

SEVERE UPPER LIMB INJURIES IN UNITED STATES ACTIVE COMPONENT
MILITARY PERSONNEL: INCIDENCE, RISK FACTORS AND OUTCOMES, 2003
TO 2012

by

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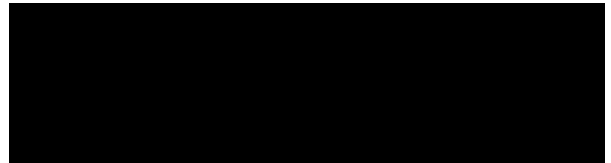
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DEDICATION

I dedicate this work to the men and women of the United States Armed Forces for their daily sacrifice and selfless service to our Nation.

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November 1, 2016

ABSTRACT

Title of Dissertation: Severe Upper Limb Injuries In U.S. Active Component Military Personnel: Incidence, Risk Factors and Outcomes, 2003 to 2012

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Purpose: The primary research objective was to determine the incidence, risk factors, and outcomes associated with Severe Upper Limb Injuries (SULI) in U.S. active component military personnel. The secondary research objective was to develop a surveillance definition for upper limb salvage (SAL) and determine risk factors for specific outcomes (chronic pain and attrition) in service members who underwent upper limb salvage.

Research Design: The present is an observational study of existing data contained in the Defense Medical Surveillance System (DMSS) and Defense Medical Epidemiology Database (DMED). The study utilized a retrospective cohort and case control study design. Additional descriptive analyses were conducted.

Methodology: All Active Component (AC) U.S. Military Personnel who served at any time during the period January 1, 2003 to December 31, 2012 who met the case definition for SULI were identified from DMSS. A random sample of military personnel from the same study period without SULI was identified and used as a comparison group for the analyses in Aims 2 and 3. Denominator data to calculate rates were obtained from DMED. Cases were characterized and incidence rates, incident rate ratios, upper extremity

healthcare utilization rates and 95% confidence intervals (CI) were estimated. Multiple logistic regression models were developed to analyze risk factors (i.e. gender, age, race, grade, service) associated with SULI. Among deployed service members a separate logistic regression model was used to evaluate additional deployment related factors (deployment length, location and frequency of deployment). Cox proportional hazards analyses were used to compare attrition rates between SMs with SULI and non-SULI and to compare attrition and chronic pain rates between SMs with and without SAL procedures. All analyses were performed using SAS version 9.3 and STATA version 13.

Results: During the ten-year study period 213,745 service members (SMs) were identified as having severe upper limb injury (SULI), an incidence of 15 per 1,000 person years, based on approximately 14 million person years, representing less than 1% of the Armed Forces. There was a significant negative trend in SULI rates for four of the six SULI types over the 10 year study period: traumatic amputation ($r = -0.90$, $p < 0.001$), blood vessel injury ($r = -0.89$, $p \leq 0.001$), and peripheral nerve injury ($r = -0.92$, $p < 0.001$) rates decreased about 3% per year while the rates for open wound ($r = -0.86$, $p < 0.001$) decreased about 1% per year.

Demographic characteristics associated with higher risk of SULI included male gender, age 25-29 years, white race and junior enlisted rank. After controlling for age, rank, race, grade, service and deployed status in a multivariate logistic regression model, males were at increased risk for SULI compared to females (OR= 1.25; 95% CI 1.22-1.27). The highest risk for SULI was among those 25-29 years, than those age 20-24 (OR= 1.07; 95% CI 1.05-1.09). Being non-white compared to white was protective for SULI. Odds ratio for blacks was lowest (OR= 0.82; 95% CI 0.80-0.83) when compared

to whites. Compared to junior enlisted (E1-E4), non-commissioned officers (E5-E9) had the highest risk of SULI (OR= 1.14; 95% CI 1.12 - 1.17). Both Air Force (OR= 1.17; 95% CI 1.14-1.19) and Coast Guard (OR= 1.62; 95% CI 1.56-1.68) had increased risk of SULI relative to the Army, while serving in the Navy (OR= 0.95; 95% CI 0.93-0.97) and Marine Corps (OR= 0.94; 95% 0.92-0.96) was protective.

A history of deployment was a strong predictor for SULI. The odds of SULI was doubled in those who deployed (OR= 2.16; 95% CI 2.12-2.19) compared to non-deployers controlling for gender, age, race, grade and service.

Certain military occupations had increased risk for SULI. More than 90% of SULI occurred in military occupations assigned to enlisted military personnel. Non-occupational enlisted (602 per 10,000 p-y), craft workers (221 per 10,000 p-y), health care specialists (207 per 10,000 p-y) and infantry (178 per 10,000 p-y) demonstrated the highest SULI rates.

SULI was associated with a 23% increased risk of overall attrition. One of the strongest predictors of increased risk for attrition was age (35 years and older) (HR= 1.49; 95% CI 1.45-1.53) and those 40 year and older [HR= 2.69; 95% CI 2.62-2.76] relative to those age 25-29 years. Risk of attrition was increased for SMs with specific SULI types. Median time to discharge was approximately 4 years for SMs with SULI and 5 years for SMs without SULI. The strongest predictors of risk of attrition were peripheral nerve injury (HR= 1.21; 95% CI 1.17-1.24), blood vessel injury (HR= 1.17; 95% CI 1.09-1.26), traumatic amputation (HR= 1.09; 95% CI 1.04-1.14), and open fracture (HR= 1.07; 95% CI 1.02-1.11) compared to SM with no SULI.

Upper limb salvage (SAL) incidence rate in this population was approximately 10 per 10,000 person-years in SM with SULI. SAL occurred more often in males (IR= 10.6 per 10,000 p-y), those 20-24 years old (IR=7.6 per 10,000 p-y), among blacks (IR=10.4 per 10,000 p-y), junior enlisted [IR=12.8 per 10,000 p-y], Marines (IR=18.2 per 10,000 p-y) and in SMs with a deployment history (IR=13.8 per 10,000 p-y). Attrition was higher for SMs with SAL ($p < 0.001$). Median time to discharge was 3 years for those with SAL and 5 years for SMs without SAL.

Conclusion: This was the first known study in the U.S. military to report on the incidence of SULI and SAL. The present study identified certain risk factors, some of which may be modifiable, and reported on the impact of SULI on attrition and upper limb salvage, which has also not been previously identified in the U.S. military. The findings of this study provide preliminary evidence on the natural history of severe upper limb injuries and the distribution of severe upper limb injuries within the US military that may inform the fields of public health practice, occupational therapy and orthopedic hand surgery. These results lay the groundwork for identifying high-risk occupational specialties and opportunities for primary prevention (mitigating certain risk factors related to SULI) and tertiary prevention (preventing complications of SULI).

TABLE OF CONTENTS

LIST OF TABLES	xvi
LIST OF FIGURES	xviii
CHAPTER 1: Introduction	1
Background and Literature review	1
Research Objectives and Study Aims	6
Specific Aim 1:	6
Specific Aim 2:	6
Specific Aim 3:	7
Specific Aim 4:	7
CHAPTER 2: Methodology.....	8
STUDY DESIGN.....	8
Study Population.....	9
Data Sources	9
Case Definitions.....	10
Expert Panel	10
Severe Upper Limb Injury (SULI) case definition:	11
Hierarchy of SULI:	14
Classification of SULI	15
Upper Limb Reconstruction/Limb Salvage (SAL) case definition:	16

Hierarchy of SAL.....	17
Classification of SAL.....	18
Outcome Variables.....	19
Dates	19
Attrition.....	19
Upper Extremity Health Care Utilization	19
(i) Hospitalization	20
(ii) Ambulatory visits	20
Healthcare Utilization rates.....	21
Risk Factors for SULI.....	21
Demographic Variables	21
Deployment Factors	21
Military Occupation	22
Enlisted	22
(i) Infantry, Gun crew and Seamanship Specialists (10)	22
(ii) Electronic Equipment Repairers (11)	23
(iii) Communications and Intelligence Specialists (12)	23
(iv) Health Care Specialists (13)	24
(v) Other Technical and Allied Specialists (14).....	24
(vi) Functional Support and Administration (15).....	25
(vii) Electrical/Mechanical Equipment Repairers (16).....	25
(viii) Craftworkers (17)	26
(ix) Service and Supply Handlers (18)	26

(x) Non-Occupational (19)	27
Officer	27
(i) General Officers and Executives (21).....	27
(ii) Tactical Operations Officers (22)	28
(iii) Intelligence Officers (23)	28
(iv) Engineering and Maintenance Officers (24).....	28
(v) Scientists and Professionals (25)	29
(vi) Health Care Officers (26)	29
(vii) Administrators (27)	30
(viii) Supply, Procurement and Allied Officers (28).....	30
(ix) Non-Occupational (29)	31
Additional Outcome Variables	31
Failed Limb Salvage (Secondary Amputation).....	31
Chronic pain.....	31
Data Analysis	32
Aim 1	32
Aim 2	33
Aim 3	34
Aim 4	35
Study Investigators.....	36
Sample size and Power Estimates	37
CHAPTER 3: Results	38

Section 1: Epidemiology of Severe Upper Limb Injuries in the U.S Military: Incidence, and Healthcare Utilization	38
Study population	38
Incidence and Descriptive Characteristics	38
Military Occupation Categories for SMs with SULI	39
Overall SULI Incidence and Rate Ratios for SULI Population	39
SULI Incidence for specific SULI types	40
SULI associated Health Care Utilization	41
SULI Combinations	42
SULI Incidence Trends	43
Section 2: Deployment Related Risk Factors And Attrition Associated With Severe Upper Limb Injuries In The Us Military, 2003-2012	45
Risk factors for SULI (unadjusted)	45
Risk for SULI by Military Occupational Specialties	46
Risk factors for SULI (adjusted)	47
Risk factors for SULI for deployed SMs (adjusted)	48
Risk of Attrition by SULI	50
Section 3: Analysis Of Limb Salvage Procedures Of The Upper Extremity In Us Military, 2003-2012: Incidence And Outcomes	52
Incidence and Descriptive Characteristics	52
SAL Combinations and SULI-SAL patterns	53
Risk for Chronic Pain and Attrition	54
Failed Limb Salvage Descriptive Analysis	55

CHAPTER 4: DISCUSSION.....	57
Study Strengths	63
Limitations	63
Public Health Significance.....	66
Future Research	67
Conclusion	69
TABLES	72
FIGURES.....	95
APPENDICES	100
Appendix A Acronyms/Definitions	101
Appendix B IRB Approval	102
Appendix C Sample Size Tables.....	103
Appendix D. Variables List	105
REFERENCES	108

LIST OF TABLES

Table 1 SULI Diagnostic Types	12
Table 2 SAL Diagnostic Types.....	17
Table 1.1 Characteristics of U.S. Military Personnel Identified as Having a Severe Upper Limb Injury (SULI), 2003-2012	73
Table 1.2 Distribution of SULI, by Military Occupations, 2003-2012	74
Table 1.3 SULI Study Population, Overall Incidence Density and Rate ratios	75
Table 1.4 Incidence Density with 95% CI, by SULI Type, 2003-2012.....	76
Table 1.5 Incidence Rate Ratios for SULI among Active Component Service Members, 2003-2012*	77
Table 1.6 SULI Healthcare Utilization Rates: Ambulatory visits and Hospital Admissions, 2003-2012	78
Table 1.7 Ranking of SULI types, single and combinations of SULIs by Frequency.....	79
Table 2.1 Risk Factors for Severe Upper Limb Injury (SULI) in U.S. Active Component Service Members, 2003-2012	83
Table 2.2 Military Occupations in U.S. Active Component Service Members with SULI and Non-SULI, 2003-2012	84
Table 2.3 Risk Factors for SULI in U.S. Active Component Service Members, 2003-2012	85
Table 2.4 Risk Factors for SULI for Previously Deployed U.S. Active Component Service Members, 2003-2012	86
Table 3.1 Risk of Attrition, by Demographics in U.S. Active Component Service Members, 2003-2012	87

Table 3.2 Hazard Ratios for Attrition, by SULI types versus No SULI, in U.S. Active Component Service Members, 2003-2012	88
Table 4.1 Characteristics of Upper Limb Salvage (SAL) Procedures in U.S. Active Component Service Members, with SULI, 2003-2012*	89
Table 4.2 Upper Limb Salvage (SAL) types, by Frequency in U.S. Active Component Service Members, 2003-2012	90
Table 4.3 Frequency of Combined SAL Procedures and Diagnoses with SULI types	91
Table 4.4 Risk of Attrition in U.S. Active Component Service Members With SULI, 2003-2012	92
Table 4.5 Risk of Chronic Pain Diagnoses in U.S. Active Component Service Members after SULI, 2003 to 2012	93
Table 4.6 Frequency of U.S. Active Component Service Members, with Failed Limb Salvage and Traumatic Amputation, by demographic characteristics, 2003-2012 ..	94

LIST OF FIGURES

Figure 1 Hierarchy of Severe Upper Limb Injury (SULI) Types	15
Figure 2 Hierarchy of Limb Salvage (SAL) Types	18
Figure 1-1 SULI counts, by year and type of SULI.....	96
Figure 1-2 SULI rates, by year and type of SULI.....	97
Figure 3-1 Survival Curve for Attrition, by SULI status	98
Figure 4-1 Survival Curve for Attrition, by Limb salvage procedure status, 2003-2012.	99

CHAPTER 1: Introduction

BACKGROUND AND LITERATURE REVIEW

Upper limb injuries (ULI), a subset of musculoskeletal injuries, may pose a significant public health challenge to the military. While these injuries alone rarely result in mortality, they are a prevalent source of morbidity and disability (13; 28; 32). Upper limb injuries may range from sprains, strains, tendonitis, tendon injuries, simple or complex fractures, nerve or blood vessel injuries, and soft tissue injuries to limb loss. As of 2012, more than 200 U.S. service members (SMs) had lost one limb due to an upper limb or extremity injury sustained in Iraq or Afghanistan (17). Additionally, several thousand more had sustained limb threatening upper extremity injuries that did not result in a limb loss but may potentially lead to life-long disabilities (17). Besides the direct impact on individual Soldiers, Sailors, Airmen, and Marines' ability to perform their functional daily activities (such as feeding, bathing dressing, driving), upper limb injuries impose a substantial economic burden on the military and have a negative impact on military readiness (13; 17; 28; 32). Cross et al (13) examined unfitting medical conditions leading to discharge by the U.S. Army Physical Evaluation Board (PEB) in a cohort of SMs wounded in Iraq and Afghanistan between 2001 and 2005 and found orthopedic related injuries accounted for the majority of disabling conditions preventing service members from returning to active duty service; upper limb amputation accounted for the greatest average percent disability. In the Army alone, SMs with extremity-related injuries accounted for 65% of all resources required for initial hospitalization totaling over \$65 million between 2001-2005 and represented 64% of all Soldiers found

unfit for duty by the Physical Evaluation Board (PEB) with projected disability costs of up to \$1.2 billion (28).

The epidemiology and impact of upper limb injuries in the U.S. military is poorly understood. Previous studies have either reported on musculoskeletal injuries in general or have focused more specifically on injuries to the lower limbs. The principal investigator of this study completed an extensive review of the available literature on upper limb or extremity injuries using multiple databases, including PubMed, Cochrane and Embase used the following search criteria: ("Military Personnel"[Mesh] OR "Military Facilities"[Mesh] OR "Psychology, Military"[Mesh] OR "Military Psychiatry"[Mesh] OR "Military Nursing"[Mesh] OR "Military Medicine"[Mesh] OR "Veterans"[Mesh] OR "Veterans Health"[Mesh] OR "Hospitals, Veterans"[Mesh] OR "Warfare and Armed Conflicts"[Mesh]) AND ("Upper Extremity/injuries"[Major] AND English[lang]). This search found 48 articles of which 10 contained “upper limb or upper extremity injuries” in the title, 1 addressed pediatric injuries, 14 articles addressed combat related upper limb injuries, 9 related to amputation and wounds and 14 related to surgical management or specific rehabilitation treatment. In addition to the above strategy, additional articles were identified by reviewing the reference lists of selected articles, using the "find related citations" feature offered in PubMed, and identifying other works by selected authors. These additional search strategies identified 23 additional articles, of which 14 addressed orthopedic or musculoskeletal extremity injuries in general, 3 focused on lower extremity/limb trauma and 5 addressed upper extremity/limb, however none of these studies focused on incidence, risk factors or

outcomes in the upper limb. Two of these studies, one military and one civilian study, addressed traumatic limb injuries with respect to outcomes, however neither of these studies involved upper limb injuries (5; 14). Bosse et al (5) conducted a multicenter prospective study of a civilian cohort of patients who sustained severe lower extremity injuries resulting in traumatic amputation or reconstruction to determine functional outcomes. Patients were followed up at 3, 6, 12 and 24 months after injury for functional outcomes using self reported measures of 12 categories of function: ambulation, mobility, body care and movement, social interaction, alertness, emotional behavior, communication, sleep and rest, eating, work, home management and recreation. Two-year outcomes found no significant difference in outcomes in patients who underwent amputation and patients who underwent reconstruction.

Doukas et al (14) conducted a similar retrospective study to examine functional outcomes in a military cohort of Service members (SMs) who previously deployed to Iraq or Afghanistan who sustained a lower-limb injury requiring either amputation or limb salvage (reconstruction) involving revascularization, bone graft/bone transport, local/free flap coverage, repair of a major nerve injury, or a complete compartment injury/compartment syndrome. They found significant differences in musculoskeletal function standardized test self-report scores between SMs in the amputation and SMs in the limb salvage groups. SMs who underwent amputation reported better outcomes than SMs who underwent limb salvage.

Attempts to study injuries of the upper limb have either focused on non-severe injury types such as repetitive strain and cumulative disorders such as the discussion

undertaken by (16) in his review of the literature on work related upper extremity disorders. Other studies and reviews have been dedicated to specific injury types such as vascular injuries (12), soft tissue wounds (34) or compound limb fractures (2) or specific treatment such as the management of dominant upper extremity injuries as reported on by (41), and management of upper extremity amputees as outlined by Smurr et al (38). Several authors studied specific injury patterns of: combat wounds (33), non-emergent orthopedic injuries (20), and upper extremity injuries in peace time years versus war time years (7). The following authors presented information on surgical and reconstructive management (3; 6; 8; 10; 18; 26; 35).

Understanding the natural history, disease burden, incidence, risk factors and outcomes of upper limb injuries, specifically, severe or trauma associated injuries in the U.S. military are limited to the few available studies. Additionally, available studies are typically case studies, case series, or reviews. This area of research is therefore lacking in analytical and observational studies from which incidence rates can be calculated or associations with risk factors and outcomes can be ascertained. Further, available studies do not span the ten-year period during the recent conflicts in Iraq and Afghanistan. Despite the increased attention given to the upper extremity in recent years, studies have focused on combat related extremity trauma injuries: upper extremity reconstruction and management of dismounted complex blast injuries (4; 17; 27; 33), however, no studies have reported on severe upper limb injuries (SULI) in the context of incidence, risk factors or specific outcomes. This gap in knowledge leaves very little data on which to base practice guidelines for occupational therapists for rehabilitation of these injuries, or

to determine resource allocation. There is very little to guide the education and training needs of therapists, very little for orthopedic hand surgeons to use when assisting patients to make informed decisions. Understanding the incidence, risk factors and outcomes of SULI can help providers to set realistic goals and expectations for patients or to help inform military leaders on the health care burden and impact of these injuries on mission capabilities and leakage from the military. This knowledge gap also presents challenges to public health practice and the ability to inform primary or tertiary prevention efforts.

The present study was undertaken to report on the incidence, risk factors, and specific outcomes associated with severe upper limb injuries in the U.S. military. Information from this study will directly impact the U.S. military for several reasons. First, it is an important step for injury epidemiology and public health, because no previous study has reported on both upper extremity injury incidence and outcomes. An understanding of the risk factors and outcomes would help tertiary prevention efforts as far as reducing complications and may assist primary prevention efforts of specific injuries through mitigating certain risk factors or secondary prevention efforts by screening known at risk groups for specific injury types. Further, a better understanding of the burden imposed on the military and military health system and what costs are associated with certain procedures can inform resource allocation and public health policy such as the retention of SMs. Second, upper extremity neuromusculoskeletal providers including occupational therapists, may benefit from knowing which specific injuries are prevalent and the distribution of certain conditions in the current military population in order to shape practice guidelines, guide therapeutic treatment and better

inform curriculum development for education and training efforts. Third, information from this study may be of interest to military orthopedic hand surgeons faced with decisions regarding definitive treatment for severe upper limb injuries and counseling patients regarding expected outcomes.

RESEARCH OBJECTIVES AND STUDY AIMS

The primary objective of this study was to determine the incidence, risk factors, and outcomes associated with severe upper limb injuries in U.S. active component (AC) military personnel. The secondary research objective was to develop a surveillance definition for upper limb salvage, and determine risk factors for specific outcomes (i.e. chronic pain, secondary amputation, and attrition) in service members who underwent upper limb salvage.

Specific Aim 1:

To describe the epidemiologic characteristics of severe upper limb injuries (SULI) in active component (AC) U.S. military members.

Specific Aim 2:

To examine the association between specific deployment related and demographic factors and the occurrence of severe upper limb injury.

Research Hypothesis: Service members (SMs) who experience SULI are more likely to have a history of certain deployment-related factors than service members without SULI. The rates of SULI will differ by age, gender, race/ethnicity, military occupation, branch of service and time in service.

Specific Aim 3:

To determine the association between severe upper limb injury and separation from the U.S. Armed Forces.

Research Hypothesis: SMs with SULI experienced higher rates of attrition when compared to the service members without SULI.

Specific Aim 4:

To describe the frequency and types of limb salvage procedures among service members with SULI and compare outcomes of chronic pain and attrition between service members with limb salvage procedures versus those with SULI and no limb salvage procedures.

Research Hypothesis: Rates of chronic pain, and attrition will differ in SMs with SULI and upper limb salvage procedures versus SMs without limb salvage procedures.

CHAPTER 2: Methodology

STUDY DESIGN

This an observational study of existing data contained in the Defense Medical Surveillance System (DMSS) and Defense Medical Epidemiology Database (DMED). These data sources are defined below. The overall design of the study was retrospective, with risk factors for SULI identified using a case-control study design and SULI outcomes examined using a retrospective cohort.

To address specific Aim 1, a retrospective analysis was conducted using data in the Defense Medical Surveillance System (DMSS) and Defense Medical Epidemiology Database (DMED) to determine the incidence of SULI in U.S. military personnel serving in Active Component (AC), 2003-2012. To address specific Aim 2, a case-control study was conducted to investigate risk factors associated with SULI, in AC military personnel, 2003-2012. SULI cases were identified through a query of DMSS by researchers at the Armed Forces Health Surveillance Branch. A comparison group of AC military personnel without a defining diagnosis of SULI in their records (non-SULI) was randomly selected from the same cohort of AC military personnel as the cases. To address specific Aim 3, a retrospective cohort study was conducted to investigate the association between SULI and rates of attrition. The attrition rates were obtained by querying each service member's records contained in DMSS. The rates were compared between service members with a SULI (cases identified in specific aim 2) and without a SULI (noncases identified in specific aim 2). To address Aim 4, an analysis of SULI cases that underwent limb salvage procedures (SAL cases) compared to SULI cases that did not undergo limb salvage procedures (non-SAL) was conducted. The incidence of SAL and distribution

within the SULI cohort was determined. SAL cases were further characterized by frequency, coexisting SAL types and SAL procedures by SULI distribution. The rates of chronic pain and attrition were compared for SMs with SAL and those with SULI and no SAL. Overall incidence and frequencies by SAL type were determined for cases of failed limb salvage.

STUDY POPULATION

The population for this study consisted of all active component (AC) U.S. military personnel who served at any time during the period January 1, 2003 to December 31, 2012.

DATA SOURCES

This study utilized data contained in the DMSS and DMED. DMSS is a central repository of medical surveillance data for the U.S. Armed Forces. DMSS maintains up-to-date and historical data on diseases and medical events of all active and reserve component U.S. military members to include hospitalization and ambulatory encounters in U.S. military and civilian (contracted/ purchased care through the Military Health System [MHS]) medical facilities worldwide (1). DMED provides remote access to a de-identified subset of data contained within DMSS, through which users may perform customized queries regarding medical conditions and determine rates and relative burdens of disease in active duty populations.

The data for Aim 1 were obtained from two sources. Numerator data to calculate SULI incidence was obtained from a de-identified dataset created by the Armed Forces

Health Surveillance Branch (AFHSB) from data contained in DMSS. Denominator data (person-years) to calculate incidence rates of SULI were obtained from DMED.

Data for Aims 2 and 3 were obtained from the same de-identified dataset created by AFHSB and used in Aim 1. DMSS was queried to identify all AC military personnel serving during the period January 1, 2003 to December 31, 2012 with a SULI defining diagnosis in their inpatient or ambulatory health record to be used as cases and a random sample, equal in number, of active component U.S. military personnel serving during the same period, January 1, 2003 to December 31, 2012, without a SULI defining diagnosis in their inpatient or ambulatory health record to be used as a comparison group for Aims 2 and 3. Data for Aim 4 was obtained from the same de-identified dataset created by AFHSC that we used for Aims 1, 2, and 3.

CASE DEFINITIONS

SULI has not been previously defined in the literature. Therefore the first step was to develop a case definition for SULI and SAL.

Expert Panel

A convenience sample of four physicians was selected to advise and provide expert opinion to assist with the development of a surveillance case definition for severe upper limb injury (SULI) and upper limb salvage (SAL). The four panelists represented physicians specializing in orthopedic hand surgery at the Walter Reed National Military Medical Center, Bethesda, Maryland and Kimbrough Army Community Center, Fort Meade, Maryland. All panel members were active duty physicians from the U.S. Army (USA) and U.S. Navy (USN) with a cumulative 40+ years of experience working in

general orthopedics and reconstructive orthopedic hand surgery in the military. The panel, Patricia McKay CAPT, MC, USN; George Nanos, CDR, MC, USN; Leon Nesti, LTC, MC, USA and Derek Ipsen, LTC, MC, USA, reviewed injury and procedure criteria used to classify limb trauma and limb salvage from two previous studies related to lower extremity injuries, namely the lower extremity assessment project (LEAP) (5) and military extremity trauma amputation and limb salvage study (METALS) (14). Panel members were able to reach consensus on criteria that would serve as case definitions for severe upper limb injury (Table 1) and upper extremity limb salvage (Table 2) based on the current practice of upper limb salvage in the U.S. military and previous literature on the lower extremity which resulted in the development of an ICD-9-CM based case definition for severe upper limb salvage and ICD-9-PCS, CPT-based surveillance definition for upper limb salvage. The PI communicated with expert panel members in person and via e-mail as often as needed.

Severe Upper Limb Injury (SULI) case definition:

An incident case of SULI was identified as the first occurrence of one of the SULI defining ICD-9-CM codes (Table 1) in the primary, secondary or tertiary diagnostic field position of a record of an inpatient or outpatient encounter.

The conditions described as SULI are similar to those reported by Doukas et al (14) and Bosse et al (5) which were adapted for the upper extremity. The International Classification of Diseases (commonly known as ICD), published by the World Health Organization is a standard diagnostic tool for epidemiology, health management and clinical purposes. ICD is used worldwide for morbidity and mortality statistics,

reimbursement systems, and automated decision support in health care. ICD assigns unique alpha-numeric codes, up to six characters long, to classify diseases and a wide variety of signs, symptoms, abnormal findings, complaints, social circumstances and external causes of injury or disease (9).

Six SULI injury types were identified, as shown in Table 1 and described below.

Table 1 SULI Diagnostic Types

Abbreviation	SULI Type	ICD-9-CM
TA	Traumatic Amputation of the upper limb	885-887
PN	Injury to peripheral nerve(s) of the upper limb	955.0-955.8
BV	Injury to blood vessels of the upper limb	903.0-903.9
OF	Open Fracture of the upper limb	810.1, 811.1, 812.1, 813.1, 814.1, 815.1, 816.1, 817.1, 818.1
CI	Crushing injury of the upper limb	927.0, 927.1, 927.2, 927.3, 927.8, 927.9
OW	Open wound of the upper limb	880-884

SULI descriptions are provided below with corresponding ICD-9-CM codes in parentheses. All descriptions were taken from the 2013, ICD-9-CM (9):

1) Traumatic Amputation: involves loss to the upper limb including thumb, complete or partial (885), fingers, complete or partial (886), arm and hand (887), which occurred at the point of injury. These include injuries resulting from animal bite, avulsion, cut, laceration, or puncture wound. These do not include injuries due to burn, crush injury or superficial injury incidental to dislocation or fracture.

2) Injury to peripheral nerve: involves axillary (955.0), median (955.1), ulnar (955.2), radial (955.3), musculocutaneous (955.4), cutaneous sensory (955.5), and digital (955.6) nerves; injury to other specified nerve of shoulder girdle and upper limb (955.7), injury to multiple nerves of shoulder girdle and upper limb (955.8) and injury to

unspecified nerve of shoulder girdle and upper limb. These include division of nerve, lesion in continuity (with open wound), traumatic neuroma (with open wound), and traumatic transient paralysis (with open wound). These do not include injuries resulting from accidental puncture or laceration during medical procedure.

3) Injury to blood vessels: involves axillary blood vessel (903.0), brachial blood vessel (903.1), radial blood vessel (903.2), ulnar blood vessel (903.3), palmar blood vessel (903.4), digital blood vessel (903.5), other specified blood vessel of the upper limb (903.8), unspecified blood vessel of the upper limb (903.9). These include injuries from arterial hematoma of blood vessel, avulsion of blood vessel, cut of blood vessel, laceration of blood vessel, rupture of blood vessel, and traumatic aneurysm or fistula (arteriovenous) of blood vessel, secondary to other injuries, e.g., fracture or open wound.

4) Open fracture: involves fractures of the clavicle (810.1), scapula (811.1), humerus (812.1), radius and ulna (813.1), carpal bones (814.1), metacarpal bones (815.1), or more phalanges of the hand (816.1), multiple hand bones (817.1), ill-defined fractures of the upper limb (818.1), and multiple fractures involving both upper limbs (819.1). These include compound, infected, missile, puncture, or foreign body. These do not include malunion, nonunion, stress fractures or pathologic or spontaneous fractures.

5) Crushing injury: involves crush injury of the shoulder and upper arm (927.0), elbow and forearm (927.1), wrist and hand (927.2), fingers (927.3), multiple sites of upper limb (927.8), unspecified sites of upper limb (927.9).

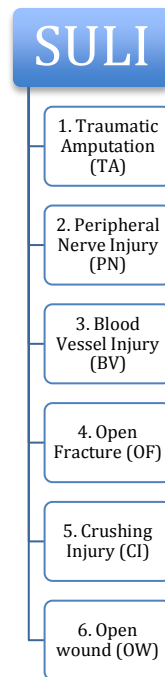
6) Open wound: involves complicated and uncomplicated wounds of the upper limb, with or without tendon involvement including shoulder and upper arm (880),

elbow, forearm, and wrist (881), hand except fingers (882) and fingers (883), multiple and unspecified open wounds of the upper limb (884). These include wounds resulting from animal bite, avulsion, cut, laceration, puncture wound, and traumatic amputation. Injuries in this category do not include injuries due to burn, or crushing, that incidental to dislocation, or fracture. Complicated wounds involve wounds with mention of delayed healing, delayed treatment, foreign body or infection.

Hierarchy of SULI:

The following hierarchy was developed based on feedback from the expert panel Mckay et al (29) and was intended to be used to classify individuals with multiple SULI according to the most severe SULI type. The hierarchy includes the six SULI categories ordered from most severe (traumatic amputation) to least severe (open wound) with respect to potential for long-term impairment or functional disability. For analyses by SULI type, cases with multiple SULI types were counted separately within each type. For analyses of overall SULI each case was counted once regardless of how many SULI types were recorded.

Figure 1 Hierarchy of Severe Upper Limb Injury (SULI) Types



Classification of SULI

Based on the hierarchy in Figure 1, if a record reflected multiple SULI defining ICD-9-CM codes to include traumatic amputation, in any diagnostic position, the case was coded as “TA”. If a record reflected multiple SULI defining ICD-9-CM codes to include peripheral nerve injury (excluding traumatic amputation) the case was coded as “PN”. If a record reflected multiple SULI defining ICD-9-CM codes to include blood vessel injury (and does not include a diagnosis of traumatic amputation or peripheral nerve injury) the case was coded as “BV”. If a record reflected multiple SULI defining ICD-9-CM codes to include open fractures (and does not include a diagnosis of traumatic amputation, peripheral nerve or blood vessel injury) the case was coded as “OF”. If a record reflected multiple SULI defining ICD-9-CM codes to include crushing injury (and does not include a diagnosis of traumatic amputation, peripheral nerve, blood vessel

injury or open fracture) the case was coded as “CI”. If a record reflected multiple SULI defining ICD-9-CM codes to include open wound (and does not include a diagnosis of traumatic amputation, peripheral nerve, blood vessel injury, open fracture or crushing injury) the case was coded as “OW”.

Upper Limb Reconstruction/Limb Salvage (SAL) case definition:

International Classification of Diseases, Ninth Revision (ICD-9-PCS) procedure codes (PCS) and Common Procedural Terminology (CPT) codes listed in the inpatient or outpatient encounter obtained from DMSS were used to identify incident SULI cases who underwent upper limb salvage procedures (SAL). SAL was defined as:

(i) Presence of one or more of the following conditions listed in any diagnostic position: revascularization, skin graft, compartment injury or compartment syndrome, complete brachial plexopathy (Table 2)

(ii) Presence of two or more of the following conditions listed in any diagnostic position: multiple tendon repairs, bone transfers or transport, multiple ray involvement (table 2).

The procedures described as SAL were previously described by Bosse et al (5) and adapted for the upper extremity based on the recommendations of the expert panel of orthopedic hand surgeons (29) (Table 2).

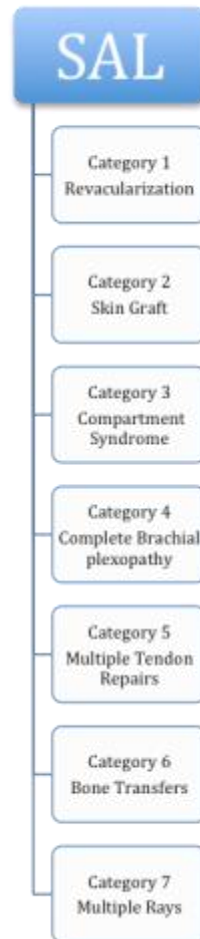
Table 2 SAL Diagnostic Types

SAL Abbreviations	Categories	ICD-9-PCS or CPT Codes
RV	All dysvascular limbs and vascular injury requiring revascularization	CPT 35206, 35207, 35266, 35518, 35522, 35523, 35650
SG	Local or free flap coverage or skin graft	ICD-9 PCS 86.60-86.62, 86.70-86.73
CS	Compartment injury of compartment syndrome	CPT 25020, 25025
BP	Complete brachial plexopathy	CPT 64861
MT	Multiple tendon repairs or transfers with or without muscle loss (AND one other criteria)	CPT 20924, 24301, 23406, 24341, 25260, 25262, 25262, 25270, 25272, 25274
BT	Open fractures, with bone loss requiring bone transfer or transport; all intra-articular fractures of the wrist, elbow, forearm and shoulder (AND one other criteria)	CPT 23480, 23485, 25425, 25426, ICD-9 PCS 78.01-78.04
MR	Severe hand injuries with multiple rays (metacarpal fractures involvement (AND one other criteria)	CPT 26615, 26665, 26735, 26735, 26746, 26765, ICD-9 PCS 78.12, 73.13, 78.14, 78.52, 78.53, 78.54

Hierarchy of SAL

For most analyses, cases with multiple SAL types were counted separately within each type. However, for analyses that require mutually exclusive categories, the following hierarchy was developed based on feedback from the expert panel (29) and was intended to be used to classify multiple SAL procedures to allow identification/categorization of mutually exclusive SAL categories. The hierarchy includes the seven SAL categories ordered from the most severe (revascularization) to least severe (multiple rays involvement) with respect to potential for long-term impairment and/or functional disability.

Figure 2 Hierarchy of Limb Salvage (SAL) Types



Classification of SAL

If a record reflected a SAL defining CPT code of revascularization (and does not include a code of skin graft, compartment syndrome, complete brachial plexopathy, multiple tendon transfer, bone transfer or multiple rays) the case was coded as “RV”. If a record reflected a CPT code of skin graft (and does not include a code of revascularization, compartment syndrome, complete brachial plexopathy, multiple tendon transfer, bone transfer or multiple rays) the case was coded as “SG”. If a record reflected

a SAL defining CPT code of complete compartment syndrome (and does not include a code of revascularization, skin graft, complete brachial plexopathy, multiple tendon transfer, bone transfer or multiple rays), the case was coded as “CS”. If a record reflected a CPT code of complete brachial plexopathy (and does not include a code of revascularization, skin graft, compartment syndrome, multiple tendon transfer, bone transfer or multiple rays), the case was coded as “BP”. If a record reflected multiple CPT defining codes to include multiple tendon transfers the case was coded as “MT”. If a record reflected multiple CPT defining codes to include bone transfers the case was coded as “BT”. If a record reflected multiple CPT defining codes to include multiple rays involvement the case was coded as “MR”.

OUTCOME VARIABLES

Dates

All dates, to include deployment date, date of admission, date of discharge, date of accession and separation, were provided as number of days from the reference date (day 0). The reference date is defined as date of enlistment for each study subject. To preserve data confidentiality, only year of enlistment was provided.

Attrition

Years of accession (i.e. enlistment or commissioning) and separation for SULI cases and Non-SULI controls were obtained from DMSS.

Upper Extremity Health Care Utilization

Information on health care utilization was obtained from DMSS to include the following:

(i) Hospitalization

Dates of admission and discharge (provided as number of days from reference date), the primary to tertiary diagnosis for each admission (identified by ICD-9 code), and procedure codes (identified by ICD-9-PCS code) for each admission. Information on hospitalization were extracted from a combination of administrative records collected from 1) hospitalizations in DoD military treatment facilities, and 2) hospitalizations in non-DOD facilities for which the DoD reimbursed the care facility (outsourced care). Each hospitalization resulted in a series of ICD-9-CM codes, with up to eight diagnostic codes, which are based on the health care provider's review and interpretation of results of tests, consults and diagnostic and therapeutic procedures. Only information related to upper limb related hospitalization, as indicated by ICD-9-CM codes 800-959, was available for this study.

(ii) Ambulatory visits

Ambulatory visits (identified by ICD-9 code in the primary position) for each encounter, date of each encounter (provided as number of days from reference date), procedures for each encounter (identified by CPT code) and Medical Expense and Performance Reporting System (MEPRS) code. The ambulatory encounter data is a combination of administrative records collected from: 1) encounters in DoD military treatment facilities, and 2) hospitalizations in non-DOD facilities for which the DoD reimbursed the care facility (outsourced care). Each ambulatory encounter resulted in a

series of ICD-9-CM codes, with up to four diagnoses per encounter based on the health care provider's review and interpretation of results of test, and diagnostic and therapeutic procedures. Only information related to upper limb related ambulatory visits, as indicated by ICD-9-CM codes 800-959 was available for this study.

Healthcare Utilization rates

Utilization rates were calculated in two ways:

1. Visits or admits per injured person: Numerators were total number of visits with a SULI ICD-9 code in the primary to tertiary position. Denominators were number of cases in each SULI category.

2. Visit or Admission rate: Numerators were total number of visits or admit with a SULI ICD-9 code in the primary to tertiary position. Denominators were total person years for the 10-year study period.

RISK FACTORS FOR SULI

Demographic Variables

Demographic information for SULI cases and non-SULI controls were obtained from DMSS to include age at first SULI, gender, race, grade, branch of service and military occupation.

Deployment Factors

Deployment information for SULI cases and Non-SULI controls were obtained from DMSS to include deployment dates (which was provided as numbers of days from

the reference date) and location (OIF, OEF, OND, Other). These values were used to calculate number and duration of deployments.

Military Occupation

Military occupation information for SULI cases and non-SULI controls were obtained from DMSS to include occupational areas and groups. Denominator information (person-years) for all occupational groups was obtained from DMED. Military Occupations were classified by Enlisted and Officer DoD Occupation categories. Definitions are provided for all Occupational Areas and Occupational Groups with the DoD Occupational area two digit code and Occupational group three digit code in parentheses (all definitions were taken from the DoD Occupational Conversion Index) (31).

Enlisted

(i) Infantry, Gun crew and Seamanship Specialists (10)

Infantry, Gun crew and Seamanship special occupational area (10) includes individual weapons specialists and crew-served artillery specialists, armor and amphibious crewmen, and specialists in combat engineering and seamanship to include the following occupational groups (101-107): Infantry general, special forces and infantry training instructors; armor and amphibious (land and amphibious tank crews and leaders); combat engineering; artillery/gunnery, rocket artillery and missile artillery (operating crew); air crew (general), pilots, navigators, flight engineers and other air crewmen; seamanship and installation security.

(ii) Electronic Equipment Repairers (11)

Electronic Equipment Repairers special occupational area (11) includes specialists in the maintenance and repair of various types of electronic and allied equipment, including radio, radar, navigation, weapons, and computers among others in the following occupational groups (110-119): Radio/radar general, communication, fixed and mobile radio, navigation and electronic countermeasure gear, air traffic and tracking radar; fire control electronic systems (non-missile); missile guidance, control and checkout equipment for guided and ballistic missiles; sonar equipment specialists; nuclear weapons equipment repair specialists; ADP computers; teletype and cryptographic equipment repair; other electronic equipment includes training devices; shipboard inertial navigation systems and electronic instruments specialists.

(iii) Communications and Intelligence Specialists (12)

Communications and Intelligence Specialists Occupational area (12) includes the operation and monitoring of radio, radio teletype, radar, sonar and allied communications and intelligence consoles; also includes the gathering and interpretation of photographic, electronic, and documentary intelligence in the following occupational groups (120-126): radio and radio code operators and visual communications equipment; sonar operators; radar and air traffic control; signal intelligence/electronic warfare, intercept officers, foreign communication analysts, electronic countermeasures equipment operators; language interrogation/interpretation, image interpretation, operational intelligence, counter-intelligence and investigative activities; combat operations control and communications center operations.

(iv) Health Care Specialists (13)

Health Care Specialists Occupational area (13) includes specialists in patient care and treatment, ancillary medical support, and in technical and related medical and dental services, administration and logistics in the following occupational groups (130-134): medical care and treatment, surgical and therapy specialists (behavioral sciences, therapy, orthopedic, aerospace and undersea medicine); ancillary medical support (biomedical laboratory services, pharmacy, radiology); biomedical sciences and allied health (veterinary medicine, environmental health services, ophthalmology/optometry, physiology, diet therapy and biomedical equipment maintenance and repair); dental care (includes specialists in dental care and treatment and in dental laboratory services); medical administration and logistics (includes specialists in health care, medical logistics and patient administration and management).

(v) Other Technical and Allied Specialists (14)

Other Technical and Allied Specialists Occupational area (14) includes specialists in technical and professional-typed skills not elsewhere classified to include photography, cartography, meteorology, ordnance disposal, laboratory analysis and music among others in the following occupational groups (140-149): photography; mapping, surveying, drafting and illustrating; weather (includes specialists in the collection of weather and sea condition data); explosive ordnance disposal and diving (underwater demolition and other types of diving); musicians and technical specialists, N.E.C. (includes physical science laboratory analysts, specialists in memorial activities, safety, nuclear, biological and

chemical warfare and firefighting and damage control, and other technical specialists and aids such as scientific and engineering assistants.

(vi) Functional Support and Administration (15)

Functional Support and Administration Occupational area (15) includes general administrative, clerical and personnel specialists. Also includes administrative specialists in data processing, information, and related areas, and functional supports specialists in areas such as supply, transportation and flight operations in the following occupational groups (150-157): personnel, recruiting and counseling; clerks, stenography, legal and medical administrative specialists; combined personnel and administrative specialists and senior enlisted personnel whose primary responsibilities are non-technical (first sergeants/sergeants major); computer operators/analysts, and programmers; auditing and accounting and disbursing clerks; supply administration, unit supply and procurement, transportation, flight operations and related areas; chaplains assistants and specialists in theater, arts, recreation and related activities; information and education (specialists in public affairs, radio/tv, and other types of information and education.

(vii) Electrical/Mechanical Equipment Repairers (16)

Electrical/Mechanical Equipment Repairers Occupational area (16) includes specialists in the maintenance and repair of electrical, mechanical, hydraulic, and pneumatic equipment in the following occupational groups (160-169): aircraft engines, electrical systems, structural components and surfaces and launch equipment; automotive (construction equipment and other wheeled and tracked vehicles); wire communications (installation and maintenance of telephones, switchboards, and central office and related

interior communications equipment); missiles and missile systems and related components; armament maintenance (small arms repair, artillery, mines, bombs and associated mountings, nuclear weapons and ammunition renovation); shipboard propulsion (marine main engines, boilers and auxiliary equipment); power generating equipment (nuclear power reactors and primary electrical generating plants); precision equipment and other mechanical and electrical equipment

(viii) Craftworkers (17)

Craftworkers Occupational area (17) includes the formation, fabrication, and installation of structures and components, the installation and maintenance of utilities, and related trades and crafts to include the following occupational groups (170-179): metal working (welding, machinists, sheet metal, metal body repair); construction (includes specialists in construction trades and construction equipment operation); utilities (includes plumbers, heating and cooling specialists and electricians); lithography; industrial gas and fuel production; fabric leather, and rubber; and other craftworkers (includes specialists in trades such as molding, camouflage, and plastic work, which are not readily classifiable elsewhere).

(ix) Service and Supply Handlers (18)

Service and Supply Handlers Occupational area (18) includes personnel involved in protective and personal services and non-clerical personnel in warehousing, food handling, and motor transportation to include the following occupational groups (180-187): food service (stewards and enlisted aides); motor transport (includes operation of wheeled and tracked vehicles, except construction equipment and railway equipment);

material receipt, storage and issue (includes missile fuel and petroleum, warehousing and equipment handling, except ammunition); law enforcement; laundry and personal service; auxillary labor (includes unskilled laborers and their supervisors); forward area equipment support (includes specialists in parachute packing and repair, in aerial delivery operations, and in flight equipment fitting and maintenance); other services (includes service specialists who are not readily classifiable in one of the other groups in this section).

(x) Non-Occupational (19)

Non- Occupational area (19) includes patients and prisoners, students and trainees, and other enlisted and civilian personnel and designators of a non-occupational nature to include the following occupational groups (190-195): patients; prisoners; cadets and other officer candidates and students (includes personnel or authorizations for personnel in training to become commissioned or warrant officers and personnel or authorizations for personnel in the student status); undesignated occupations (includes personnel or authorizations for personnel serving on duties of a special or otherwise undesignated nature); not occupationally qualified (includes new recruits and other personnel in a training status).

Officer

(i) General Officers and Executives (21)

General Officers and Executives occupational area (21) includes all officers of General/Flag rank and all commanders, directors and planners not elsewhere classified to

include the following occupational groups (2101-2102): General and flag; Executives (includes all directors, planners and executives and all Marine Corps Colonels.

(ii) Tactical Operations Officers (22)

Tactical Operations Officers (22) includes pilots, crews and operations staff officers to include the following occupational groups (2201-2208): fixed-wing fighter/bomber pilots; other fixed-wing pilots (includes non-fighter and bomber fixed-wing pilots such as those engaged in transport, supply and reconnaissance); helicopter pilots; aircraft crews; ground and naval arms (includes infantry, artillery, armor and close support officers, and Naval ship commanders and other warfare-related officers); missiles; operations staff (includes combat, operations and intelligence staff officers) and civilian pilots (include all non-military pilots).

(iii) Intelligence Officers (23)

Intelligence Officers occupational area (23) includes strategic, general and communications intelligence officers, and counterintelligence officers to include the following occupational groups (2301-2303): general intelligence (includes strategic, general, and technical intelligence gathering, analysis, interpretation and summary); communications intelligence (includes intercept, analysis, translation, carpology, and related communications intelligence); counterintelligence includes installation, area, and other internal and counterintelligence.

(iv) Engineering and Maintenance Officers (24)

Engineering and Maintenance Officers occupational area (24) includes design, development, production, and maintenance engineering officers to include the following occupational groups (2401-2414): construction and utilities; electrical/electronic; communications and radar; aviation maintenance and allied; ordinance; missile maintenance; ship construction and maintenance; ship machinery; safety (includes ground, aviation, weapons and nuclear safety officers); chemical (includes chemical engineers and staff officers); automotive and allied (includes engineering and maintenance officers whose concern is with automobiles and related equipment); surveying and mapping; Other includes engineering and maintenance officers that are not readily classified in one of the previous groups.

(v) Scientists and Professionals (25)

Scientists and Professionals occupational area (25) includes physical, biological and social scientists, and other professionals such as lawyers and chaplains to include the following occupational groups (2501-2514): physical scientists (includes physicists, chemists, geologists, and other physical scientists, except meteorologists); meteorologists; biological scientists (includes microbiologists, entomologists, and other biological scientists); social scientists (includes historians, economists, sociologists and other social scientists, except psychologists); psychologists; legal; chaplains; mathematicians and statisticians; educators and instructors; research and development coordinators; community activities officers; scientists and professionals, N.E.C (includes scientists and professionals that are not readily classifiable in one of the previous groups).

(vi) Health Care Officers (26)

Health Care Officers occupational area (26) includes physicians; dentists; nurses; veterinarians; biomedical sciences and allied health officers; health services administration officers to include the following occupational groups (2601-2608): physicians; dentists; nurses; veterinarians (includes all veterinary officers and warrant officer food inspection technicians); biomedical science and allied health officers (includes therapists, optometrists, pharmacists, biomedical laboratory, environmental health, psycho/social physiologists, and other allied health and biomedical science officers).

(vii) Administrators (27)

Administrators occupational area (27) general and specialized administration and management officers to include the following occupational groups (2701-2714): general administrators (includes adjutants, aids, general administrative officers and others not classifiable in one of the following groups); training administrators (involves officers engaged in the planning, management and operation of training programs); manpower and personnel; comptrollers and fiscal; data processing (includes computer systems officers); pictorial (includes photographic, motion picture, and television officers); information (includes public and internal information officers); police; inspection (includes inspector general and technical inspection positions); morale and welfare (includes band, recreation and special services officers).

(viii) Supply, Procurement and Allied Officers (28)

Supply, procurement and allied officers occupational area (28) includes officers in supply, procurement and production, transportation, food service and related logistics not

elsewhere classified to include the following occupational groups (2802-2807): general logistics; supply; transportation (includes land, sea, and air transportation operations officers, and traffic and travel control officers); procurement and production; food service; exchange and commissary; other (includes printing and publications, housing and other supply service officers not classifiable in one of the previous groups).

(ix) Non-Occupational (29)

Non-Occupational occupational area (29) includes patients, students, trainees, and other officers who for various reasons are not occupationally qualified to include the following occupational groups (2901, 2092, 2905): patients (includes officers holding patient designations); students (includes law students, medical students, flight students, and other trainees; other (includes billet designators, officers new to their occupational field, and other non-occupational officers and designations not included in the previous groups).

ADDITIONAL OUTCOME VARIABLES

Failed Limb Salvage (Secondary Amputation)

ICD-9 procedure codes and CPT codes from DMSS were used to identify cases of failed limb salvage, which is also referred to as secondary amputation or delayed amputation, which occurred any time after any of the upper limb salvage procedures listed in Table 2.

Chronic pain

ICD-9 procedure codes and CPT Codes from DMSS were used to identify cases of chronic pain (Appendix D), which occurred arbitrarily at least three months after an identified SULI to distinguish from acute post-SULI pain.

DATA ANALYSIS

The AFHSB dataset contained a file with all medical encounters (inpatient and outpatient) for every service member in the study population with at least one ICD-9 code corresponding to a SULI. Each service member (SM) represented multiple rows in the dataset based on number of medical encounters and ICD-9 diagnostic codes.

The data was reorganized so that each ICD-9 code could be analyzed using the case definition for SULI, (traumatic amputation, blood vessel injury, peripheral nerve injury, open fracture, crush injury or open wound) based on the case definition.

Following this analysis the data was collapsed to create a new dataset with one row per SM and indicator variables for each of the six SULI categories. Final analyses were conducted to assess whether each SM had the presence or absence of each SULI type based on the ICD-9 codes. Each SM could be identified as having multiple SULI types based on the ICD-9 codes in their records.

Aim 1

To address Aim 1 incidence rates (new cases divided by person-years), incidence rate ratios, upper extremity healthcare utilization rates and 95% confidence intervals (CI) were estimated. Incidence rates were calculated as number of cases by SULI category (from DMSS) as the numerator and person-time at risk (from DMED) as denominator

Rates were stratified by demographics (gender, age, race, grade, and service) and military occupation. Rates were compared using chi square tests. Statistical significance was set at an alpha of less than 0.05.

Aim 2

To address Aim 2, multiple logistic regression models were developed to analyze risk factors associated with SULI. Odds ratios (OR) and 95% confidence intervals (CI) were calculated to evaluate the strength of association between SULI and the risk factors of interest to include demographics (age, gender, race, rank and branch of service) and deployment related factors (deployment history). Among deployed service members a separate logistic regression model was used to evaluate additional deployment related factors (deployment length, location and frequency of deployment).

The primary exposure variables for this aim were military occupation and deployment related factors (deployment history, deployment frequency and deployment location).

Model 1:

Dependent variable: SULI

Primary Independent variable: Military occupation

Analysis: Multiple Logistic Regression

Model 2:

Dependent variable: SULI

Primary Independent variable: deployment history dichotomous variable

Covariates: gender, age, service, race, grade, service

Analysis: Multiple Logistic Regression

Model 3:

Dependent variable: SULI

Primary Independent variables: deployment location (OIF, OEF, OND), deployment frequency (1-2, 3-4, >5) and, deployment duration (<12 months, 12-15 months, >15 months)

Covariates: gender, age, service, race, grade, service

Analysis: Multiple Logistic Regression

Aim 3

To address Aim 3, Cox proportional hazards analysis was employed to compare attrition rates between SULI and non-SULI reported as hazard ratios (HR) and 95% confidence intervals (95% CI). Univariate analyses were conducted to explore the association with the outcome of each potential confounding variable. Potential covariates adjusted in all models included age, gender, race, service and deployment factors (deployment history, length, location, and frequency). Variables that were significant at the 0.20 level based on univariate tests (correlation, t tests and ANOVA) were further considered for inclusion in the model. Forward stepwise selection was considered to select which of these variables would be included in the final model but was not applicable because all variables were highly significant.

The primary exposure variables for this aim were the dichotomous SULI variable and deployment frequency.

Model 1:

Dependent variable: Attrition

Primary Independent variables: SULI (yes, no), deployment frequency (0, 1-2, 3-4, >5)

Covariates: gender, age, service, race, grade, service,

Analysis: Cox proportional hazards

Model 2:

Dependent variable: Attrition

Independent variables: SULI Types

Covariates: gender, age, service, race, grade, service, deployment frequency (0, 1-2, 3-4, >5)

Analysis: Cox proportional hazards

Aim 4

To address Aim 4 logistic regression analyses and Cox proportional hazards analysis were used to compare SAL cases with non-SAL cases to identify predictors of chronic pain and attrition. Chi-square test was used to compare frequencies and distribution of those SM with failed limb salvage to those with traumatic amputation. ORs and HRs and 95% CIs were reported.

The primary exposure variables for this aim were the dichotomous “yes/no” variables for SAL, chronic pain and failed limb salvage. Outcome variables were attrition and chronic pain. The covariates to be controlled for in the models are identical to those used for specific aims 2 and 3. Specific variables to be included in each model are listed below:

Model 1:

Dependent variable: Attrition (separation from active military service)

Primary Independent variables: SAL, chronic pain, failed limb salvage

Covariates: previous deployment and demographic characteristics (gender, age, race, grade/rank, and branch of service)

Analysis: Kaplan-Meier curves were created to display cumulative survival probabilities in the SAL and compared with the Log Rank test and no SAL groups) and Cox proportional hazards regression was performed.

Model 2:

Dependent variable: Chronic pain (history of chronic pain diagnosis greater than 3 month after incident SULI).

Primary Independent variable: SAL, failed limb salvage

Covariates: previous deployment and demographic characteristics (gender, age, race, grade/rank, and branch of service).

Analysis: Multivariable Logistic Regression.

All analyses were performed using SAS version 9.3 for recoding of variables and organizing the dataset and STATA version 13 for preparing descriptive and analytic results.

STUDY INVESTIGATORS

Colleen A. Daniels, MAJ, USA, SP was responsible for the overall design, management, and data analysis for this study. Dr. Angelica Cost and staff at the Armed Forces Health Surveillance Branch (AFHSB) performed the data abstraction and creation

of the data set. Assistance in data management was received from Dr. Cara Olsen, Department of Preventive Medicine and Biometrics at the Uniformed Services University (USUHS).

SAMPLE SIZE AND POWER ESTIMATES

Sample size estimates were based on traumatic amputation since we deemed this to be the most severe and least common outcome. We assumed that the incidence in the unexposed would be similar to the incidence in the total population, which we determined based on preliminary analysis of information reported in DMED. The approximate sample size required for a RR of 2.0 with .02% incidence in the unexposed, 80% power, and alpha .05 was 117,775 in each group (Appendix C). Based on the preliminary analysis of data contained in DMED, there are over 400,000 incident cases of SULI in the 10-year study period, 2003-2012.

Required sample sizes for models with attrition as the dependent variable (Aim 3) were smaller because the outcome is more common (Appendix C).

CHAPTER 3: Results

SECTION 1: EPIDEMIOLOGY OF SEVERE UPPER LIMB INJURIES IN THE U.S MILITARY: INCIDENCE, AND HEALTHCARE UTILIZATION

Study population

A total of 215, 663 SMs were identified as having a SULI qualifying diagnosis during the 10-yr study period (from the AFHSC created dataset). We excluded 87 SMs with records indicating incident-year date prior to 2003 and 1830 SMs with no SULI diagnosis codes in their records. An additional 14,364 SMs that met the study criteria were excluded from some of the analyses owing to the fact that their records did not contain complete demographic data. Therefore, for the present analysis the remaining 199,381 SMs with complete demographic data were included in Tables 1.1 to 1.4.

Incidence and Descriptive Characteristics

During the ten-year study period (2003-2012), 213,745 SMs were diagnosed with severe upper limb injury (SULI), an incidence of 15 per 1,000 person years, based on a total person years of 13,928,563, representing less than 1% of the Armed Forces.

Of the 213,745 SMs, 199,381 (93%) had records that were sufficiently complete with full demographic information to be used in all analyses in Aim One. Table 1.1 shows the demographic distribution of SM identified with SULI during the 10-year study period. SULI primarily occurred in males (89%), ages 20-24 years (42%), white (67%), and grade E1- E4 (57%). The Army made up the largest percent of SMs with SULI (38%) followed by the Air Force (23%). The distribution of the SULI population was similar to that of active duty personnel during the ten-year period, although the SULI

population had slightly higher proportion of males (89% versus 85%), non-white (33% versus 28%), and lower enlisted (57% versus 44%) based on information from DMED.

Military Occupation Categories for SMs with SULI

Table 1.2 shows the distribution of SULI by primary Department of Defense (DoD) Military Occupation Categories. Four occupational groups contributed the most person years to the study: Electrical/Mechanical Equipment Repairers (4.2 million p-y), Infantry/Gun Crews/Seamanship Specialists (2.0 million p-y), Functional Support and Administration personnel (1.7 million p-y) and Communications and Intelligence Specialists (1.1 million p-y). More than 90% of SULI occurred in military occupations assigned to enlisted military personnel. Non-occupational enlisted (602 per 10,000 p-y), craft workers (221 per 10,000 p-y), health care specialists (207 per 10,000 p-y) and infantry (178 per 10,000 p-y) accounted for the highest SULI rates. Among officers, the highest SULI rates were attributed to health care officers (140 per 10,000 p-y), non-occupational officers (116 per 10,000 p-y) and engineering/maintenance officers (109 per 10,000 p-y) while intelligence officers (87 per 10,000 p-y) and General officers (92 per 10,000 p-y) had the lowest SULI rates.

Overall SULI Incidence and Rate Ratios for SULI Population

Table 1.3 shows the analysis of demographic factors associated with SULI. The rates in the reference groups (arbitrarily selected based on previous studies of military populations) were compared against all other groups for gender, age, race, rank and military service. The rate of SULI was higher in males than females (RR= 1.32; 95% CI 1.30-1.34). For age, compared to the twenty to twenty-four year age group, SMs in all

39

other age categories had lower rates of SULI (RR ranged from 0.60 – 0.98). Among racial groups, blacks had lower SULI rates than whites (RR= 0.81; 95% CI 0.80-0.82), conversely, the SULI rate was almost doubled in the “other” race category compared to whites (RR= 1.45; 95% CI 1.43-1.47). When compared to SMs in E1-E4 rank category, all other pay grades had lower rates of SULI (RR ranged from 0.07-0.72). Among branch of service, SMs serving in the Marine Corps had slightly higher rates of SULI than those serving in the Army (RR= 1.02; 95% CI 1.01-1.04), while lower rates of SULI were observed among SM serving in the Navy (RR= 0.82; 95% CI 0.81-0.83) and Air Force (RR= 0.90; 95% CI 0.89-0.91) than Army (Table 1.3).

SULI Incidence for specific SULI types

The incidence rates and incidence rate ratios per 100,000 person-years for each SULI type by gender, age, race, pay grade and branch of service are shown in Table 1.4 and Table 1.5. Of all the SULI categories, open wounds had the highest incidence rate, per 100,000 p-y, (ID= 1326; 95% CI 1320-1332), followed by peripheral nerve injuries (ID= 82; 95% CI 81-84), while blood vessel injuries (ID= 9.1; 95% CI 8.6–9.6) had the lowest rate (Table 1.4). The SULI rates were significantly different for males than females for all SULI types; of interest males had an almost three-fold increased rate of traumatic amputation (RR= 2.94; 95% CI 2.56-3.44) and open fractures (RR= 2.85; 95% CI 2.50-3.23) than females (Table 1.5). All analyses for age were compared to the twenty to twenty-four age stratum as the reference group. Compared to the reference group, the thirty-five to thirty-nine year old stratum had similar rate of peripheral nerve injury (RR= 1.01; 95% CI 0.94-1.10), while the less than twenty-year stratum had an

increased rate of crush injuries (RR= 1.10; 95% CI 1.03-1.19). Similarly, the forty and older age group had an increased rate of peripheral nerve injuries (RR= 1.29; 95% CI 1.22–1.39). For all other SULI types, the rate was significantly decreased compared to the reference group, with a general trend of decreasing rate with increasing age (Table 1.5). All analyses for race were compared to the “white” race category. Among blacks, the SULI rates were significantly lower (ranged from 4% - 34% lower) than whites, while SULI rates were significantly higher among the “other” race category (7%-36% higher) than whites (Table 1.5). Junior enlisted (E1-E4) had similar rate of peripheral nerve injury as non-commissioned officers (E5-E9) (RR=1.02; 95% CI 0.98-1.06), although being junior enlisted was associated with higher rates of SULI in general. Of note, SULI rates for junior officers (O1-O3) were at least 90% lower than rates for junior enlisted SMs for all SULI types (Table 1.5). Among branches of military service, when compared to the Army as the reference group, the Navy and Air Force had significantly lower rates for all SULI types. Conversely, the Marine Corps had slightly increased rates of traumatic amputation (RR= 1.11; 95% CI 1.01-1.22), blood vessel injuries (RR= 1.21; 95% CI=1.04-1.40), open fractures (RR= 1.23; 95% CI 1.14-1.33) and open wounds (RR= 1.03; 95% CI 1.02-1.05). The Marine Corps had a similar rate of peripheral nerve injury as the Army (RR= 1.04; 95% CI 0.99-1.10), however, the rate of crush injuries was lower than the rate for Army (RR= 0.90; 95% CI 0.84 - 0.96) (Table 1.5).

SULI associated Health Care Utilization

Health care utilization was defined as all ambulatory visits or hospitalizations with a primary to tertiary diagnosis of any one of the six SULI types during the ten-year

study period. In total there were 1,187,987 ambulatory visits and 41,579 hospital admissions attributed to SULI in the study period, for a utilization rate of 872 per 10,000 p-y ambulatory visits and 31 per 10,000 p-y hospital admissions (Table 1.6).

Open wounds were associated with the highest utilization rate for ambulatory visits (590 per 10,000 p-y) and resulted in as much as 26 times more visits than blood vessel injuries (22.24 per 10,000 p-y), 16 times the utilization rate of crush injuries (36.6 per 10,000 p-y) and 10 times the utilization rate of traumatic amputations (58.1 per 10,000 p-y) (Table 1.6).

While open wounds had the highest ambulatory utilization rates of all the SULI types, open wounds also had the lowest number of visits per injured person of all SULI types. For example, the number of ambulatory visits per person was about five times higher for blood vessel injuries and traumatic amputation than open wounds (23 and 22 visits respectively compared to 4 visits per person), and about four times higher for open fractures (17 visits per person) and peripheral nerve injuries (12 visits per person), compared to 4 visits per person (Table 1.6). SULI hospital utilization rates ranged from less than 1 to 17 per 10,000 person-years with open wounds accounting for the highest utilization rate (17.5 per 10,000 p-y) (Table 1.6). Both blood vessel injuries and open fractures resulted in at least one admission per person. The number of admissions per injured person for all the other SULI types was less than one.

SULI Combinations

SULI categories were not mutually exclusive. In total, 13,424 SMs (6%) were identified as having multiple SULI (two or more SULI types). There was considerable

overlap among those identified with multiple SULI with open wounds. 94% of SMs with coexisting SULI types also had a diagnosis of open wound (Table 1.7). The most commonly coexisting SULI types were: peripheral nerve injury with open wound (n=3,571), crush injury with open wound (n=2,859), open fracture with open wound (n=2,166), and traumatic amputation with open wound (n=1,207). A total of 57 SMs (<1%) had 5 or more coexisting SULI types; three SMs had all 6 SULI types coexisting (Table 1.7).

SULI Incidence Trends

Pearson correlation was used to determine the linear association between time and counts of SULI occurrences (Figure 1-1), and SULI rates (Figure 1-2) for the 10-yr study period. SULI counts decreased each year during the 10-year study period with the exception of open fracture and crushing injury. The occurrence of open fracture remained stable over the ten-year period ($r = -0.47$, $p = 0.17$), while crush injury increased ($r = 0.93$, $p < 0.001$). There was significant negative trend for all other SULI types; traumatic amputation ($r = -0.87$, $p < 0.001$), blood vessel injury ($r = -0.88$, $p < 0.001$), and peripheral nerve injury ($r = -0.92$, $p < 0.001$) and open wound ($r = -0.82$, $p < 0.05$) (Figure 1-1).

Similarly, for SULI rates, there was a significant negative trend in SULI rates for traumatic amputation, blood vessel injury and peripheral nerve injury. Traumatic amputation ($r = -0.90$, $p < 0.001$), blood vessel injury ($r = -0.89$, $p \leq 0.001$), and peripheral nerve injury ($r = -0.92$, $p < 0.001$) rates decreased about 3% per year; the rates for open wound ($r = -0.86$, $p < 0.001$) decreased about 1% per year. There was no

significant change in rate for open fractures while crush injuries increased about 1% per year.

SECTION 2: DEPLOYMENT RELATED RISK FACTORS AND ATTRITION ASSOCIATED WITH SEVERE UPPER LIMB INJURIES IN THE US MILITARY, 2003-2012

Hypothesis 1: Service members who experience severe upper limb injuries (SULI) are more likely to have a history of certain deployment-related factors than service members without SULI. The rates of SULI will differ by age, gender, race, military occupation, branch of service and grade.

Hypothesis 2: Service members with SULI will experience higher rates of attrition when compared to service members without SULI.

Risk factors for SULI (unadjusted)

The distribution of SULI cases and a random sample of non-SULI controls are broken out by demographics (gender, age, race, grade, service) and two deployment variables (deployment history and deployment location) (Table 2.1). Demographic characteristics associated with higher risk of SULI include male gender (OR= 1.39; 95% CI 1.37-1.42) and older age. The <20 year age category had 71% lower odds of SULI compared to the 20-24 year age category (OR= 0.29; 95% CI 0.28-0.29), while all of the other age categories have significantly higher odds of SULI (Table 2.1). Compared to whites, the risk of SULI was significantly lower among blacks (OR= 0.94; 95% CI 0.92-0.96) and among personnel in the other/unknown race (OR= 0.96; 95% CI 0.94-0.97) (Table 2.1). Relative to the Army, Air Force (OR= 1.14; 95% CI 1.12-1.16) and Coast Guard (OR= 1.21; 95% CI 1.17-1.25) had increased risk of SULI while Marine Corps (OR= 0.81; 95% CI 0.79-0.82) and Navy (OR= 0.94; 95% CI, 0.92-0.95) was protective for SULI. Junior enlisted rank (E1-E4) was protective for SULI compared to all other ranks (Table 2.1). Non-Commissioned Officer Rank (E5-E9) was the strongest predictor

45

of SULI (OR= 2.05; 95% CI 2.02-2.08). Junior Officers (O1-O3) had 75% increased SULI risk (OR= 1.75; CI 1.62-1.87) of SULI and senior officers (O4 and higher) had 19% increased SULI risk (OR= 1.19; 95% CI 1.16-1.23) compared to junior enlisted (E1-E4). Service Members (SMs) with a deployment history had significantly higher odds of SULI compared to SMs who never deployed. SMs with more than four deployments had the highest odds of SULI (OR= 3.33; 95% CI 3.08-3.61), followed by SM with 3-4 deployments (OR= 3.00; 95% CI 2.91-3.09) and SM with a history of 1-2 deployments (OR= 2.68; 95% CI 2.64-2.72). Service Members who deployed to Iraq (OIF) had 148% higher odds of SULI (OR= 2.48; 95% CI 2.44-2.52) compared to non-deployers, and SM who deployed to Afghanistan (OEF) had 84% higher odds of SULI (OR= 1.84; 95% CI 1.81-1.88), while SM who deployed to Operations other than OIF and OEF had 52% higher odds of SULI (OR= 1.52; 95% CI 1.49-1.55) compared to non-deployers.

Risk for SULI by Military Occupational Specialties

The distribution by occupational categories was similar for SMs with SULI compared to SMs with no SULI with two exceptions. There were a higher proportion of electrical/mechanical equipment repairers (20% versus 11%) and a lower proportion of those listed as non-occupational enlisted (4% versus 28%) in the SULI group compared to Non-SULI (Table 2.2). Compared to infantry, electronic equipment repairers, healthcare specialists, electrical/mechanical equipment repairers, crafts workers, and service/supply handlers had increased risk of SULI. SULI odds ratios were highest for crafts workers (OR= 1.49; 95% CI 1.44-1.55) and electrical/mechanical equipment repairers (OR= 1.43; 95% CI 1.40-1.47). The odds ratios of SULI were increased for

electronic electrical repairers (OR= 1.17; 95% CI 1.14 - 1.21), health care specialists (OR= 1.18; 95% CI 1.15-1.22), and service/supply handlers (OR= 1.24; 95% CI 1.21-1.28) while all other military occupations were protective of SULI (Table 2.2). Odds of SULI in the “other technical/allied specialist” occupation group was not different from infantry (Table 2.2). Among occupations held by enlisted (ranks E1-E9), functional support and administration and communications/intelligence specialists had the lowest SULI odds. Functional support and administration had 13% lower odds (OR= 0.87; 95% CI 0.84-0.89) while communications and intelligence specialists had 17% lower SULI odds (OR= 0.83; 95% CI 0.81-0.85) compared to infantry. Odds of SULI were 89% lower in the non-occupational enlisted group compared with infantry. For Officers, those in non-occupational (OR= 0.32; 95% CI 0.30-0.34), General Officers and Executives (OR= 0.54; 95% CI 0.44-0.66) and Intelligence officers (OR= 0.55; 95% CI 0.51- 0.66) occupational categories had the lowest SULI odds (Table 2.2).

Risk factors for SULI (adjusted)

After controlling for age, race, grade, branch of service and deployed status in a multivariate logistic regression model, the odds of SULI for males was still high compared to females (OR= 1.25; 95% CI 1.22- 1.27).

The highest risk for SULI was among those 25-29 years, with 7% higher odds than those age 20-24 (OR= 1.07; 95% CI 1.05-1.09) controlling for gender, race, grade, branch of service and deployment status. All other age groups had significantly lower odds of SULI relative to those age 20-24 years, with ORs ranging from 0.32 (95% CI 0.32- 0.33) among those <20 years old to 0.91 (95% CI 0.88 - 0.93) among those age 30-

34 years (Table 2.3). Being non-white compared to white was protective for SULI. Odds ratio for blacks was lowest (OR= 0.82; 95% CI 0.80-0.83) when compared to whites. Odds ratio for SULI for SM in the other race category was 9% lower than whites (OR= 0.91; 95% CI 0.90-0.93), while controlling for all variables in the model. Compared to junior enlisted (E1-E4), non-commissioned officers (E5-E9) had the highest risk of SULI (OR= 1.14; 95% CI 1.12 - 1.17) after controlling for all other variables in the model. Junior officer rank (O1-O3) was not associated with risk of SULI relative to junior enlisted rank after controlling for age, race, service and deployed status. After controlling for all other variables, Air Force (OR= 1.17; 95% CI 1.14-1.19) and Coast Guard (OR= 1.62; 95% CI 1.56-1.68) had increased risk of SULI relative to the Army, while serving in the Navy (OR= 0.95; 95% CI 0.93-0.97) and Marine Corps (OR= 0.94; 95% 0.92-0.96) was protective.

Being deployed was a strong predictor for SULI. The odds of SULI was doubled in those who deployed (OR= 2.16; 95% CI 2.12-2.19) compared to non-deployers controlling for gender, age, race, grade and branch of service. All logit model odds ratios except junior officers (vs. junior enlisted) were significant at the $p < 0.001$ level (Table 2.3).

Risk factors for SULI for deployed SMs (adjusted)

The SULI odds for males, those in the 25-29 years age group and whites remain high in the subset of those who previously deployed when deployment factors (location, frequency and duration) were considered, while the SULI odds for NCOs (E5-E9) was no longer increased (Table 2.4). Serving in the Coast Guard and Navy was no longer

associated with increased SULI risk after including deployment location, frequency and duration in the model (Table 2.4). Deployment to Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) was significantly associated with increased SULI risk when compared to deployment to other campaigns, during the 2003-2012 time period. SMs with a deployment history of OIF had 27% higher risk of SULI (OR= 1.27; 95% CI 1.24-1.31) compared to other campaigns, while SMs with a deployment history of OEF had 8% increased SULI risk (OR= 1.08; 95% CI 1.05-1.11) after controlling for deployment frequency, deployment duration and all other variables in the model. High deployment frequency (three or more vs two or less) was also a predictor of increased SULI risk (Table 2.4). Compared to SMs with a deployment history of one to two deployments, SMs who deployed three or more times were more likely to have SULI regardless of deployment location, duration and all other independent variables, with a deployment history of five or more deployments being the strongest predictor of increased SULI risk (OR= 1.20; 95% CI 1.02-1.31). Deployment duration was significantly associated with increased SULI risk, after controlling for deployment frequency, deployment location, gender, age, race, grade and branch of service (except Navy and Coast Guard) (Table 2.4). Compared to SMs who deployed for less than 12 months, those with a history of deployment duration greater than 15 months had highest SULI odds (OR= 1.14; 95% CI 1.09-1.18), those who deployed for 12 to 15 months had 6% higher risk of SULI than the comparison group (OR= 1.06; 95% CI 1.02-1.10), after controlling for all other variables in the model.

Risk of Attrition by SULI

Figure 3-1 shows risk of attrition for SM with and without SULI. Attrition rates were greater among SMs with SULI ($p < .001$). Median time to discharge was approximately 4 years for SMs with SULI and 5 years for SMs without SULI. Tables 3.1 and 3.2 show the results of Cox proportional hazards regression analyses for risk of attrition for U.S. military personnel during the 2003-2012 time period. SULI was associated with a 23% increased risk of attrition (Table 3.1). One of the strongest predictors of increased risk for attrition was increased age, 35 years and older. Those age 35-39 years had 49% increased risk of attrition (HR= 1.49; 95% CI 1.45-1.53) and those greater than 40 years had almost three times the risk of attrition (HR= 2.69; 95% CI 2.62-2.76) relative to those age 25-29 years, while those between ages 30-35 years had the lowest attrition rates (Table 3.1). Relative to white service members, black service members (HR= 0.81; 95% CI 0.80-0.83) and service members of the other race category (HR= 0.82; 95% CI 0.81-0.83) had a decreased risk of attrition. Junior Enlisted rank (E1-E4) had significantly higher attrition than all other grades (Table 3.1). Navy and Marine Corps had an increased risk of attrition compared to Army, whereas Air Force and Coast Guard had a decreased risk (Table 3.1). Relative to never deployed, being deployed 1-2 times was associated with an increased risk of attrition (HR= 1.13; 95% CI 1.12-1.15) while being deployed three to four times (HR= 0.91; 95% CI 0.89-0.94) and greater than five times (HR= 0.84; 0.78-0.90) was protective for attrition, after controlling for all variables in the model (Table 3.1).

Relative to service members with no SULI, the risk of attrition was increased for service members with specific SULI types. The strongest predictors of risk of attrition

were peripheral nerve injury (HR= 1.21; 95% CI 1.17-1.24), blood vessel injury (HR= 1.17; 95% CI 1.09-1.26), traumatic amputation (HR= 1.09; 95% CI 1.04-1.14), and open fracture (HR= 1.07; 95% CI 1.02-1.11) all having an increased risk even after adjusting for all variables in the model. Conversely, the risk of attrition was decreased for service members with crush injury (HR= 0.87; 95% CI 0.84-0.90) and open wound, (HR= 0.86; 95% CI 0.84-0.88) compared to service members with no SULI, after controlling for gender, age (at time of injury), race, grade, branch of service and number of deployments (Table 3.2).

SECTION 3: ANALYSIS OF LIMB SALVAGE PROCEDURES OF THE UPPER EXTREMITY IN US MILITARY, 2003-2012: INCIDENCE AND OUTCOMES

This section is a descriptive analysis of SULI cases who underwent upper limb salvage (SAL) procedures. SULI cases who underwent a primary traumatic amputation were excluded from this analysis.

Incidence and Descriptive Characteristics

Figure 4-1 shows risk of attrition for SM with and without SAL among those with SULI. Attrition rates were higher for SMs with SAL (log rank test, $p < .001$). Median time to discharge was 3 years for those with SAL and 5 years for SM without SAL. Table 4.1 shows the demographic distribution of SMs with SULI who underwent limb salvage procedures or had a limb salvage procedure codes in their record during the 10-year study period. In total, 615,874 person-years (p-y) in 210,130 cases of SULI were used for this analysis, of which 610 underwent limb salvage (SAL) procedures. The SAL incidence rate was approximately 10 per 10,000 person-years in persons with SULI. SAL occurred more often in males (IR= 10.6 per 10,000 p-y); 20-24 age category (IR=7.6 per 10,000 p-y), among blacks (IR=10.4 per 10,000 p-y), junior enlisted (IR=12.8 per 10,000 p-y) and in the Marine Corps (IR=18.2 per 10,000 p-y) and in SMs with a deployment history (IR=13.8 per 10,000 p-y). Of all SAL categories, critical soft tissue loss requiring local or free flap coverage or skin graft (IR=4.9 per 10,000 p-y) and vascular injury requiring revascularization (IR=2.8 per 10,000 p-y) constituted the highest incidence. While it did not reach statistical significance, clinically complete brachial plexopathy had the lowest SAL incidence, and only occurred in SMs serving in the Navy and Air Force.

The Air Force also had the lowest incidence of revascularization (1.7 per 10,000 p-y), while the Navy had the lowest incidence of injuries requiring skin graft or local or free flap coverage (2.6 per 10,000 p-y).

SAL Combinations and SULI-SAL patterns

Similar to SULI, there was overlapping of SAL types. A total 200 SMs were identified with two or more coexisting SALs (Table 4.2). The conditions/ procedures which frequently existed concomitantly were: bone transfer and multiple rays (n=49, 8%), skin graft and multiple ray involvement (n=44, 7%), revascularization and multiple tendon transfers (n=29, 5%), skin graft and bone transfer (n=14, 2%). Only 29 SMs (5%) had three or more SAL types concomitantly. Skin graft, bone transfer and multiple rays involvement was the most common SAL combination of those with three or more SAL types.

Table 4.3 shows the SAL procedures and diagnoses associated with specific SULI types. There were 610 SULI cases that met criteria for SAL. 14% of those with a blood vessel injury diagnosis met criteria for SAL, whereas only 2% of those with peripheral nerve injury, and 5% of those with open fracture diagnoses met SAL criteria. SULI cases with crush injury or open wound were less likely to have a SAL procedure or diagnosis. 11% of SULI cases with a blood vessel injury had a subsequent revascularization; approximately 7% had other SAL procedures. Approximately 3% of the SULI cases with open fractures underwent a subsequent free or local flap coverage or skin graft; while about 4% had bone transfer or transport procedures and multiple ray involvement.

Risk for Chronic Pain and Attrition

Nearly half (46%) of service members with SULI separated from military service during the study, with a median time from SULI to separation being 5 years. In contrast 42% of service members without SULI separated from military service. There were 4,171 cases (2%) of all SULI with evidence of chronic pain diagnoses occurring at least three months after incident SULI. Table 4.4 shows the results of Cox proportional hazards regression analyses for risk of attrition. After adjusting for all variables in the model, SAL was associated with a 21% increased risk of attrition. SMs with SULI and subsequent SAL separate from military faster than those with no SAL. The median time to attrition in the SAL group was 3 years while the median time to attrition in the no SAL group was 5 years after SULI incidence (Figure 4-1). Among SMs with SULI, the risk of attrition was 5% higher (OR= 1.05; 95% CI 1.04-1.07) in those with a deployment history regardless of whether they had a SAL or not. SMs with failed limb salvage were 36% less likely (OR= 0.64; 95% CI 0.31-1.28) to leave the military than SMs with SULI and no record of failed limb salvage. The risk of attrition was decreased by 20% among SMs with a chronic pain history when compared to SMs with no history of chronic pain (OR= 0.80; 95% CI 0.76-0.84).

Table 4.5 shows the logistic regression for odds of chronic pain in SMs with SULI. After adjusting for all variables in the model, the odds of chronic pain were 6 times higher in those with SAL compared to no SAL (OR= 6.09; 95% CI 4.67-7.94), similarly the odds of chronic pain was significantly higher in SMs with a failed limb salvage compared to SMs without a failed limb salvage (OR= 4.46; 95% CI 1.70-11.78).

The odds of chronic pain were 12% higher in deployers than non-deployers (OR= 1.12;

95% CI 1.04-1.20). Females had 70% higher odds of chronic pain compared to their male counterparts (OR= 1.70; 95% CI 1.54-1.85). There was a dose-response relationship with chronic pain and increasing age up to age 39. Compared to whites, SMs in the other two race categories had lower odds of chronic pain (OR= 0.58, for blacks; OR=0.78 for other race). Similarly, relative to the Army being in all other branches of service had lower odds of chronic pain (ORs ranged from 0.31 to 0.58). All odds ratios were statistically significant.

Failed Limb Salvage Descriptive Analysis

Due to the small number of cases, it was not feasible to model the failed limb salvage data using regression or other multivariate models, therefore, a descriptive analysis of the 19 cases of failed limb salvage which occurred in the 610 SMs with a SAL is shown. Table 4.6 shows the demographic distribution of the 19 SMs with failed limb salvage (secondary amputation). All cases of failed limb salvage occurred in males; almost 50% were 20-24 years, and primarily white (74%), junior enlisted (63%), serving in the Army (84%) or Marine Corps (16%). The demographics are similar for SMs with failed limb salvage (secondary amputation) to SMs with traumatic amputation (primary amputation).

There were differences by SAL category, chronic pain and deployment history. Failed limb salvage occurred more frequently in SMs who sustained critical soft tissue loss requiring local or free flap coverage or skin graft (84%), and in SMs who had a dysvascular limb or vascular injury requiring revascularization (11%). SMs with a history of multiple rays involvement or multiple tendon repairs or transfers with or

without a muscle loss, also had higher frequencies of failed limb salvage (32% and 16% respectively). A smaller proportion of SMs with a history of chronic pain had failed limb salvage than those who did not have a chronic pain history (42% compared to 58%). The frequency of failed limb salvage also differed for SMs with a deployment history. While 26% of SMs without a deployment history underwent failed limb salvage, failed limb salvage occurred more frequently in SMs with a history of two or less deployments. 68% of failures occurred in SMs with a history of one deployment, while only one SM (5%) with a history of two deployments had a failure. 58 percent of failed limb salvages occurred within 1 year of SAL with 16 percent one to five years and 26 percent occurred more than 5 years.

CHAPTER 4: DISCUSSION

This study used secondary data to evaluate the occurrence of severe upper limb injuries (SULI) in a cohort of U.S. military personnel who served on active duty during the 10-year period of military conflict in Iraq and Afghanistan. The study design used a retrospective cohort and case-control to achieve three primary study aims:

1. Describe the epidemiologic characteristics of severe upper limb injuries (SULI) in active component (AC) U.S. military members
2. Examine the association between specific deployment related and demographic risk factors and occurrence of severe upper limb injury
3. Determine the association between severe upper limb injury and separation from the U.S. Armed Forces.

This is the first known study to estimate the incidence of SULI in the U.S. military. The incidence of SULI was 15/1,000 person-years and was higher in males, SMs between ages 20-24, lower enlisted (E1-E4), “other” race, and Marines. These results are approximately similar to the demographic distribution of upper limb injuries reported by Brininger et al (7) in a study of a military cohort during 1998-2006. Increased incidence rates for work related upper extremity injuries have also been reported by the Bureau of Labor and Statistics among civilian males, older age (45-54 years) and white race (40). Differences noted in the civilian cohort and the present cohort may be attributed to several factors to include different work exposures in the military, younger population in the military and the healthy worker cohort effect in the military.

SULI incidence reported in the present study may have been underestimated for the following reasons: First, results in this study represented cases for which information was available; since theater data or purchased care records were not available for the present study incident cases that were treated earlier and far forward or in civilian facilities may have been missed. Second, this study only used injury diagnoses coded in primary to tertiary field positions to determine cases. Therefore some cases such as complex cases involving those with the need for life sustaining interventions, where it is possible that a traumatic amputation or other SULI type would have been rated lower, may have been excluded from the study dataset. Subsequently, it is expected that the actual SULI incidence is higher than reported in this study.

It is possible that some of the open wound cases were not as severe (i.e. mild or uncomplicated) and classified as SULI potentially leading to false positive results. I expect that the number of misclassified cases would be small with little impact on SULI estimates.

This study found a significant negative trend in the rates over the time period studied of most SULI types (traumatic amputation, blood vessel injury, peripheral nerve injury and open wound), while other studies reported increases in similar injury types such as amputations (3; 7) and peripheral nerve injuries of the radial and ulna nerve (7) during the same time period. The conflict in results may be due to differences in how the three studies were conducted. Brininger et al (7) compared peacetime rates to combat rates between two different time periods (1998-2001 and 2001-2006) and noted an increase in the latter time period but did not study the trend by year for the 5 yr period,

2001-2006, as was done in the present study. Andersen et al (3) reported increased number of patients with amputations (notably triple and quadruple amputees), open pelvic injuries, mangled extremities, and genitourinary injuries after the surge in Afghanistan in 2010, but did not compare rates. The negative trend found in this study is possibly due to factors such as differences in medical diagnostic coding practices over the 10-year study period, or changes in exposures in theater due to maturity of the battlefield, or factors such as improved protective equipment could play a role. Additionally, the rates found in this study may be different from previous studies which reported on combat related injuries while this study reported on all cause severe upper limb injuries in general to include combat and non-combat related injuries. The present findings may suggest that the majority of SULI injuries may be non-combat related (such as training related, recreational, or non-operational such as motor vehicular).

SULI accounted for over one million ambulatory visits and about forty-one thousand hospital admissions during the ten-year period. Open wounds, the least severe SULI studied, accounted for the greatest healthcare utilization for both ambulatory visits and hospitalization. Both blood vessel injuries and traumatic amputation had the greatest individual burden as far as having the highest number of ambulatory visits per injured person. This likely represents the severity and complexity of these injuries requiring more frequent visits.

Blood vessel injuries and open fractures accounted for the greatest number of hospital admissions per injured person. Surprisingly, traumatic amputation did not result in greater than one hospitalization per person on average. We did not have information

on length of hospitalization or ambulatory visits or hospitalizations during deployment or for purchased (non-military treatment facilities) care. This may explain why the number of hospitalizations per injured person for certain SULI types, such as traumatic amputation, was surprisingly low. It is also likely that a hospitalization involving upper limb traumatic amputation may be missed in SMs with other more critical life threatening injuries, such as penetrating head or torso injury or associated injuries such as open pelvic injuries, or other critical organ injuries requiring hospitalization at the same time.

As expected, there was considerable overlap of SULI types. The majority of the cases of multiple SULI (two or more SULI types) had a diagnosis of open wound. The results suggest that these more severe upper extremity injuries most often correlate with tissue loss as described in other studies (3; 24; 33).

This study found an association between SULI and deployment history. It is unknown whether this finding is consistent with other injuries or among deployed personnel. While other military studies have found a relationship with increased injury types (amputations, brachial plexus injury, and peripheral nerve injuries) during periods of military conflict compared to peacetime (7; 13), no similar studies linking deployment related risk factors to outcomes could be found as comparison.

Interestingly, while SULI was associated with previous deployment history, length of deployment and deployment frequency in this study, many of the military occupations associated with increased risk of SULI were in non-combat related occupational groups such as electronic equipment repairers, healthcare specialists, electrical/mechanical equipment repairers, crafts workers, and service/supply handlers.

This finding is a deviation from what was reported in prior literature in similar studies of military occupational specialties (MOS). For example, Gronroos et al (22) investigated the risk of hospitalization among Marines deployed during OEF and OIF (September 2001 to January 2007) by MOS. They found an association with non-infantry occupational specialty and lower risk for hospitalization from open wound injuries or trauma to extremities in comparison to infantry MOS. The findings in the present study may suggest that majority of deployment-related SULI injuries may have occurred under non-operational or non-combat conditions, that is some are non-operational or non-combat related. The mechanisms of injury of the deployment-related SULI found in the present study are unknown. A clearer understanding of the mechanism of injury, whether they were directly combat related (such as blast injury or gunshot wounds), operational (such as motor vehicular accidents rollover during convoy), duty related (such as injuries from performing maintenance tasks on equipment, maneuvering or lifting heavy equipment) or from other causes, such as recreational/sports may assist primary prevention strategies.

The present study identified 19 cases of failed limb salvage (delayed or secondary amputation). The low number of failed limb salvage may indicate that more SMs are opting to spare their limbs, regardless of devastating injuries or functional status, over delayed amputation owing to limitation in available upper limb prosthesis. It may also indicate advances in surgical management or surgeon's preference based on practice and experience. Other unknown factors such as the psychological and social implications of upper limb loss, or the notion that a "bad hand" is still functionally better than a good

upper limb prosthesis, as some have reported, may also have played a role. Several authors have reported upper limb reconstruction as preferred to amputation due to the limitations in modern day upper limb prosthesis, lacking in the functionality and aesthetics often present in lower limb prosthesis when compared (3;10, 36).

The small number of failed limb salvage cases in this study may also represent more severe cases of SAL or cases where chronic pain may have played a role in the decision to convert to amputation after limb salvage. This finding would be consistent with what has been reported in the literature on the association of persistent pain and limb salvage (19). Goff et al (19) reported chronic pain as a common sequelae of limb salvage and noted pain associated with limb salvage may be the result of several factors to include: direct result of injury to the soft tissue and/or bones, fused or partially fused joints, or heterotrophic ossification, or secondary to posttraumatic arthritis or neuropathic pain. Owing to the small number of failed limb salvage in the present study these associations could not be explored.

SULI was associated with higher rates of attrition and chronic pain. This finding is consistent with what has been reported previously for UE injuries, disability and separation from the military (13). The association of chronic pain and white race found in this study has been reported in some recent studies of racial ethnic disparities and chronic pain. Several studies comparing pain experiences and clinical outcomes among whites, African Americans and Hispanics have yielded mixed results (11; 21; 25; 37). Some studies have suggested evidence of enhancement of pain experience among non-whites (Hispanics and African Americans), however most of these studies did not control

for possible confounding factors such as demographics, medical, physical and psychological confounders (such as pain coping strategies, impact of psychological stress or psychosocial and secondary gain) among racial ethnic groups. In studies where comparisons were adjusted to control for potential confounding variables, results were similar, i.e. no significant difference in measures of chronic pain were found across racial groups (15; 23; 30). The difference noted in this study may be due to factors related to being in the military such as unlimited and available access to care and possible ethnic or racial disparities in care seeking patterns in the military.

STUDY STRENGTHS

This study is the first known study to my knowledge focusing on SULI using a large population across all branches of military service. Comparable incidence rates, and association with risk factors and outcomes are absent from the literature; few studies have reported on incidence rates and used statistical modeling to control for potential confounding variables. Therefore, this study extends what is presently known about SULI in the U.S. military. The large number of service members in the present cohort gave sufficient power to detect small differences and study multiple associations.

LIMITATIONS

Since SULI is not a specific ICD-9 diagnosis, some cases may have been missed due to variability in diagnostic coding practices between healthcare providers. In an attempt to identify only incident cases, SULI diagnosis codes were limited to primary, secondary and tertiary diagnoses only which may have resulted in an underestimation of

SULI cases. The number of potential missed cases in the general military population is unknown but expected to be demographically similar to the cases identified. There are several limitations of using data from a large database. First, DMSS only contained diagnostic codes of encounters that were coded by multiple providers from a variety of specialties, training and experience, which may have led to inaccuracies in identifying specific types of SULI and even distinguishing SULI from non-SULI. We expected this misclassification to occur equally in cases and controls. The resulting effect of this non-differential misclassification is that any observed association of SULI may be biased to the null, underestimating the true effect. Second, we were unable to directly assess the impact of multiple injuries on risk of chronic pain and attrition. It is likely that some service members may have had multiple injuries/ poly-trauma or injuries that may exist concurrently with SULI, such as injuries to the lower extremity, head, chest or abdomen/pelvis. It was estimated that this would occur in about 15% of the present cohort, based on previous longitudinal study of a civilian cohort with limb injuries (5). Third, the occurrence of chronic pain post SULI and attrition could not be directly measured (with medication use for example, as pharmaceutical information was unavailable), so a proxy case criteria for chronic pain was used and may have led to an under estimation of chronic pain cases. Additionally, cases of chronic pain may have been missed due to provider coding practices. It is possible that true cases with chronic pain in cases of poly trauma may not have been coded for the chronic pain but the primary reason for visit. It is also possible that chronic pain may not be related to SULI and from other cause, in cases of poly-trauma. Similarly, since attrition was from all

causes, the data did not lend itself to assess whether a separation from the military is related to SULI or some other medical conditions or administrative reasons (such as the end of the service member's obligation or other administrative separation unrelated to SULI), therefore any observed associations could have resulted from other trauma or unknown factor not directly associated with SULI but associated with attrition. Multivariable modeling was used to attempt to remove the effect of other likely factors that could explain any observation. Fourth, DMSS did not contain data on medical encounters during deployment. Controlling for deployment may minimize the effect in our models, however since we did not have data on deployment or theater medical records, a direct association between SULI and combat could not be established. The study attempted to show a relationship between SULI and possible combat related occupations by examining the distribution of SULI across different occupational specialties. Finally, DMSS data did not contain information on potentially important variables such as hand dominance and which side was affected and functional outcomes. Therefore the present study could not determine whether the SULI occurred in the dominant hand which has been reported in previous studies to be the most often injured (41) and may further impact recovery. The functional capacity/impairment (e.g. Basic and Instrumental Activities of Daily Living, ability to drive, employability) data post SULI was also not available in this study which is of critical importance to SMs recovery or ability to return to active duty service.

The low number of delayed or failed limb salvage cases reported in this study limited the power to detect associations in study Aim four. However, this study was able

to perform a descriptive comparison between the distributions of SMs with primary traumatic amputation to those of failed limb salvage (secondary amputation) and found the demographic and clinical distributions to be similar.

The findings from this study may be applied to all branches of service in the U.S. military active component. While the findings may also be generalized to the U.S. military reserve component and foreign military population with similar demographic distribution and similar exposures as the U.S. military, extending the observed associations outside of the context of the military is limited due to the healthy worker effect within the military compared to non-military populations that do not have the strict medical accession, deployment, retention and physical fitness standards of the U.S. military.

PUBLIC HEALTH SIGNIFICANCE

While the overall SULI rate was relatively small in comparison to other chronic illness, cancer, infectious diseases or lower extremity injuries in the military, SULI may represent significant impairment for individuals (41) and health burden to the military (13).

The body of literature on severe/complex injuries of the upper extremity is limited therefore there are multiple unanswered questions which are of public health and clinical significance to include the following: 1) What groups are affected in the military? 2) How many are affected? 3) Is one group at higher risk than others? 4) What factors are associated with these injuries? 5) What are outcomes of persons with these injury types as it relates to their ability to continue in the military and their ability to function in

everyday life? To get to the heart of the field of public health, ultimately to prevent SULIs in the future, the military must be able to identify modifiable risk factors and determine how they can be mitigated or averted?

The findings of this study provide preliminary evidence on the natural history of severe upper limb injuries and the distribution of SULI within the U.S. military. These results may serve as the ground work for identifying high risk occupational specialties and modifiable risk factors and opportunities for primary and tertiary prevention of SULI. Early identification of associations between occupation groups, or deployment factors would allow public health practitioners, ergonomists, industrial hygienists, occupational medicine providers and occupational therapy rehabilitation clinicians to offer early intervention. Further public health policies related to the conditions described in this study such as studies of the feasibility of retention of SMs with SULIs are needed.

This information is also relevant to the field of rehabilitation science and occupational therapy. Clinicians involved with development of treatment protocols may use this information to assist with reshaping existing protocols or developing new ones based on outcome data. It may also assist occupational therapy leaders with decisions related to resource allocation of occupational therapists working in upper extremity rehabilitation, identify possible training needs or changes in practice needed to more effectively treat individuals with these injuries and to avert complications such as delayed amputation due to poor function of the severely injured upper extremity or avert permanent impairment or disability.

FUTURE RESEARCH

This study presents several opportunities for future studies. First, further characterization of SULI is needed to gain a better understanding of its impact on functional performance. Future studies should explore the impact of having multiple SULI (to include unilateral versus bilateral extremity) and the effect of SULI in the case of multiple injuries involving two or more extremities (upper and lower) in cases of “poly-trauma” (multiple SULI) and how likely are SMs to recover and return to full duty, compared to SMs with only one SULI type. In addition, future studies should assess information on related co-morbid conditions to assist with the estimation of the association between SULI and SAL, chronic pain and attrition in the presence of co-existing conditions.

Further attention is needed to define upper limb salvage. Additional future studies are needed to fully develop and validate the upper limb salvage definition and compare outcomes among individuals with traumatic amputation (occurring at time of injury or as definitive treatment for SULI), limb salvage (as definitive treatment for SULI) and secondary amputation (failed limb salvage). Future studies should also focus on the effectiveness of specific therapeutic interventions on outcomes of SULI. Other potential area of study includes hand dominance to look at the impact of SULI when the dominant versus non-dominant hand is affected.

While the present study reported on injury and utilization rates of SULI across the military, the cause of injuries could not be assessed. An important next step would be to identify the mechanism of injury, and to ascertain the linkage between the cause of injury and outcomes. Future research should include Joint Theater trauma registry to look

specifically at deployment-related SULI to better understand the relationship with the mechanism of injury.

This study also presents opportunities for future program development research. For example, while a specific formal protocol exists for the treatment and rehabilitation of traumatic amputations of the upper limb, no formal protocol or programs for upper limb reconstruction of SULI exist. Being able to study the effectiveness of having a formal protocol and available assets/resources, such as specialized equipment and specially trained and experienced personnel, dedicated to the treatment of limb reconstruction after SULI, similar to traumatic amputations, may have direct impact on outcomes, recovery and decisions for delayed or secondary amputations.

This study provides a foundation for: planning the development of a specific treatment protocol and algorithm for limb salvage rehabilitation similar to what was done for upper limb amputation and additional studies to further explore associations between risk factors in specific military occupational groups, and deployment risk factors. It can be speculated while the true numbers are unknown that the cause for all SULIs were not due to a combat related injury and some were the result of other operational incidents such as vehicular accidents, rollovers or non-operational or sports related in addition to combat engagement or other combat exposure. Future research should use the combat trauma registry to look specifically at deployment trauma-related SULIs and link the injury cause to outcomes.

CONCLUSION

SMs are demanding a higher level of function in their future life, which challenges rehabilitation specialists to help patients achieve their functional goals. Severe upper limb injuries (SULI) may impact SMs ability to work in their military occupational specialty and may result in time away from work/missed time, impact mission readiness such as the ability to deploy and may result in long term disability or separation from the military (13). The cost to the military to retrain SMs affected by SULI may be significant.

Early treatment and effective management of upper extremity injuries is critically important to the recovery of function needed for an array of activities important to every SM. Good hand function allows SMs to show expression, hold or cradle their newborn, engage in their favorite sport, play a musical instrument, complete a cooking task, write or use a keyboard for school or personal tasks, perform daily activities such as self care (grooming or pulling on military boots and tying the laces) give a hand shake or render a salute in addition to being able to perform functional MOS tasks such as firing their assigned weapon, detonating an unexploded object or performing convoy operations. The role of the occupational therapist (OT) is to facilitate recovery and restore SM functional independence. That is, the occupational therapists job is to help SMs return to full independence in their Basic and Instrumental Activities of Daily Living (B/IADLs) of self care, work, as well as their leisure/avocational activities. To the SM, being able to perform his/her leisure pursuits may just be as or more important to being able to perform in their military occupational roles. Leisure/past time activities are varied and may involve video games, bowling, fishing, horseback riding, remodeling cars, or household

projects. Therefore, it is of significance for OTs to have an understanding of how SMs are affected by these injuries, the nature of these injuries and be able to predict the impact on recovery and develop rehabilitation protocols to assist recovery.

This study adds to the growing body of research on seven severe injuries of the upper limb. The current study provides information on severe upper limb injuries, which will inform public health practice, and the fields of occupational therapy and orthopedic hand surgery. The present study lays the groundwork for understanding the natural history of SULI, as well as aid in the identification of certain risk factor for SULI which provides a better understanding of who are at risk for unfavorable outcomes and creates opportunities for primary prevention (mitigating certain risk factors related to SULI) and tertiary prevention (preventing complications of SULI).

An understanding of the SULI sequelae will inform occupational therapists and hand surgeons and provide opportunities for optimizing treatment, and informing patients on expected outcomes. This study also laid the groundwork for estimating the upper limb related healthcare burden across military branches. Finally, this study provides information on the impact of SULI on amputation secondary to failed limb salvage, and military separation associated with SULI, which may create opportunities for reducing impairment, disability, attrition and developing evidence-based military retention policies.

TABLES

Table 1.1 Characteristics of U.S. Military Personnel Identified as Having a Severe Upper Limb Injury (SULI), 2003-2012

SULI Demographics		Any SULI (n=199,381)	SULI Types*					
			Traumatic Amputation (n=3,465)	Peripheral Nerve Injury (n=11,481)	Blood vessel Injury (n=1,263)	Open Fracture (n=4,568)	Crush Injury (n=9,547)	Open Wound (n=184,669)
			----- n (%)	----- n (%)	----- n (%)	----- n (%)	----- n (%)	----- n (%)
Gender	Male	176,601	3,277 (95)	10,088 (88)	1,174 (93)	4,310 (94)	8,251 (86)	164,050 (89)
	Female	22,780	188 (5)	1,393 (12)	89 (7)	258 (6)	1,296 (14)	20,619 (11)
	Total	199,381	3,465 (100)	11,481 (100)	1,263 (100)	4,568 (100)	9,547 (100)	184,669 (100)
Age	<20	16,713	237 (7)	644 (6)	86 (7)	377 (8)	986 (10)	15,636 (8)
	20-24	83,454	1,415 (41)	3,958 (34)	605 (48)	2,051 (45)	4,343 (45)	78,113 (42)
	25-29	42,440	688 (20)	2,391 (21)	264 (21)	967 (21)	2,042 (21)	39,397 (21)
	30-34	22,294	455 (13)	1,426 (12)	109 (9)	480 (11)	981 (10)	20,543 (11)
	35-39	18,571	346 (10)	1,442 (13)	110 (9)	364 (8)	655 (7)	16,919 (9)
	40+	15,909	324 (9)	1,620 (14)	89 (7)	329 (7)	540 (6)	14,061 (8)
Race	White	134,334	2,396 (69)	7,840 (68)	831 (66)	3,162 (69)	6,345 (66)	124,587 (67)
	Black	27,642	398 (11)	1,623 (14)	202 (16)	499 (11)	1,323 (14)	25,442 (14)
	Other	37,405	671 (19)	2,018 (18)	230 (18)	907 (20)	1,879 (20)	34,640 (19)
Grade	E1-E4	113,597	1,854 (54)	5,538 (48)	766 (61)	2,655 (58)	6,200 (65)	105,835 (57)
	E5-E9	74,747	1,437 (41)	5,146 (45)	451 (37)	1,685 (37)	3,025 (32)	68,721 (37)
	O1-O3 (W01- W03)	1,714	34 (1)	118 (1)	9 (1)	41 (1)	62 (1)	1,572 (1)
	O4-O10 (W04- W05)	9,323	140 (4)	679 (6)	37 (3)	187 (4)	260 (3)	8,541 (5)
Service	Army	76,750	1,516 (44)	4,896 (43)	589 (47)	2,111 (46)	3,731 (39)	70,718 (38)
	Navy	41,220	610 (18)	2,168 (19)	200 (16)	750 (16)	1,653 (17)	38,417 (21)
	Air Force	44,987	610 (18)	2,238 (19)	183 (14)	638 (14)	2,325 (24)	41,687 (23)
	Marines	28,423	612 (18)	1,843 (16)	258 (20)	943 (21)	1,214 (13)	26,406 (14)
	Coast Guard	8,001	117 (3)	336 (3)	33 (3)	126 (3)	624 (7)	7,441 (4)

*The total for each category is given, with the percentage in parentheses. SULI categories are not mutually exclusive and include SM with multiple SULI types;

¶ Total (N) = 199, 381 (based on total number of SM with SULI with full demographic information)

Table 1.2 Distribution of SULI, by Military Occupations, 2003-2012

Military Occupational Specialties	Person years (n=213,722)	ALL SULI	SULI Rates§	SULI Types					
				Traumatic Amputation (n=3,663)	Peripheral Nerve Injury (n=12,190)	Blood Vessel Injury (n=1,339)	Fractures (open) (n=4,842)	Crush Injury (n=9950)	Open Wound (n=198,232)
				n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Enlisted									
Infantry, Gun Crews, Seamanship Special	2,015,621	35,936	178	1,033 (28)	2,587 (21)	395 (30)	1,569 (32)	1,601 (16)	33,315 (17)
Electronic Equipment Repairers	968,777	14,033	145	181 (5)	713 (6)	60 (4)	256 (5)	660 (7)	13,033 (7)
Communications & Intelligence Specialists	1,128,040	14,609	130	213 (6)	977 (8)	93 (7)	312 (6)	575 (6)	13,507 (7)
Health Care Specialists	657,377**	13,581	207	122 (3)	766 (6)	72 (5)	190 (4)	421 (4)	12,669 (6)
Other Technical & Allied Specialists	364,922	5,977	164	132 (4)	351 (3)	49 (4)	130 (3)	271 (3)	5,548 (3)
Functional Support & Administration	1,735,892	20,681	119	242 (7)	1,281 (11)	125 (9)	254 (5)	929 (9)	19,004 (10)
Electrical/Mechanical Equipment Repairers	4,241,112	43,772	103	722 (20)	2,080 (17)	207 (16)	857 (18)	2,672 (27)	40,533 (20)
Crafts workers	420,294	9,289	221	202 (6)	433 (4)	54 (4)	235 (5)	587 (6)	8,644 (4)
Service and Supply Handlers	1,227,026	21,857	178	336 (9)	1,090 (9)	118 (9)	399 (8)	1,000 (10)	20,356 (10)
Non-occupational, Enlisted	142,851	8,597	602	108 (3)	405 (3)	44 (3)	138 (3)	509 (5)	7,936 (4)
Enlisted, Unknown	6,743	723	1,072	6 (<1)	37 (<1)	4 (<1)	14 (<1)	26 (<1)	681 (<1)
Officers									
General Officers and Executives	19,246	177	92	5 (<1)	14 (<1)	1 (<1)	5 (<1)	6 (<1)	160 (<1)
Tactical Operations Officers	827,931	8,558	103	162 (4)	498 (4)	50 (4)	250 (5)	242 (2)	8,022 (4)
Intelligence Officers	132,863	1,179	87	19 (<1)	88 (<1)	2 (<1)	15 (<1)	38 (<1)	1,071 (<1)
Engineering and Maintenance Officers	314,356	3,439	109	57 (2)	214 (2)	14 (1)	64 (1)	113 (1)	3,173 (2)
Scientists and Professionals	129,928	1,302	100	19 (<1)	89 (1)	8 (1)	23 (<1)	43 (<1)	1,186 (1)
Health Care Officers	362,930	5,082	140	43 (1)	261 (2)	21 (2)	47 (1)	96 (1)	4,800 (2)
Administrators	148,124	1,453	98	19 (<1)	98 (1)	6 (<1)	27 (1)	44 (<1)	1,336 (1)
Supply, Procurement & Allied Officers	192,426	1,817	94	29 (1)	139 (1)	8 (1)	32 (1)	67 (1)	1,651 (1)
Non-occupational, Officer	142,851	1,660	116	13 (<1)	66 (<1)	8 (1)	25 (<1)	50 (<1)	1,586 (1)
Officer Unknown	14,246	---	---	---	---	---	---	---	---

*The total for each category is given, with the percentage in parentheses.

§SULI Rates are calculated per 10,000 p-y

** Excludes Marine Corps

Table 1.3 SULI Study Population, Overall Incidence Density and Rate ratios

Totals		SULI (N = 199,381)	Person Years (N = 13,928,563)	Rate (per 100,000 p-y)	Rate Ratios (95% CI)
Demographics					
Gender	Male	176,601	11,903, 447	1,483	1.32 (1.30, 1.34)
	Female	22,780	2,025,116	1,124	Ref.
Age	<20	16,713	951,398	1,756	0.98 (0.96, 0.99)
	20-24	83,454	4,635,487	1,800	Ref.
	25-29	42,440	3,162, 191	1,342	0.75 (0.74, 0.75)
	30-34	22,294	2,033, 973	1,096	0.61 (0.60, 0.62)
	35-39	18,571	1,675,130	1,108	0.62 (0.60, 0.63)
	40+	15,909	1,470,236	1,082	0.60 (0.59, 0.61)
Race	White	134,334	9,641,084	1,393	Ref.
	Black	27,642	2,441,391	1,132	0.81 (0.80, 0.82)
	Other	37,405	1,846,120	2,026	1.45 (1.43, 1.47)
Grade	E1-E4	113,597	6,099,524	1,862	Ref.
	E5-E9	74,747	5,542,245	1,348	0.72 (0.72, 0.73)
	O1-O3 (W01-W03)	1,714	1,393,699	122	0.07 (0.06, 0.07)
	O4-O10 (W04-W05)	9,323	893,124	1,043	0.56 (0.55, 0.57)
Service	Army	76,750	5,222,305	1,469	Ref.
	Navy	41,220	3,400,982	1,212	0.82 (0.81, 0.83)
	Air Force	44,987	3,415,378	1,317	0.90 (0.89, 0.91)
	Marines	28,423	1,889,930	1,503	1.02 (1.01, 1.04)
	Coast Guard	8,001	Not available	Not available	Not available

Table 1.4 Incidence Density with 95% CI, by SULI Type, 2003-2012

Demographics		SULI TYPES*					
		Traumatic Amputation	Peripheral Nerve Injury	Blood vessel Injury	Open Fracture	Crush Injury	Open Wound
	All SM [§]	24.9 (24.1, 25.7)	82.4 (80.9, 84.0)	9.07 (8.6, 9.6)	32.8 (31.9, 33.8)	68.5 (67.2, 69.9)	1326.0 (1320.0, 1332.0)
Gender	Male	27.5 (26.6, 28.5)	84.8 (83.1, 86.4)	9.9 (9.3, 10.4)	36.2 (35.1, 37.3)	69.3 (67.8, 70.8)	1378.2 (1371.5, 1384.9)
	Female	9.28 (8.0, 10.7)	68.8 (65.2, 72.5)	4.4 (3.5, 5.5)	12.7 (11.2, 14.4)	64.0 (60.6, 67.6)	1018.2 (1004.3, 1032.2)
Age	<20	24.9 (21.8, 28.3)	67.7 (62.6, 73.1)	9.0 (7.2, 11.2)	39.6 (35.7, 43.8)	103.6 (97.3, 110.3)	1643.5 (1617.8, 1669.4)
	20-24	30.5 (29.0, 32.2)	85.4 (82.8, 88.1)	13.1 (12.0, 14.1)	44.3 (42.4, 46.2)	93.7 (90.9, 96.5)	1685.1 (1673.3, 1697.0)
	25-29	21.8 (20.2, 23.5)	75.6 (72.6, 78.7)	8.4 (7.4, 9.4)	30.6 (28.7, 32.6)	64.7 (61.8, 67.4)	1245.9 (1233.6, 1258.2)
	30-34	22.4 (20.4, 24.5)	70.1 (66.5, 73.8)	5.4 (4.4, 6.5)	23.6 (21.5, 25.8)	48.2 (45.3, 51.4)	1010.0 (996.2, 1023.9)
	35-39	20.7 (18.5, 23.0)	86.1 (81.7, 90.6)	6.6 (5.4, 7.9)	21.7 (19.6, 24.1)	39.1 (36.2, 42.2)	1010.0 (994.9, 1025.4)
	40+	22.0 (19.7, 24.6)	110.2 (104.9, 115.7)	6.1 (4.9, 7.5)	22.4 (20.0, 24.9)	36.7 (33.7, 40.0)	956.4 (940.6, 972.3)
Race	White	24.9 (23.9, 25.9)	81.3 (79.5, 83.1)	8.6 (8.0, 9.2)	32.8 (31.7, 34.0)	65.8 (64.2, 67.5)	1292.3 (1285.1, 1299.5)
	Black	16.3 (14.7, 18.0)	66.5 (63.3, 69.8)	8.3 (7.2, 9.5)	20.4 (18.7, 22.3)	54.2 (51.3, 57.2)	1042.1 (1029.3, 1055.0)
	Other	26.2 (25.2, 27.1)	83.6 (81.9, 85.3)	9.1 (8.5, 9.6)	34.7 (33.6, 35.8)	69.6 (68.1, 71.2)	1352.0 (1346.0, 1359.0)
Grade	E1-E4	30.4 (20.0, 31.8)	90.8 (88.4, 93.2)	12.6 (11.7, 13.5)	43.5 (41.9, 45.2)	101.7 (99.1, 104.2)	1735.1 (1724.7, 1745.6)
	E5-E9	25.9 (24.6, 27.3)	92.9 (90.3, 95.4)	8.1 (7.4, 8.9)	30.4 (29.0, 31.9)	54.6 (52.7, 56.6)	1240.0 (1230.7, 1249.3)
	O1-O3 (W01-W03)	2.4 (1.7, 3.4)	8.5 (7.0, 10.1)	<.01 (<.01, 1.2)	2.9 (2.1, 4.0)	4.5 (3.4, 5.7)	112.8 (107.3, 118.5)
	O4-O10 (W04-W05)	15.7 (13.2, 18.5)	76.0 (70.4, 82.0)	4.1 (2.9, 5.7)	20.9 (18.0, 24.2)	29.1 (25.7, 32.9)	956.3 (936.1, 976.8)
Service							
	Army	29.0 (27.6, 30.5)	93.8 (91.1, 96.4)	11.3 (10.4, 12.2)	40.4 (38.7, 42.2)	71.4 (69.2, 73.8)	1354.2 (1344.2, 1364.2)
	Navy	17.9 (16.5, 19.4)	63.8 (61.1, 66.5)	5.9 (5.1, 6.8)	22.1 (20.5, 23.7)	48.6 (46.3, 51.0)	1129.6 (1118.3, 1140.9)
	Air Force	17.9 (16.5, 19.3)	65.5 (62.8, 68.3)	5.4 (4.6, 6.2)	18.7 (17.3, 20.2)	68.1 (65.3, 70.9)	1220.6 (1208.9, 1232.3)
	Marine Corps	32.4 (29.9, 35.1)	97.5 (93.1, 102.1)	13.7 (12.0, 15.4)	49.9 (46.8, 53.2)	64.2 (60.7, 68.0)	1397.2 (1380.4, 1414.2)

* Incidence Density reported as events divided by 100,000 person years with 95% confidence interval in parentheses

§ Total N = 199,381 (based on total number of SM with SULI with full demographic information)

Table 1.5 Incidence Rate Ratios for SULI among Active Component Service Members, 2003-2012*

		SULI Types					
		Traumatic Amputation	Peripheral Nerve Injury	Blood vessel Injury	Fractures (open)	Crush Injury	Open Wound
Gender	<i>Male (vs. female)</i>	2.94 (2.56, 3.44)	1.23 (1.16, 1.30)	2.22 (1.82, 2.78)	2.85 (2.50, 3.23)	1.09 (1.02, 1.15)	1.35 (1.33, 1.37)
Age	<20	0.82 (0.71, 0.94)	0.79 (0.73, 0.86)	0.69 (0.55, 0.87)	0.90 (0.80, 1.00)	1.10 (1.03, 1.19)	0.98 (0.96, 0.99)
	20-24	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
	25-29	0.71 (0.65, 0.78)	0.89 (0.84, 0.93)	0.64 (0.55, 0.74)	0.69 (0.64, 0.75)	0.69 (0.65, 0.73)	0.74 (0.73, 0.75)
	30-34	0.73 (0.66, 0.82)	0.82 (0.77, 0.87)	0.41 (0.33, 0.50)	0.53 (0.48, 0.59)	0.51 (0.48, 0.55)	0.60 (0.59, 0.61)
	35-39	0.68 (0.60, 0.76)	1.01 (0.94, 1.07)	0.50 (0.41, 0.62)	0.49 (0.44, 0.55)	0.42 (0.38, 0.45)	0.60 (0.59, 0.61)
	40+	0.72 (0.64, 0.82)	1.29 (1.22, 1.37)	0.46 (0.37, 0.58)	0.51 (0.45, 0.57)	0.39 (0.36, 0.43)	0.57 (0.56, 0.58)
Race	White	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
	Black	0.66 (0.59, 0.73)	0.82 (0.77, 0.86)	0.96 (0.82, 1.12)	0.62 (0.57, 0.69)	0.82 (0.78, 0.87)	0.81 (0.80, 0.82)
	Other	1.33 (1.21, 1.45)	1.17 (1.11, 1.24)	1.31 (1.12, 1.52)	1.35 (1.25, 1.46)	1.36 (1.29, 1.44)	1.29 (1.27, 1.31)
Grade	E1-E4	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
	E5-E9	0.85 (0.80, 0.91)	1.02 (0.98, 1.06)	0.65 (0.58, 0.73)	0.70 (0.66, 0.74)	0.53 (0.51, 0.56)	0.71 (0.71, 0.72)
	O1-O3 (W1-W3)	0.08 (0.06, 0.11)	0.09 (0.08, 0.11)	0.05 (0.02, 0.10)	0.07 (0.05, 0.09)	0.04 (0.03, 0.06)	0.07 (0.06, 0.07)
	O4-O10 (W4-W-5)	0.52 (0.43, 0.61)	0.84 (0.77, 0.91)	0.33 (0.23, 0.46)	0.48 (0.41, 0.56)	0.28 (0.25, 0.32)	0.55 (0.54, 0.56)
Service	<i>Army</i>	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
	<i>Navy</i>	0.62 (0.56, 0.68)	0.68 (0.65, 0.72)	0.52 (0.44, 0.61)	0.54 (0.50, 0.59)	0.68 (0.64, 0.72)	0.83 (0.82, 0.84)
	<i>Air Force</i>	0.62 (0.56, 0.68)	0.70 (0.66, 0.73)	0.48 (0.40, 0.56)	0.46 (0.42, 0.51)	0.95 (0.90, 1.00)	0.90 (0.89, 0.91)
	<i>Marine</i>	1.11 (1.01, 1.22)	1.04 (0.99, 1.10)	1.21 (1.04, 1.40)	1.23 (1.14, 1.33)	0.90 (0.84, 0.96)	1.03 (1.02, 1.05)

*Incidence rate ratios are given with 95% confidence intervals in parentheses. Reference categories were selected to reflect the group that is most common based on demographics in the military population, during 2003-2012 period

Table 1.6 SULI Healthcare Utilization Rates: Ambulatory visits and Hospital Admissions, 2003-2012

	Ambulatory Visits			Hospital Admissions		
	Total Visits	*Visits (per injured person)	†Visit rate (95% CI)	Total No. Admissions	*Admits (per injured person)	†Admission rate (95% CI)
ALL SULI	1,187,987	6	871.6 (870.1, 873.2)	41,579	0.19	30.5 (30.2, 30.8)
Traumatic Amputation (n= 3,663)	79,135	22	58.1 (57.7, 58.5)	3,185	0.87	2.3 (2.3, 2.4)
Peripheral nerve injury (n= 12,190)	143,817	12	105.5 (105.0, 106.1)	5,706	0.47	4.2 (4.1, 4.3)
Blood vessel injury (n= 1,339)	30,307	23	22.24 (22.0, 22.5)	2,074	1.55	1.5 (1.5, 1.6)
Open fracture (n = 4,842)	80,878	17	59.3 (58.9, 59.8)	5,721	1.19	4.2 (4.1, 4.3)
Crush injury (n= 9,950)	49,906	5	36.6 (36.3, 36.9)	981	0.10	0.7 (0.7, 0.8)
Open wound (n= 198, 232)	803,944	4	589.9 (588.6, 591.1)	23,912	0.12	17.5 (17.3, 17.8)

*Visits and admits per person are based on 213,745 SMs (including those with missing demographic information)

†Utilization rate is given as the rate per 10,000 person years with the 95% confidence interval in parenthesis

Rates are calculated based on total of 13,629,623 person years among all AC military for the period 2002-2013

Table 1.7 Ranking of SULI types, single and combinations of SULIs by Frequency

Table 1.7a One SULI Type				
Rank No.	SULI Type	Frequency (n=200,321)	(% of All SULI)*	(% of SM with one SULI)
1	Open wound	185,591	87	93
2	Peripheral nerve injury	7,034	3	3
3	Crush injury	5,829	3	3
4	Traumatic amputation	1,215	1	<1
5	Open fracture	368	<1	<1
6	Blood vessel injury	284	<1	<1

*Based on 213,745 SMs including those with missing demographic information

Table 1.7b Combination of Two SULI Types				
Rank No.	SULI Types	Frequency (n=10,849)	Percentage * (% of All SULI)	(% of SM with two SULIs)
1	Peripheral nerve injury and open wound	3,571	2	33
2	Crush injury and open wound	2,859	1	26
3	Open fracture and open wound	2,166	1	20
4	Traumatic amputation and open wound	1,207	1	11
5	Blood vessel injury and open wound	358	<1	3
6	Open fracture and crush injury	242	<1	2
7	Traumatic amputation and open fracture	113	<1	1
8	Traumatic amputation and crush injury	103	<1	1
9	Peripheral nerve injury and open fracture	99	<1	1
10	Peripheral nerve injury and crush injury	61	<1	1
11	Other**	70	<1	1

*Based on 213,745 SMs including those with missing demographic information

**Other category includes 70 cases with the following combinations:

TA and PN=32

PN and BV=26

BV and CI= 5

TA and BV= 4

BV and CF= 3

Table 1.7c Combination of Three SULI Types				
Rank No.	SULI Types	Frequency (n=2,160)	Percentage* (% of All SULI)	(% of SM with three SULIs)
1	Crush injury, peripheral nerve injury and open wound	487	<1	23
2	Open fracture, crush injury and open wound	427	<1	20
3	Traumatic amputation, open fracture and open wound	424	<1	20
4	Peripheral nerve injury, blood vessel injury and open wound	381	<1	18
5	Traumatic amputation, crush injury and open wound	123	<1	6
6	Traumatic amputation, peripheral nerve injury and open wound	89	<1	4
7	Peripheral nerve injury, crush injury, and open wound	75	<1	3
8	Blood vessel injury and open fracture and open wound	53	<1	2
9	Traumatic amputation, open fracture, and crush injury	32	<1	1
10	Peripheral nerve injury, blood vessel injury and open fracture	17	<1	1
11	Other**	52	<1	2

*Based on 213,745 SMs including those with missing demographic information

**Other category includes 52 cases with the following combinations:

TA and PN and OF=15

TA and BV and OW =9

PN and OF and CI =8

BV and CI and OW=5

BV and OF and CI=5

TA and PI and CI = 4

TA and BV and OF=2, TA and PN and BV=2

TA and BV and CI=1, PN and BV and CI=1

Table 1.7d Combination of Four SULI Types				
Rank No.	SULI Types	Frequency (n=361)	(% of All SULI)*	(% of SM with four SULIs)*
1	Traumatic amputation, open fracture, crush injury and open wound	96	<1	27
2	Traumatic amputation, peripheral nerve injury, open fracture and open wound	93	<1	26
3	Peripheral nerve injury, blood vessel injury, open fracture and open wound	91	<1	25
4	Peripheral nerve injury, open fracture, crush injury and open wound	21	<1	6
5	Traumatic amputation, peripheral nerve injury, blood vessel injury, and open wound	20	<1	6
6	Traumatic amputation, blood vessel injury, crush injury and open wound	15	<1	4
7	Traumatic amputation, peripheral nerve injury, crush injury and open wound	6	<1	2
8	Blood vessel injury, open fracture, crush injury and open wound	5	<1	1
9	Peripheral nerve injury, blood vessel injury, crush injury and open wound	5	<1	1
10	Traumatic amputation, peripheral nerve injury, open fracture and crush injury	4	<1	1
10	Other**	5	<1	1

*Based on 213,745 SMs including those with missing demographic information

**Other category includes 5 cases with the following combinations:

TA and BV and CI and OW= 2

TA and PN and BV and OF=2

PN and BV and OF and CI=1

Table 1.7e Combination of Five or more SULI Types				
Rank No.	SULI Types	Frequency (n=57)	Percentage (% of All SULI)	(% of SM with five or more SULIs)
1	Traumatic amputation, peripheral nerve injury, blood vessel injury, open fracture and open wound	24	<1	42
2	Traumatic amputation, peripheral nerve injury, open fracture, crush injury and open wound	12	<1	21
3	Traumatic amputation, blood vessel injury, open fracture, crush injury and open wound	9	<1	16
4	Peripheral nerve injury, blood vessel injury, open fracture, crush injury and open wound	4	<1	7
5	Traumatic amputation, peripheral nerve injury, blood vessel injury, open fracture, crush injury and open wound	3	<1	5
6	Traumatic amputation, peripheral nerve injury, blood vessel injury, crush injury and open wound	1	<1	2
7	Traumatic amputation, peripheral nerve injury, blood vessel injury, open fracture and crush injury	1	<1	2
8	Traumatic amputation, peripheral nerve injury, blood vessel injury, open fracture, crush injury and open wound	3	<1	5

*Based on 213,745 SMs including those with missing demographic information

Table 2.1 Risk Factors for Severe Upper Limb Injury (SULI) in U.S. Active Component Service Members, 2003-2012

		SULI (n=213,745)		Non-SULI (n=205, 215)		SULI vs. Non-SULI
		No.	%	No.	%	Unadjusted Odds ratio (95% CI)
Gender	Male	188,261	88	172, 654	84	1.39 (1.37-1.42)
	Female	25,484	12	32, 561	16	1.0
Age	<20	16,713	8	52,093	25	0.29 (0.28-0.29)
	20-24	86,011	40	77,054	38	1.0
	25-29	47,903	22	31,787	16	1.35 (1.33-1.37)
	30-34	26,112	12	17,823	9	1.31 (1.28 – 1.34)
	35-39	20,283	10	13,739	7	1.32 (1.29 -1.35)
	>40	16,723	8	12,721	6	1.18 (1.15 – 1.21)
Service	Army	81,675	38	77,561	39	1.0
	Navy	44,605	21	45,179	22	0.94 (0.92- 0.95)
	Air Force	49,340	23	41,015	20	1.14 (1.12- 1.16)
	Marines	29,657	14	34,828	17	0.81 (0.79- 0.82)
	Coast Guard	8,468	4	6,634	3	1.21 (1.17-1.25)
Race	White	145,283	68	137,148	67	1.0
	Black	28,607	13	28,725	14	0.94 (0.92- 0.96)
	Unknown/ Other	39,855	19	39,344	19	0.96 (0.94-0.97)
Grade	E1-E4	113,597	57	132,654	72	1.0
	E5-E9	74,747	38	42,539	23	2.05 (2.02- 2.08)
	O1-O3	1,714	1	1,144	1	1.75 (1.62- 1.87)
	O4+	9,323	5	9,108	5	1.19 (1.16- 1.23)
Deployment Frequency	None	110,296	52	152,720	74	1.0
	1-2	87,499	41	45,229	22	2.68 (2.64- 2.72)
	3-4	13,833	7	6,389	3	3.00 (2.91- 3.09)
	>4	2,117	1	879	0.4	3.33 (3.08- 3.61)
Deployment Location	None	110,296	52	152,720	74	1.0
	OIF	62,108	29	28,054	14	2.48 (2.44- 2.52)
	OEF	32,881	15	16,365	8	1.84 (1.81-1.88)
	Other	35,500	17	21,444	11	1.52 (1.49-1.55)

Table 2.2 Military Occupations in U.S. Active Component Service Members with SULI and Non-SULI, 2003-2012

Military Occupation	Total %	SULI	NON-SULI	Unadjusted Odds Ratio	95% CI
		N (%)	N (%)		
	418,922	213,722	205,200	--	--
Infantry, Gun Crews, Seamanship Special	62,119 (15)	35,936 (17)	26,183 (13)	1.0	--
Electronic Equipment Repairers	22,754 (5)	14,033 (7)	8,721 (4)	1.17	1.14 - 1.21
Communications & Intel Specialist	27,454 (7)	14,609 (7)	12,845 (6)	0.83	0.81-0.85
Health Care Specialists	21,944 (5)	13,581 (6)	8,363 (4)	1.18	1.15-1.22
Other Technical & Allied Specialists	10,223 (2)	5,977 (3)	4,246 (2)	1.03	0.98-1.07
Functional Support & Administration	38,082 (9)	20,681 (10)	17,401 (8)	0.87	0.84-0.89
Electrical/Mechanical Equipment Repairers	66,020 (16)	43,772 (20)	22,248 (11)	1.43	1.40-1.47
Crafts workers	13,819 (3)	9,289 (4)	4,530 (2)	1.49	1.44-1.55
Service and Supply Handlers	34,657 (8)	21,857 (10)	12,800 (6)	1.24	1.21-1.28
Non-occupational, Enlisted*	66,449 (16)	8,597 (4)	57,852 (28)	0.11	0.11-0.11
Unknown, Officer	2,128 (1)	723 (<1)	1,405 (1)	0.37	0.34-0.41
General Officers and Executives	416 (<1)	177 (<1)	239 (<1)	0.54	0.44-0.66
Tactical Operations Officers	17,985(4)	8,558 (4)	9,427 (5)	0.66	0.64-0.68
Intelligence Officers	2,736 (1)	1,179 (1)	1,557 (1)	0.55	0.51-0.60
Engineering and Maintenance Officers	7,243 (2)	3,439 (2)	3,804 (2)	0.66	0.63-0.69
Scientists and Professionals	2,855 (1)	1,302 (1)	1,553 (1)	0.61	0.57-0.66
Health Care Officers	9,536 (2)	5,082 (2)	4,454 (2)	0.83	0.80-0.87
Administrators	3,047 (1)	1,453 (1)	1,594 (1)	0.67	0.62-0.71
Supply, Procurement and Allied Officers	3,999 (1)	1,817 (1)	2,182 (1)	0.61	0.57-0.65
Non-occupational, Officer§	5,456 (1)	1,660 (1)	3,796 (2)	0.32	0.30-0.34

* Non-occupational enlisted (include patients, prisoners, officer candidates and students)

§ Non-occupational officer (include patients, students, prospective officers, trainees, cadets, midshipmen, USUHS students and officer candidates)

Table 2.3 Risk Factors for SULI in U.S. Active Component Service Members, 2003-2012

Demographics		Odds Ratio¶	95% CI
Gender	Male	1.25	(1.22- 1.27)
	Female	1.0	-
Age, at time of injury	<20	0.32	(0.32- 0.33)
	20-24	1.0	-
	25-29	1.07	(1.05- 1.09)
	30-34	0.91	(0.88 - 0.93)
	35-39	0.89	(0.86- 0.91)
	≥40	0.87	(0.84- 0.90)
Race	White	1.0	-
	Black	0.82	(0.80- 0.83)
	Other	0.91	(0.90- 0.93)
Grade	E1-E4	1.0	-
	E5-E9	1.14	(1.12 - 1.17)
	O1-O3	0.99	(0.91 - 1.07)
	O4+	0.73	(0.70 - 0.76)
Service	Army	1.0	-
	Navy	0.95	(0.93 - 0.97)
	Air Force	1.17	(1.14 – 1.19)
	Marine	0.94	(0.92 – 0.96)
	Coast Guard	1.62	(1.56 – 1.68)
Deployed	Yes	2.16	(2.12 - 2.19)
	No	1.0	-

Odds ratios estimated using multivariable logistic regression analysis including all variables shown.

¶ All significant P values < .001

Table 2.4 Risk Factors for SULI for Previously Deployed U.S. Active Component Service Members, 2003-2012

Demographics		Odds Ratio (OR)	95% CI
Gender	Male	1.39	1.34-1.44
	Female	1.0	-
Age, at time of injury	<20	0.51	0.47-0.55
	20-24	1.0	-
	25-29	1.10	1.07-1.14
	30-34	0.91	0.87-0.95
	35-39	0.89	0.86-0.93
	≥40	0.87	0.83-0.92
Race	White	1.0	-
	Black	0.63	0.61-0.65
	Other	0.73	0.71-0.75
Grade	E1-E4	1.0	-
	E5-E9	0.73	0.71-0.76
	O1-03	0.58	0.52-0.63
	O4+	0.44	0.42-0.47
Service	Army	1.0	Ref
	Navy	1.03	1.00-1.07
	Air Force	1.07	1.03-1.10
	Marine	0.84	0.81-0.87
	Coast Guard	1.01	0.86-1.20
Deployment location	OIF	1.27	1.24-1.31
	OEF	1.08	1.05-1.11
	Other	1.0	-
Deployment frequency	1-2	1.0	-
	3-4	1.11	1.07-1.15
	≥5	1.20	1.10-1.31
Deployment Duration	<12 mos.	1.0	-
	12-15 mos.	1.06	1.02-1.10
	>15 mos.	1.14	1.09-1.18

Odds ratios estimated using multivariable logistic regression analysis including all variables shown.

¶ All significant P values < .001

Table 3.1 Risk of Attrition, by Demographics in U.S. Active Component Service Members, 2003-2012

Characteristics	Categories	Hazard Ratio (HR)	95% CI for HR
SULI	Yes	1.23	1.22-1.24
	No	1.0	-
Gender	Male	0.83	0.82-0.84
	Female	1.0	-
	<20	1.06	1.05-1.08
	20-24	1.0	-
	25-29	0.87	0.86-0.89
	30-34	0.74	0.72-0.76
	35-39	1.49	1.45-1.53
	≥40	2.69	2.62-2.76
Age, at time of injury (years)	White	1.0	-
	Black	0.81	0.80-0.83
	Other	0.82	0.81-0.83
Grade	E1-E4	1.0	-
	E5-E9	0.58	0.57-0.59
	O1-O3	0.32	0.31-0.35
	O4+	0.35	0.34-0.36
Service	Army	1.0	-
	Navy	1.05	1.04-1.07
	Air Force	0.82	0.81-0.83
	Marine	1.22	1.20-1.23
	Coast Guard	0.66	0.64-0.68
Deployment Frequency	0	1.0	-
	1-2	1.13	1.12-1.15
	3-4	0.91	0.89-0.94
	≥5	0.84	0.78-0.90

Hazard ratios estimated using multivariate Cox proportional hazards regression. Model includes all variables in the table.

Table 3.2 Hazard Ratios for Attrition, by SULI types versus No SULI, in U.S. Active Component Service Members, 2003-2012

SULI Types	Unadjusted Hazard Ratio	95% CI for UHR	*Adjusted Hazard Ratio	95% CI for AHR
Traumatic Amputation	1.11	1.06- 1.17	1.09	1.04-1.14
Peripheral Nerve Injury	1.25	1.22- 1.28	1.21	1.17-1.24
Blood vessel injury	1.24	1.16- 1.34	1.17	1.09-1.26
Open Fracture	1.10	1.06- 1.15	1.07	1.02-1.11
Crushing injury	0.89	0.87- 0.92	0.87	0.84-0.90
Open wound	0.83	0.81 -0.85	0.86	0.84-0.88

* Adjusted for gender, age (at time of injury), race, grade, service, number of deployment
Hazard ratios estimated using multivariate Cox proportional hazards regression
All P values<.001

Table 4.1 Characteristics of Upper Limb Salvage (SAL) Procedures in U.S. Active Component Service Members, with SULI, 2003-2012*

	SAL Categories*							
	Any SAL	RV	SG	CS	BP	MT	BT	MR
	N (incidence)	N (incidence)	N (incidence)	N (incidence)	N (incidence)	N (incidence)	N (incidence)	N(incidence)
Total	610 (9.90)	172 (2.79)	301 (4.88)	79 (1.28)	2 (0.03)*	62 (1.00)*	97 (1.57)	138 (2.24)
Gender								
Male	580 (10.61)	157 (2.87)	294 (5.37)	74 (1.35)	2 (0.03)	56 (1.02)*	91 (1.67)	131 (2.39)
Female	30 (4.33)	15 (2.17)	7 (1.01)*	5 (0.72)*	0 (0.00)	6 (0.87)*	6 (0.87)*	7 (1.01)*
Age								
<20	35 (7.63)	11 (2.40)	17 (3.70)	5 (1.09)*	0 (0.00)	5 (1.09)*	6 (1.31)*	8 (1.74)*
20-24	310 (13.73)	85 (3.75)	156 (6.90)	44 (1.94)	1 (0.04)	34 (1.50)	43 (1.90)	69 (3.05)
25-29	153 (10.40)	41 (2.78)	76 (5.16)	21 (1.42)*	0 (0.00)	7 (0.47)*	30 (2.03)	36 (2.44)
30-34	53 (5.54)	16 (1.67)	29 (3.02)	3 (0.31)*	0 (0.00)	5 (0.52)*	6 (0.63)*	8 (0.83)*
35-39	31 (4.92)	9 (1.43)*	12 (1.90)	3 (0.48)*	0 (0.00)	5 (0.79)*	8 (1.27)*	9 (1.43)*
40+	28 (7.32)	10 (2.61)	11 (2.87)	3 (0.78)*	1 (0.26)	6 (1.57)*	4 (1.04)*	8 (2.09)
Service								
Army	336 (15.11)	75 (3.36)	179 (8.03)	43 (1.93)	0 (0.00)	24 (1.08)*	63 (2.83)	80 (3.60)
Navy	78 (5.92)	28 (2.12)	34 (2.58)	10 (0.76)*	1 (0.01)	12 (0.91)*	8 (0.61)*	13 (0.99)*
Air Force	59 (3.66)	28 (1.74)	17 (1.05)*	9 (0.56)*	1 (0.01)	12 (0.74)*	9 (0.56)*	12 (0.74)*
Marine Corps	132 (18.16)	39 (5.35)	70 (9.62)	16 (2.20)	0 (0.00)	11 (1.51)*	16 (2.19)	31 (4.25)
Coast Guard	5 (1.79)*	2 (0.72)*	1 (0.36)*	1 (0.36)*	0 (0.00)	3 (1.07)*	1 (0.36)*	2 (0.72)*
Race								
White	407 (9.87)	102 (2.47)	210 (5.09)	57 (1.38)	1 (0.02)	38 (0.92)*	71 (1.72)	98 (2.37)
Black	90 (10.41)	34 (3.93)	40 (4.62)	10 (1.15)*	0 (0.00)	7 (0.81)*	7 (0.81)*	13 (1.50)*
Other	113 (9.66)	36 (3.07)	51 (4.35)	12 (1.02)*	1 (0.09)	17 (1.45)*	19 (1.62)	27 (2.30)
Grade								
E1-E4	368 (12.79)	99 (3.44)	193 (6.70)	51 (1.77)	1 (0.03)	35 (1.21)*	52 (1.80)	71 (2.46)
E5-E9	193 (7.98)	58 (2.39)	88 (3.63)	22 (0.91)*	0 (0.00)	18 (0.74)*	35 (1.44)	50 (2.06)
O1-O3	5 (8.03)	2 (3.21)*	2 (3.21)*	0 (0.00)	0 (0.00)	2 (3.21)*	1 (1.60)*	1 (1.60)*
O4+	7 (2.44)	2 (0.70)*	4 (1.40)*	1 (0.35)*	0 (0.00)	1 (0.35)*	1 (0.35)*	3 (1.05)*
Previous Deployment								
Yes	389 (13.81)	102 (3.61)	202 (7.16)	44 (1.56)	2 (0.07)	29 (1.03)*	67 (2.37)	92 (3.26)
No	221 (6.61)	70 (2.09)	99 (2.96)	35 (1.05)	0	33 (0.99)*	30 (0.90)*	46 (1.38)

* This analysis excludes SM with traumatic amputation

N=number of cases with incidence rates per 10,000 person-years in parenthesis; SAL categories are non-exclusive
Incidence rates reflect incidence density calculated using 615,874 person-years in 210,130 individuals with a SULI

*Limb Salvage (SAL) Categories:

RV: dysvascular limbs and vascular injury requiring revascularization

SG: major soft tissue injury/critical soft tissue loss requiring local or free flap coverage or skin graft;

CS: complete compartment injury or compartment syndrome

BP: complete brachial plexopathy

MT: multiple tendon repairs or transfers with or without muscle loss and one other from any SAL category

BT: open fractures, with bone loss requiring bone transfer or transport, or intra-articular fractures of the wrist, elbow, forearm and shoulder and one other from any SAL category

MR: severe hand injuries with multiple rays (metacarpal fractures) involvement and one other from any SAL category

Table 4.2 Upper Limb Salvage (SAL) types, by Frequency in U.S. Active Component Service Members, 2003-2012

Table 4.2. a. One SAL Type				
Rank No.	Upper Limb Salvage	Frequency (n=400)	(% of ALL SAL)*	(% of SM with one SAL)**
1	Skin graft	219	36	55
2	Revascularization	122	20	31
3	Compartment syndrome	58	10	15
4	Complex brachial plexopathy	1	<1	<1

*Based on SAL (N) of 610

** %ages may exceed 100 due to rounding

Table 4.2. b. Two SAL Types				
Rank No.	Upper Limb Salvage	Frequency (n=181)	(% of ALL SAL)*	(% of SM with two SAL)**
1	Bone transfer and multiple rays	49	8	27
2	Skin graft and multiple rays	44	7	24
3	Revascularization and multiple tendon repairs	29	5	16
4	Skin graft and bone transfer	14	2	8
5	Multiple tendon repairs and multiple rays	9	1	5
6	Multiple tendon and bone transfer	6	1	3
7	Compartment syndrome and multiple tendon repair	6	1	3
8	Revascularization and multiple rays	6	1	3
9	Skin graft and multiple tendon repair	4	1	4
10	Other	14	2	8

*Based on SAL (N) of 610

** %ages may exceed 100 due to rounding

Table 4.2. c. Three or more SAL Types				
Rank No.	Upper Limb Salvage	Frequency (n=29)	(% of ALL SAL)*	(% of SM with three or more SAL)
1	Skin graft, bone transfer and multiple rays	12	2	41
2	Other	17	3	59

*Based on SAL (N) of 610

SAL= limbs requiring revascularization, soft tissue loss requiring skin graft, complete brachial plexopathy, and all compartment injury or compartment syndrome OR Two or more of the following: multiple tendon repairs, open fractures requiring bone transfer, severe hand injuries with multiple rays involvement
Total SAL (N) = 610

Table 4.3 Frequency of Combined SAL Procedures and Diagnoses with SULI types
(excludes traumatic amputation) in U.S. Active Component Service Members, 2003-2012

SAL Procedure Categories	SULI Diagnostic Categories				
	Blood vessel injury	Peripheral Nerve injury	Fractures (open)	Crush Injury	Open Wound
	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
Total SMs with SULI (irrespective of SAL procedures)	1245 (0.6)	11896 (5.7)	4021 (1.9)	9, 559 (4.5)	196139 (93.3)
Total SMs with SAL procedures	169 (13.6)	232 (1.9)	208 (5.2)	28 (0.3)	564 (0.3)
Specific SAL:					
<i>Revascularization</i>	134 (10.8)	92 (0.8)	28 (0.7)	8 (0.1)	160 (0.1)
<i>Skin graft</i>	23 (1.8)	84 (0.7)	128 (3.2)	10 (0.1)	282 (0.1)
<i>Compartment syndrome</i>	12 (1.0)	28 (0.2)	19 (0.5)	7 (0.1)	71 (0.03)
<i>Complete brachial plexopathy</i>	1 (0.1)	0	0	0	1 (0)
<i>Multiple tendon repairs or transfers</i>	29 (2.3)	28 (0.2)	14 (0.3)	2 (0)	60 (0)
<i>Bone transfer or transport</i>	15 (1.0)	42 (0.4)	64 (1.6)	5 (0)	90 (0)
<i>Multiple rays involvement</i>	18 (1.0)	58 (0.4)	91 (2.3)	6 (0)	129 (0)

SULI, severe upper limb injury; SAL, upper limb salvage

Table depicts total number of SULI in each SAL category with % of all SULI by category in parentheses

Total SULI (N)= 210 137 cases

Total SAL (n)= 610

Table 4.4 Risk of Attrition in U.S. Active Component Service Members With SULI, 2003-2012

Variable	Description	(HR)*	95% CI
SAL	Yes	1.21	(1.07-1.35)
	No	1.0	--
Failed Limb Salvage**	Yes	0.64	(0.31-1.28)
	No	1.0	--
Chronic pain	Yes	0.80	(0.77-0.84)
	No	1.0	--
Gender	Male	0.84	(0.82-0.86)
	Female	1.0	--
Age, at time of injury	<20	1.0	--
	20-24	1.06	(1.04-1.08)
	25-29	0.90	(0.87-0.92)
	30-34	0.74	(0.71-0.77)
	35-39	1.49	(1.44-1.55)
	40+	2.73	(2.63-2.83)
Race	White	1.0	--
	Black	0.88	(0.86-0.89)
	Other	0.85	(0.83-0.86)
Grade	E1-E4	1.0	--
	E5-E9	0.54	(0.53-0.55)
	O1-O3	0.29	(0.27-0.32)
	O4+	0.32	(0.30-0.33)
Service	Army	1.0	--
	Navy	1.08	(1.07-1.10)
	Air Force	0.79	(0.78-0.81)
	Marine Corps	1.23	(1.21-1.25)
	Coast Guard	0.63	(0.61-0.66)
Previous Deployment	Yes	1.05	(1.03-1.07)
	No	1.0	--

*All estimates are adjusted for all variables shown

** Failed Limb Salvage was defined as secondary amputation or delayed amputation, which occurred any time after any of the upper limb salvage (SAL) procedures

Total Attrition (N) = 96,424 SM of 210,130 (46%) with SULI had a history of attrition in their record

Table 4.5 Risk of Chronic Pain Diagnoses in U.S. Active Component Service Members after SULI, 2003 to 2012

Variables	Description	(OR)*	95% CI
SAL	Yes	6.17	4.73-8.04
	No	1.0	-
Failed Limb Salvage**	Yes	4.49	1.70-11.86
	No	1.0	-
Previous Deployment	Yes	1.12	1.04-1.20
	No	1.0	-
Gender	Male	0.60	0.55-0.66
	Female	1.0	-
Age, at time of injury	>20	1.0	-
	20-24	1.64	1.39-1.93
	25-29	2.65	2.23-3.14
	30-34	4.20	3.50-5.04
	35-39	4.45	3.67-5.39
	40+	4.05	3.29-4.97
Race	White	1.0	-
	Black	0.58	0.53-0.65
	Other	0.78	0.72-0.85
Grade	E1-E4	1.0	-
	E5-E9	0.88	0.81-0.96
	O1-O3	0.44	0.31-0.61
	O4+	0.32	0.26-0.40
Service	Army	1.0	-
	Navy	0.30	0.27-0.34
	Air Force	0.33	0.30-0.36
	Marine Corps	0.58	0.52-0.64
	Coast Guard	0.30	0.24-0.37

Total Chronic Pain: 4,171 SM of 210, 137 (2%) had a history of chronic pain in their record

Chronic Pain was defined as history of chronic pain diagnosis, based on any of the following CPT codes: CPT 04.81, CPT 64510 or ICD9 codes: ICD-9 338.2, ICD-9 338.4; ICD-9 337.20, in any diagnostic position listed greater than 3 months after injury (SULI).

*All estimates are adjusted for all variables shown

** Failed Limb Salvage was defined as secondary amputation or delayed amputation, which occurred any time after any of the upper limb salvage (SAL) procedures

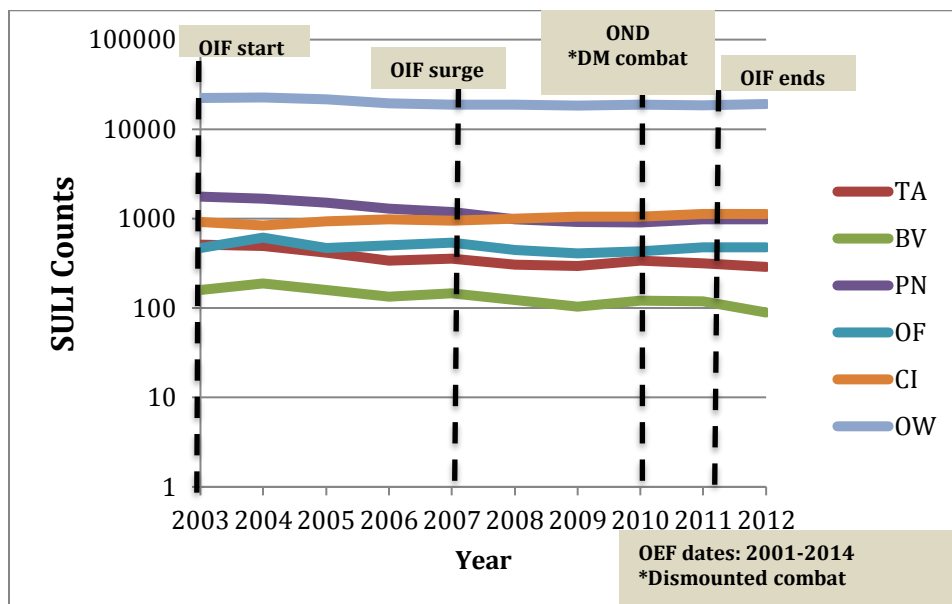
Table 4.6 Frequency of U.S. Active Component Service Members, with Failed Limb Salvage and Traumatic Amputation, by demographic characteristics, 2003-2012

Demographics		Failed Limb Salvage		Traumatic Amputation (Primary SAL procedure)	
		Frequency	(%)	Frequency	(%)
Gender	Male	19	100	3,277	95
	Female	0	0	188	5
Age, at time of injury	<20	2	11	237	7
	20-24	9	47	1,415	41
	25-29	5	26	688	20
	30-34	2	11	455	13
	35-39	1	5	346	10
	40+	0	0	324	9
Race	White	14	74	2,396	69
	Black	3	16	398	11
	Other	2	10	671	19
Grade	E1-E4	12	63	1,854	54
	E5-E9	7	37	1,437	41
	O1-O3	0	0	34	1
	O4+	0	0	140	4
Service	Army	16	84	1,516	44
	Navy	0	0	610	18
	Air Force	0	0	610	18
	Marine Corps	3	16	612	18
	Coast Guard	0	0	117	3
Other Variables for Failed Limb Salvage					
		Frequency	(%)		
SAL Types	Revascularization	2	11		
	Skin graft or flap	16	84		
	Compartment syndrome	1	5		
	Brachial plexopathy	0	0		
	Multiple tendon repairs	3	16		
	Bone transfer	0	0		
	Multiple rays involvement	6	32		
Chronic pain	Yes	8	42		
	No	11	58		
Time to limb salvage failure	<1 yr	11	58		
	1-5 yrs	3	16		
	5-9 yrs	5	26		
Deployed Frequency	0	5	26		
	1	13	68		
	2	1	5		
	3	0	0		

Total (n) limb salvage failure/secondary amputation = 19; incidence = 0.3 per 10,000 person-years

FIGURES

Figure 1-1 SULI counts, by year and type of SULI



Test for trend: TA ($r = -0.87$); BVI ($r = -0.88$); PI ($r = -0.92$); CF ($r = -0.47$), CI ($r = 0.93$); OW ($r = -0.82$); $p < 0.05$ for all except OF

TA = Traumatic Amputation; BVI = Blood vessel injuries; PI= Peripheral Nerve injuries; OF= Open Fractures; CI= Crush injuries; OW = Open Wounds

Figure 1-2 SULI rates, by year and type of SULI

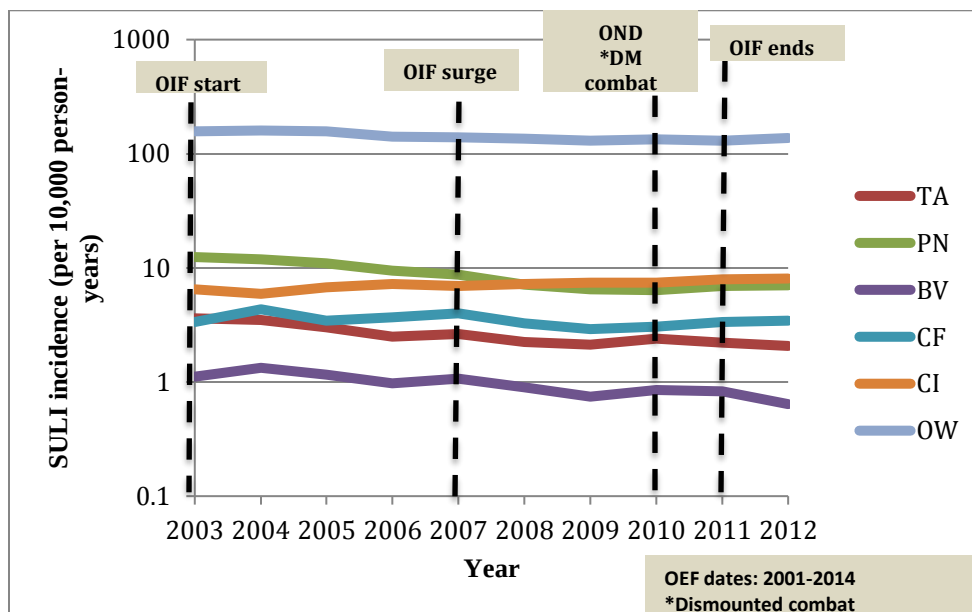


Figure is displayed on Logarithmic scale

Test for trend: *TA ($r = -0.87$); *BVI ($r = -0.88$); *PI ($r = -0.92$); CF ($r = -0.47$); *CI ($r = 0.93$); **OW ($r = -0.82$)

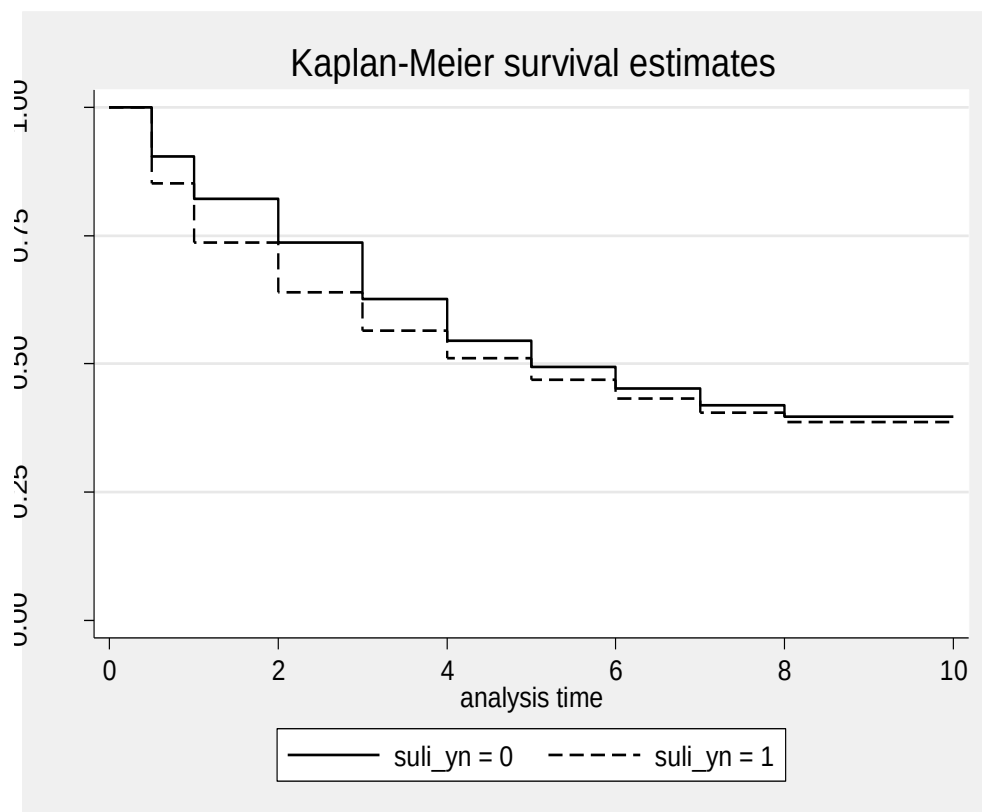
* $p < 0.001$

** $p < 0.05$

TA = Traumatic amputation; BV= blood vessel injury; PN= peripheral nerve injury;

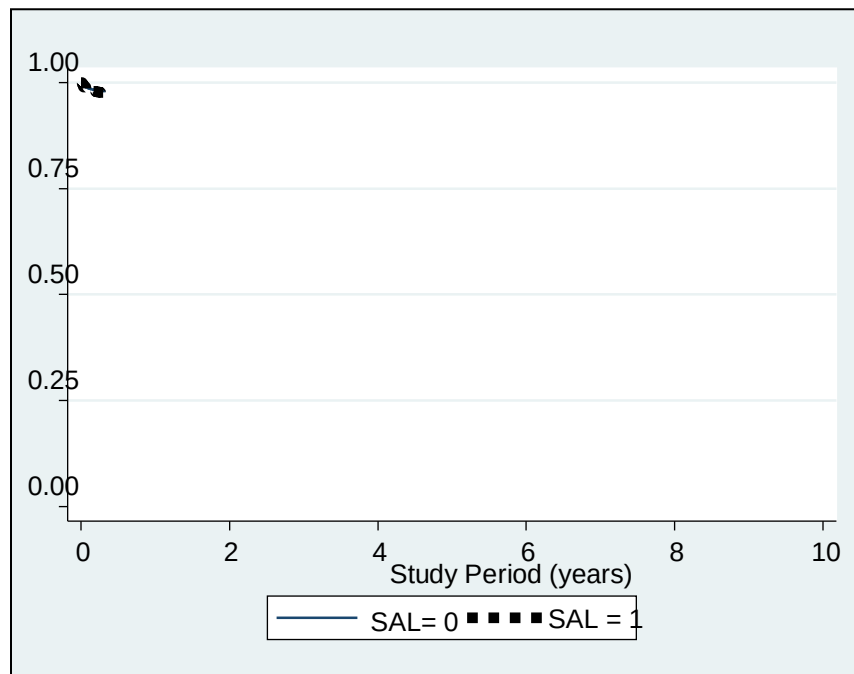
OF= open fracture; CI= crush injury; OW = open wound

Figure 3-1 Survival Curve for Attrition, by SULI status



SULI status (present versus absent) Survival Curves for SULI cases from incident SULI to discharge
 SULI= 0 (absent)
 SULI=1 (present)
 Log rank Test: $P < .001$

Figure 4-1 Survival Curve for Attrition, by Limb salvage procedure status, 2003-2012



Limb Salvage (SAL) status (present versus absent) Survival Curves for SULI cases from incident SULI to discharge

SAL= 0 (absent)

SAL=1 (present)

Log rank Test: $P < .001$

Adjusted HR 1.21, 95% CI 1.07-1.35

APPENDICES

APPENDIX A ACRONYMS/DEFINITIONS

AFHSB. Armed Forces Health Surveillance Branch

CPT. Current Procedural Terminology Codes

DMDC. Defense Manpower Data Center

DMED. Defense Medical Epidemiology Database

DMSS. Defense Medical Surveillance System

ICD-9-CM. International Classification of Diseases, Ninth Revision, Clinical Code

ICD-9-PCS. International Classification of Diseases, Ninth Revision, Procedure Code

OEF. Operation Enduring Freedom

OIF. Operation Iraqi Freedom

OND. Operation New Dawn

ULI. Upper Limb Injuries

SULI. Severe Upper Limb Injury

SAL. Upper Limb Reconstruction/Limb Salvage

APPENDIX B IRB APPROVAL



UNIFORMED SERVICES UNIVERSITY
of the Health Sciences

OFFICE OF RESEARCH

4301 JONES BRIDGE ROAD
BETHESDA, MARYLAND 20814
PHONE: (301) 295-3303; FAX: (301) 295-6771

NOTICE OF PROJECT APPROVAL

Change Number: Original

VPR Site Number: T0-PMB-87-2436-01
Principal Investigator: Daniels, Colleen (PMB-87)
Department: Preventive Medicine & Biometrics
Project Type: Student
Project Title: Severe Upper Limb Injuries in US Active Military Personnel: Incidence, Risk Factors & Outcomes; 2002 to 2011
Project Period: 6/1/2013 to 5/31/2014

Assurance and Progress Report Information:

Name	Sup	Approval Type	Status	Approved On	Forms Received
Progress Report	0			To be Submitted	N/A

Remarks:

This Notice of Project Approval has been reviewed and approved. Please remember that you must submit a final Progress Report (Form 3210) upon completion of this project.

Questions regarding this approval should be directed to the following person in the Office of Research:
Ronda Dudley, (301) 295-9818.


Richard R. Levine, Ph.D.
(Acting) Vice President for Research
Uniformed Services University of the Health Sciences
Date 12 July 13

cc: Daniels, Colleen (PMB-87)
File
Cara Olsen
Eleanor Metcalf

APPENDIX C SAMPLE SIZE TABLES

Table 1: Sample Size Calculation using Traumatic Amputation as Outcome:
Number of exposed required in a cohort study, with range of power, 80% to 95%, α 0.05, 2 sided, at incidence of traumatic amputation .02%, and range of relative risk of 2.0 to 6.0. Ratio exposed to unexposed, 1:1

Power (%)	Relative Risk						
	2.0	2.5	3.0	4.0	5.0	5.5	6.0
	80	117775	61072	39263	21815	14727	12606
	85	134723	69861	44913	24954	16846	14420
	90	157666	81758	52561	29204	19714	16875
	95	194989	101111	65004	36116	24380	20870

Source: Fleiss, Statistical Methods for Rates and Proportions, formulas 3.18 & 3.19

<http://www.openepi.com/OE2.3/SampleSize/SSCohort.htm>

Table 2. Sample Size Estimate using Attrition as Outcome:
The Number of subjects required with the exposure (SULI) in a cohort study, with 80% power,
 α 0.05, 2 sided, at various proportions of attrition and range of relative risk from 1.2 to 2.0.

Attrition in unexposed (%)	Relative Risk (RR)					
		1.2	1.4	1.6	1.8	2.0
	5	8363	2214	1065	637	436
	10	3756	1016	498	293	199
	15	2476	635	303	179	121
	20	1721	441	210	123	82

Source: Fleiss, Statistical Methods for Rates and Proportions, formulas 3.18 & 3.19
<http://www.openepi.com/OE2.3/SampleSize/SSCohort.htm> (39).

APPENDIX D. VARIABLES LIST

Request to Armed Forces Health Surveillance Center

1. Special Notes

a. *Dates*: For confidentiality ALL dates will be provided as number of days from reference date (day 0). The reference date is defined as the date of enlistment.

b. Inclusion Criteria for Cases and Controls:

Cases (SULI):

US Armed Forces, Active Component, 2003-2012 AND

one inpatient or outpatient medical encounter with any ICD-9 code defining a diagnosis of severe upper limb injury, in the primary to tertiary diagnostic position.

Controls (non-SULI): Controls will be a random sample of US Armed Forces, Active

Component, 2003-2012 AND *NOT A CASE*. The random sample of controls will be equal in size to the cases.

2. List of Variables Requested

Variable #	Variable Type	Required Field (s)
1	Unique study Identification	Study identification #
2	Demographics (at time of injury/diagnosis for cases, and for controls incident date of the matched case)	Age (years) Gender Race/ethnicity Service Branch Grade Military Occupation
3	Deployment	Deployment History: Location (OIF/OEF/Other) Deployment dates Deployment Exposures: Question 9a, sections 1, 2, 3, 4 & 5 (DD FORM 2796, JAN 2008) Question 10a, sections 1, 2, 3, & 4 (DD FORM 2796, SEP 2012)
4	Attrition	Date of accession/Date of separation
5	Cases (SULI)	Select as case if <i>one inpatient OR outpatient medical encounter</i> with any of the following defining diagnoses of severe upper limb injury listed, in the primary, secondary or tertiary diagnostic position; ICD-9 Codes: 810.1, 811.1, 812.1, 812.3, 812.5, 813.1, 813.3, 813.9, 814.1, 815.1, 816.1, 817.1, 818.1, 819.1 880, 881, 882, 883, 884, 885, 886, 887, 903.0, 903.1, 903.2, 903.3, 903.4, 903.5, 903.8, 903.9, 927.0, 927.1, 927.2, 927.3, 927.8, 927.9; 955
6	Controls (Non-SULI)	Randomly Select as control US Armed Forces, Active Component, 2003-2012 AND <i>Without any of the SULI defining diagnostic codes about (NOT A CASE) in any diagnostic position</i>
7	Clinical Information for cases (SULI) and controls (non-SULI)	Dates of ambulatory visits (expressed as number of days from reference date) Dates of hospitalization (admission and discharge)-expressed as number of days from reference date ICD-9 diagnostic and procedure Codes; in any diagnostic position CPT Codes; in any diagnostic position
8	Comorbid conditions for cases (SULI) and controls (non-SULI) For each comorbid condition: Date of first encounter ICD-9 Codes	ICD-9 diagnostic codes; in any diagnostic position to include the following: Traumatic Brain injury (TBI): ICD-9 310.2; ICD-9 850; ICD9 959.01 Mental disorders: ICD-9 295-298; Epilepsy/Seizures: ICD9 345 Headache: ICD-9 339 Migraine: ICD9 346 Dorsopathies: ICD-9 720, 721, 722, 723, 724 Sleep disorders: ICD-9 327

		Severe Lower extremity injuries: Fractures: ICD-9 824, 825, 826, 827, 828 Crush injury: ICD-9 928 Peripheral Nerve Injury: ICD-9 956 Complete compartment injury/compartment syndrome: ICD-9 958.92 Traumatic Amputation: ICD9 896, 897 Other Medical Conditions: Osteoarthritis: ICD-9 715 Rheumatoid Arthritis: ICD-9 714 Poly Neuropathy/Diabetic Neuropathy: ICD-9 357.2
9	Outcomes For each outcome: ICD-9 and CPT Code Date	Chronic Pain: ICD-9 code or CPT code listed, post-injury date to include the following, in any diagnostic position: Chronic pain syndrome, ICD-9 338.2, 338.4; Complex regional pain syndrome, upper limb, ICD-9 337.20; Injection of anesthetic into peripheral nerve, CPT 04.81; Stellate Ganglion Injection, CPT 64510
10	Surgical Procedures For each procedure: Date CPT Code ICD-9 Procedural codes	Amputation: CPT 24900, 25900, 25920, 25927, 26910 Reconstruction: One or more of the following, in any diagnostic position <u>Revascularization:</u> CPT 35206, 35207, 35236, 35266, 35518, 35522, 35523, 35650; <u>Local or free flap coverage or skin graft:</u> ICD-9 PCS 86.60, 86.61, 86.62, 86.70, 86.71, 86.72, 86.73 <u>Compartment injury or compartment syndrome:</u> CPT 25020, 25023, 25024, 25025 <u>Complete brachial plexopathy:</u> CPT 64861 <u>Multiple tendon repairs or transfers:</u> CPT 20924, 24301, 23406, 24341, 25260, 25263, 25265, 25270, 25272, 25274; <u>Bone transfer or transport:</u> CPT 23480, 23485, 24435, 25425, 25426; ICD-9 PCS 78.01, 78.02, 78.03, 78.04 <u>Multiple rays (metacarpal or phalangeal fractures) :</u> CPT 26615, 26665, 26735, 26746, 26765; ICD-9 PCS 78.12, 78.13, 78.14, 78.52, 78.53, 78.54

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