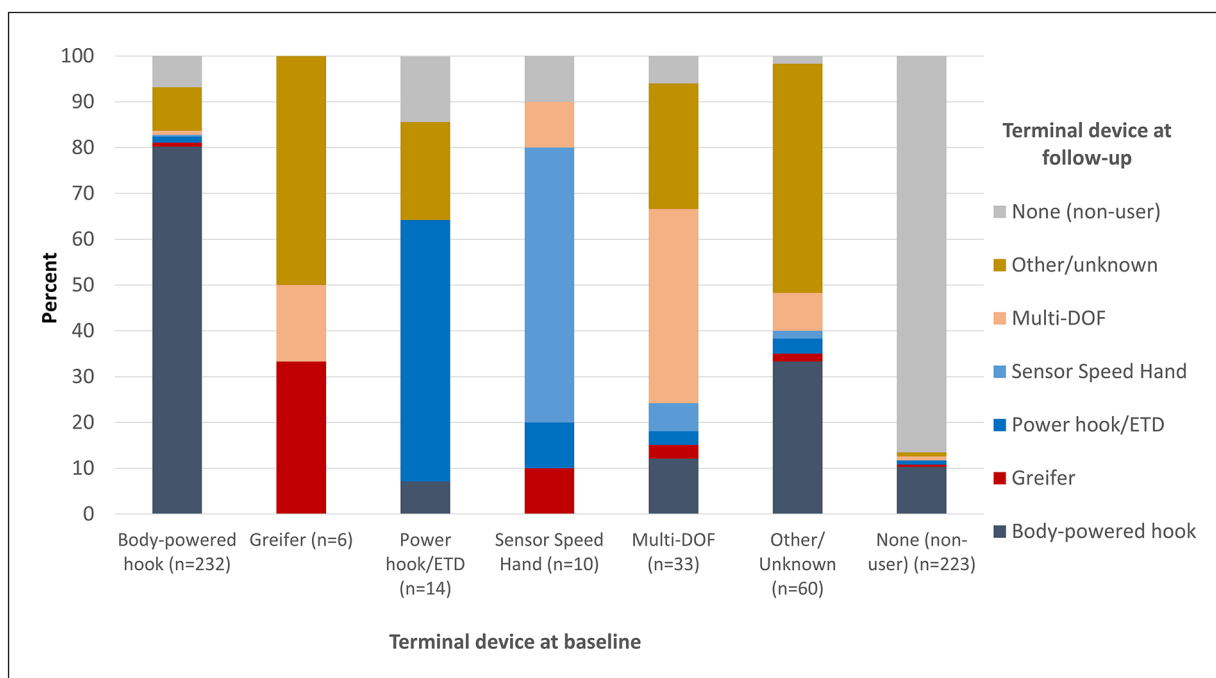


Figure 4. Primary terminal device type at baseline and follow-up: respondents with unilateral or bilateral amputation ($n = 578$).

prosthesis use compared with those who reported prosthesis use at both time points ($P < 0.0001$).

Transition to new type of prosthesis in prior year

The majority of participants with unilateral or bilateral amputation used the same type of primary prosthesis at baseline and follow-up (Figure 3). Twelve percent of

myoelectric/hybrid users and 13% of body-powered users reported changing primary prosthesis type between baseline and follow-up. In addition, half of the 14 cosmetic users switched to using either a body-powered (36%) or myoelectric (14%) prosthesis as their primary prosthesis type between baseline and follow-up.

Overall, 24.0% of respondents used a different primary terminal prosthesis type at follow-up and baseline (Figure 4). Specifically, 20% of body-powered users,

40% of sensor speed users, 43% of powered hook users, 50% of unknown type, 58% multi-degree of freedom (DOF) users, and 67% of Greifer users reported using a different type of terminal device at follow-up than baseline. A significantly higher proportion ($\chi^2=13.5$, $P=0.0002$) of body-powered users transitioned to myoelectric devices as compared with myoelectric users transitioning to body-powered prosthesis.

Receipt of new prosthesis in prior year

At baseline, 122 participants (15.1%) had received a new prosthesis in the prior year; at follow-up 84 (14.4%) had received a new prosthesis. Among follow-up participants who received a new prosthesis, 29 (34.5%) received a different prosthesis type than they reported using at baseline.

Training for new prosthesis recipients

Among those who received a new prosthesis at follow-up, rates of training with the new prosthesis were higher among those who received a prosthesis type that was different than any of the types they had reported using at baseline (52%) compared with those who received a previously reported type (31%); $\chi^2(1, 84)=3.5$, $P=0.0618$. However, the difference was not statistically significant.

Satisfaction with prostheses

TAPES scores were significantly higher at follow-up ($M=4.0$, $SD=0.7$) than at baseline ($M=3.6$, $SD=0.6$) for new prosthesis recipients (Signed-rank test statistic (S)=466.5, $P=0.002$). However, OPUS CSD scores were similar at follow-up ($M=38.2$, $SD=17.7$) and baseline ($M=40.2$, $SD=15.5$) with no significant difference ($S=-115$, $P=0.34$). There were no differences in satisfaction scores between baseline and follow-up for those who used the same type of primary prosthesis at both time points (TAPES $S=1701.5$, $P=0.18$; CSD $S=549.5$, $P=0.58$). Those who ceased the use of a prosthesis between baseline and follow-up had 0.4 lower TAPES scores at baseline ($M=3.5$, $SD=0.8$) than those who continued to use a prosthesis at follow-up ($M=3.9$, $SD=0.6$; $S=2756$, $P=0.03$). There was no statistically significant difference in baseline OPUS CSD scores between prosthesis abandoners and continued users (Wilcoxon Mann–Whitney $U=4062$, $P=0.11$).

Discussion

Many cross-sectional studies have examined prosthesis use and abandonment.^{3,7,16,17} However, no prior study had followed a large cohort of persons with upper limb amputation (including 23 persons with bilateral upper limb

loss) over time to observe changes in prosthesis use and satisfaction. Our study followed Veterans with upper limb amputation for 1 year to examine changes in prosthesis use, as well as rates of receipt of new prostheses and terminal devices.

We found that prosthesis use, use of more than one prosthesis, types of prostheses used, terminal device and suspension used, and rate of new prosthesis receipt were relatively stable over 1 year. However, a small proportion of body-powered and myoelectric users (12%–13%) switched primary prosthesis types and more than a third of cosmetic users began using a functional prosthesis. A higher proportion of body-powered users transitioned to myoelectric devices as compared with myoelectric users transitioning to body-powered prosthesis. While the small numbers of respondents who transitioned device types precluded further analysis, we believe that studying transitions between prosthesis types may be of interest in future studies.

Respondents who received a new prosthesis type were more likely to receive prosthetic training as compared with those receiving a prosthesis of the same type. However, only 52% of persons receiving a new type of prosthesis received training, which is somewhat surprising, given that prosthetic training is fundamental to rehabilitation of persons with upper limb amputation.^{18,19} We do not know whether respondents had been offered training and declined it, or if they were never offered training.

We found 14% to 15% of participants received a new prosthesis in the prior year. This figure is almost twice as high as the incidence rate estimated in an earlier study.¹⁰ That study used VA national prosthetics prescription data from 2000 to 2010 and did not include any prostheses received from sources not associated with VA care.¹⁰

Although primary terminal device type was stable across all terminal device types, more than half of participants who reported using a multi-DOF terminal device and more than two-thirds of those who used a Greifer at baseline switched primary terminal device types during the 1-year period. The results related to Greifers should be interpreted cautiously due to the small sample size of Greifer users ($n=6$). Given that multi-DOF terminal devices are costly, future studies examining satisfaction with these devices and reasons for discontinuing their use as the primary terminal device are needed.

Our prior analysis of baseline data found no significant differences in prosthesis satisfaction between persons who used body-powered and myoelectric/hybrid devices, and no differences in satisfaction ratings by terminal device used.²⁰ The current study adds to our understanding of prosthesis satisfaction and its impact on continued prosthesis use. We identified individuals who abandoned a prosthesis between baseline and follow-up and compared intensity of prosthesis use and prosthesis satisfaction with those who continued prosthesis use. Those with lower

intensity prosthesis use or poorer device satisfaction scores at baseline were more likely to report abandoning a prosthesis at follow-up. Together, these findings suggest that prosthesis abandonment may not be a sudden act, but instead, is predicated by dissatisfaction with the device, as well as irregular wearing patterns. If those at risk for prosthesis abandonment could be identified in advance, perhaps through regular prosthetic check-ups, targeted efforts to improve their prosthetic experience could be initiated.

Limitations

This is the first longitudinal study of upper limb prosthesis use and utilizes a large, and nationally representative US Veteran population. However, findings are limited to Veterans who had received care at the VA and therefore may not be generalizable outside of the Veteran population and the VA system of care. Second, there are some limitations to the interpretation of prosthesis hours of use. Our survey question asked, "How many hours a day do you typically use a prosthesis?" We found that among persons who abandoned their prosthesis during the year, 40% reported using the prosthesis less than 2 hours per day, while 62% reported daily use. While it is evident that the device abandoners were less intense and less frequent prosthesis users, we cannot say with certainty how respondents interpreted this question: whether they reported the hours that they were wearing their device, or the hours that they were actively engaging their device during activities. Our study also did not examine the association between training receipt and outcomes. Future studies are needed to understand the impact of training to use a new prosthesis on prosthesis abandonment and prosthesis satisfaction.

Although we asked respondents about the receipt of a new prosthesis in the prior year, we did not collect data on why a new prosthesis was received, and do not have granular data on device make and model. We expect that many persons who received the same overall type of device had obtained the new device as a replacement for a device that was broken or worn out. However, new devices may have had new or different features and may have been obtained to offer improved or new functionality.

Conclusion

Rates of upper limb prosthesis use, frequency and intensity of use, and types of primary prostheses used by Veterans were stable over 1 year. At follow-up, 15% reported receiving a new prosthesis, 13% used a different primary prosthesis type, and 6% had discontinued prosthesis use. New prosthesis receipt resulted in improved prosthesis satisfaction. Findings suggest that prosthesis abandonment is predicated on dissatisfaction with the device, as well as irregular wearing patterns. These

findings can be used to identify those at risk for prosthesis abandonment to improve their prosthesis experience.

Author contributions

~~The author(s) disclosed the following roles as contributors to this article: Linda Resnik obtained the funding, designed the study, and led data analyses and manuscript writing. Matthew Borgia assisted in study design, performed data analyses, and wrote portions of the manuscript. Sarah Diester assisted in study design, was responsible for study coordination and communications, and participated in discussions of data analyses and manuscript writing. Melissa Clark participated in study design, supervised data collection, and participated in data analyses and manuscript writing.~~ [AQ: 3]

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Supplemental material

Supplemental material for this article is available online.

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Dexterity, activity performance, disability, quality of life, and independence in upper limb Veteran prosthesis users: a normative study

L. RESNIK ET AL.

Upper limb prosthesis users: a normative study

[AQ0]

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ABSTRACT

Purpose: To present population data on standardized measures of dexterity, activity performance, disability, health-related quality of life (HRQoL) and community integration for persons with upper limb amputation (ULA), compare outcomes to normative values, and examine differences by prosthesis type and laterality (unilateral vs. bilateral amputation). **Materials and methods:** Multi-site, cross-sectional design, with in-person evaluations, functional performance, and self-report measures. Descriptive and comparative analyses were performed by amputation level and prosthesis type, data were compared for unilateral and bilateral amputation. **Results:** One hundred and twenty-seven individuals participated; mean age 57 years, 59% percent body-powered prostheses users. All measures of dexterity differed ($p < 0.05$) by amputation level and by laterality. All measures of activity differed by amputation level with the best scores in transradial (TR) amputation groups. Comparisons of body-powered users with TR amputation found that dexterity was better for those with bilateral compared to unilateral amputation. **Conclusions:** Dexterity is markedly impaired in persons with ULA. Individuals with more proximal ULA levels are most impacted. HRQoL and community participation are less impacted and more equivalent to unimpaired persons. Further research is needed to examine differences by terminal device type and determine how best to match persons with ULA to the optimal prosthesis type and componentry,

based on individual characteristics.

Keywords: Upper limb amputation ; upper limb prosthesis ; prosthesis use ; disability evaluation ; outcomes

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Introduction

A National Academy of Sciences report concluded that “despite advances in prosthetic designs and research, currently available upper extremity prostheses (UEPs) are limited in their ability to mitigate impairments related to limb loss” [1]. However, the extent of limitation associated with prosthesis use and the impact of contextual factors on these limitations is not fully understood. There are a wide variety of devices and components available to persons with upper limb amputation (ULA), but little data comparing outcomes for populations of users at differing amputation levels, users with single or bilateral upper limb loss, or users of various device types. Such data would inform patients and clinicians and could enable benchmarking of outcomes to realistic expectations for prosthetic rehabilitation. These data can also be used to facilitate comparative effectiveness evaluations of existing prosthetic components and as newer technology becomes available.

The most prevalent types of UEPs are body-powered (cable harnesses operated), and externally powered (myoelectric) – most commonly operated by surface myoelectrodes. A recent systematic review that compared body-powered and myoelectric prostheses found no clear superiority by device type, and called for additional research to compare prostheses types [2].

In the past decade, new and more costly types of prostheses and components have become available, making the need for additional research even more pressing. A variety of multi-degree of freedom (DOF) prosthetic terminal devices that enable multiple grip patterns are now commercially available and – according to a national study of Veterans with major ULA – are used by nearly 11% of Veterans who use upper limb prostheses [3]. Although multiple grip terminal devices are penetrating the market, and are desired by consumers [4,5], it is unclear what benefit patients or clinicians can expect from these devices. There have been few studies comparing single- vs. multi-degree DOF terminal devices, or other terminal device types. Small studies, for instance, did not show a clear advantage of any particular type of terminal device [6–11].

Our recently completed national survey of Veterans with major upper limb loss did not identify differences by device or terminal device type in perceived difficulty with activities, likelihood of needing assistance with activities of daily living (ADL), self-reported disability or health-related quality of life (HRQoL) [12]. However, that study was limited because prosthesis and terminal device type, and function were self-reported and were therefore subject to potential misclassification of device type, and to recall bias. Further research utilizing in-person assessment of prosthesis configuration and performance measures of dexterity and function are needed to compare outcomes of users of different types of prostheses and terminal devices to confirm or refute these findings.

To help address the clinical and research gaps, an in-person, multi-site study of upper limb prosthesis users was conducted which allowed verification of prosthesis and terminal device type and the ability to quantify a wide variety of outcomes. The purposes of this manuscript are to: (1) describe the methods of this study; (2) present normative and comparative data on outcomes by amputation level and prosthesis type; and compare outcomes to prior studies; and (3) compare outcomes for unilateral and bilateral upper limb amputees, with the overarching goal of assisting policy makers, clinicians, and patients to better match individual upper limb amputees with the most appropriate devices and components.

Methods

Study design

The study used a cross-sectional, observational design with data collected at five study sites across the U.S. The study was approved by the Veterans Administration (VA) Central Institutional Review Board (IRB), Regional Health Command-Central IRB and by the Human Research Protection Office. participants provided voluntary informed consent.

Sample

We enrolled a convenience sample of 127 persons with major ULA (defined as having at least one amputation at or proximal to the level of wrist disarticulation), who used an active prosthesis (body-powered, myoelectric, hybrid or Life Under Kinetic Evolution (LUKE Arm) [13]. Participants with unilateral or bilateral amputations were included. Participants who could not tolerate wearing a prosthesis for at least 3 h and those with a severe health condition that might limit their ability to participate in study assessment activities were excluded. Veteran participants who participated in an earlier survey study [3] and who agreed to future study contact were invited to participate. Other participants were recruited through clinical contacts, advertisements, and word of mouth.

Data collection

Participants attended an in-person study visit at a data collection site. Physical or occupational therapists, assisted by a research coordinator, assessed participants. Study visits lasted approximately 3–4 h with rest breaks provided as needed. Study visits included collection of demographic data (age, race, ethnicity, employment), history of the participant's amputation and prosthesis use (military status, amputation etiology, history of amputation-related rehabilitation, prosthesis use), and a physical examination (weight, height, limb length, residual limb inspection). During the prosthetic evaluation, the device and its components were described by the assessor and the prosthesis and terminal device were photographed. Measures of functional performance were collected by the study assessor to quantify dexterity and activity performance. Self-reported measures, which were interviewer administered, addressed satisfaction with the prostheses, disability, HRQoL, community integration, and need for assistance with ADL. A brief description of the collected standardized measures is provided in Table 1.

Table 1. Brief description of key outcome measures.

	Construct	Item content	Rating criteria	Interpretation
Functional performance				
Dexterity				
Jebsen-Taylor Hand Function (JTHF)	Dexterity	7 separate tests of fine motor activities: writing, page turning, small objects, eating, placing checkers, light cans, heavy cans	Performance speed; items per second (modified scoring)	Higher scores indicate better dexterity
Nine Hole Peg (NHP)	Dexterity	Accurately place and remove 9 plastic pegs into a pegboard	Timed measure (time limited to 6 min), score calculated as items/second (modified scoring)	Higher scores indicate faster speed, better dexterity
Box and Block	Dexterity	Number of wooden blocks transported in 60 s	Performance speed; total number of blocks transported	Higher scores indicate better performance
Southampton Hand Assessment Procedure (SHAP)	Dexterity/index of function	26 unilateral timed tasks of hand function: 12 abstract tasks and 14 activities of daily (such as zip-ping, pouring, buttoning)	Performance speed	Higher scores indicate better dexterity
Activity performance				

	Construct	Item content	Rating criteria	Interpretation
Activities Measure for Upper Limb Amputation (AM-ULA)	Activity performance	18-everyday tasks: brush/comb hair, don t-shirt, doff t-shirt, button shirt, zip jacket, don socks, tie shoes, drink from a cup, use fork, use spoon, pour 12 oz can, write, use scissors, turn doorknob, hammer nail, fold towel, use phone, reach overhead	Each item is rated on task completion: speed, movement quality, skillfulness of prosthesis use and independence. Total score is the average score $\times 10$.	Higher scores indicate better activity performance
Brief Activities Measure for Upper Limb Amputation (BAM-ULA)	Activity performance	10 everyday tasks: tuck in shirt, lift 20 lbs, open and drink from water bottle, remove wallet from back pocket, replace wallet, lift gallon jug, open and pour jug, brush/comb hair, use a fork, open door with round knob	Ability to complete each task (yes/no). Total score is the number of activities that were completed.	Higher scores indicate better activity performance
Timed Measure of Activity Performance (T-MAP)	Activity performance	5 everyday activities: drink from a cup, wash face, food preparation, eating, dressing	Timed Measure: sum of time to complete each activity	Lower scores indicate faster speed, less difficulty
Self-report measures				
Device satisfaction				
Trinity Amputation and Prosthesis Experience Satisfaction Scale (TAPES)	Prosthetic satisfaction	10 items satisfaction with prosthesis: color, shape, noise, appearance, weight, usefulness, reliability, fit, comfort, and overall satisfaction	Satisfaction	Higher scores indicate greater prosthetic satisfaction
Quick Disability of the Arm, Shoulder, and Hand (QuickDASH)	Disability	Self-reported functional difficulty (8 items), 3 items about sleep, sensation and pain	Performance difficulty and impairment severity	Higher scores indicate greater disability
HRQoL				
Veterans RAND 12-Item Health Survey Mental Composite Score (VR-12 MCS)	Quality of life	Measure for Mental Health Component Summary	Self-rated quality of life	Higher scores indicate greater satisfaction
Veterans RAND 12-Item Health Survey Physical Composite Score (VR-12 PCS)	Quality of life	Measure for Physical Health Component Summary	Self-rated quality of life	Higher scores indicate greater satisfaction
Community Reintegration of Injured Service Members-Computer Adapted-Test (CRIS-CAT)	Extent of participation	Computer adaptive testing measuring participation in life roles	Frequency and amount of participation	Higher scores indicate better community integration
CRIS-CAT	Perceived difficulty	Computer adaptive testing measuring participation in life roles	Perceived limitations in participation	Higher scores indicate better community integration
CRIS-CAT	Satisfaction	Computer adaptive testing measuring participation in life roles	Satisfaction with participation	Higher scores indicate better community integration

	Construct	Item content	Rating criteria	Interpretation
Need for ADL help	Independence	Any need for help with daily activities	Yes/no	No required help indicates greater independence

Key independent variables

To allow robust comparisons, given the small sample sizes, we collapsed categories of amputation level into three categories: transradial (TR), which included persons with wrist disarticulation and TR amputation; transhumeral (TH), which included persons with elbow disarticulation and TH amputation; and shoulder (SH), which included persons with SH disarticulation and interscapulothoracic amputation. We also compared persons with unilateral [or](#) and bilateral amputation.

A three-level categorical variable to classify the prostheses types used based on prosthesis and terminal device type DOF was developed. The three categories were: body-powered, myoelectric single DOF terminal device, and myoelectric multi-DOF terminal device. Assessors first characterized the prosthesis as either body-powered, myoelectric, hybrid, or LUKE Arm. LUKE Arm was categorized as myoelectric, and hybrid devices were categorized based on the function of their terminal devices (body-powered or myoelectric). The type of terminal device utilized was documented by the study assessor and verified by the study prosthetist who viewed photographs of the device. Myoelectric terminal device categories were categorized based on their DOF. Electronic terminal devices (ETDs), Greifers [14] and sensor speed hands [15] were categorized as single DOF; I-Limb [16], Michelangelo [17], Bebionic [18], and LUKE hands [13] were categorized as multi-DOF.

Data analyses

We described participant characteristics, and prosthesis type for unilateral and bilateral amputation and by amputation level. Outcomes were compared by amputation level and laterality using the Kruskal–Wallis and Wilcoxon Mann–Whitney non-parametric tests due to small sample sizes. To establish normative values and test for differences by prosthesis type, the sample was stratified by amputation level to allow comparison of outcomes by prosthesis type for individuals with TR and TH amputations using Kruskal Wallis tests. Analyses of individuals with SH-level amputation were not included due to their small sample size ($n = 5$). Subsequent analyses were stratified by amputation level and age categories, and by prosthesis type and age categories to allow for comparison of outcomes by age group.

To contextualize the magnitude of outcome impairment, we compared our findings to data available on normative (unimpaired) samples. To facilitate comparison, we stratified our sample into three subgroups by age (18–44, 45–64, and ≥ 65 years) and compared to similar general population age cohorts when possible. Since our sample was predominantly male, when possible we compared them to males in the general population. Finally, when possible, we used normative values for the non-dominant side for comparison, given that upper limb prostheses are used typically as the “helper hand”, not the dominant hand, in persons with unilateral amputation. For dexterity measures, we compared population values of the Jebsen Taylor Hand Function (JTHF) test [19,20], Box and Blocks test [21], Nine Hole Peg (NHP) [22,23], and Southampton Assessment Procedure (SHAP) [10,24] to values in our sample. As it was not possible to obtain exact data from prior publications due to our revised scoring method for JTHF and the NHP test, we instead transformed reported average timed scores to items completed per second, using the maximum number of items for each specific task.

Given that Activities Measure for Upper Limb Amputation (AM-ULA) [25], Brief Activities Measure for Upper Limb Amputation (BAM-ULA) [26], and Timed Measure of Activity Performance (T-MAP) [27] are amputation-specific measures, comparisons to unimpaired samples were not possible. Instead, we compared our data to values previously published on Quick Disability of the Arm, Shoulder, and Hand (QuickDASH), Veterans RAND 12-Item Health Survey Mental Composite Score (MCS), and Physical Composite Score (PCS). As there are no published population normative values available for the Community Reintegration of Injured Service Members-Computer Adapted-Test (CRIS-CAT) [28] measures for persons in their mid-50s (the mean age of our sample), we compared the scores reported for employed Veterans with no history of mental illness or substance abuse (who had a mean age of 47.7 years; range 25–60) [29]. Scores of the VR-12 MCS and PCS were compared to age-matched norms [30].

Given that dexterity measures involve single hand (or prosthesis) use, data were first combined from those with bilateral and unilateral amputation and dexterity scores were compared by amputation level and prosthesis type. Comparisons for persons with unilateral amputation only were then repeated. For activity performance measures, which involve bimanual tasks, as well as prosthesis satisfaction, self-report disability measures, HRQoL, and community integration we compared scores of persons with unilateral amputation by amputation level.

We controlled for multiple comparisons to adjust for false discovery rates in “families” or categories of tests using the Benjamini–Hochberg method to maintain a false discovery rate of 0.10 within each test category [31]. The following categories were used: dexterity (10 measures), activity performance (three measures), and self-reported function, disability, HRQoL, and community integration (six measures). Prosthesis satisfaction was evaluated only by the Trinity Amputation and Prosthesis Experience Satisfaction Scale (TAPES) [32].

Wilcoxon Mann–Whitney tests were used to compare dexterity scores for persons with unilateral TR and persons with bilateral amputation who had TR amputation on their dominant side (our largest sub-group).

Results

Demographics and prosthesis characteristics are provided in Table 2. The sample was 97% male, 75% white, 85% Veterans, with a mean age of 56.9 (SD 16.5). The most common self-reported etiologies of amputation were traumatic; with 55% indicating accident and 36% combat injury (participants could indicate more than one etiology). The prosthesis that subjects wore for testing was mostly body-powered prostheses (59%) with some myoelectric single DOF (21%) and myoelectric multi-DOF (20%) devices. Prosthesis weight was 3.9 lbs (SD 2.3). One-quarter of the sample had received prosthesis training for the device used in testing. All hybrid devices in our sample were classified as myoelectric (two single DOF terminal device, five multi-DOF terminal device).

Table 2. Demographics and prosthesis characteristics of participants by amputation level ($N = 127$).

	Unilateral amputation ($N = 112$)				Bilateral amputation ($N = 15$)	All ($N = 127$)
	WD/TR ($N = 75$)	ED/TH ($N = 32$)	SH/FQ ($N = 5$)	Total ($N = 112$)		
	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)
Age (years)	56.6 (17.3)	57.1 (16.3)	55.1 (23.4)	56.7 (17.1)	58.5 (10.7)	56.9 (16.5)
Years since amputation	24.2 (19.7)	18.5 (16.1)	23.3 (23.6)	22.5 (18.9)	23.1 (18.8)	22.6 (18.9)
Prosthesis weight (lbs)	3.2 (1.6)	5.2 (2.5)	6.9 (2.9)	3.9 (2.2)	4.1 (2.6)	3.9 (2.3)
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Age category						
18 ≤ age < 45	22 (29.3)	5 (15.6)	2 (40.0)	29 (25.9)	2 (13.3)	31 (24.4)
46 ≤ age < 65	20 (26.7)	16 (50.0)	0 (0.0)	36 (32.1)	9 (60.0)	45 (35.4)
66 ≤ age < 75	26 (34.7)	10 (31.3)	3 (60.0)	39 (34.8)	4 (26.7)	43 (33.9)
75+	7 (9.3)	1 (3.1)	0 (0.0)	8 (7.1)	0 (0.0)	8 (6.3)
Gender						
Male	73 (97.3)	31 (96.9)	5 (100.0)	109 (97.3)	14 (93.3)	123 (96.9)
Female	2 (2.7)	1 (3.1)	0 (0.0)	3 (2.7)	1 (6.7)	4 (3.2)
Race						
White	58 (77.3)	20 (62.5)	5 (100.0)	83 (74.1)	12 (80.0)	95 (74.8)
Black	8 (10.7)	5 (15.6)	0 (0.0)	13 (11.6)	1 (6.7)	14 (11.0)
Mixed/other	9 (12.0)	7 (21.9)	0 (0.0)	16 (14.3)	2 (13.3)	18 (14.2)

	Unilateral amputation (<i>N</i> = 112)				Bilateral amputation (<i>N</i> = 15)	All (<i>N</i> = 127)
	WD/TR (<i>N</i> = 75)	ED/TH (<i>N</i> = 32)	SH/FQ (<i>N</i> = 5)	Total (<i>N</i> = 112)		
	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)
Ethnicity						
Hispanic	8 (10.7)	7 (21.9)	0 (0.0)	15 (13.4)	1 (6.7)	16 (12.6)
Not Hispanic	63 (84.0)	25 (78.1)	5 (100.0)	93 (83.0)	14 (93.3)	107 (84.3)
Unknown	4 (5.3)	0 (0.0)	0 (0.0)	4 (3.6)	0 (0.0)	4 (3.2)
Employment status ^a						
Employed full-time	15 (20.0)	6 (18.8)	0 (0.0)	21 (18.8)	1 (6.7)	22 (17.3)
Employed part-time	2 (2.7)	2 (6.3)	0 (0.0)	4 (3.6)	1 (6.7)	5 (3.9)
Student	2 (2.7)	4 (12.5)	0 (0.0)	6 (5.4)	0 (0.0)	6 (4.7)
Retired, employed after amputation	30 (40.0)	10 (31.3)	1 (20.0)	41 (36.6)	5 (33.3)	46 (36.2)
Retired, not employed after amputation	9 (12.0)	3 (9.4)	2 (40.0)	14 (12.5)	4 (26.7)	18 (14.2)
Medical leave	1 (1.3)	2 (6.3)	1 (20.0)	4 (3.6)	3 (20.0)	7 (5.5)
Unknown	16 (21.3)	5 (15.6)	1 (20.0)	22 (19.6)	1 (6.7)	23 (18.1)
Military status						
Active duty	2 (2.7)	0 (0.0)	0 (0.0)	2 (1.8)	0 (0.0)	2 (1.6)
Veteran	66 (88.0)	28 (87.5)	5 (100.0)	99 (88.4)	9 (60.0)	108 (85.0)
Civilian	7 (9.3)	4 (12.5)	0 (0.0)	11 (9.8)	6 (40.0)	17 (13.4)
Etiology of amputation ^a						
Congenital	3 (13.0)	0 (0.0)	0 (0.0)	3 (8.6)	1 (10.0)	4 (8.9)
Combat	27 (44.3)	8 (29.6)	1 (25.0)	36 (39.1)	2 (14.3)	38 (35.9)
Accident	30 (49.2)	15 (55.6)	4 (100.0)	49 (53.3)	9 (64.3)	58 (54.7)
Burn	4 (6.6)	2 (7.4)	0 (0.0)	6 (6.5)	4 (28.6)	10 (9.4)
Cancer	4 (6.6)	1 (3.7)	0 (0.0)	5 (5.4)	0 (0.0)	5 (4.7)
Diabetes	1 (1.6)	0 (0.0)	0 (0.0)	1 (1.1)	0 (0.0)	1 (0.9)
Infection	8 (13.1)	4 (14.8)	0 (0.0)	12 (13.0)	3 (21.4)	15 (14.2)
Prosthesis type						
Body powered	45 (60.0)	18 (56.3)	2 (40.0)	65 (58.0)	10 (66.7)	75 (59.1)
Myoelectric single DOF terminal device	12 (16.0)	9 (28.1)	2 (40.0)	23 (20.5)	4 (26.7)	27 (21.3)
Myoelectric multi-DOF terminal device	18 (24.0)	5 (15.6)	1 (20.0)	24 (21.4)	1 (6.7)	25 (19.7)
Terminal device type						

	Unilateral amputation (<i>N</i> = 112)				Bilateral amputation (<i>N</i> = 15)	All (<i>N</i> = 127)
	WD/TR (<i>N</i> = 75)	ED/TH (<i>N</i> = 32)	SH/FQ (<i>N</i> = 5)	Total (<i>N</i> = 112)		
	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)		
Body-powered hook	45 (60.0)	18 (56.3)	2 (40.0)	65 (58.0)	10 (66.7)	75 (59.1)
Externally powered prehensors	7 (9.3)	5 (15.6)	1 (20.0)	13 (11.6)	3 (20.0)	16 (12.6)
Multi-DOF Myo hand	18 (24.0)	5 (15.6)	1 (20.0)	24 (21.4)	1 (6.7)	25 (19.7)
Single-DOF Myo hand	5 (6.7)	4 (12.5)	1 (20.0)	10 (8.9)	1 (6.7)	11 (8.7)
Receipt of any training to use current prosthesis						
Yes	20 (26.7)	6 (18.8)	1 (20.0)	27 (24.1)	6 (40.0)	33 (26.0)
No	55 (73.3)	26 (81.3)	4 (80.0)	85 (75.9)	9 (60.0)	94 (74.0)

^aEtiology of amputation: respondents could indicate multiple etiologies.

Amputation level

All measures of dexterity (JTHF tasks [33], Box and Blocks [21], NHP [22], and SHAP IOF [10]) were significantly different ($p < 0.05$) by amputation level (Table 3) and remained statistically significant after Benjamini–Hochberg adjustments. Persons with TR amputation had the best dexterity, followed persons with TH and SH amputation. Three measures of activity performance, the AM-UL, BAM-ULA, and T-MAP were significantly different by amputation level after Benjamini–Hochberg adjustment (Table 3). Those with TR amputation had the best scores for all three measures of activity.

Table 3. Outcomes by amputation laterality, amputation level. [AQ4]

	Unilateral amputation (<i>N</i> = 112)				All amputation (<i>N</i> = 127)		
	WD/TR (<i>N</i> = 75)	ED/TH (<i>N</i> = 32)	SH/FQ (<i>N</i> = 5)	Kruskal–Wallis	Unilateral (<i>N</i> = 112)	Bilateral (<i>N</i> = 15)	WMW
	Mn (SD)	Mn (SD)	Mn (SD)	<i>p</i> Value	Mn (SD)	Mn (SD)	<i>p</i> Value
Dexterity measures							
JTHFT							
Writing	0.48 (0.29)	0.26 (0.22)	0.13 (0.14)	0.0004*	0.41 (0.29)	0.86 (0.23)	<0.0001*
Page turning	0.13 (0.09)	0.05 (0.05)	0.01 (0.02)	<0.0001*	0.10 (0.09)	0.26 (0.16)	<0.0001*
Small objects	0.10 (0.08)	0.04 (0.05)	0.01 (0.02)	<0.0001*	0.08 (0.08)	0.22 (0.15)	<0.0001*
Eating	0.17 (0.11)	0.07 (0.07)	0.00 (0.00)	<0.0001*	0.13 (0.11)	0.22 (0.10)	0.0021*
Checkers	0.09 (0.07)	0.05 (0.06)	0.01 (0.01)	0.0004*	0.07 (0.07)	0.20 (0.14)	0.0001*
Light cans	0.22 (0.13)	0.10 (0.08)	0.06 (0.01)	<0.0001*	0.18 (0.13)	0.40 (0.25)	0.0005*
Heavy cans	0.22 (0.16)	0.09 (0.10)	0.07 (0.04)	<0.0001*	0.18 (0.15)	0.39 (0.23)	0.0002*

	Unilateral amputation (N = 112)				All amputation (N = 127)		
	WD/TR (N = 75)	ED/TH (N = 32)	SH/FQ (N = 5)	Kruskal–Wallis	Unilateral (N = 112)	Bilateral (N = 15)	WMW
	Mn (SD)	Mn (SD)	Mn (SD)	p Value	Mn (SD)	Mn (SD)	p Value
Box and Blocks	17.2 (8.4)	8.2 (8.1)	0.8 (1.8)	<0.0001*	13.9 (9.5)	25.7 (7.5)	<0.0001*
9-Hole peg	0.05 (0.05)	0.02 (0.04)	0.0 (.)	0.0205*	0.04 (0.05)	0.13 (0.07)	<0.0001*
SHAP IOF	41.4 (18.3)	11.3 (13.9)	0.6 (1.3)	<0.0001*	31.0 (22.4)	46.2 (21.2)	<0.0001*
Activity measures							
AM-ULA	15.3 (6.0)	11.4 (5.2)	9.1 (6.5)	0.0006*	13.9 (6.1)	15.4 (6.9)	0.3659
BAM-ULA	7.3 (2.1)	4.2 (2.8)	.	0.0027*	6.8 (2.5)	8.4 (1.5)	0.1155
T-MAP (min)	4.5 (1.6)	5.5 (2.3)	.	0.0829*	4.8 (1.8)	8.9 (4.5)	0.0027*
Prosthesis satisfaction							
TAPES	3.9 (0.7)	3.6 (0.7)	2.7 (1.5)	0.0538	3.8 (0.8)	3.9 (0.7)	0.5800
Disability, HRQoL, and community integration							
QuickDASH	28.8 (18.4)	31.8 (17.7)	30.0 (19.0)	0.7263	29.7 (18.1)	30.1 (15.6)	0.7514
VR-12 MCS	52.1 (11.1)	50.9 (12.7)	53.9 (8.0)	0.8073	51.8 (11.4)	54.7 (7.2)	0.5958
VR-12 PCS	39.3 (8.7)	38.2 (11.4)	31.6 (13.5)	0.4089	38.6 (9.8)	39.7 (11.5)	0.6115
CRIS-CAT extent	49.1 (9.0)	47.9 (9.4)	46.1 (10.1)	0.6520	48.6 (9.1)	53.6 (7.7)	0.0482
CRIS-CAT perceived	49.0 (7.4)	47.2 (6.0)	44.0 (5.3)	0.1838	48.3 (7.0)	51.2 (9.0)	0.1873
CRIS-CAT satisfaction	50.3 (9.3)	46.6 (5.6)	46.8 (9.0)	0.1543	49.1 (8.5)	52.3 (10.8)	0.2771
	N (%)	N (%)	N (%)	Exact p	N (%)	N (%)	Exact p
Need for ADL help	12 (22.6)	6 (25.0)	2 (50.0)	1.0000	20 (24.7)	7 (58.3)	0.0353

*Significant after Benjamini–Hochberg adjustment with false discovery rate = 0.1.

Unilateral versus bilateral amputation

Those with bilateral amputation had better dexterity scores of all measures as compared to those with unilateral amputation, and differences remained significant after adjustment for multiple comparisons (Table 3). Those with unilateral amputation had faster ($p = 0.003$) T-MAP scores (mn 4.8) than those with bilateral amputation (8.9) even after adjustment for multiple activity measure comparisons (Table 3). Those with bilateral amputation had better CRIS-CAT scores on the extent of limitation subscale ($p = 0.048$), though this difference was no longer significant after correction for multiple comparisons. Normative values by age group are shown in Appendix.

Comparison of outcomes of persons with and without upper limb amputation

Table 4 provides comparative data to contextualize the magnitude of outcome impairment. In summary, the subgroup of persons with unilateral TR amputation ages 18–44 had JTHF scores that were 0.09–0.62 times that of unimpaired males aged 20–55. The subsample with TR unilateral amputation aged 45–64 had 0.07–0.97 times the JTHF scores of unimpaired males aged 60–69. The subsample of TRs who were 65 years or older had 0.05–0.82 times the

JTHF scores of unimpaired males aged 70–89. The least amount of impairment across all age categories was in the writing task. All three subgroups, by age, of subjects with TR amputation had 0.20–0.26 the Box and Blocks scores compared to unimpaired male groups (left or right hands, approximately same age groups). The youngest group with TR amputation had NHP scores 0.08 of age matched norms, and older sub-groups scores were 0.11–0.16 that of age matched norms. The average SHAP IOF scores of those with TR amputation was 0.43–0.44 times that of unimpaired males, with little difference in age sub-group.

Table 4. Outcomes of unilateral TR amputation group and normative values of standardized tests.

	Unimpaired males ^c			TR unilateral amputations (prothesis side)		Ratio of scores
	Age group	Side	Mn	Age group	Mn	
JTHFT (item/s)						
Writing	20–59	NonDom	0.74 ^a	18–44	0.46	0.62
Writing	60–69	NonDom	0.66 ^a	45–64	0.64	0.97
Writing	70–89	NonDom	0.50 ^a	65+	0.41	0.82
Page turning	20–59	NonDom	0.90 ^a	18–44	0.11	0.12
Page turning	60–69	NonDom	1.14 ^a	45–64	0.17	0.15
Page turning	70–89	NonDom	1.40 ^a	65+	0.12	0.09
Small objects	20–59	NonDom	1.03 ^a	18–44	0.10	0.10
Small objects	60–69	NonDom	1.25 ^a	45–64	0.09	0.07
Small objects	70–89	NonDom	1.35 ^a	65+	0.10	0.07
Eating	20–59	NonDom	1.58 ^a	18–44	0.15	0.09
Eating	60–69	NonDom	1.85 ^a	45–64	0.19	0.10
Eating	70–89	NonDom	2.05 ^a	65+	0.16	0.08
Checkers	20–59	NonDom	0.95 ^a	18–44	0.12	0.13
Checkers	60–69	NonDom	1.37 ^a	45–64	0.09	0.07
Checkers	70–89	NonDom	1.47 ^a	65+	0.07	0.05
Light cans	20–59	NonDom	0.64 ^a	18–44	0.27	0.42
Light cans	60–69	NonDom	0.79 ^a	45–64	0.24	0.30
Light cans	70–89	NonDom	0.97 ^a	65+	0.18	0.19
Heavy cans	20–59	NonDom	0.62 ^a	18–44	0.26	0.42
Heavy cans	60–69	NonDom	0.81 ^a	45–64	0.24	0.30
Heavy cans	70–89	NonDom	0.95 ^a	65+	0.18	0.19
Box and Blocks	20–44	Left	82.4	18–44	16.9 ^b	0.21
Box and Blocks	45–64	Left	74.4	45–64	19.3 ^b	0.26
Box and Blocks	65+	Left	64.4	65+	16.0 ^b	0.25
Box and Blocks	20–44	Right	84.1	18–44	16.9 ^b	0.20
Box and Blocks	45–64	Right	75.7	45–64	19.3 ^b	0.25
Box and Blocks	65+	Right	66.0	65+	16.0 ^b	0.24
Nine hole peg (item/s)	21–45	Left	0.50 ^a	18–44	0.04 ^b	0.08

	Unimpaired males ^c			TR unilateral amputations (prothesis side)		Ratio of scores
	Age group	Side	Mn	Age group	Mn	
Nine hole peg (item/s)	46–65	Left	0.44 ^a	45–64	0.07 ^b	0.16
Nine hole peg (item/s)	66+	Left	0.37 ^a	65+	0.04 ^b	0.11
Nine hole peg (item/s)	21–45	Right	0.52 ^a	18–44	0.04 ^b	0.08
Nine hole peg (item/s)	46–65	Right	0.46 ^a	45–64	0.07 ^b	0.15
Nine hole peg (item/s)	66+	Right	0.37 ^a	65+	0.04 ^b	0.11
SHAP IOF	18–45	Not specified	98.8	18–44	42.9	0.43
SHAP IOF	46–65	Not specified	98.0	45–64	43.6	0.44
SHAP IOF	66–75	Not specified	92.0	65+	39.1	0.43
QuickDASH	20–49	Not applicable	8.0	18–44	31.5	3.94
QuickDASH	50–69	Not applicable	11.5	45–64	28.9	2.52
QuickDASH	70+	Not applicable	18.0	65+	26.8	1.49
VR12 MCS	18–44	Not applicable	38.3	18–44	48.1	1.25
VR12 AQ6 MCS	45–64	Not applicable	38.8	45–64	49.3	1.27
VR12 MCS	65+	Not applicable	50.9	65+	56.5	1.11
VR12 PCS	18–44	Not applicable	35.3	18–44	41.3	1.17
VR12 PCS	45–64	Not applicable	28.9	45–64	40.4	1.40
VR12 PCS	65+	Not applicable	40.7	65+	37.2	0.91
CRIS-CAT extent	25–60	Not applicable	55.8	18–44	45.4	0.81
CRIS-CAT extent	25–60	Not applicable	55.8	45–64	48.5	0.87
CRIS-CAT perceived	25–60	Not applicable	56.6	18–44	48.1	0.85
CRIS-CAT perceived	25–60	Not applicable	56.6	45–64	48.2	0.85
CRIS-CAT satisfaction	25–60	Not applicable	54.9	18–44	47.9	0.87
CRIS-CAT satisfaction	25–60	Not applicable	54.9	45–64	50.4	0.92

^aCalculation of average items/s is not mathematically exact – instead we use the maximum items possible/average time.

^bProsthetic side tested.

^cUsed only male data when possible (some studies are a mostly male mix).

Compared to normative values [34], those with TR amputation aged 18–44 have 3.94 times the QuickDASH scores as unimpaired aged 20–49 (higher scores indicate greater disability). Persons with TR amputation aged 45–64 and 65+ had 2.52 and 1.49 times higher QuickDASH scores as unimpaired males aged 50–69 and 70+, respectively, demonstrating that the magnitude of disability is greater for younger persons with TR amputation. Compared to age-matched normative samples, those with TR amputation had 1.11–1.27 greater MCS scores. PCS scores in our sample were higher than age matched norms in the persons ages 18–44 and 45–64 (1.17 and 1.40, respectively), but lower 0.91 in the group 65 and older. Our sample with TR amputation aged 18–44 and 45–65 had 0.81–0.92 times the CRIS-CAT scores than the normative comparison group, indicating worse community integration.

Outcomes by prosthesis type

Comparison of dexterity measures by amputation level (unilateral and bilateral amputation groups combined) (Table 5) revealed significant differences by prosthesis type for those with TR amputation in the JTHF small objects tasks ($p < 0.05$), Box and Blocks ($p < 0.05$), and the NHP test ($p < 0.001$). Differences in Box and Blocks and NHP remained after correction for multiple comparisons. For the TH group, statistically significant differences were observed before ($p < 0.05$), but not after adjustment for multiple comparison, by prosthesis type for JTHF small objects and NHP test. In all cases, body powered users had the best dexterity scores.

Table 5. Dexterity outcomes by amputation level and device type (all subjects; bilateral amputation classified by dominant side).

	Transradial				Transhumeral			
	Body powered (<i>N</i> = 53)	Myo-single DOF (<i>N</i> = 15)	Myo multi-DOF (<i>N</i> = 19)	K–W	Body powered (<i>N</i> = 20)	Myo-single DOF (<i>N</i> = 10)	Myo multi-DOF (<i>N</i> = 5)	K–W
	Mn (SD)	Mn (SD)	Mn (SD)	<i>p</i>	Mn (SD)	Mn (SD)	Mn (SD)	<i>p</i>
Dexterity								
JTHF								
Writing	0.56 (0.33)	0.47 (0.27)	0.53 (0.29)	0.5301	0.38 (0.35)	0.23 (0.20)	0.25 (0.17)	0.6274
Page turning	0.17 (0.13)	0.15 (0.09)	0.12 (0.07)	0.2945	0.07 (0.06)	0.04 (0.07)	0.04 (0.04)	0.2432
Small objects	0.13 (0.11)	0.12 (0.12)	0.08 (0.09)	0.0176	0.07 (0.06)	0.03 (0.06)	0.02 (0.02)	0.0110
Eating	0.19 (0.11)	0.17 (0.13)	0.13 (0.09)	0.1275	0.09 (0.09)	0.07 (0.08)	0.04 (0.04)	0.4514
Checkers	0.09 (0.08)	0.13 (0.14)	0.12 (0.08)	0.2988	0.07 (0.07)	0.05 (0.07)	0.03 (0.03)	0.7279
Light cans	0.25 (0.19)	0.23 (0.12)	0.27 (0.15)	0.6802	0.14 (0.11)	0.09 (0.10)	0.11 (0.05)	0.3597
Heavy cans	0.25 (0.22)	0.27 (0.12)	0.25 (0.13)	0.2398	0.09 (0.10)	0.09 (0.10)	0.15 (0.08)	0.2419
Box and Blocks	20.6 (9.2)	15.1 (9.1)	15.4 (6.0)	0.0209	18.8 (9.8)	5.2 (5.7)	7.6 (6.5)	0.2118
9 hole peg	0.07 (0.06)	0.06 (0.06)	0.01 (0.01)	0.0001*	0.05 (0.06)	0.01 (0.03)	0.00 (0.00)	0.0312
SHAP IOF	44.0 (19.6)	41.0 (21.1)	39.6 (14.8)	0.5697	14.4 (15.3)	10.8 (16.6)	12.8 (12.7)	0.6742

*Significant after Benjamini–Hochberg adjustment with false discovery rate = 0.1.

Comparisons of outcomes for persons with unilateral amputation only found similar patterns in differences in dexterity scores (Table 6). Significant differences in dexterity were observed in the TR group by device type for JTHF small objects and heavy cans ($p < 0.05$), and for NHP ($p < 0.001$). Only NHP differences remained after adjustment for multiple comparisons. In the TH group, significant differences were observed before and after adjustment for multiple comparisons in JTHF small objects and NHP. In all cases, those using BP devices had better dexterity scores.

Table 6. Functional and self-report outcomes by amputation level and device type (unilateral amputation group only).

	Transradial				Transhumeral			
	Body powered (<i>N</i> = 45)	Myo-single DOF (<i>N</i> = 12)	Myo multi-DOF (<i>N</i> = 18)	K–W	Body powered (<i>N</i> = 18)	Myo-single DOF (<i>N</i> = 9)	Myo multi-DOF (<i>N</i> = 5)	K–W
	Mn (SD)	Mn (SD)	Mn (SD)	<i>p</i>	Mn (SD)	Mn (SD)	Mn (SD)	<i>p</i>
Dexterity								
JTHF								
Writing	0.49 (0.30)	0.41 (0.26)	0.52 (0.30)	0.4274	0.29 (0.26)	0.21 (0.20)	0.25 (0.17)	0.8279
Page turning	0.13 (0.09)	0.14 (0.10)	0.12 (0.07)	0.8182	0.06 (0.05)	0.02 (0.03)	0.04 (0.04)	0.1505
Small objects	0.11 (0.07)	0.11 (0.11)	0.07 (0.09)	0.0288	0.07 (0.06)	0.01 (0.02)	0.02 (0.02)	0.0053*
Eating	0.18 (0.12)	0.17 (0.14)	0.14 (0.09)	0.4160	0.08 (0.09)	0.05 (0.06)	0.04 (0.04)	0.5489
Checkers	0.08 (0.06)	0.08 (0.09)	0.12 (0.08)	0.0957	0.06 (0.07)	0.03 (0.05)	0.03 (0.03)	0.5968
Light cans	0.20 (0.13)	0.22 (0.11)	0.28 (0.15)	0.2995	0.12 (0.09)	0.06 (0.07)	0.11 (0.05)	0.2330

	Transradial				Transhumeral			
	Body powered (<i>N</i> = 45)	Myo-single DOF (<i>N</i> = 12)	Myo multi-DOF (<i>N</i> = 18)	K–W	Body powered (<i>N</i> = 18)	Myo-single DOF (<i>N</i> = 9)	Myo multi-DOF (<i>N</i> = 5)	K–W
Heavy cans	0.20 (0.17)	0.26 (0.12)	0.25 (0.14)	0.0481	0.08 (0.11)	0.08 (0.09)	0.15 (0.08)	0.1519
Box and Blocks	19.00 (8.73)	14.27 (7.88)	15.28 (6.19)	0.0645	10.53 (9.34)	4.00 (4.47)	7.60 (6.50)	0.2154
9 hole peg	0.06 (0.05)	0.06 (0.06)	0.01 (0.01)	0.0008*	0.04 (0.04)	0.00 (0.00)	0.00 (0.00)	0.0194*
SHAP IOF	42.4 (18.4)	39.3 (23.1)	40.2 (15.0)	0.8298	13.4 (16.2)	6.6 (10.3)	12.8 (12.7)	0.5407
Activity measures								
AM-ULA	14.9 (5.3)	14.9 (7.7)	16.4 (6.5)	0.6800	12.3 (6.2)	9.4 (4.2)	11.9 (1.8)	0.2335
BAM-ULA	6.6 (2.1)	9.2 (1.0)	8.0 (1.6)	0.0023	5 (3.4)	4.0 (.)	3.5 (0.7)	0.8307
T-MAP (min)	5.0 (1.8)	3.9 (0.6)	3.9 (0.9)	0.0810	4.5 (1.7)	4.9 (1.2)	7.4 (3.0)	0.1824
Prosthesis satisfaction								
TAPES	4.0 (0.7)	3.5 (0.7)	3.8 (0.7)	0.0514	3.7 (0.9)	3.5 (0.5)	3.7 (0.5)	0.6402
Disability, HRQoL, and community integration								
QuickDASH	29.2 (19.4)	30.9 (15.8)	26.3 (18.1)	0.7196	34.0 (20.7)	28.2 (13.8)	30.5 (13.3)	0.8488
VR-12 MCS	53.5 (10.1)	46.3 (12.8)	52.4 (11.5)	0.0854	50.4 (13.1)	50.6 (14.6)	52.9 (9.4)	0.9820
VR-12 PCS	37.5 (8.9)	43.2 (6.9)	41.1 (8.2)	0.0854	34.7 (13.2)	41.9 (5.6)	44.0 (8.1)	0.1719
CRIS-CAT extent	50.1 (8.7)	44.6 (9.6)	49.5 (8.8)	0.2424	45.4 (8.3)	50.1 (10.9)	53.2 (8.6)	0.1312
CRIS-CAT perceived	49.4 (6.8)	44.3 (4.7)	51.1 (9.1)	0.0333	46.2 (5.0)	48.3 (7.1)	48.8 (7.9)	0.8735
CRIS-CAT satisfaction	51.2 (9.2)	46.9 (7.7)	50.2 (10.5)	0.3651	45.6 (4.9)	47.9 (5.8)	47.7 (7.9)	0.5518
	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	exact p	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	exact p
Need for ADL help	7 (21.2)	3 (37.5)	2 (16.7)	0.5738	3 (25.0)	2 (28.6)	1 (20.0)	1.0000

*Significant after Benjamini–Hochberg adjustment with false discovery rate = 0.1.

Table A1. Normative values for transradial and transhumeral unilateral amputation by age category.

	Unilateral amputation WD/TR			Unilateral amputation ED/TH		
	<i>(N</i> = 75)			<i>(N</i> = 32)		
	18 to <45	45 to <65	65+	18 to <45	45 to <65	65+
	<i>(N</i> = 22)	<i>(N</i> = 20)	<i>(N</i> = 33)	<i>(N</i> = 5)	<i>(N</i> = 16)	<i>(N</i> = 11)
	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)
Dexterity measures						
JTHFT						
Writing	0.46 (0.23)	0.64 (0.35)	0.41 (0.26)	0.11 (0.16)	0.30 (0.22)	0.29 (0.24)
Page turning	0.11 (0.07)	0.17 (0.08)	0.12 (0.10)	0.03 (0.05)	0.06 (0.05)	0.05 (0.05)
Small objects	0.10 (0.10)	0.09 (0.07)	0.10 (0.08)	0.02 (0.02)	0.04 (0.05)	0.06 (0.06)
Eating	0.15 (0.10)	0.19 (0.12)	0.16 (0.12)	0.05 (0.05)	0.05 (0.07)	0.10 (0.09)
Checkers	0.12 (0.08)	0.09 (0.07)	0.07 (0.05)	0.06 (0.10)	0.05 (0.06)	0.04 (0.03)

	Unilateral amputation WD/TR			Unilateral amputation ED/TH		
	(N = 75)			(N = 32)		
	18 to <45	45 to <65	65+	18 to <45	45 to <65	65+
	(N = 22)	(N = 20)	(N = 33)	(N = 5)	(N = 16)	(N = 11)
	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)
Light cans	0.27 (0.10)	0.25 (0.15)	0.18 (0.13)	0.05 (0.08)	0.10 (0.08)	0.12 (0.09)
Heavy cans	0.26 (0.12)	0.24 (0.16)	0.18 (0.17)	0.05 (0.04)	0.12 (0.11)	0.08 (0.09)
Box and Blocks	16.9 (6.9)	19.3 (8.2)	16.0 (9.3)	3.6 (4.4)	7.7 (7.3)	10.9 (9.8)
9-Hole peg	0.04 (0.04)	0.07 (0.05)	0.04 (0.05)	0.02 (0.04)	0.02 (0.04)	0.03 (0.03)
SHAP IOF	42.9 (15.5)	43.6 (20.1)	39.1 (19.1)	5.8 (8.8)	13.0 (12.9)	11.3 (17.2)
Activity measures						
AM-ULA	19.0 (6.5)	16.6 (6.6)	13.2 (5.2)	11.8 (5.0)	11.3 (6.1)	11.3 (4.9)
BAM-ULA	8.5 (1.6)	7.6 (2.3)	6.3 (1.7)	8.0 (.)	2.8 (1.9)	4.8 (3.0)
T-MAP (min)	4.0 (1.0)	4.3 (2.1)	5.1 (1.3)	5.5 (0.9)	5.9 (2.7)	3.2 (0.5)
Prosthesis satisfaction						
TAPES	3.8 (0.8)	3.7 (0.7)	4.0 (0.7)	3.8 (0.8)	3.7 (0.8)	3.5 (0.7)
Disability, HRQOL and community integration						
QuickDASH	31.5 (18.3)	28.9 (18.8)	26.8 (18.5)	31.6 (19.4)	31.6 (18.3)	32.3 (17.8)
VR-12 MCS	50.0 (13.7)	51.2 (13.0)	59.2 (6.0)	45.8 (13.6)	54.2 (10.8)	50.1 (16.6)
VR-12 PCS	44.2 (8.6)	43.4 (7.2)	40.9 (8.3)	44.8 (12.3)	41.9 (11.6)	39.1 (12.3)
VR-12 MCS imputed	48.1 (13.3)	49.3 (12.8)	56.5 (5.8)	48.8 (14.2)	52.2 (10.4)	49.8 (15.9)
VR-12 PCS imputed	41.3 (8.6)	40.4 (7.2)	37.2 (9.3)	41.5 (10.0)	38.5 (11.9)	36.2 (11.7)
CRIS-CAT extent	45.4 (10.7)	48.5 (9.6)	52.0 (6.1)	44.9 (13.4)	48.2 (9.1)	48.9 (8.4)
CRIS-CAT perceived	48.1 (9.3)	48.2 (7.9)	50.1 (5.4)	45.7 (5.6)	47.6 (6.8)	47.2 (5.4)
CRIS-CAT satisfaction	47.9 (10.3)	50.4 (9.5)	51.8 (8.5)	45.8 (7.2)	47.4 (5.9)	45.9 (4.8)
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Need for ADL help	5 (35.7)	3 (20.0)	4 (16.7)	2 (50.0)	2 (15.4)	2 (28.6)

Table A2. Functional and self-report outcomes by age category and device type (unilateral, transradial amputation only).

	Body powered (N = 45)			Myo-single DOF (N = 12)			Myo multi-DOF (N = 18)		
	18-<45	45-<65	66+	18-<45	45-<65	66+	18-<45	45-<65	66+
	(N = 6)	(N = 11)	(N = 28)	(N = 7)	(N = 3)	(N = 2)	(N = 9)	(N = 6)	(N = 3)
	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)	Mn (SD)
Dexterity									
JTHF	0.43 (0.24)	0.70 (0.33)	0.42 (0.27)	0.48 (0.28)	0.38 (0.13)	0.21 (0.30)	0.46 (0.20)	0.65 (0.44)	0.43 (0.12)
Writing	0.12 (0.09)	0.18 (0.08)	0.12 (0.09)	0.12 (0.07)	0.19 (0.12)	0.15 (0.21)	0.10 (0.05)	0.14 (0.07)	0.14 (0.11)
Page turning	0.08 (0.05)	0.10 (0.07)	0.12 (0.08)	0.15 (0.11)	0.06 (0.09)	0.02 (0.01)	0.09 (0.11)	0.06 (0.08)	0.03 (0.03)
Small objects	0.11 (0.07)	0.21 (0.10)	0.18 (0.12)	0.18 (0.13)	0.20 (0.19)	0.10 (0.10)	0.16 (0.08)	0.14 (0.11)	0.07 (0.04)
Eating	0.10 (0.07)	0.09 (0.06)	0.07 (0.06)	0.10 (0.09)	0.08 (0.12)	0.02 (0.02)	0.15 (0.09)	0.10 (0.08)	0.09 (0.04)
Checkers	0.19 (0.10)	0.23 (0.14)	0.20 (0.13)	0.27 (0.07)	0.20 (0.18)	0.09 (0.04)	0.32 (0.11)	0.30 (0.19)	0.11 (0.03)

	Body powered (<i>N</i> =45)			Myo-single DOF (<i>N</i> =12)			Myo multi-DOF (<i>N</i> =18)		
	18-<45	45-<65	66+	18-<45	45-<65	66+	18-<45	45-<65	66+
	(<i>N</i> =6)	(<i>N</i> =11)	(<i>N</i> =28)	(<i>N</i> =7)	(<i>N</i> =3)	(<i>N</i> =2)	(<i>N</i> =9)	(<i>N</i> =6)	(<i>N</i> =3)
Light cans	0.16 (0.10)	0.24 (0.19)	0.19 (0.18)	0.29 (0.06)	0.25 (0.22)	0.15 (0.01)	0.32 (0.13)	0.24 (0.10)	0.10 (0.10)
Heavy cans	18.0 (7.9)	23.1 (7.3)	17.6 (9.1)	15.7 (7.2)	12.7 (11.7)	4.5 (4.9)	17.1 (6.7)	15.7 (4.7)	9.0 (4.0)
Box and Blocks	0.04 (0.03)	0.09 (0.04)	0.05 (0.05)	0.07 (0.06)	0.07 (0.07)	0.00 (0.00)	0.01 (0.02)	0.00 (0.00)	0.00 (0.00)
9 hole peg	39.7 (21.2)	46.0 (17.5)	41.6 (18.6)	43.3 (18.1)	37.7 (34.6)	27.5 (33.2)	44.7 (9.7)	42.0 (20.0)	23.3 (2.1)
SHAP IOF									
Activity measures									
AM-ULA	16.1 (1.4)	17.5 (6.3)	13.7 (5.1)	18.3 (5.8)	11.5 (10.3)	7.8 (3.1)	18.9 (6.7)	15.1 (6.5)	11.3 (2.8)
BAM-ULA	7.5 (0.7)	7.1 (2.8)	6.1 (1.8)	9.2 (1.1)	9.0 (.)	. (.)	8.3 (2.2)	8.0 (1.4)	7.5 (0.7)
T-MAP (min)	4.4 (1.4)	4.7 (2.6)	5.3 (1.4)	3.8 (0.5)	3.5 (0.3)	4.3 (0.8)	3.8 (0.9)	3.8 (1.2)	4.3 (0.2)
Prosthesis satisfaction									
TAPES	4.2 (0.6)	3.8 (0.8)	4.1 (0.7)	3.4 (0.9)	3.6 (0.3)	3.9 (0.2)	4.0 (0.7)	3.6 (0.7)	3.7 (0.8)
Disability, HRQOL, and community integration									
Quick-DASH	27.7 (14.6)	34.1 (21.4)	27.6 (19.7)	39.0 (9.7)	22.0 (22.8)	15.9 (3.2)	28.3 (24.5)	23.0 (9.6)	27.3 (10.4)
VR-12 MCS	52.5 (9.3)	49.6 (15.4)	59.4 (6.5)	44.4 (15.4)	50.2 (6.6)	55.8 (1.0)	52.7 (14.8)	54.5 (11.2)	59.7 (1.8)
VR-12 PCS	45.6 (8.0)	41.8 (7.8)	39.3 (8.1)	45.9 (6.9)	44.9 (8.9)	49.4 (8.6)	41.8 (10.4)	45.8 (5.8)	47.5 (4.8)
VR-12 MCS imputed	50.4 (8.8)	47.5 (15.4)	56.6 (6.3)	42.7 (15.7)	49.6 (6.5)	5.4 (0.0)	50.7 (13.9)	52.4 (10.8)	57.5 (2.6)
VR-12 PCS imputed	42.8 (8.2)	38.7 (7.7)	35.8 (9.2)	43.1 (6.6)	41.5 (8.9)	46.1 (8.3)	39.0 (10.4)	43.0 (5.6)	43.7 (5.4)
CRIS-CAT extent	46.1 (12.7)	47.6 (10.8)	52.0 (6.3)	40.2 (8.9)	49.9 (8.5)	52.2 (7.3)	49.1 (10.0)	49.4 (9.2)	51.3 (5.6)
CRIS-CAT perceived	48.6 (7.4)	47.7 (9.0)	50.3 (5.7)	43.1 (5.4)	45.2 (4.2)	47.0 (3.2)	51.6 (11.7)	50.8 (7.5)	50.6 (4.0)
CRIS-CAT satisfaction	47.7 (7.9)	49.1 (10.9)	52.8 (8.7)	44.2 (7.8)	53.4 (7.1)	46.5 (2.5)	50.9 (13.1)	51.3 (8.5)	45.8 (5.4)
	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)
Need for ADL help	2 (33.3)	2 (28.6)	3 (15.0)	2 (66.7)	1 (33.3)	0 (0.0)	1 (20.0)	0 (0.0)	1 (50.0)

Table A3. Comparison of function participants with unilateral and bilateral amputation: TR body-powered users only.

	Unilateral	Bilateral	
	WD/TR (<i>N</i> = 45)	WD/TR (<i>N</i> = 8)	WMW
	Mn (SD)	Mn (SD)	<i>p</i> Value
Dexterity measures			
JTHFT			
Writing	0.49 (0.30)	0.93 (0.2)	0.0008*
Page turning	0.13 (0.09)	0.36 (0.15)	0.0012*
Eating	0.11 (0.07)	0.27 (0.18)	0.0094*
Small objects	0.18 (0.12)	0.27 (0.08)	0.0287*
Checkers	0.08 (0.06)	0.19 (0.13)	0.0083*
Light cans	0.20 (0.13)	0.51 (0.28)	0.0059*
Heavy cans	0.20 (0.17)	0.53 (0.22)	0.0010
Box and Blocks	19.0 (8.7)	29.8 (6.2)	0.0035
9-Hole peg	0.06 (0.05)	0.15 (0.08)	0.0036*
SHAP IOF	42.4 (18.4)	52.9 (25.1)	0.0878*
Activity measures			
AM-ULA	14.9 (5.3)	16.8 (5.9)	0.2334
BAM-ULA	6.6 (2.1)	9.0 (0.8)	0.0124*
T-MAP	5.0 (1.8)	7.6 (3.7)	0.0826
Prosthesis satisfaction measures			
TAPES	4.0 (0.7)	4.2 (0.4)	0.8044
Disability, HRQoL, and community integration			
QuickDASH	29.2 (19.4)	22.7 (13.2)	0.5339
VR-12 MCS	55.8 (10.7)	56.6 (8.9)	0.9569
VR-12 PCS	40.9 (8.1)	46.8 (9.5)	0.0787
VR-12 MCS imputed	53.5 (10.1)	55.2 (8.2)	0.8424
VR-12 PCS imputed	37.5 (8.9)	43.6 (9.1)	0.0865
CRIS-CAT extent	50.2 (8.7)	55.4 (5.9)	0.1265
CRIS-CAT perceived	49.4 (6.8)	53.6 (11.0)	0.2634
CRIS-CAT satisfaction	51.2 (9.2)	52.8 (7.1)	0.4446
	<i>N</i> (%)	<i>N</i> (%)	Exact <i>p</i>
Need for ADL help	7 (21.2)	3 (60.0)	0.1026

*Significant after Benjamini–Hochberg adjustment with false discovery rate = 0.1.

Activity measures differed significantly by prosthesis type before and after adjustment for multiple comparisons in the TR group for the BAM-ULA ($p < 0.01$), with body-powered users completing the fewest BAM-ULA items. No differences in activity scores by prosthesis type were observed for the TH group. TAPES satisfaction scores did not differ by prosthesis type. Among the remaining measures, the CRIS-CAT perceived limitations scores in the TR group showed significant differences by prosthesis type after adjustment for multiple comparisons. No differences in QuickDASH or VR-12 scores were observed. A greater proportion of TR and TH participants who used myoelectric single-DOF devices reported needing assistance with everyday activities as compared to other groups, but these differences were not statistically significant.

Comparisons of outcomes of unilateral and bilateral amputation groups by prosthesis type

Comparisons of participants with bilateral and unilateral TR amputation who used body-powered devices found significant differences in all dexterity measures except the SHAP ($p < 0.01$) (Appendix, Table A3). Dexterity was better for those with bilateral amputation as compared to unilateral amputation in all cases. When adjusted for multiple comparisons, all measures, including the SHAP IOF were statistically significantly different for groups with unilateral and bilateral amputation. Additionally, those with bilateral amputation completed significantly more BAM-ULA items than those with unilateral amputation, even after adjustment for multiple comparisons. No measures of satisfaction, disability, HRQoL, or community integration differed significantly for persons with unilateral and bilateral amputation using body powered devices.

Discussion

This study reported normative values for dexterity, activity performance, prosthesis satisfaction disability, HRQoL, and community integration in persons with ULA by amputation level and prosthesis type. This work builds on prior observational studies that reported on many of the same outcome measures by amputation level, but did not compare outcomes by device type [25–27,33,35]. Findings confirm results reported in earlier studies that dexterity, as measured by standardized tests, is significantly impaired in upper limb prosthesis users and that impairment is greater in prosthesis users with more proximal level limb loss.

We compared normative data on activity performance by amputation level but were unable to compare activity scores to unimpaired persons. Although it would be inappropriate to compare scores of the AM-ULA to unimpaired persons because it is an amputation-specific measure, we can compare our findings to those previously reported. An earlier study with a smaller ($N = 46$) and younger (mean age 45.8 ± 16.5) sample reported AM-ULA scores of 19–22 for those with TR amputation and 14–16 for those with TH amputation [25]. The lower AM-ULA scores we observed in the current study (TR mn 15.8, TH mn 11.4) may be explained by differences in age as our sample was older (mn 56.7 vs. 45.8), proportion of Veterans in the samples, or by unobserved differences in health of the samples. Normative values of the T-MAP and BAM-ULA which, in theory, could be comparable because the scoring is not amputation specific, are not yet available. BAM-ULA scores in the current study (TR mn 7.3, TH 4.2) were roughly equivalent to that reported by Resnik et al. (mn 6.3) in a sample consisting of 57% TR and 37% TH amputation [26]. T-MAP values reported in the current study (TR mn 4.5, TH mn 5.5) were faster than earlier reported values (mn 6.2 min) [27]. However, the earlier study did not stratify scores by amputation level and included 27 TR and 21 TH amputees [27].

QuickDASH scores confirm that ULA results in significant disability, and disability is greater for those with more proximal amputation levels [36–38]. The ratio of QuickDASH scores compared to normative values differed by age group; those in the youngest age group reported disability scores that were relatively worse than those in the older age groups. Whereas, scores of MCS and PCS, both measures of HRQoL were not impaired in our sample as compared to age-matched norms except among those aged 65 and over. In fact, it appears that participants in our sample rated their overall mental health (MCS) higher in all age groups, and their physical related HRQoL (PCS) higher than age matched norms in the groups under ages 65. The reasons for these differences should be explored in future research. Our comparison groups came from a single large study [30].

Our study failed to find statistically significant differences in dexterity or activity performance by prosthesis type. This may be because our measures lack sensitivity to subtle differences, or because other factors are confounding this relationship and need to be accounted for when making direct comparisons. It is also possible that prosthesis type is not associated with these outcomes. Future, larger studies will be needed to examine these factors. Future studies may also explore the impact of prosthesis weight on satisfaction.

An interesting finding was that dexterity was significantly better for those who had bilateral amputation as compared to those who had unilateral amputation. This suggests that increased prosthesis engagement, as would be expected in persons with bilateral amputation, results in better prosthetic function. Persons with bilateral amputation, however, did have worse scores on measures of ADL performance including the BAM-ULA and T-MAP, measures which include multiple items that typically required bimanual engagement, with a higher proportion requiring assistance with ADL.

Limitations

Our study utilized a convenience sample and consisted predominantly of Veterans. Thus, there are limits to the generalizability of findings to the entire civilian population. Although our study was one of the largest outcome studies of persons with ULA to date, the sample sizes in some subgroups (e.g., SH disarticulation and interscapulothoracic amputation; myoelectric single and multi-DOF device users, particularly at the TH level) were small, and this likely affected the precision of our estimates, and resulted in underpowered comparisons. Further research is needed to accrue larger samples and generate more precise estimates of normative values by prosthesis type and level. Our sample was limited to prosthesis users with amputation at the wrist or above. Findings are not generalizable to prosthesis users with partial hand amputation. Future research is needed to understand dexterity, activity performance, prosthesis satisfaction disability, HRQoL, and community integration of persons with partial hand amputation.

Our analyses of the impact of prosthesis type compared outcomes by amputation level but did not attempt to adjust for other factors which could potentially confound outcomes; including experience with prosthesis use and training to use the device. Although we believe that these factors should be examined in future work, the vast majority of participants in our study had been using their prostheses for many years because participants had, on average, had their amputation for more than 20 years. However, only 26% of our sample reported that they had received training to use the prosthesis that they used in testing. We did not collect data on receipt of initial prosthesis training during our in-person data collection. There are limits to the interpretability of our findings based on study design, as our subjects were not randomly assigned to their prosthesis configuration. Instead, devices had been prescribed and/or selected based on personal preferences and needs. It is possible that persons with lower levels of function are prescribed more complex devices with the expectation that they would receive the most benefit from them, or more simple devices that are easier to learn and control. Future studies which follow subjects who transition from one type of a prosthesis to another are needed.

Not all possible relationships were deemed to be in the scope of this investigation. Although we compared prosthesis type, we did not conduct more granular analyses of the impact of myoelectric terminal device type (single DOF vs. multi-DOF), due to small sample sizes. Although, we grouped all body powered terminal devices together, we acknowledge that there may be differences between types of body powered terminal devices that we were not able to discern. Our study did not have a sufficient number of participants who were using voluntary closing terminal devices, or prehensors to enable comparisons. We did not attempt to compare makes or brands of terminal devices within the categories of single and multi-DOF myoelectric devices, because of small sample sizes. Future studies, which include larger numbers of subjects would be needed to make robust comparisons. However, these studies will likely face the challenge of recruiting the needed participation, due to the relative rarity of upper limb and SH amputations. Furthermore, our study did not examine prosthesis characteristics, such as weight, or other factors associated with device satisfaction or wear time. However, prosthesis weight is included in [Table 2](#). Such data are needed to understand drivers of satisfaction.

Responsiveness of the prostheses was not independently measured but rather subsumed in dexterity measures. Dexterity, in this context, results from the speed or responsiveness of prosthesis movement, the grip options, the shape of the prosthesis terminal device, and the need to switch between grips or other movements to orient the terminal device to perform an activity. Another worthy topic outside the scope of this study is whether  particular componentry or prosthetic model offers notable benefits or limitations compared to others in the same .

Our comparisons of normative data for those with TR amputation to unimpaired samples was limited by the data available in current literature. Not all age groups matched perfectly. We did not find age-stratified nondominant hand data for the SHAP, thus some of the difference between those with TR amputation and the unimpaired sample may be due to use of a dominant hand. Non-dominant hand data were also not available for the Box and Block or NHP tests; however, we were able to compare to both left- and right-hand data for unimpaired groups. It was not possible to identify age-grouped data in a completely male sample for the VR-12, so some bias by gender may exist given that only 3% of our sample were women. Calculations of JTHF and NHP average items/second were not mathematically exact – instead we had to use the maximum items completed divided by the average times taken. However, given the low variance in reported times for unimpaired samples, we believe our comparisons to those with TR amputation are accurate.

Conclusions

This study estimated normative values by amputation level for standardized measures of dexterity, activity performance, disability, HRQoL, and community integration and estimated magnitude of impairment of these outcomes. We found that dexterity is markedly impaired in prosthesis users with ULA and that there is substantial upper limb related disability at all levels of ULA. Persons with more proximal amputation levels are most impacted. In contrast, HRQoL of life and community participation appear to be less impacted and more equivalent to that of unimpaired persons. Furthermore, this study estimated normative values for three prosthesis configurations (body-powered, myoelectric with single DOF terminal, and myoelectric devices with multi-DOF terminal devices) by amputation level. These data may inform clinicians and researchers and help them create benchmarks for these standardized measures by amputation level and prosthesis types.

This study did not detect differences in dexterity, activity performance, disability, HRQoL, or community integration by overall type of prosthesis used, suggesting that that more complex, expensive devices (such as myoelectric multi-DOF terminal devices) do not offer clear advantages for the average person with ULA. Further research with larger sample sizes or different designs, is needed to confirm or refute these findings, to explore whether there are differences by specific terminal device brands or functionality, and to determine how best to match prosthesis type to person based on individual characteristics.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix

AUTHOR QUERIES

Query: AQ0: Please review the table of contributors below and confirm that the first and last names are structured correctly and that the authors are listed in the correct order of contribution. This check is to ensure that your names will appear correctly online and when the article is indexed.

Sequence	Prefix	Given name(s)	Surname	Suffix
1		Linda	Resnik	
2		Matthew	Borgia	
3		Jill	Cancio	
4		Jeffrey	Heckman	
5		Jason	Highsmith	
6		Charles	Levy	
7		Samuel	Phillips	
8		Joseph	Webster	

Author Response: Ok

Query: AQ1: Please confirm the author names as set in the proof are accurate.

Author Response: Ok

Query: AQ2: Please check whether the affiliation has been typeset correctly, and correct if inaccurate.

Author Response: Ok

Query: AQ3: Please resupply the corresponding author's email address if it is inaccurate.

Author Response: Ok

Query: AQ4: Please provide the significance of bold values in Table 3.

Author Response: Bold values are those that are statistically significant at $p < 0.05$. If you wish to unbold, that is fine, alternatively you can add something under the table that states, "bold values are statistically significant at $P < 0.05$ "

Query: AQ5: The funding information provided has been checked against the Open Funder Registry and we failed to find a match. Please check and resupply the funding details if necessary.

Author Response: Please change funder to: Orthotics and Prosthetics Outcomes Research Program Prosthetics Outcomes Research Award and add the following funder: VA RR&D A9265-S

Query: AQ6: Please provide the significance of shading in Table 4.

Author Response: Shaded cells indicate that the field (in this case (side) is not relevant to the outcome measure. You can fill with NA- as I have done.

COMMENTS

C1 Author: Please add (HRPO) after Human Research Protection Office- although this only appears once, most people are familiar with the HRPO as the IRB of the DoD, but are not familiar with the name. Alternatively, you can revise to read, "and by HRPO, the Human Research Protection Office." Thanks;

C2 Author: Bold values in this table indicate values statistically significant at $P \leq 0.05$, as in other tables. You can unbold if you prefer- keeping consistent with other tables;

C3 Author: Bold values are statistically significant at $P \leq 0.05$. Please see comment in prior table;

C4 Author: Bold values are statistically significant at $P \leq 0.05$. See comments in earlier table about unbolding if the journal prefers.;

C5 Author: It is not clear to me whether the sentences is broken across pages- please correct if so- it looks like the words "14-16 for those" end mid page- and that the sentence continues on the next page. If that is the case, please correct spacing.;

C6 Author: Is this sentence breaking over a page, it appears that it is, please check spacing.;



Frequency and Severity of Phantom Limb Pain in Veterans with Major Upper Limb Amputation: Results of a National Survey

Journal:	<i>PM&R: The journal of injury, function and rehabilitation</i>
Manuscript ID	PMR-20-0154.R2
Wiley - Manuscript type:	Original Research
Classifications:	Amputation (including Prosthetics/Orthotics), Pain Medicine, Musculoskeletal Medicine
Keywords:	Pain, Amputations-Upper Extremity, Musculoskeletal Conditions
Abstract:	ABSTRACT Objective: To describe the frequency and severity of phantom limb pain (PLP) in Veterans with major upper limb amputation and determine the association between PLP and person, amputation, and prosthesis characteristics. Design: Cross-sectional design Setting: National survey of Veterans living in the community Participants: United States military Veterans (N=776) with major upper limb amputations Main Outcome Measures: Frequency and intensity of phantom limb pain, person characteristics such as age and gender, amputation characteristics such as level and etiology, and prosthesis characteristics such as type and intensity of prosthesis use Results: Respondents were 97% male with a mean age of 63 years and a mean time since amputation of 31 years. The most common amputation level was transradial (36%) and 62% reported accident as the amputation etiology. 73% of amputees reported PLP with a mean intensity score of 4.2 (SD 3.4). PLP frequency in the daily to always category was reported in 42% of amputees. Weekly and more frequent residual limb pain was associated with having any PLP. Amputation at the shoulder [OR 3.78 (1.93, 7.39)], amputation at the transhumeral level [OR 1.76 (1.10, 2.81)], and amputation due to cancer [OR 5.33 (1.15, 24.81)] were also associated with any PLP. Moderate ($\beta=1.34$, $p<0.0001$) and severe ($\beta=3.31$, $p<0.0001$) residual limb pain intensity was associated with higher PLP intensity among those with pain. Amputation at the shoulder level was associated with a 1.5 points higher average pain intensity score ($p=0.0001$) compared to the transradial level. Multivariable models failed to show an association between PLP prevalence and amputation of the dominant limb ($p=0.08$) and PLP was not associated with intensity of daily prosthesis use in bivariate analyses. Discussion/Conclusions: This study of a large cohort of Veterans with major upper limb amputation highlights the long-term persistence of moderate frequency and intensity PLP.



ABSTRACT

Objective: To describe the frequency and severity of phantom limb pain (PLP) in Veterans with major upper limb amputation and determine the association between PLP and person, amputation, and prosthesis characteristics.

Design: Cross-sectional design

Setting: National survey of Veterans living in the community

Participants: United States military Veterans (N=776) with major upper limb amputations

Main Outcome Measures: Frequency and intensity of phantom limb pain, person characteristics such as age and gender, amputation characteristics such as level and etiology, and prosthesis characteristics such as type and intensity of prosthesis use

Results: Respondents were 97% male with a mean age of 63 years and a mean time since amputation of 31 years. The most common amputation level was transradial (36%) and 62% reported accident as the amputation etiology. 73% of amputees reported PLP with a mean intensity score of 4.2 (SD 3.4). PLP frequency in the daily to always category was reported in 42% of amputees. Weekly and more frequent residual limb pain was associated with having any PLP. Amputation at the shoulder [OR 3.78 (1.93, 7.39)], amputation at the transhumeral level [OR 1.76 (1.10, 2.81)], and amputation due to cancer [OR 5.33 (1.15, 24.81)] were also associated with any PLP. Moderate ($\beta=1.34$, $p<0.0001$) and severe ($\beta=3.31$, $p<0.0001$) residual limb pain intensity was associated with higher PLP intensity among those with pain. Amputation at the shoulder level was associated with a 1.5 points higher average pain intensity score ($p=0.0001$) compared to the transradial level. Multivariable models failed to show an

association between PLP prevalence and amputation of the dominant limb ($p=0.08$) and PLP was not associated with intensity of daily prosthesis use in bivariate analyses.

Discussion/Conclusions: This study of a large cohort of Veterans with major upper limb amputation highlights the long-term persistence of moderate frequency and intensity PLP.

Introduction

There are two types of amputation-related pain that frequently occur following limb amputation. Residual limb pain (RLP) is pain that is perceived to originate from the remaining portion of the amputated limb.¹⁻³ Phantom limb pain (PLP) is a condition in which pain is perceived in the amputated limb which is no longer present.²⁻⁶ Persons with limb loss often report both PLP and RLP, but RLP is more common in the acute and subacute periods after amputation while PLP can be more predominate months after amputation.¹ The prevalence of PLP previously reported in the literature has a wide range from 40% to 80%.³⁻¹² The prevalence of PLP in persons with upper extremity amputation has been reported to be in the 40-50% range,^{3,4,13,14} whereas PLP following lower limb amputation has been reported to be as high as 70-80%.^{3,4,9,15-17} For some, the intensity and frequency of phantom limb pain may subside with time, but PLP may persist indefinitely and result in significant pain interference, impairment and disability.^{3,4,9,15-17} Most research to date has focused on lower limb loss and PLP, perhaps due to the higher occurrence rate or the larger population of individuals with lower limb amputation. Consequently, the prevalence and factors associated with PLP in persons with upper extremity amputation has been less well described.

There is incomplete data available in the literature regarding risk factors associated with PLP especially in those with upper limb amputation. Chronic PLP has been previously associated with pre-operative pain, residual limb pain and time period since amputation.^{3,4,7,9,18-19} Persons with upper limb amputation who experience phantom limb sensation also have an increased risk of PLP with a relative risk for PLP of 11.3.⁷ Hanley et al. demonstrated that those who wore a prosthesis were more likely to have chronic PLP, but the authors could not deduce whether using a prosthesis contributed to pain or if the prosthesis was used in order to help relieve pain.² Additional studies have found that individuals who reported using a prosthesis were significantly more likely to have PLP, these studies have not explored the relationship between PLP and intensity of daily prosthesis use.^{2,7}

In those with upper limb loss, more proximal amputation levels (amputations above the elbow and more proximal compared to amputations below the elbow) have been associated with an increased risk of PLP.^{4,10} Smith et al. showed that amputation of the dominant limb was associated with greater PLP, but use of the prosthesis on the dominant side was not associated with change in pain symptoms.²⁰ Others have not been able to establish a relationship between limb dominance and PLP.⁷ Depressive symptoms have predicted higher levels of PLP intensity and bothersomeness while other psychological factors including stress and catastrophizing have been noted to play a role in maintaining or aggravating PLP.^{5,21} In those with lower limb amputation, a positive association between PLP and low back pain has been noted.¹³

Leveraging survey results from a large sample of Veterans with upper limb amputation, the purposes of this manuscript are to describe the frequency and severity of phantom limb pain (PLP) in Veterans with major upper limb amputation and quantify the association between PLP and person, amputation, and prosthesis characteristics.

Methods

Data for this study was derived from a larger, survey study (described in this paper) that collected comprehensive data on function, needs, preferences, and prosthetic satisfaction in a large cohort of Veterans with major upper limb amputation. Our analyses include the subset of respondents who had unilateral major upper limb amputation.

Survey Recruitment and Data Collection

The Veteran sample was identified through the Veterans Affairs (VA) Corporate Data Warehouse (CDW). Participants included all Veterans with major upper limb amputation who received care at the VA between 2010-2016. Major upper limb amputation levels were defined in our study as amputation at the forequarter, shoulder disarticulation, transhumeral (TH), elbow disarticulation (ED), transradial (TR), or wrist disarticulation (WD) level. The sampling frame was identified from VA CDW sources including Inpatient, Outpatient, and Fee domains; the main source for information regarding VHA Benefit compensation and pension benefits paid to Veterans and their beneficiaries; and Veteran’s Benefits Administration (VBA) disability ratings. A list of diagnosis and procedure codes used to identify the sample has been provided in a separate publication.²²

All non-deceased Veterans with valid addresses and phone numbers were sent an initial recruitment package containing an invitation letter, a study information sheet explaining the study, and a card with stamped envelope to return if they wished to opt out of participation. Veterans who did not opt-out of study participation by returning the postcard or calling the study telephone number within 30 days were contacted by the study interviewers. To maximize study recruitment, up to ten attempts were made to contact potential participants. All participants provided oral informed consent to participate. A waiver of documentation of informed consent was obtained from the VA Central IRB. All surveys were conducted via telephone by trained interviewers and were approximately 45 minutes in length. The analyses presented in this paper utilize data from respondents with unilateral limb loss. Persons with bilateral upper limb amputation were excluded.

Measures

The survey instrument was comprehensive in nature and included questions designed to obtain data related to person-level characteristics, amputation-specific characteristics (including amputation level, years since amputation, and etiology of amputation), and prosthesis use characteristics. Respondents indicated all etiologies of amputation that applied, and thus may have indicated more than one etiology. Pain-related questions were used to assess phantom limb pain and residual limb pain. In order to facilitate participant's understanding, phantom limb was defined as feeling of the presence of limb that was lost. Residual limb was defined as portion of the limb remaining after the amputation.

109 **Pain Frequency:** Participants were asked to rate their pain frequency in the past 4 weeks:
110 never, only once or twice, about once per week, two to three times per week, four to six times
111 per week, several times every day, all the time or almost all the time. For the purposes of data
112 analysis, pain frequency was categorized into 4 levels: Never, Weekly or less frequent, 2 to 6
113 times per week, and Daily to always.

114
115 **Pain Intensity:** Participants were also asked to rate their phantom and residual limb pain
116 intensity over the past 4-week time period. Pain intensity was scored on a 10-point scale with 0
117 representing no pain and 10 representing the worst possible pain. Pain intensity was
118 recategorized into 4 levels: Never had Pain, None to Mild (0-3), Moderate (4-7), and Severe (8-
119 10).

120 **Amputation Level:** For the purposes of data analysis, amputation levels were consolidated into
121 three amputation level categories. The transradial level includes those with wrist
122 disarticulation, transhumeral level includes those with elbow disarticulation, and shoulder level
123 includes forequarter and shoulder disarticulation amputation levels.

124 **Statistical Methods**

125 We examined descriptive statistics to characterize respondents by amputation level. We used
126 bivariate analyses to examine the relationships of covariates with PLP prevalence (using chi-
127 squared and two-tailed Fisher's exact tests) and PLP intensity (using Kruskal-Wallis tests
128 because the assumption of normality was rejected by the Shapiro-Wilk test). The purpose of the
129 bivariate analyses was to identify possible associations between covariates and PLP prevalence

and intensity that would be added to our multivariable models. We then used a two-part multivariable model; first using logistic regression predicting any PLP and then using linear regression predicting PLP intensity for those with any pain. Covariates that were statistically significant at $P < 0.1$ in bivariate analysis were added to the multivariable logistic and linear regressions to control for potential confounding and to identify other factors that were independent predictors of PLP intensity and frequency.

Results

Study Participants

Seven hundred fifty-five male participants and 21 female participants with unilateral major upper limb amputation completed some or all of the telephone survey. There were 20 participants who did not complete all items in the survey; 16 of these did not complete the items addressing pain frequency and intensity. Further details regarding the person, amputation, and prosthesis characteristics of the study population by amputation level are included in (Table 1). The average age was 63.2 years, 97.3% were males and 75.1% reported their race as White. The average time since amputation was 31.3 years. Approximately half of the participants (50.6%) reported amputation involving the dominant side. Transradial amputation was the most common level at 36%. Sixty-two percent of the sample reported accident as the etiology of amputation. Among those who reported wearing a prosthesis ($N=461$; 59%), the majority (70.7%) reported using a body-powered prosthesis and 42.1% reported using a prosthesis for more than 8 hours per day.

Frequency and Severity of Pain Syndromes

Table 2 shows the reported frequency of both PLP and RLP in study participants. PLP frequency in the “daily to always” category was reported in 42% of the sample. 27% of participants reported that they never had PLP in the past 4 weeks. RLP frequency in the “daily to always” category was reported by 29.6%. Prevalence of PLP in the “daily to always” frequency category was higher in respondents with more proximal amputation levels; 47.9% at transhumeral level and 57.0% at the shoulder level compared to 34.6% at the transradial level (Figure 1).

Table 3 details the reported levels of pain intensity. In our sample, 73% reported some PLP with a mean pain intensity of 4.2 (SD 3.4). Only about a quarter of participants reported PLP intensity in the “never” category. Similar to residual limb pain frequency, pain intensity in the “moderate” and “severe” categories was also commonly reported in the residual limb. Again, similar to PLP frequency, PLP intensity in the “moderate” and “severe” categories was more prevalent in those with more proximal amputation levels; 65.5% at transhumeral level and 67.4% at the shoulder level compared to 48.6% at the transradial level (Figure 2). Of note, about 23% of the Veterans rated their PLP intensity in the “severe” category which is significantly higher compared to the residual limb (13%).

Associations between Person, Amputation, and Prosthesis Characteristics and PLP

In bivariate analyses of PLP frequency, the following variables were statistically significant at $p \leq 0.1$: race, amputation of dominant side, age, time since amputation, amputation level, amputation etiology (from combat, burns, and cancer), residual limb and neck pain frequency and intensity, and self-suspension prosthesis types [Appendix Table 1]. In bivariate analyses of

PLP intensity (for those with any pain), the following variables were statistically significant at $p \leq 0.1$: race, ethnicity, age, amputation level, residual limb and neck pain frequency and intensity, and prosthesis types using harnessing [Appendix Table 2].

In multivariable models (Table 4), we found that those who had residual limb pain “weekly or less frequent” [OR 3.32 (1.77, 6.20)], “2 to 6 times per week” [OR 6.55 (2.78, 15.44)], and “daily to always” [OR 8.75 (3.52, 21.79)], had significantly higher odds of having any PLP compared to those who never had residual limb pain in the prior 4 weeks. Amputation at shoulder level [OR 3.78 (1.93, 7.39)], amputation at transhumeral level [OR 1.76 (1.10, 2.81)], etiology of cancer [OR 5.33 (1.15, 24.81)] and use of self-suspending prostheses [OR 1.79 (1.06, 3.03)] were also associated with any PLP. Amputation etiology of combat injury [OR 0.62 (0.40, 0.97)] and burn [OR 0.50 (0.26, 0.94)] were associated with reduced occurrence of PLP.

Moderate ($\beta=1.34$, $p<0.0001$) and severe ($\beta=3.31$, $p<0.0001$) residual limb pain intensity was associated with higher PLP intensity among those with pain. However, those who had neck pain “daily to always” had lower ($\beta=-0.77$, $p=0.03$) PLP intensity than those who never had neck pain. Amputation at the shoulder level was associated with a 1.5 points higher pain scores ($p=0.0001$) compared to at the transradial level. Multivariable models failed to show an association between PLP and amputation of the dominant limb. Bivariate analyses did not indicate any statistically significant relationship between PLP and type of prosthesis, or intensity of daily prosthesis use.

Discussion

Major upper limb amputation has the potential to result in significant alterations in physical performance, body image, and activity participation.²² Phantom limb pain is an important consideration following upper limb amputation because it is both frequently occurring and long-lasting. Appropriate awareness and identification of PLP is also critical because of its potential associated functional implications.^{2,3,15-17,23-24}

The pathophysiology underlying PLP is complex and multifaceted.^{3,12,25-29} While several different theories exist, the etiology of phantom phenomena has been categorized primarily into three anatomical locations and mechanisms: supraspinal, spinal and peripheral.^{3,25-29} The supraspinal mechanism focuses on reorganization of somatosensory cortex surrounding the area representing deafferented limb.^{1, 3,25-31} The spinal mechanism focuses on functional changes in the dorsal horn due to deafferentation from peripheral nerve injury.^{1,3,30-31} Finally, the peripheral mechanism describes axonal nerve damage during amputation and the downstream effects of inflammation and regenerative sprouting.^{1,3,30-31} Inevitably, pain after amputation is likely a combination of multiple different mechanisms and the contribution from each mechanism may vary by individual.

Although prior studies have examined the frequency of phantom limb pain following amputation, there is variability in the previously reported prevalence and a limited body of investigations specific to individuals with upper limb amputation.³⁻¹¹ Many prior studies have

also been limited by small sample sizes and incomplete descriptions of PLP chronicity, intensity, and frequency. In addition, the pathophysiology underlying PLP is complex as described above, so understanding of the factors associated with pain frequency and intensity may provide insights into the management of those factors that are modifiable. For example, addressing residual limb pain may have the potential to impact the intensity and frequency of PLP. The currently available literature has not clearly delineated these variables associated with PLP.^{3-11,32}

The findings from this study are significant for several reasons. This investigation involved a large cohort and specifically addresses the population of Veterans with upper limb amputation. This cohort represents a broad sample of Veterans with upper limb amputation who received any type of care in the Department of Veterans Affairs. The study adds to the previously reported literature on the prevalence of PLP, confirming that PLP is a very common condition and that the prevalence may be higher than previous reports. The accuracy of our prevalence estimates is strengthened by the large sample size and representativeness of the sample. Findings also supports the commonly held belief that PLP symptoms are frequently chronic in those with upper limb amputation as the average time since amputation in our sample was 31 years. Providers should be aware of the chronicity of PLP and continue to recognize signs and symptoms of this phenomena.

The results of our study may also provide clinicians a greater appreciation of the relationship between patient, amputation, and prosthesis characteristics and PLP. Despite our original

hypotheses, we found no significant association between PLP and amputation of dominant limb, intensity of prosthesis use, or type of prosthesis used in bivariate analyses and did not add these variables to the multivariable models. Our study adds to the literature reporting an association between frequency and intensity of PLP and amputation level with Veterans with more proximal upper limb amputation being more likely to have higher intensity and frequency PLP. This is an important finding for clinicians to take into consideration in the counseling and management of persons with more proximal amputation levels. Similar to prior investigations, this study found an association between moderate intensity residual limb pain and any PLP as well as higher PLP intensity among those with worse residual limb pain intensity.⁹ The finding that participants with neck pain in our study experienced lower PLP intensity is interesting and might be explained by the pain signals in the more proximal neck segment creating a modulating effect on the more distal PLP signals. This finding should be explored further in the future.

When comparing amputations due to cancer to amputations not due to cancer, we found that amputation due to cancer was associated with PLP. This finding is consistent with reports from prior studies that found that PLP was highly prevalent in individuals with amputation due to cancer.^{10,33} These prior studies also reported that PLP was more common than residual limb or stump pain in persons with amputation due to cancer.^{10,33} Higher PLP in persons with an amputation etiology of cancer could be secondary to hypersensitization of nerves in setting of the malignancy or perhaps due to adjunct therapies such as chemotherapy and/or radiation.

The finding that burn amputation etiology is associated with a reduced occurrence of PLP is novel and the underlying mechanism for this finding is not clear. These findings should be interpreted with some caution because the etiology of amputation was determined by self-report and participants were able to identify more than one etiology. Thus, it was unclear in these cases which etiology was primary. Further studies should be performed to help delineate the association between cause of amputation and PLP.

This investigation has several limitations. Survey respondents were all Veterans who received some care in the Department of Veterans Affairs which may limit the generalizability of findings to a wider population of persons with upper limb amputation. Our data was collected through telephone survey and pain-related questions asked participants to rate their pain level over a 4-week time period. It is possible that some participants did not recall their pain accurately over this time period. This methodology differs from some previously published studies which used self-applied questionnaires instead of interviews.^{7,15} Our survey instrument was long, and it is possible that some respondents became fatigued during interviews, and that this adversely affected their recall. Because of the cross-sectional nature of this study, we were not able to characterize changes in PLP intensity or frequency over time. Our sample was primarily male, and findings may not generalize well to females with limb loss. Finally, the observational study design identifies factors associated with PLP and cannot be used to demonstrate causality.

Conclusion

278 This study found that moderate intensity PLP and daily to constant PLP is common in Veterans
279 with upper limb amputation. It also found an association between PLP and residual limb pain,
280 proximal amputation levels, and amputation due to cancer. The study found no significant
281 association between PLP and amputation of dominant limb, intensity of daily prosthesis use, or
282 type of prosthesis used.

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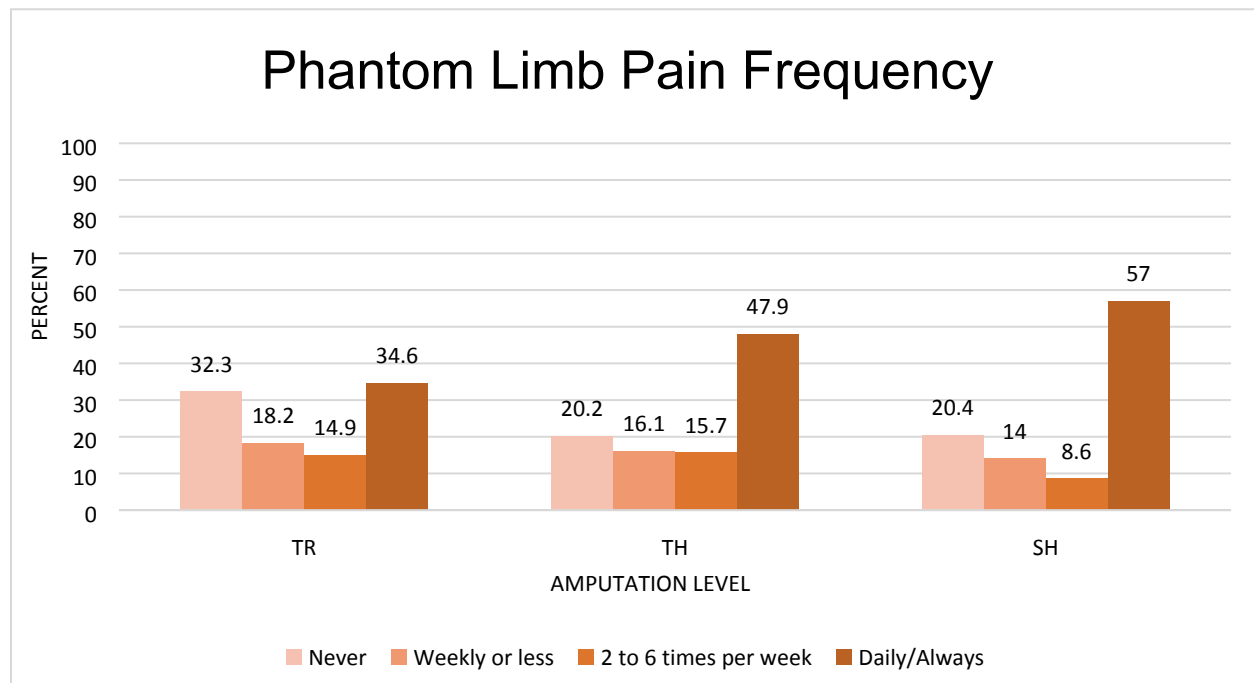
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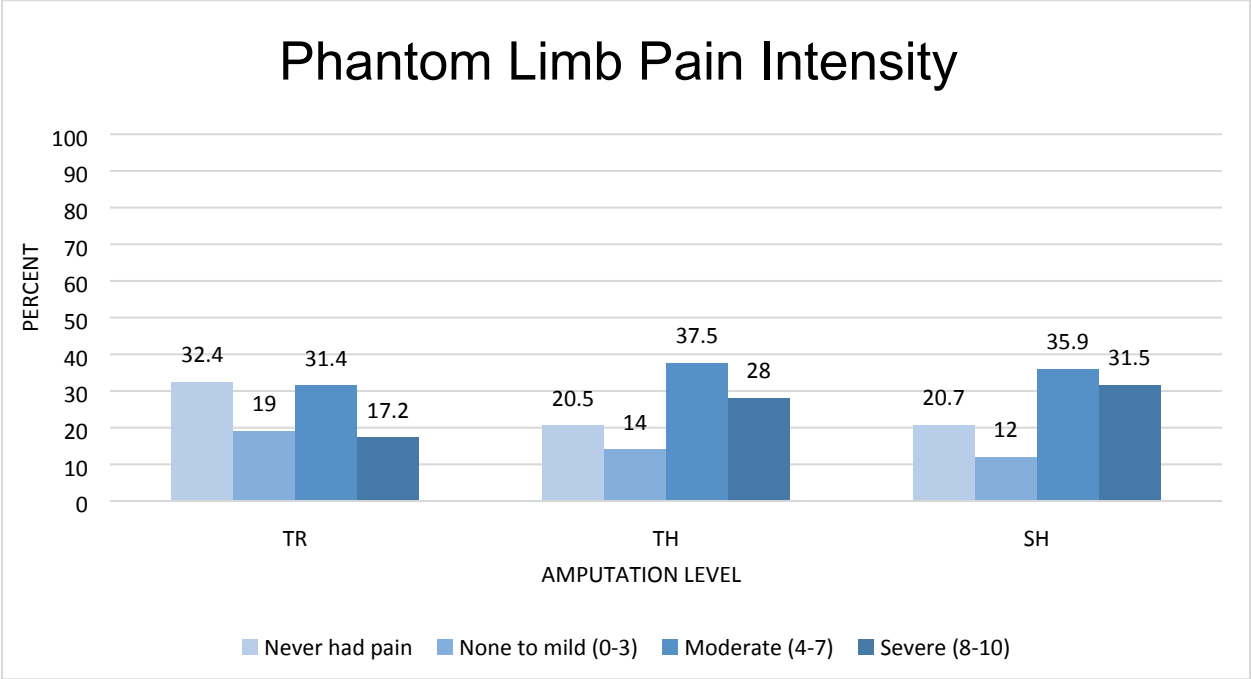
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Figure 1: Phantom Limb Pain Frequency by Amputation Level

*TR= Transradial, TH= Transhumeral, SH= Shoulder/Forequarter

**Pain Frequency in last 4 weeks classified as Never= 'Never'; Weekly or less frequent= 'only once or twice' and 'about once per week'; 2 to 6 times per week= '2 to 3 times per week' and '4 to 6 times per week'; and Daily/Always= 'several times every day' and 'all the time or almost all the time'.

Figure 2: Phantom Limb Pain Intensity by Amputation Level



*TR= Transradial, TH= Transhumeral, SH= Shoulder/Forequarter

Manuscript Tables and Graphs**Table 1. Characteristics of Study Participants (N=776)**

	Transradial (N=406)	Transhumeral (N=276)	Shoulder/FQ (N=94)
PERSON CHARACTERISTICS	Mn (sd)	Mn (sd)	Mn (sd)
Age (Yrs)	63.6 (14.2)	62.8 (13.4)	63.0 (15.5)
	N (%)	N (%)	N (%)
Gender			
Male	397 (97.8)	266 (96.4)	92 (97.9)
Female	9 (2.2)	10 (3.6)	2 (2.1)
Race			
White	320 (78.8)	194 (70.3)	69 (73.4)
Black	36 (8.9)	34 (12.3)	16 (17.0)
Unknown	35 (8.6)	31 (11.2)	6 (6.4)
Other/Mixed	15 (4.7)	17 (6.2)	3 (3.2)
Hispanic			
Yes	27 (6.7)	30 (10.9)	5 (5.3)
No	360 (88.7)	231 (83.7)	87 (92.6)
Don't Know/Unsure	19 (4.7)	15 (5.4)	2 (2.1)
AMPUTATION CHARACTERISTICS	Mn (sd)	Mn (sd)	Mn (sd)
Years Since Amputation	32.4 (18.5)	31.3 (17.8)	26.4 (18.7)
Age at Time of Amputation	31.1 (13.1)	31.7 (13.3)	36.4 (16.6)
	N (%)	N (%)	N (%)
Amputation Level			
Forequarter	0 (0.0)	0 (0.0)	23 (24.5)
Shoulder disarticulation	0 (0.0)	0 (0.0)	71 (75.5)
Transhumeral	0 (0.0)	236 (85.5)	0 (0.0)
Elbow disarticulation	0 (0.0)	40 (14.5)	0 (0.0)
Transradial	280 (69.0)	0 (0.0)	0 (0.0)
Wrist disarticulation	126 (31.0)	0 (0.0)	0 (0.0)
Amputation Etiology			
Combat injury	161 (39.7)	89 (32.3)	25 (26.6)
Accident	261 (64.3)	168 (60.9)	54 (57.5)
Burn	57 (14.0)	19 (6.9)	5 (5.3)
Cancer	7 (1.7)	7 (2.5)	16 (17.0)
Diabetes	5 (1.2)	5 (1.8)	1 (1.1)
Infection	32 (7.9)	40 (14.5)	14 (14.9)
Amputation of Dominant Side			
Yes	221 (54.4)	127 (46.0)	45 (47.9)
No	182 (44.8)	148 (53.6)	48 (51.1)
Unknown	3 (0.7)	1 (0.4)	1 (1.1)
Prosthetic Users	TR (N=313)	TH (N=121)	SH (N=27)
PROSTHESIS CHARACTERISTICS	N (%)	N (%)	N (%)
Type of Primary Prosthesis			
Body powered	217 (69.3)	95 (78.5)	14 (51.9)
Myoelectric	71 (22.7)	17 (14.0)	8 (29.6)
Hybrid	3 (1.0)	2 (1.7)	1 (3.7)

Cosmetic	14 (4.5)	4 (3.3)	4 (14.8)
Sports/recreation	4 (1.3)	2 (1.7)	0 (0.0)
Unknown	4 (1.3)	1 (0.8)	0 (0.0)
Type Suspension			
Suction	105 (33.6)	45 (37.2)	6 (22.2)
Gel or silicone liner with pin	60 (19.2)	25 (20.7)	6 (22.2)
Vacuum	32 (10.2)	17 (14.1)	2 (7.4)
Self-suspending	123 (39.3)	41 (33.9)	8 (29.6)
Harnessing	210 (67.1)	109 (90.1)	26 (96.3)
External sleeve	42 (13.4)	18 (14.9)	2 (7.4)
Intensity of daily Prosthesis Use			
Less than 2 hours	49 (15.7)	32 (26.5)	7 (25.9)
2 to less than 4 hours	20 (6.4)	15 (12.4)	7 (25.9)
4 to less than 8 hours	54 (17.3)	25 (20.7)	6 (22.2)
8 to less than 12 hours	67 (21.4)	19 (15.7)	2 (7.4)
12 hours or more	121 (38.7)	26 (21.5)	5 (18.5)
Don't know/unsure	2 (0.6)	4 (3.3)	0 (0.0)

Table 2. Pain Frequency in Study Participants by Amputation Level (N=776)

	Transradial (N=406)	Transhumeral (N=276)	Shoulder/FQ (N=94)
<i>Pain Frequency*</i>	N (%)	N (%)	N (%)
Phantom Limb Pain			
Never	128 (32.3)	54 (20.2)	19 (20.4)
Weekly or less frequent	72 (18.2)	43 (16.1)	13 (14.0)
2 to 6 times per week	59 (14.9)	42 (15.7)	8 (8.6)
Daily/Always	137 (34.6)	128 (47.9)	53 (57.0)
Residual Limb Pain			
Never	151 (38.0)	80 (30.1)	
Weekly or less frequent	81 (20.4)	56 (21.1)	
2 to 6 times per week	66 (16.6)	33 (12.4)	
Daily/Always	99 (24.9)	97 (36.5)	

* Pain Frequency in last 4 weeks classified as Never='Never'; Weekly or less frequent='only once or twice' and 'about once per week'; 2 to 6 times per week='2 to 3 times per week' and '4 to 6 times per week'; and Daily/Always='several times every day' and 'all the time or almost all the time'.

Table 3. Pain Intensity in Study Participants by Amputation Level (N=776)

	Transradial (N=406)	Transhumeral (N=276)	Shoulder/FQ (N=94)
<i>Pain Intensity</i>			
Phantom Limb Pain			
Never had pain	128 (32.4)	54 (20.5)	19 (20.7)
None to Mild	75 (19.0)	37 (14.0)	11 (12.0)
Moderate	124 (31.4)	99 (37.5)	33 (35.9)
Severe	68 (17.2)	74 (28.0)	29 (31.5)
Residual Limb Pain			
Never had pain	151 (38.0)	80 (30.1)	
None to Mild	72 (18.1)	41 (15.4)	
Moderate	135 (34.0)	98 (36.8)	
Severe	39 (9.8)	47 (17.7)	

Table 4. Separate Multivariable models of Presence of Phantom Limb Pain and Phantom Limb Pain Intensity

	Logistic Regression: Any PLP (yes/no) N=710		Linear Regression: Intensity (0-10) N=541	
	OR (95% CI)	P	B (95%CI)	P
Race				
White (ref) (n=583)				
Black (n=86)	1.77 (0.84, 3.71)	0.13	0.18 (-0.41, 0.77)	0.55
Unknown (n=72)	1.16 (0.50, 2.68)	0.73	0.85 (-0.09, 1.79)	0.08
Other/Mixed (n=35)	1.07 (0.35, 3.20)	0.91	0.38 (-0.48, 1.23)	0.39
Hispanic				
Yes (n=62)			0.51 (-0.29, 1.31)	0.21
No (ref) (n=678)				
Don't Know/Unsure (n=36)			-0.18 (-1.87, 1.52)	0.84
Amputation of Dominant Side				
Yes (n=393)	0.70 (0.48, 1.04)	0.08		
No (ref) (n=376)				
Age at time of study				
[18,45) (ref) (n=99)				
[45,65) (n=207)	0.99 (0.44, 2.22)	0.97	0.16 (-0.48, 0.79)	0.63
[65,75) (n=340)	0.91 (0.40, 2.05)	0.82	-0.10 (-0.70, 0.51)	0.76
75+ (n=106)	0.79 (0.30, 2.05)	0.63	-0.43 (-1.21, 0.35)	0.28
Time since amputation				
[0,20) (ref) (n=264)				
[20,50) (n=391)	0.80 (0.45, 1.42)	0.45		
50+ (n=100)	0.89 (0.40, 1.97)	0.78		
Amputation Level				
Shoulder/FQ (n=94)	3.78 (1.93, 7.39)	0.0001	1.54 (0.79, 2.30)	<0.0001
Transhumeral/ED (n=276)	1.76 (1.10, 2.81)	0.01	0.21 (-0.24, 0.67)	0.35
Transradial/WD (ref) (n=406)				
Residual Limb Pain Frequency				
Never had pain (ref) (n=325)				
Weekly or less frequent (n=137)	3.32 (1.77, 6.20)	0.0002	-0.34 (-1.04, 0.36)	0.34
2 to 6 times per week (n=99)	6.55 (2.78, 15.44)	<0.0001	-0.18 (-0.97, 0.61)	0.65
Daily/Always (n=196)	8.75 (3.52, 21.79)	<0.0001	-0.41 (-1.20, 0.38)	0.30
Residual Limb Pain Intensity				
None to Mild (ref) (n=113)				
Moderate (n=233)	1.39 (0.68, 2.85)	0.37	1.34 (0.74, 1.93)	<0.0001
Severe (n=86)	1.15 (0.42, 3.14)	0.79	3.31 (2.50, 4.11)	<0.0001
Neck Pain Frequency				
Never had pain (ref) (n=303)				
Weekly or less frequent (n=151)	1.13 (0.62, 2.06)	0.69	-0.65 (-1.31, 0.01)	0.05
2 to 6 times per week (n=111)	1.04 (0.50, 2.19)	0.91	-0.73 (-1.49, 0.03)	0.06
Daily/Always (n=195)	1.20 (0.55, 2.59)	0.65	-0.77 (-1.50, -0.05)	0.03
Neck Pain Intensity				
None to Mild (ref) (n=115)				
Moderate (n=254)	1.64 (0.88, 3.06)	0.12	1.37 (0.76, 1.98)	<0.0001

Severe (n=88)	1.48 (0.55, 4.02)	0.44	1.90 (1.09, 2.71)	<0.0001
Amputation Etiology				
<i>Combat injury</i>				
Yes (n=275)	0.62 (0.40, 0.97)	0.03		
No (ref) (n=500)				
<i>Burn</i>				
Yes (n=81)	0.50 (0.26, 0.94)	0.03		
No (ref) (n=693)				
<i>Cancer</i>				
Yes (n=30)	5.33 (1.15, 24.81)	0.03		
No (ref) (n=744)				
Prosthesis Use				
Yes (n=461)	0.97 (0.60, 1.56)	0.88	-0.65 (-1.30, 0.00)	0.04
No (ref) (n=306)				
Suspension Type				
<i>Self-suspending</i>				
Yes (n=172)	1.79 (1.06, 3.03)	0.03		
No (ref) (n=273)				
<i>Harnessing</i>				
Yes (n=345)			0.33 (-0.27, 0.94)	0.28
No (ref) (n=113)				

*Empty shaded boxes indicate variables that were not significant at p<0.1 in bivariate analyses, and were not included in the models.

ABSTRACT

Objective: To describe the frequency and severity of phantom limb pain (PLP) in Veterans with major upper limb amputation and determine the association between PLP and person, amputation, and prosthesis characteristics.

Design: Cross-sectional design

Setting: National survey of Veterans living in the community

Participants: United States military Veterans (N=776) with major upper limb amputations

Main Outcome Measures: Frequency and intensity of phantom limb pain, person characteristics such as age and gender, amputation characteristics such as level and etiology, and prosthesis characteristics such as type and intensity of prosthesis use

Results: Respondents were 97% male with a mean age of 63 years and a mean time since amputation of 31 years. The most common amputation level was transradial (36%) and 62% reported accident as the amputation etiology. 73% of amputees reported PLP with a mean intensity score of 4.2 (SD 3.4). PLP frequency in the daily to always category was reported in 42% of amputees. Weekly and more frequent residual limb pain was associated with having any PLP. Amputation at the shoulder [OR 3.78 (1.93, 7.39)], amputation at the transhumeral level [OR 1.76 (1.10, 2.81)], and amputation due to cancer [OR 5.33 (1.15, 24.81)] were also associated with any PLP. Moderate ($\beta=1.34$, $p<0.0001$) and severe ($\beta=3.31$, $p<0.0001$) residual limb pain intensity was associated with higher PLP intensity among those with pain. Amputation at the shoulder level was associated with a 1.5 points higher average pain intensity score ($p=0.0001$) compared to the transradial level. Multivariable models failed to show an

22 association between PLP prevalence and amputation of the dominant limb ($p=0.08$) and PLP
23 was not associated with intensity of daily prosthesis use in bivariate analyses.

24 **Discussion/Conclusions:** This study of a large cohort of Veterans with major upper limb
25 amputation highlights the long-term persistence of moderate frequency and intensity PLP.

26

27 **Introduction**

28 There are two types of amputation-related pain that frequently occur following limb
29 amputation. Residual limb pain (RLP) is pain that is perceived to originate from the remaining
30 portion of the amputated limb.¹⁻³ Phantom limb pain (PLP) is a condition in which pain is
31 perceived in the amputated limb which is no longer present.²⁻⁶ Persons with limb loss often
32 report both PLP and RLP, but RLP is more common in the acute and subacute periods after
33 amputation while PLP can be more predominate months after amputation.¹ The prevalence of
34 PLP previously reported in the literature has a wide range from 40% to 80%.³⁻¹² The prevalence
35 of PLP in persons with upper extremity amputation has been reported to be in the 40-50%
36 range,^{3,4,13,14} whereas PLP following lower limb amputation has been reported to be as high as
37 70-80%.^{3,4,9,15-17} For some, the intensity and frequency of phantom limb pain may subside with
38 time, but PLP may persist indefinitely and result in significant pain interference, impairment
39 and disability.^{3,4,9,15-17} Most research to date has focused on lower limb loss and PLP, perhaps
40 due to the higher occurrence rate or the larger population of individuals with lower limb
41 amputation. Consequently, the prevalence and factors associated with PLP in persons with
42 upper extremity amputation has been less well described.

43

44

45 There is incomplete data available in the literature regarding risk factors associated with PLP
46 especially in those with upper limb amputation. Chronic PLP has been previously associated
47 with pre-operative pain, residual limb pain and time period since amputation.^{3,4,7,9,18-19} Persons
48 with upper limb amputation who experience phantom limb sensation also have an increased
49 risk of PLP with a relative risk for PLP of 11.3.⁷ Hanley et al. demonstrated that those who wore
50 a prosthesis were more likely to have chronic PLP, but the authors could not deduce whether
51 using a prosthesis contributed to pain or if it the prosthesis was used in order to help relieve
52 pain.² Additional studies have found that individuals who reported using a prosthesis were
53 significantly more likely to have PLP, these studies have not explored the relationship between
54 PLP and intensity of daily prosthesis use.^{2,7}

55

56 In those with upper limb loss, more proximal amputation levels (amputations above the elbow
57 and more proximal compared to amputations below the elbow) have been associated with an
58 increased risk of PLP.^{4,10} Smith et al. showed that amputation of the dominant limb was
59 associated with greater PLP, but use of the prosthesis on the dominant side was not associated
60 with change in pain symptoms.²⁰ Others have not been able to establish a relationship between
61 limb dominance and PLP.⁷ Depressive symptoms have predicted higher levels of PLP intensity
62 and bothersomeness while other psychological factors including stress and catastrophizing have
63 been noted to play a role in maintaining or aggravating PLP.^{5,21} In those with lower limb
64 amputation, a positive association between PLP and low back pain has been noted.¹³

65

66 Leveraging survey results from a large sample of Veterans with upper limb amputation, tThe
67 purposes of this manuscript are to describe the frequency and severity of phantom limb pain
68 (PLP) in Veterans with major upper limb amputation and quantify the association between PLP
69 and person, amputation, and prosthesis characteristics. ~~We hypothesized that greater hours of~~
70 ~~daily prosthesis use would be associated with reduced PLP intensity and frequency. We also~~
71 ~~hypothesized that amputation of the dominant limb would be associated with greater PLP~~
72 ~~intensity and frequency.~~

Commented [RL1]: Consider removing per Reviewer suggestion

74 **Methods**

75 Data for this study was derived from a larger, survey study (described in this paper) that
76 collected comprehensive data on function, needs, preferences, and prosthetic satisfaction in a
77 large cohort of Veterans with major upper limb amputation. Our analyses include the subset of
78 respondents who had unilateral major upper limb amputation.

80 **Survey Recruitment and Data Collection**

81 The Veteran sample was identified through the Veterans Affairs (VA) Corporate Data
82 Warehouse (CDW). Participants included all Veterans with major upper limb amputation who
83 received care at the VA between 2010-2016. Major upper limb amputation levels were defined
84 in our study as amputation at the forequarter, shoulder disarticulation, transhumeral (TH),
85 elbow disarticulation (ED), transradial (TR), or wrist disarticulation (WD) level. The sampling
86 frame was identified from VA CDW sources including Inpatient, Outpatient, and Fee domains;
87 the main source for information regarding VHA Benefit compensation and pension benefits

88 paid to Veterans and their beneficiaries; and Veteran's Benefits Administration (VBA) disability
89 ratings. A list of diagnosis and procedure codes used to identify the sample has been provided
90 in a separate publication.²²

91 All non-deceased Veterans with valid addresses and phone numbers were sent an initial
92 recruitment package containing an invitation letter, a study information sheet explaining the
93 study, and a card with stamped envelope to return if they wished to opt out of participation.
94 Veterans who did not opt-out of study participation by returning the postcard or calling the
95 study telephone number within 30 days were contacted by the study interviewers. To maximize
96 study recruitment, up to ten attempts were made to contact potential participants. All
97 participants provided oral informed consent to participate. A waiver of documentation of
98 informed consent was obtained from the VA Central IRB. All surveys were conducted via
99 telephone by trained interviewers and were approximately 45 minutes in length. The analyses
100 presented in this paper utilize data from respondents with unilateral limb loss. Persons with
101 bilateral upper limb amputation were excluded.

102 **Measures**

103 The survey instrument was comprehensive in nature and included questions designed to obtain
104 data related to person-level characteristics, amputation-specific characteristics (including
105 amputation level, years since amputation, and etiology of amputation), and prosthesis use
106 characteristics. Respondents indicated all etiologies of amputation that applied, and thus may
107 have indicated more than one etiology. Pain-related questions were used to assess phantom
108 limb pain and residual limb pain. In order to facilitate participant's understanding, phantom

109 limb was defined as feeling of the presence of limb that was lost. Residual limb was defined as
110 portion of the limb remaining after the amputation.

111
112 **Pain Frequency:** Participants were asked to rate their pain frequency in the past 4 weeks:
113 never, only once or twice, about once per week, two to three times per week, four to six times
114 per week, several times every day, all the time or almost all the time. For the purposes of data
115 analysis, pain frequency was categorized into 4 levels: Never, Weekly or less frequent, 2 to 6
116 times per week, and Daily to always.

117
118 **Pain Intensity:** Participants were also asked to rate their phantom and residual limb pain
119 intensity over the past 4-week time period. Pain intensity was scored on a 10-point scale with 0
120 representing no pain and 10 representing the worst possible pain. Pain intensity was
121 recategorized into 4 levels: Never had Pain, None to Mild (0-3), Moderate (4-7), and Severe (8-
122 10).

123 **Amputation Level:** For the purposes of data analysis, amputation levels were consolidated into
124 three amputation level categories. The transradial level includes those with wrist
125 disarticulation, transhumeral level includes those with elbow disarticulation, and shoulder level
126 includes forequarter and shoulder disarticulation amputation levels.

127 **Statistical Methods**

128 We examined descriptive statistics to characterize respondents by amputation level. We used
129 bivariate analyses to examine the relationships of covariates with PLP prevalence (using chi-

squared and two-tailed Fisher's exact tests) and PLP intensity (using Kruskal-Wallis tests because the assumption of normality was rejected [by the Shapiro-Wilk test in univariate analyses](#)). The purpose of the bivariate analyses was to identify possible associations between covariates and PLP prevalence and intensity that would be added to our multivariable models. We then used a two-part multivariable model; first using logistic regression predicting any PLP and then using linear regression predicting PLP intensity for those with any pain. Covariates that were statistically significant at $P < 0.1$ in bivariate analysis were added to the multivariable logistic and linear regressions to control for potential confounding and to identify other factors that were independent predictors of PLP intensity and frequency.

Results

Study Participants

Seven hundred fifty-five male participants and 21 female participants with unilateral major upper limb amputation completed some or all of the telephone survey. [There were 20 participants who did not complete all items in the survey; 16 of these did not complete the items addressing pain frequency and intensity.](#) Further details regarding the person, amputation, and prosthesis characteristics of the study population by amputation level are included in (Table 1). The average age was 63.2 years, 97.3% were males and 75.1% reported their race as White. The average time since amputation was 31.3 years. Approximately half of the participants (50.6%) reported amputation involving the dominant side. Transradial amputation was the most common level at 36%. Sixty-two percent of the sample reported accident as the etiology of amputation. Among those who reported wearing a prosthesis

151 (N=461; 59%), the majority (70.7%) reported using a body-powered prosthesis and 42.1%
152 reported using a prosthesis for more than 8 hours per day.

153

154 **Frequency and Severity of Pain Syndromes**

155 Table 2 shows the reported frequency of both PLP and RLP in study participants. PLP frequency
156 in the “daily to always” category was reported in 42% of the sample. 27% of participants
157 reported that they never had PLP in the past 4 weeks. RLP frequency in the “daily to always”
158 category was reported by 29.6%. Prevalence of PLP in the “daily to always” frequency category
159 was higher in respondents with more proximal amputation levels; 47.9% at transhumeral level
160 and 57.0% at the shoulder level compared to 34.6% at the transradial level (Figure 1).

161

162 Table 3 details the reported levels of pain intensity. In our sample, 73% reported some PLP with
163 a mean pain intensity of 4.2 (SD 3.4). Only about a quarter of participants reported PLP
164 intensity in the “never” category. Similar to residual limb pain frequency, pain intensity in the
165 “moderate” and “severe” categories was also commonly reported in the residual limb. Again,
166 similar to PLP frequency, PLP intensity in the “moderate” and “severe” categories was more
167 prevalent in those with more proximal amputation levels; 65.5% at transhumeral level and
168 67.4% at the shoulder level compared to 48.6% at the transradial level (Figure 2). Of note,
169 about 23% of the Veterans rated their PLP intensity in the “severe” category which is
170 significantly higher compared to the residual limb (13%).

171

172 **Associations between Person, Amputation, and Prosthesis Characteristics and PLP**

In bivariate analyses of PLP frequency, the following variables were statistically significant at $p \leq 0.1$: race, amputation of dominant side, age, time since amputation, amputation level, amputation etiology (from combat, burns, and cancer), residual limb and neck pain frequency and intensity, and self-suspension prosthesis types [Appendix Table 1]. In bivariate analyses of PLP intensity (for those with any pain), the following variables were statistically significant at $p \leq 0.1$: race, ethnicity, age, amputation level, residual limb and neck pain frequency and intensity, and prosthesis types using harnessing [Appendix Table 2].

In multivariable models (Table 4), we found that those who had residual limb pain “weekly or less frequent” [OR 3.32 (1.77, 6.20)], “2 to 6 times per week” [OR 6.55 (2.78, 15.44)], and “daily to always” [OR 8.75 (3.52, 21.79)], had significantly higher odds of having any PLP compared to those who never had residual limb pain in the prior 4 weeks. Amputation at shoulder level [OR 3.78 (1.93, 7.39)], amputation at transhumeral level [OR 1.76 (1.10, 2.81)], etiology of cancer [OR 5.33 (1.15, 24.81)] and use of self-suspending prostheses [OR 1.79 (1.06, 3.03)] were also associated with any PLP. Amputation etiology of combat injury [OR 0.62 (0.40, 0.97)] and burn [OR 0.50 (0.26, 0.94)] were associated with reduced occurrence of PLP.

Moderate ($\beta=1.34$, $p<0.0001$) and severe ($\beta=3.31$, $p<0.0001$) residual limb pain intensity was associated with higher PLP intensity among those with pain. However, those who had neck pain “daily to always” had lower ($\beta=-0.77$, $p=0.03$) PLP intensity than those who never had neck pain. Amputation at the shoulder level was associated with a 1.5 points higher pain scores ($p=0.0001$) compared to at the transradial level. Multivariable models failed to show an association between PLP and amputation of the dominant limb. Bivariate analyses did not

195 indicate any statistically significant relationship between PLP and type of prosthesis, or intensity
196 of daily prosthesis use.

197

198 **Discussion**

199 Major upper limb amputation has the potential to result in significant alterations in physical
200 performance, body image, and activity participation.²² Phantom limb pain is an important
201 consideration following upper limb amputation because it is both frequently occurring and
202 long-lasting. Appropriate awareness and identification of PLP is also critical because of its
203 potential associated functional implications.^{2,3,15-17,23-24}

204

205 The pathophysiology underlying PLP is complex and multifaceted.^{3,12,25-29} While several
206 different theories exist, the etiology of phantom phenomena has been categorized primarily
207 into three anatomical locations and mechanisms: supraspinal, spinal and peripheral.^{3,25-29} The
208 supraspinal mechanism focuses on reorganization of somatosensory cortex surrounding the
209 area representing deafferented limb.^{1, 3,25-31} The spinal mechanism focuses on functional
210 changes in the dorsal horn due to deafferentation from peripheral nerve injury.^{1,3,30-31} Finally,
211 the peripheral mechanism describes axonal nerve damage during amputation and the
212 downstream effects of inflammation and regenerative sprouting.^{1,3,30-31} Inevitably, pain after
213 amputation is likely a combination of multiple different mechanisms and the contribution from
214 each mechanism may vary by individual.

215

Although prior studies have examined the frequency of phantom limb pain following amputation, there is variability in the previously reported prevalence and a limited body of investigations specific to individuals with upper limb amputation.³⁻¹¹ Many prior studies have also been limited by small sample sizes and incomplete descriptions of PLP chronicity, intensity, and frequency. In addition, the pathophysiology underlying PLP is complex as described above, so understanding of the factors associated with pain frequency and intensity may provide insights into the management of those factors that are modifiable. For example, addressing residual limb pain may have the potential to impact the intensity and frequency of PLP. The currently available literature has not clearly delineated these variables associated with PLP.^{3-11,32}

The findings from this study are significant for several reasons. This investigation involved a large cohort and specifically addresses the population of Veterans with upper limb amputation. This cohort represents a broad sample of Veterans with upper limb amputation who received any type of care in the Department of Veterans Affairs. The study adds to the previously reported literature on the prevalence of PLP, confirming that PLP is a very common condition and that the prevalence may be higher than previous reports. The accuracy of our prevalence estimates is strengthened by the large sample size and representativeness of the sample. Findings also supports the commonly held belief that PLP symptoms are frequently chronic in those with upper limb amputation as the average time since amputation in our sample was 31 years. Providers should be aware of the chronicity of PLP and continue to recognize signs and symptoms of this phenomena.

237

238 The results of our study, may also provide clinicians a greater appreciation of the relationship
239 between patient, amputation, and prosthesis characteristics and PLP. Despite our original
240 hypotheses, we found no significant association between PLP and amputation of dominant
241 limb, intensity of prosthesis use, or type of prosthesis used in bivariate analyses and did not add
242 these variables to the multivariable models. Our study adds to the literature reporting an
243 association between frequency and intensity of PLP and amputation level with Veterans with
244 more proximal upper limb amputation being more likely to have higher intensity and frequency
245 PLP. This is an important finding for clinicians to take into consideration in the counseling and
246 management of persons with more proximal amputation levels. Similar to prior investigations,
247 this study found an association between moderate intensity residual limb pain and any PLP as
248 well as higher PLP intensity among those with worse residual limb pain intensity.⁹ The finding
249 that participants with neck pain in our study experienced lower PLP intensity is interesting and
250 might be explained by the pain signals in the more proximal neck segment creating a
251 modulating effect on the more distal PLP signals. This finding should be explored further in the
252 future.

253

254 When comparing amputations due to cancer to amputations not due to cancer, we found that
255 amputation due to cancer was associated with PLP. This finding is consistent with reports from
256 prior studies that found that PLP was highly prevalent in individuals with amputation due to
257 cancer.^{10,33} These prior studies also reported that PLP was more common than residual limb or

stump pain in persons with amputation due to cancer.^{10,33} Higher PLP in persons with an amputation etiology of cancer could be secondary to hypersensitization of nerves in setting of the malignancy or perhaps due to adjunct therapies such as chemotherapy and/or radiation. The finding that burn amputation etiology is associated with a reduced occurrence of PLP is novel and the underlying mechanism for this finding is not clear. These findings should be interpreted with some caution because the etiology of amputation was determined by self-report and participants were able to identify more than one etiology. Thus, it was unclear in these cases which etiology was primary. Further studies should be performed to help delineate the association between cause of amputation and PLP.

This investigation has several limitations. Survey respondents were all Veterans who received some care in the Department of Veterans Affairs which may limit the generalizability of findings to a wider population of persons with upper limb amputation. Our data was collected through telephone survey and pain-related questions asked participants to rate their pain level over a 4-week time period. It is possible that some participants did not recall their pain accurately over this time period. This methodology differs from some previously published studies which used self-applied questionnaires instead of interviews.^{7,15} Our survey instrument was long, and it is possible that some respondents became fatigued during interviews, and that this adversely affected their recall. Because of the cross-sectional nature of this study, we were not able to characterize changes in PLP intensity or frequency over time. Our sample was primarily male, and findings may not generalize well to females with limb loss. Finally, the observational study design identifies factors associated with PLP and cannot be used to demonstrate causality.

279

280 **Conclusion**

281 This study found that moderate intensity PLP and daily to constant PLP is common in Veterans

282 with upper limb amputation. It also found an association between PLP and residual limb pain,

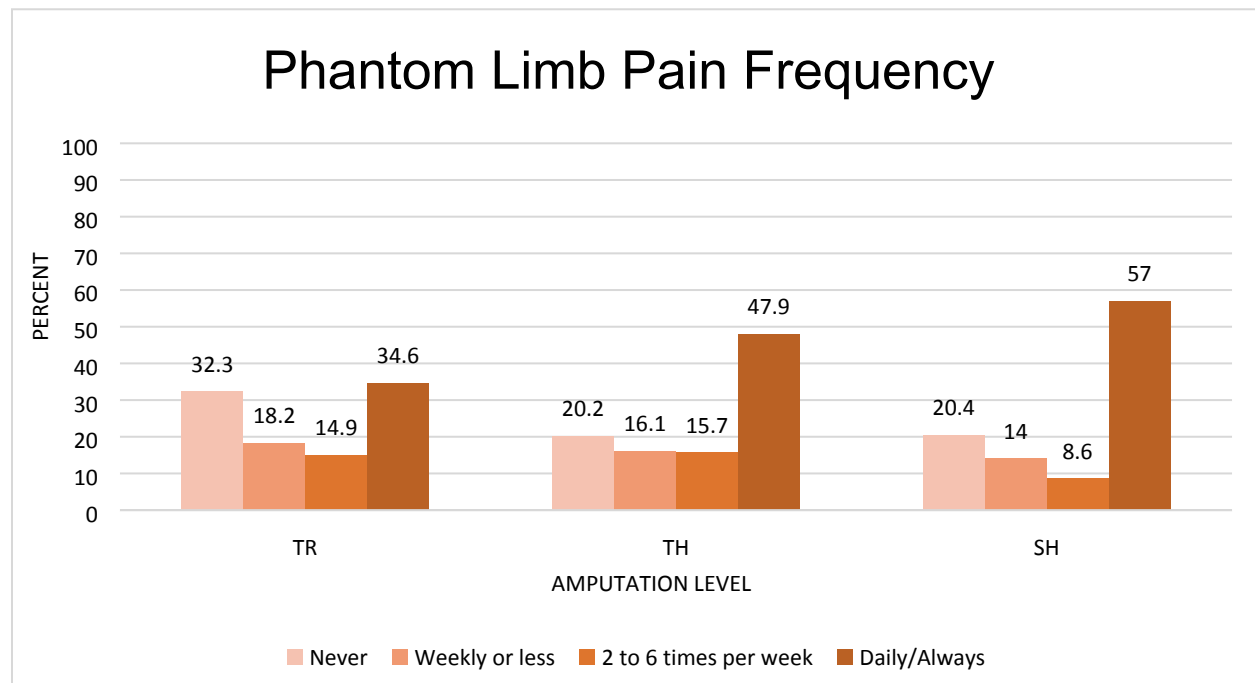
283 proximal amputation levels, and amputation due to cancer. The study found no significant

284 association between PLP and amputation of dominant limb, intensity of daily prosthesis use, or

285 type of prosthesis used.

286

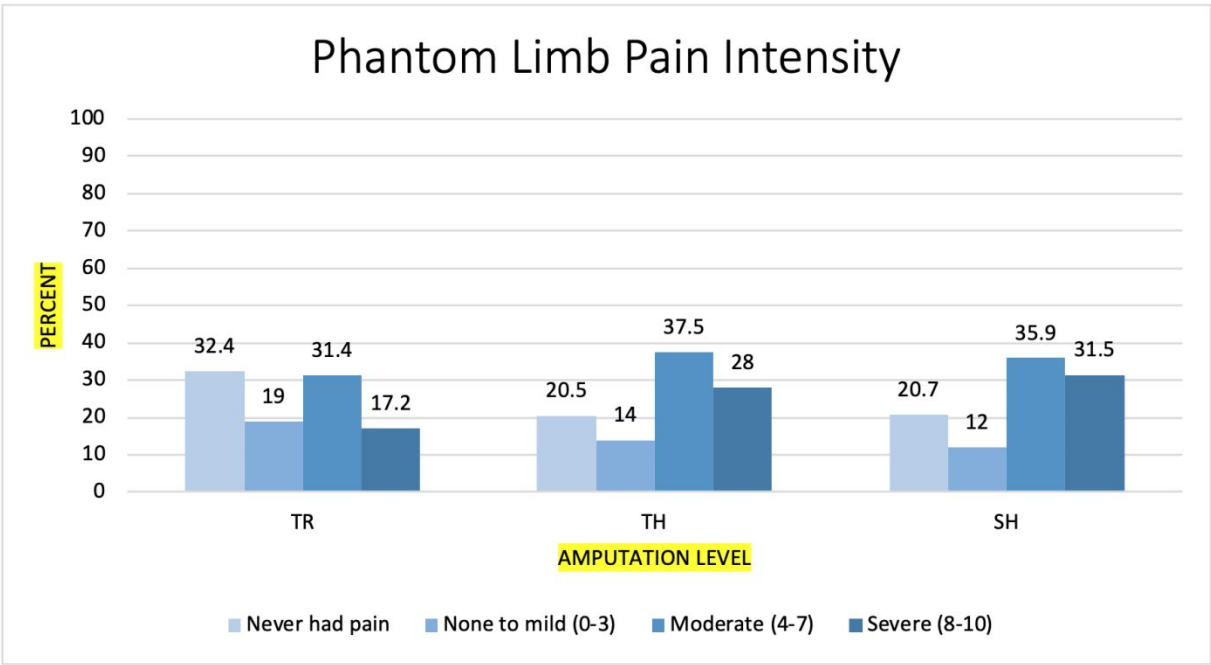
287

Figure 1: Phantom Limb Pain Frequency by Amputation Level

*TR= Transradial, TH= Transhumeral, SH= Shoulder/Forequarter

**Pain Frequency in last 4 weeks classified as Never= 'Never'; Weekly or less frequent= 'only once or twice' and 'about once per week'; 2 to 6 times per week= '2 to 3 times per week' and '4 to 6 times per week'; and Daily/Always= 'several times every day' and 'all the time or almost all the time'.

Figure 2: Phantom Limb Pain Intensity by Amputation Level



*TR= Transradial, TH= Transhumeral, SH= Shoulder/Forequarter

Manuscript Tables and Graphs

Table 1. Characteristics of Study Participants (N=776)

Characteristic	Transradial (N=406)	Transhumeral (N=2756)	Shoulder/FQ (N=954)
PERSON CHARACTERISTICS	Mn (sd)	Mn (sd)	Mn (sd)
Age (Yrs)	63.6 (14.2)	62.8 (13.4)	632.09 (15.5)
	N (%)	N (%)	N (%)
Gender			
Male	397 (97.8)	2656 (96.4)	923 (97.9)
Female	9 (2.2)	10 (3.6)	2 (2.1)
Race			
White	320 (78.8)	194 (70.36)	69 (723.64)
Black	36 (8.9)	343 (12.03)	167 (17.90)
Unknown	35 (8.6)	31 (11.32)	6 (6.43)
Other/Mixed	15 (4.7)	17 (6.2)	3 (3.2)
Hispanic			
Yes	27 (6.7)	30 (10.9)	5 (5.3)
No	360 (88.7)	2310 (83.76)	887 (92.6)
Don't Know/Unsure	19 (4.7)	15 (5.45)	2 (2.1)
AMPUTATION CHARACTERISTICS	Mn (sd)	Mn (sd)	Mn (sd)
Years Since Amputation	32.4 (18.5)	31.3 (17.8)	26.64 (18.87)
Age at Time of Amputation	31.1 (13.1)	31.87 (13.34)	36.04 (16.64)
	N (%)	N (%)	N (%)
Amputation Level			
Forequarter	0 (0.0)	0 (0.0)	23 (24.52)
-Shoulder disarticulation	0 (0.0)	0 (0.0)	712 (75.58)
-Transhumeral	0 (0.0)	236 (85.5)40 (14.6)	0 (0.0)
-Elbow disarticulation	0 (0.0)	40 (14.5)235 (85.5)	0 (0.0)
-Transradial	280 (69.0)	0 (0.0)	0 (0.0)
-Wrist disarticulation	126 (31.0)	0 (0.0)	0 (0.0)
Amputation Etiology			
Combat injury	161 (39.7)	89 (32.34)	25 (26.36)
Accident	261 (64.3)	1668 (60.49)	54 (567.85)
Burn	57 (14.0)	2190 (67.39)	54 (45.23)
Cancer	7 (1.7)	78 (2.59)	156 (157.08)
-Diabetes	5 (1.2)	5 (1.8)	1 (1.1)
Infection	32 (7.9)	4039 (14.52)	145 (145.89)
Amputation of Dominant Side			
Yes	221 (54.4)	127 (46.0)	45 (47.9)
No	182 (44.8)	148 (53.6)	48 (51.1)
Unknown	3 (0.7)	1 (0.4)	1 (1.1)
Prosthetic Users	TR (N=313)	TH (N=1201)	SH (N=278)
PROSTHESIS CHARACTERISTICS	N (%)	N (%)	N (%)
Type of Primary Prosthesis			
Body powered	217 (69.3)	95 (7978.52)	14 (501.0.9)

Myoelectric	71 (22.7)	176 (143.03)	89 (2932.61)
Hybrid	3 (1.0)	2 (1.7)	1 (3.76)
Cosmetic	14 (4.5)	4 (3.3)	4 (14.83)
Sports/recreation	4 (1.3)	2 (1.7)	0 (0.0)
Unknown	4 (1.3)	1 (0.8)	0 (0.0)
Type Suspension			
<u>Suction</u>	<u>105 (33.6)</u>	<u>45 (37.2)</u>	<u>6 (22.2)</u>
<u>Gel or silicone liner with pin</u>	<u>60 (19.2)</u>	<u>25 (20.7)</u>	<u>6 (22.2)</u>
<u>Vacuum</u>	<u>32 (10.2)</u>	<u>17 (14.1)</u>	<u>2 (7.4)</u>
<u>Self-suspending</u>	<u>123 (39.3)</u>	<u>41 (33.9)</u>	<u>8 (29.6)</u>
<u>Harnessing</u>	<u>210 (67.1)</u>	<u>109 (90.1)</u>	<u>26 (96.3)</u>
<u>External sleeve</u>	<u>42 (13.4)</u>	<u>18 (14.9)</u>	<u>2 (7.4)</u>
Intensity of daily Prosthesis Use			
Less than 2 hours	49 (15.7)	32 (26.57)	7 (25.90)
2 to less than 4 hours	20 (6.4)	15 (12.45)	7 (25.90)
4 to less than 8 hours	54 (17.3)	25 (20.78)	6 (22.24)
8 to less than 12 hours	67 (21.4)	19 (15.78)	2 (7.41)
12 hours or more	121 (38.7)	2526 (210.58)	65 (2118.45)
Don't know/unsure	2 (0.6)	4 (3.3)	0 (0.0)

Table 2. Pain Frequency in Study Participants by Amputation Level (N=776)

	Transradial (N=406)	Transhumeral (N=275276)	Shoulder/FQ (N=954)
Pain Frequency*	N (%)	N (%)	N (%)
Phantom Limb Pain			
<u>Never</u>	<u>128 (32.3)</u>	<u>54 (20.2)</u>	<u>19 (20.4)</u>
<u>Weekly or less frequent</u>	<u>72 (18.2)</u>	<u>43 (16.1)</u>	<u>13 (14.0)</u>
<u>2 to 6 times per week</u>	<u>59 (14.9)</u>	<u>42 (15.7)</u>	<u>8 (8.6)</u>
<u>Daily/Always</u>	<u>137 (34.6)</u>	<u>128 (47.9)</u>	<u>53 (57.0)</u>
–Never to Very Infrequent (1-2)–	172 (43.4)	81 (30.5)	30 (31.9)
–Low to Moderate Frequency (3-5)	87 (22.0)	56 (21.1)	12 (12.8)
–Moderate to Always (6-7)–	137 (34.6)	129 (48.5)	52 (55.3)
Residual Limb Pain			
<u>Never</u>	<u>151 (38.0)</u>	<u>80 (30.1)</u>	
<u>Weekly or less frequent</u>	<u>81 (20.4)</u>	<u>56 (21.1)</u>	
<u>2 to 6 times per week</u>	<u>66 (16.6)</u>	<u>33 (12.4)</u>	
<u>Daily/Always</u>	<u>99 (24.9)</u>	<u>97 (36.5)</u>	
–Never to Very Infrequent (1-2)–	198 (49.9)	117 (44.0)	1 (100.0)
–Low to Moderate Frequency (3-5)	100 (25.2)	52 (19.6)	0 (0.0)
–Moderate to Always (6-7)–	99 (24.9)	97 (36.5)	0 (0.0)

* Pain Frequency in last 4 weeks classified as

Legend: Never='Never'; Weekly or less frequent='only once or twice' and 'about once per week'; 2 to 6 times per week='2 to 3 times per week' and '4 to 6 times per week'; and Daily/Always='several times every day' and 'all the time or almost all the time'.

Table 3. Pain Intensity in Study Participants by Amputation Level (N=776)

	Transradial (N=406)	Transhumeral (N=2765)	Shoulder/FQ (N=954)
<i>Pain Intensity</i>			
Phantom Limb Pain			
Never had pain	128 (32.4)	54 (20.5)	19 (20.74)
None to Mild (0-3)	75 (19.0)	37 (14.04)	11 (121.80)
Moderate (4-7)	124 (31.4)	998 (37.53)	334 (356.69)
Severe (8-10)	68 (17.2)	74 (28.04)	29 (31.25)
Residual Limb Pain			
Never had pain	151 (38.0)	804 (30.15)	0 (0.0)
None to Mild (0-3)	72 (18.1)	410 (15.40)	1 (100.0)
Moderate (4-7)	135 (34.0)	98 (36.8)	0 (0.0)
Severe (8-10)	39 (9.8)	47 (17.7)	0 (0.0)

Table 4. Separate Multivariable models of Presence of Phantom Limb Pain and Phantom Limb Pain Intensity

	Logistic Regression: Any PLP (yes/no) N=706		Linear Regression: Intensity (0-10) N=541	
	OR, (95% CI)	P	B (95%CI)	P
Race				
White (ref) (n=583)				
Black (n=86)	1.77 (0.84, 3.71)	0.13	0.18 (-0.41, 0.77)	0.39
Unknown (n=72)	1.16 (0.50, 2.68)	0.73	0.85 (-0.09, 1.79)	0.09
Other/Mixed (n=35)	1.07 (0.35, 3.20)	0.91	0.38 (-0.48, 1.23)	0.34
Hispanic				
Yes (n=62)			0.51 (-0.29, 1.31)	0.21
No (ref) (n=678)				
Don't Know/Unsure (n=36)			-0.18 (-1.87, 1.52)	0.84
Amputation of Dominant Side				
Yes (n=393)	0.70 (0.48, 1.04)	0.08	-0.21	0.31
No (ref) (n=376)				
Age at time of study				
[18,45) (ref) (n=99)				
[45,65) (n=207)	0.99 (0.44, 2.22)	0.97	0.16 (-0.48, 0.79)	0.63
[65,75) (n=340)	0.91 (0.40, 2.05)	0.81	-0.10 (-0.70, 0.51)	0.76
75+ (n=106)	0.79 (0.30, 2.05)	0.63	-0.43 (-1.21, 0.35)	0.28
Time since amputation				
[0,20) (ref) (n=264)				
[20,50) (n=391)	0.80 (0.45, 1.42)	0.45		
50+ (n=100)	0.89 (0.40, 1.97)	0.78		
Amputation Level				
Shoulder/FQ (n=94)	3.78 (1.93, 7.39)	0.0001	1.54 (0.79, 2.30)	<0.0001
Transhumeral/ED (n=276)	1.76 (1.10, 2.81)	0.01	0.21 (-0.24, 0.67)	0.35
Transradial/WD (ref) (n=406)			0.24	0.31
Residual Limb Pain Frequency				
Never had pain (ref) (n=325)				
Weekly or less frequent (n=137)	3.32 (1.77, 6.20)	0.0002	-0.34 (-1.04, 0.36)	0.34
None to Mild (0-3)			0.25	0.54

<u>2 to 6 times per week (n=99)</u> <u>Moderate (4-7)</u>	6.55 (2.78, 15.44)	<0.0001	<u>-0.18 (-0.97, 0.61)</u> <u>1.16</u>	<u>0.65</u> <u>0.0053</u>
<u>Daily/Always (n=196)</u> <u>Severe (8-10)</u>	8.75 (3.52, 21.79)	<0.0001	<u>-0.41 (-1.20, 0.38)</u> <u>3.16</u>	<u>0.30</u> <0.0001
<u>Residual Limb Pain Intensity</u> <u>Residual limb pain frequency</u>				
<u>Never had pain (n=325)</u>	-			
None to Mild (ref) (n=113)				
Moderate (n=233)	1.39 (0.68, 2.85)	0.37	1.34 (0.74, 1.93)	<0.0001
Severe (n=86)	1.15 (0.42, 3.14)	0.79	3.31 (2.50, 4.11)	<0.0001
<u>Neck Pain Frequency</u>				
Never had pain (ref) (n=303)				
Weekly or less frequent (n=151)	1.13 (0.62, 2.06)	0.69	-0.65 (-1.31, 0.01)	0.05
2 to 6 times per week (n=111)	1.04 (0.50, 2.19)	0.91	-0.73 (-1.49, 0.03)	0.06
Daily/Always (n=195)	1.20 (0.55, 2.59)	0.65	-0.77 (-1.50, -0.05)	0.03
<u>Neck Pain Intensity</u>				
<u>Never had pain (n=303)</u>	-			
None to Mild (ref) (n=115)				
Moderate (n=254)	1.64 (0.88, 3.06)	0.12	1.37 (0.76, 1.98)	<0.0001
Severe (n=88)	1.48 (0.55, 4.02)	0.44	1.90 (1.09, 2.71)	<0.0001
<u>Never to Very Infrequent (1-2) (ref)</u>				
<u>Low to Moderate Frequency (3-5)</u>	<u>2.20 (1.03, 4.72)</u>	0.0425	<u>-0.11</u>	<u>0.7734</u>
<u>Moderate to Always (6-7)</u>	<u>3.31 (1.35, 8.13)</u>	0.0090	<u>-0.32</u>	<u>0.4154</u>
<u>Amputation Etiology</u>				
<u>Combat injury</u>				
<u>Yes (n=275)</u>	0.62 (0.40, 0.97)	0.0347		
<u>No (ref) (n=500)</u>				
<u>Burn</u>				
<u>Yes (n=81)</u>	0.50 (0.26, 0.94)	0.0315		
<u>No (ref) (n=693)</u>				
<u>Cancer</u>				
<u>Yes (n=30)</u>	5.33 (1.15, 24.81)	0.0329		
<u>No (ref) (n=744)</u>				
<u>Prosthesis Use</u>				
<u>Yes (n=461)</u>	0.97 (0.60, 1.56)	0.8845	<u>-0.65 (-1.30, 0.00)</u> <u>0.11</u>	<u>0.040</u> <u>0.7383</u>
<u>No (ref) (n=306)</u>				
<u>Type Prosthesis</u>				
<u>Body powered (ref)</u>				
<u>Myoelectric/Hybrid</u>	<u>0.76 (0.40, 1.43)</u>	<u>0.3869</u>	<u>0.24</u>	<u>0.4754</u>
<u>Other</u>	<u>0.93 (0.32, 2.66)</u>	<u>0.8906</u>	<u>-0.33</u>	<u>0.5602</u>
<u>Suspension Type</u>				
<u>Gel or silicone liner with pin</u>				
<u>No (ref)</u>				
<u>Yes</u>			<u>0.22</u>	<u>0.5119</u>
<u>Self-suspending</u>				

<u>Yes (n=172)</u>	1.79 (1.06, 3.03)	0.03298		
<u>No (ref) (n=273)</u>				
<u>Harnessing</u>				
<u>Yes (n=345)</u>			<u>0.33 (-0.27, 0.94)</u>	<u>0.28</u>
<u>No (ref) (n=113)</u>				
<u>—Yes</u>		0.0195		
Intensity of daily Prosthesis Use				
<u>—Less than 2 hours (ref)</u>				
<u>—2 to less than 4 hours</u>	0.68 (0.24, 1.97)	0.4789	-0.37	0.4634
<u>—4 to less than 8 hours</u>	0.56 (0.23, 1.32)	0.1837	-0.33	0.4329
<u>—8 to less than 12 hours</u>	0.50 (0.21, 1.17)	0.1114	-0.39	0.3807
<u>—12 hours or more</u>	0.78 (0.36, 1.68)	0.5242	-0.49	0.2101
Amputation Etiology				
<u>—Combat injury</u>	0.64 (0.41, 1.01)	0.0532		
<u>—Yes</u>				
<u>—No (ref)</u>				
<u>—Burn</u>				
<u>—Yes</u>	0.47 (0.25, 0.90)	0.0224		
<u>—No (ref)</u>				
<u>—Cancer</u>				
<u>—Yes</u>	5.33 (1.15, 24.72)	0.0324		
<u>—No (ref)</u>				

*Empty shaded boxes indicate variables that were not significant at $p < 0.1$ in bivariate analyses, and were not included in the models.

Appendix A

Table A1. ~~Frequency~~ Prevalence of Phantom Limb Pain by Person-Specific Characteristics:
Bivariate Analyses.

Characteristic	No Pain (N=201)	Some pain (N=555)	<u>Chi-squared</u> tests			<u>Fisher's</u> <u>Exact P</u>
			<u>Statistic</u>	<u>Degrees of</u> <u>freedom</u>	<u>p-value</u>	<u>p-value</u>
Gender			<u>1.4</u>	<u>1</u>	<u>0.23</u>	<u>0.31096</u>
Male	198 (26.9)	538 (73.1)				
Female	3 (15.0)	17 (85.0)				
Race			<u>10.8</u>	<u>3</u>	<u>0.01</u>	<u>0.0128</u>
White	170 (29.3)	411 (70.7)				
Black	13 (15.1)	73 (84.9)				
Unknown	13 (24.1)	41 (75.9)				
Other/Mixed	5 (14.3)	30 (85.7)				
Hispanic			<u>1.8</u>	<u>2</u>	<u>0.40</u>	<u>0.4029</u>
Yes	12 (19.7)	49 (80.3)				
No	183 (27.1)	493 (72.9)				
Don't Know/Unsure/missing	6 (31.6)	13 (68.4)				
Amputation of Dominant Side			<u>6.9</u>	<u>1</u>	<u>0.01</u>	<u>0.0088</u>
Yes	118 (59.0)	267 (48.2)				
No	82 (41.0)	287 (51.8)				
Hand Dominance Prior to Amputation			<u>0.4273</u>			
-Left	<u>30 (31.9)</u>	<u>64 (68.1)</u>				
-Right	<u>164 (25.9)</u>	<u>470 (74.1)</u>				
-Both	<u>6 (23.1)</u>	<u>20 (76.9)</u>				
Age at time of study			<u>10.0</u>	<u>3</u>	<u>0.02</u>	<u>0.0186</u>
[18,45)	21 (21.2)	78 (78.8)				
[45,65)	44 (21.4)	162 (78.6)				
[65,75)	97 (28.6)	242 (71.4)				
75+	38 (36.2)	67 (63.8)				
Time since amputation			<u>12.1</u>	<u>2</u>	<u>0.0023</u>	<u>0.0023</u>
[0,20)	51 (19.5)	211 (80.5)				
[20,50)	112 (29.6)	266 (70.4)				
50+	34 (35.1)	63 (65.0)				
Amputation Level			<u>14.0</u>	<u>2</u>	<u>0.0009</u>	<u>0.0009</u>
~~Shoulder/FQ—Transradial/WD~~	<u>19</u> <u>(20.4)</u> <u>128</u> <u>(32.3)</u>	<u>74 (79.6)</u> <u>268</u> <u>(67.7)</u>				
Transhumeral/ED	54 (20.2)	213 (79.8)				
~~Transradial/WD—Shoulder/FQ~~	<u>128</u> <u>(32.3)</u> <u>49</u> <u>(20.4)</u>	<u>268 (67.7)</u> <u>74</u> <u>(79.6)</u>				
Amputation Etiology						
~~Combat injury~~			<u>10.4</u>	<u>1</u>	<u>0.0013</u>	<u>0.0013</u>
Yes	90 (33.6)	178 (66.4)				
No	111 (22.8)	377 (77.3)				

Commented [BM1]: We decided amputation of dominant side was the what we wanted to look at. L vs R is not listed in text.

<i>Accident</i>			<u>0.6</u>	<u>1</u>	<u>0.50</u>	<u>0.5014</u>
Yes	121 (25.7)	349 (74.3)				
No	80 (28.0)	206 (72.0)				
<i>Burn</i>			<u>3.9</u>	<u>1</u>	<u>0.05</u>	<u>0.0494</u>
Yes	28 (35.9)	50 (64.1)				
No	173 (25.5)	505 (74.5)				
<i>Cancer</i>			<u>6.4</u>	<u>1</u>	<u>0.01</u>	<u>0.010.010</u> <u>1</u>
Yes	2 (6.7)	28 (93.3)				
No	199 (27.4)	527 (72.6)				
<i>Diabetes</i>			<u>1.8</u>	<u>1</u>	<u>0.19</u>	<u>0.3045</u>
Yes	1 (9.1)	10 (90.9)				
No	200 (26.9)	545 (73.2)				
<i>Infection</i>			<u>0.1</u>	<u>1</u>	<u>0.77</u>	<u>0.9304</u>
Yes	22 (26.2)	62 (73.8)				
No	179 (26.6)	493 (73.4)				
Residual Limb Pain Frequency			<u>130.2</u>	<u>3</u>	<u><0.0001</u>	<u><0.0001</u>
Never had pain–Never had pain	<u>124</u> <u>(68.1)</u> <u>124</u> <u>(53.9)</u>	<u>106</u> <u>(22.2)</u> <u>106</u> <u>(46.1)</u>				
Weekly or less frequent–None to Mild (0–3)	<u>30</u> (16.5) <u>22</u> <u>(19.6)</u>	<u>107</u> (22.4) <u>90</u> <u>(80.4)</u>				
2 to 6 times per week–Moderate (4–7)	<u>12</u> (6.6) <u>28</u> <u>(12.1)</u>	<u>87</u> (18.2) <u>204</u> <u>(87.9)</u>				
Daily/Always–Severe (8–10)	<u>16</u> (8.8) <u>8</u> <u>(9.3)</u>	<u>178</u> (37.2) <u>78</u> <u>(90.7)</u>				
Residual Limb Pain Intensity			<u>125.7</u>	<u>3</u>	<u><0.0001</u>	<u><0.0001</u>
Never had pain	<u>124</u> (53.9)	<u>106</u> (46.1)				
None to Mild	<u>22</u> (19.6)	<u>90</u> (80.4)				
Moderate	<u>28</u> (12.1)	<u>204</u> (87.9)				
Severe	<u>8</u> (9.3)	<u>78</u> (90.7)				
–Never to Very Infrequent (1–2)	<u>145</u> (46.2)	<u>169</u> (53.8)				
–Low to Moderate Frequency (3–5)	<u>21</u> (13.8)	<u>131</u> (86.2)				
–Moderate to Always (6–7)	<u>16</u> (8.3)	<u>178</u> (91.8)				
Neck Pain Frequency			<u>34.3</u>	<u>3</u>	<u><0.0001</u>	<u><0.0001</u>
Never had pain–Never had pain	<u>113</u> <u>(56.2)</u> <u>113</u> <u>(37.5)</u>	<u>188</u> <u>(33.9)</u> <u>188</u> <u>(62.5)</u>				
Weekly or less frequent–None to Mild (0–3)	<u>37</u> (18.4) <u>33</u> <u>(28.7)</u>	<u>114</u> (20.5) <u>82</u> <u>(71.3)</u>				
2 to 6 times per week–Moderate (4–7)	<u>21</u> (10.5) <u>45</u> <u>(17.9)</u>	<u>89</u> (16.0) <u>207</u> <u>(82.1)</u>				

Daily/Always–Severe (8–10)	30 (14.9)40 (11.4)	164 (29.6)78 (88.6)				
Neck Pain IntensityNeck Pain Frequency			<u>39.1</u>	<u>3</u>	<u><0.0001</u>	<u><0.0001</u>
Never had pain	113 (37.5)	188 (62.5)				
None to Mild	33 (28.7)	82 (71.3)				
Moderate	45 (17.9)	207 (82.1)				
Severe	10 (11.4)	78 (88.6)				
Never to Very Infrequent (1–2)	138 (35.3)	253 (64.7)				
Low to Moderate Frequency (3–5)	33 (19.3)	138 (80.7)				
Moderate to Always (6–7)	30 (15.5)	164 (84.5)				
PROSTHESIS USERS (N=461)						
Type Prosthesis			<u>0.2</u>	<u>2</u>	<u>0.92</u>	
Body powered	94 (72.3)	223 (71.3)				
Myoelectric/Hybrid	29 (22.3)	70 (22.4)				
Other	7 (5.4)	20 (6.4)				
Type Suspension						
Suction			<u>0.4</u>	<u>1</u>	<u>0.52</u>	
Yes	41 (31.5)	109 (34.7)				
No	89 (68.5)	205 (65.3)				
Gel or silicone liner with pin			<u>2.4</u>	<u>1</u>	<u>0.12</u>	
Yes	20 (15.5)	69 (22.0)				
No	109 (84.5)	245 (78.0)				
Vacuum			<u>1.2</u>	<u>1</u>	<u>0.28</u>	
Yes	11 (8.5)	38 (12.1)				
No	118 (91.5)	276 (87.9)				
Self-suspending			<u>3.3</u>	<u>1</u>	<u>0.07</u>	
Yes	42 (32.8)	129 (42.2)				
No	86 (67.2)	177 (57.8)				
Harnessing			<u>0.2</u>	<u>1</u>	<u>0.68</u>	
Yes	96 (73.9)	240 (75.7)				
No	34 (25.2)	77 (24.3)				
External sleeve			<u>0.2</u>	<u>1</u>	<u>0.66</u>	
Yes	16 (12.9)	43 (14.5)				
No	108 (87.1)	253 (85.5)				
Intensity of Daily Prosthesis Use			<u>7.4</u>	<u>4</u>	<u>0.12</u>	
Less than 2 hours	19 (14.6)	67 (21.5)				
2 to less than 4 hours	9 (86.9)	31 (9.9)				
4 to less than 8 hours	21 (16.2)	63 (20.2)				
8 to less than 12 hours	29 (22.3)	56 (18.0)				
12 hours or more	52 (40.0)	95 (30.4)				

For Review Only

Table A2. Phantom Limb Pain Intensity by Person-Specific Characteristics: Bivariate Analyses.

Characteristic	All subjects (N= ~~751~~ 575) Mn (sd)	T-test/ANOVA/Kruskal-Wallis tests		
		Chi-squared statisticP	Degrees of freedom	p-value
Gender		0.0	1	0.94
Male	5.7 (2.6)4.2 (3.4)			
Female	5.8 (2.7)5.0 (3.3)			
Race		17.3	3	0.0006
White	5.5 (2.6)5.5 (3.3)			
Black	6.5 (2.5)5.4 (3.3)			
Unknown	6.8 (2.7)5.1 (3.8)			
Other/Mixed	6.3 (2.6)3.8 (3.3)			
Hispanic		6.7	2	0.03
Yes	6.7 (2.6)5.4 (3.6)			
No	5.6 (2.6)4.1 (3.4)			
Don't Know/Unsure	5.4 (3.6)3.7 (3.9)			
Amputation of Dominant Side		0.3	1	0.57
Yes	5.7 (2.5)3.9 (3.4)			
No	5.8 (2.7)4.5 (3.4)			
Don't Know/Unsure	5.3 (3.8)			
TMR Surgery				
Yes	4.3 (3.3)			
No	4.2 (3.4)			
Don't Know/Unsure				
Age at time of study		6.9	3	0.07
[18,45)	6.0 (2.5)4.7 (3.3)			
[45,65)	5.9 (2.5)4.7 (3.3)			
[65,75)	5.7 (2.8)4.1 (3.5)			
75+	5.0 (2.5)3.1 (3.2)			
Time since amputation		1.3	2	0.52

Commented [BM2]: Redo without those who never had pain – as in our plan for separate regression

[0,20)	<u>5.9 (2.5)4.7</u> (3.3)			
[20,50)	<u>5.7 (2.7)4.0</u> (3.5)			
50+	<u>5.5 (2.8)3.5</u> (3.4)			
Amputation Level		<u>11.0</u>	<u>2</u>	<u>0.0041</u>
<u>Shoulder/FQ—Transradial/WD</u>	<u>6.2 (2.5)3.6</u> (3.3)			
Transhumeral/ED	<u>6.1 (2.7)4.8</u> (3.4)			
<u>Transradial/WD—Shoulder/FQ</u>	<u>5.4 (2.6)4.9</u> (3.4)			
Amputation Etiology				
Combat injury		<u>1.5</u>	<u>1</u>	<u>0.22</u>
<u>Yes—No</u>	<u>5.5 (2.7)4.5</u> (3.4)			
<u>No—Yes</u>	<u>5.8 (2.6)3.7</u> (3.4)			
Accident		<u>0.6</u>	<u>1</u>	<u>0.45</u>
<u>Yes—No</u>	<u>5.8 (2.7)4.1</u> (3.4)			
<u>No—Yes</u>	<u>5.6 (2.6)4.3</u> (3.4)			
Burn		<u>0.0</u>	<u>1</u>	<u>1.00</u>
<u>Yes—No</u>	<u>5.7 (2.7)4.3</u> (3.4)			
<u>No—Yes</u>	<u>5.7 (2.6)3.7</u> (3.5)			
Cancer		<u>0.20</u>	<u>1</u>	<u>0.66</u>
<u>Yes—No</u>	<u>5.6 (2.6)4.2</u> (3.4)			
<u>No—Yes</u>	<u>5.7 (2.6)5.2</u> (2.9)			
Diabetes		<u>0.5</u>	<u>1</u>	<u>0.49</u>
<u>Yes—No</u>	<u>5.2 (2.6)4.2</u> (3.4)			
<u>No—Yes</u>	<u>5.7 (2.6)4.7</u> (2.9)			
Infection		<u>0.08</u>	<u>1</u>	<u>0.78</u>
<u>Yes—No</u>	<u>5.7 (2.4)4.2</u> (3.4)			
<u>No—Yes</u>	<u>5.7 (2.7)4.3</u> (3.3)			
Other				
<u>No</u>	4.2 (3.4)			
<u>Yes</u>	4.2 (3.4)			
Residual Limb Pain FrequencyResidual limb pain intensity		<u>37.2</u>	<u>3</u>	<u><0.0001</u>

Never had pain (n=231)–Never had pain	4.5 (2.9)2.4 (3.0)			
Weekly or less frequent (n=137) None to Mild (0-3)	5.3 (2.6)3.4 (2.8)			
2 to 6 times per week (n=99) Moderate (4-7)	5.8 (2.3)5.4 (2.7)			
Daily/Always (n=196)–Severe (8-10)	6.5 (2.4)7.6 (2.9)			
Residual Limb Pain Intensity		128.1	3	<0.0001
Never had pain (n=325)	4.5 (2.9)			
None to Mild (n=113)	4.2 (2.4)			
Moderate (n=233)	5.9 (2.0)			
Severe (n=86)	8.4 (1.6)			
–Never to Very Infrequent (1-2)	2.5(3.1)			
–Low to Moderate Frequency (3-5)	4.9 (3.0)			
–Moderate to Always (6-7)	6.0 (2.9)			
Neck Pain Frequency		21.2	3	<0.0001
Never had pain (n=303)–Never had pain	5.1 (2.6)3.2 (3.2)			
Weekly or less frequent (n=151) None to Mild (0-3)	5.5 (2.6)3.4 (2.9)			
2 to 6 times per week (n=111) Moderate (4-7)	6.1 (2.5)5.4 (3.3)			
Daily/Always (n=195)–Severe (8-10)	6.4 (2.6)6.6 (3.2)			
Neck Pain Intensity		71.5	3	<0.0001
Never had pain (n=303)	5.1 (2.6)			
None to Mild (n=115)	4.3 (2.4)			
Moderate (n=254)	6.2 (2.5)			
Severe (n=88)	7.4 (2.2)			
–Never to Very Infrequent (1-2)	3.3 (3.3)			
–Low to Moderate Frequency (3-5)	4.9 (3.2)			
–Moderate to Always (6-7)	5.4 (3.4)			
PROSTHESIS USERS (N=461)	Mn (sd)			
Type Prosthesis		1.4	2	0.49
Body powered	5.4 (2.6)3.8 (3.3)			
Myoelectric/Hybrid	5.8 (2.6)4.4 (3.4)			
Other	5.3 (2.9)3.9 (3.4)			
Type Suspension				
Suction		0.0	1	0.83

<u>Yes</u> — <u>No</u>	<u>5.5 (2.6)3.8</u> (3.4)			
<u>No</u> — <u>Yes</u>	<u>5.5 (2.7)4.0</u> (3.3)			
Gel or silicone liner with pin		<u>0.9</u>	<u>1</u>	<u>0.35</u>
<u>Yes</u> — <u>No</u>	<u>5.7 (2.5)3.7</u> (3.4)			
<u>No</u> — <u>Yes</u>	<u>5.4 (2.7)4.4</u> (3.2)			
Vacuum		<u>0.9</u>	<u>1</u>	<u>0.35</u>
<u>Yes</u> — <u>No</u>	<u>5.9 (2.4)3.8</u> (3.4)			
<u>No</u> — <u>Yes</u>	<u>5.4 (2.7)4.6</u> (3.2)			
Self-suspending		<u>0.3</u>	<u>1</u>	<u>0.58</u>
<u>Yes</u> — <u>No</u>	<u>5.4 (2.6)3.7</u> (3.4)			
<u>No</u> — <u>Yes</u>	<u>5.6 (2.7)4.1</u> (3.2)			
Harnessing		<u>3.0</u>	<u>1</u>	<u>0.09</u>
<u>Yes</u> — <u>No</u>	<u>5.6 (2.6)3.5</u> (3.3)			
<u>No</u> — <u>Yes</u>	<u>5.1 (2.7)4.0</u> (3.4)			
External sleeve		<u>2.7</u>	<u>1</u>	<u>0.10</u>
<u>Yes</u> — <u>No</u>	<u>6.1 (2.8)3.8</u> (3.3)			
<u>No</u> — <u>Yes</u>	<u>5.4 (2.6)4.5</u> (3.7)			
Intensity of ~~a~~Daily Prosthesis Use		<u>7.5</u>	<u>4</u>	<u>0.11</u>
Less than 2 hours	<u>5.8 (2.5)3.2</u> (3.2)			
2 to less than 4 hours	<u>6.1 (2.2)4.7</u> (3.2)			
4 to less than 8 hours	<u>5.9 (2.7)4.4</u> (3.4)			
8 to less than 12 hours	<u>5.5 (2.8)3.6</u> (3.5)			
12 hours or more	<u>4.9 (2.7)4.5</u> (3.3)			