THE UNITED STATES ARMY MEDICAL DEPARTMENT

JOURNAL

July-December 2018

Infection Precedes Heterotopic Ossification in Combat Wounded 1
Jessica K Juarez, MS; Mary Jo Pugh, PhD; Joseph C Wenke, PhD; Jessica C Rivera, MD

Injury Mechanisms, Activities, and Limited Work Days in US Army Infantry Units 6
Michelle Canham-Chervak, PhD, MPH; Catherine Rappole, MPH; et al

Risk Factors for Sprains and Strains Among Physically Active Young Men: A US Army Study 14
Robyn C. Martin, MPH; Tyson Grier, MS; Michelle Canham-Chervak, PhD, MPH; et al

The Etiology of Injuries in US Army Initial Entry Training 22
Veronique D. Hauschild, MPH; Terrence Lee, PhD; Stephen Barnes, MPH; et al

Human Papillomavirus Incidence and Sexually Transmitted Coinfections Among US Military Recruits (2009-2015) 30
COL Paul O. Kwon,USA; Jenny Lay, MPH; David Hrncir, MD, MPH; Lynn Levin, PhD, MPH

Evaluation of NU-FlexSIV Socket Performance for Military Service Members with Transfemoral Amputation 38
Starr E. Brown, MS; Elizabeth Russell Esposito, PhD; Jason M. Wilken, PT, PhD; Stefania Fatone, PhD

Motivational Guest Speaker Presentation as an Anti-Stigma Intervention for US Army Soldiers 48
MAJ Rohul Amin, USA; CPT Sarah C. McLeroy, USA; MAJ Victor M. Johnson, USA

Lessons Learned: Military Screening for Posttraumatic Stress Disorder 54
Tiffany L. Schweitzer, PhD, MHA; Earla J. White, PhD, MEd; Ronald P. Hudak, JD, PhD

Military Medicine Implements In-home Virtual Health in Europe 59
Steven M. Cain, MPAS; LTC Robert J. Cornfeld, USA; COL Kirk H. Waibel, USA; et al

Sexual Dimorphic Features Associated with Femoroacetabular Impingement 65
CPT Victoria B Okpala, USA; CPT David J Tennent, USA; et al

Case Report: Unilateral Paresis of the Abdominal Wall with Associated Thoraco-Lumbar Pain 74
Maria Francisca Elgueta, MD; Nina Nan Wang, MD; Gaurav Gupta, MD; LCol Markus Besemann, MD

Application of High Energy Extracorporeal Shockwave Therapy on Musculoskeletal Conditions in US Military Medical Facilities 76
CPT Sally Corey, USA; LTC Terry Mueller, USA; COL (Ret) John Bojescul, USA; Craig Cameron, DO

Animal Derived Thiol Induced Work Exacerbated Asthma: A Brief Case Report of a Unique Workplace Hazard 84
LTC John W. Downs, USA; Joshua M. Renshaw, MS

Institution of Military Working Dog Physical Profile Record to Clarify Medical Readiness Category Status . . . . .
CPT Sean P. Curry, USA; CPT Jeremy W. Lewis, USA

This Article Retracted
By Publisher
February 14, 2019

THE UNITED STATES ARMY MEDICAL DEPARTMENT

A Professional Publication of the AMEDD Community

JOURNAL

Online issues of the *AMEDD Journal* are available at http://www.cs.amedd.army.mil/amedd_journal.aspx

July – December 2018 | US Army Health Readiness Center of Excellence | PB 8-18-7/8/9/10/11/12

By Order of the Secretary of the Army:
Official.

GERALD B. O'KEEFE
Administrative Assistant to the Secretary of the Army

Mark A. Milley
General, United States Army Chief of Staff

DISTRIBUTION: Special

1826906

The Army Medical Department Journal [ISSN 1524-0436] is published quarterly for The Surgeon General by the Borden Institute, USAMEDDC&S, DOTAA 3630 Stanley RD Attn: AMEDD JRNL, JBSA Fort Sam Houston, TX 78234-6100.

Articles published in *The Army Medical Department Journal* are listed and indexed in MEDLINE, the National Library of Medicine's premier bibliographic database of life sciences and biomedical information. As such, the *Journal's* articles are readily accessible to researchers and scholars throughout the global scientific and academic communities.

CORRESPONDENCE: Manuscripts, photographs, official unit requests to receive copies, and unit address changes or deletions should be sent via email to usarmy.jbsa.medcom-ameddcs.list.amedd-journal@mail.mil, or by regular mail to the above address. Telephone: (210) 221-6301, DSN 471-6301

DISCLAIMER: The *AMEDD Journal* presents clinical and nonclinical professional information to expand knowledge of domestic & international military medical issues and technological advances; promote collaborative partnerships among Services, components, Corps, and specialties; convey clinical and health service support information; and provide a peer-reviewed, high quality, print medium to encourage dialogue concerning healthcare initiatives.

Appearance or use of a commercial product name in an article published in the *AMEDD Journal* does not imply endorsement by the US Government.

Views expressed are those of the author(s) and do not necessarily reflect official policies or positions of the Department of the Army, Department of the Navy, Department of the Air Force, Department of Defense, nor any other agency of the US Government. The content does not change or supersede information in other US Army Publications. The *AMEDD Journal* reserves the right to edit all material submitted for publication (see inside back cover).

OFFICIAL DISTRIBUTION: This publication is targeted to US Army Medical Department units and organizations, other US military medical organizations, and members of the worldwide professional medical community.

Infection Precedes Heterotopic Ossification in Combat Wounded

Jessica K. Juarez, MS
Mary Jo Pugh, PhD
Joseph C. Wenke, PhD
MAJ Jessica C. Rivera, MC, USA

Abstract

Heterotopic ossification is the formation of ossified bone in soft tissue, particularly after soft tissue trauma. Heterotopic ossification is known cause of pain, prosthetic/orthotic malfit, and reoperation following combat extremity injury. The purpose of this research was to examine injury and treatment characteristics that are associated with heterotopic ossification in a broader population of deployment-injured subjects. The Department of Defense Trauma Registry and Military Orthopaedic Trauma Registry was queried for a sample of deployment-injured subjects and the complication of heterotopic ossification. Heterotopic ossification was identified in 15% of subjects following 5% of all injuries. Symptoms attributed to the heterotopic bone were present in 40% of subjects with diagnosed with heterotopic ossification. Heterotopic ossification was not associated with injury severity or aggressiveness of open wound treatment. However, infection was the only positive predictor of heterotopic ossification resulting in two-times greater odds of heterotopic bone formation. This finding is consistent with prior research suggesting that heterotopic ossification requires persistent inflammation to be present in at-risk soft tissue. Among all wounds sustained during deployment injury, heterotopic may not be abundantly common; however, the risk may be further minimized by focused infection control.

Heterotopic ossification (HO) is the formation of ectopic bone in abnormal soft tissue locations where it can cause pain, joint motion limitation, and neurovascular entrapment.[1] Heterotopic ossification formation is likely driven by excessive local and systemic inflammation and occurs following many traumatic conditions such as severe extremity trauma, certain surgical procedures about the hip and pelvis, traumatic brain injury (TBI), spinal cord injury, and systemic insults such as burn injury.[2-8] The frequency of extremity HO ranges from 11% to 20% in civilian polytrauma patients.[4]

Heterotopic ossification is of substantial significance for injured military personnel because a known risk factor for developing HO is exposure to high energy trauma such as that experienced during an explosion injury.[9,10] Following combat-related Gustilo and Anderson grade 3 open tibia fractures, HO occurred in 38% of patients and over one-fourth of these patients required symptomatic HO excision.[11] Combat-related amputations are associated with a 64% occurrence of HO.[12] Symptomatic HO is a cause of reoperation for service members with both upper and lower extremity amputations, contributing to one-fourth of amputation revisions.[13,14] Once excised, heterotopic bone can recur.[15] Higher prevalence of HO in injured US versus allied service members suggests that characteristics of combat wound care (eg, aggressive wound care practices) that are more common in US casualties may predispose wounds to HO.[16]

The published reports cited in the previous paragraph suggest a high frequency of symptomatic HO, but selectively examine very severe injuries which represent only a portion of combat wounded. When all injuries are taken into account, HO may be an outcome with closer frequency to that seen in the civilian trauma literature.[4] The first aim of this research was to examine a broader cohort of casualties with a wide variety of extremity injuries to determine the frequency of HO without selecting for the most severe extremity injuries. Our hypothesis was that in a broader cohort of combat casualties, the frequency of HO would be less than 20%, similar to the civilian trauma population. Secondarily, we aimed to determine what injury and treatments were associated with HO formation. We hypothesized that aggressive debridement timing and frequency would be predictive of HO formation.

Methods

This retrospective cohort study was conducted in accordance with a research protocol approved by the US Army Medical Research and Materiel Command Institutional Review Board. The Military Orthopaedic Trauma Registry (MOTR) (Joint Trauma System, JBSA Fort Sam Houston, Texas) was queried for subjects with at least one extremity injury sustained during deployment operations. The MOTR collects injury, treatment, and complication data for subjects who are identified in the Department of Defense Trauma Registry as having an

extremity injury.[17,18] The MOTR data sources include scanned and electronically entered documentation from role 3 theater facilities through Veteran's Administration (VA) healthcare facilities. The MOTR complication data fields were then queried to determine which extremities were eventually diagnosed with HO. The presence of HO was defined as any indication by documented physical exam, radiographic exam, or surgical findings of aberrant bone. Subjects for whom no such documentation was located were assumed to not have HO. MOTR furthermore collects data on complication treatments; therefore, the frequency of HO excision was noted. Subject age, sex, and mechanism of injury was also collected. Frequencies of HO were then calculated using simple proportions.

From this initial MOTR query, a random list of subjects with extremity injuries that included an open wound (eg, traumatic amputations, open fractures, fasciotomy wounds) was selected for further chart abstraction using MOTR and the military electronic medical record. Additional data collected on this subcohort included treatment characteristics including frequency and timing of initial wound irrigations and debridements and the use of negative pressure wound therapy (NPWT). Injury severity was collected according to the severity score of 1 to 6 in accordance with the Military Abbreviated Injury Scale coding system (updated January 2013) and designated as meeting or not meeting the definition of "severe extremity trauma" according to the Lower Extremity Assessment Project (LEAP) Study Group.[19,20] Severe extremity injuries included amputations, Gustilo and Anderson grade 3B or 3C open fractures, limbs with diagnosed compartment syndrome, large volumetric muscle loss, large segmental bone loss, or need for revascularization. Distal outcomes collected included: if diagnosed HO caused symptoms; if the patient underwent HO excision; and if the extremity wound was diagnosed with an infection.

Logistic regression analysis was then used to test for associations between the outcome HO and predictor variables related to the injury (mechanism, severity), treatments (debridements, NPWT), and presence of infection. Sequentially nested regression models were compared for model fit using Akaike Information Criteria and log-likelihood ratio. Analysis was performed using Stata 14.1/IC (StataCorp LLC, College Station, Texas).

Results

The study population comprised 96% males who were average age 26±5.4 years old. Similar with published findings of combat-related injury, a majority (73%) of injuries were due to an explosive mechanism. Among 3,255 subjects with over 14,000 separate injuries to the extremities, 480 subjects (14.7%) were diagnosed with HO. Examining the separate injuries, it was determined that 749 (5%) injuries led to HO. Among the 749 discreet injuries, 18% of injuries were traumatic amputations indicating that a majority of HO was diagnosed following nonamputation injuries. Of the nonamputation injuries that developed HO, 78% had a fracture involved in the injury; 62% had a soft tissue injury, including open fractures and isolated soft tissue injuries; 13% had an associated vascular injury; and 12% had an associated nerve injury. A majority of the HO was diagnosed at a role 5 military medical treatment facility within 169±263 days from injury (range 32 days - 9.9 years), while only 13 additional cases were identified once the service member matriculated to VA care.

To closely examine wound care practices, a random sample of 263 subjects with open wounds associated with their extremity injury underwent additional abstraction. A majority of subjects (195/263, 74%) underwent wound irrigation and debridement within 24 hours of injury. Furthermore, most subjects underwent irrigation and debridement at least every 48 hours (141/263, 54%). Negative pressure wound therapy was used between irrigation and debridements in the combat zone and during aeromedical evacuation in 33% (88/263) of subjects. Infection was diagnosed in 48% of subjects with wounds (127/263).

Of these 263 subjects, 87 subjects (33%; 87/263) developed HO. Among subjects that were diagnosed with HO, 59% (51/87) had no self-reported symptoms associated with the HO in their medical record, but had only heterotopic bone evident on radiographs without associated symptoms. Of the 36 subjects with self-reported symptoms, 58% of symptoms (21/36 subjects) were associated with prosthetic/orthotic malfit and 42% of symptoms (15/36 subjects) were associated with pain. Among the 36 subjects with symptomatic HO, 21 underwent HO excision and 9 experienced a recurrence of the heterotopic bone following excision. Though numbers are small, this suggests a 43% recurrence.

Logistic regression results, shown in the Table, indicate that classification as a "severe" injury according to the LEAP Study Group definition was associated with increased odds of HO development when only the injury mechanism and severity are modeled. However, in the full model, only infection was associated with increased

Logistic Regression Results for Heterotopic Ossification Occurrence.

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Injury Type[a]			
Penetrating (ref blunt)	1.38 (0.73-2.61)	1.37 (0.71-2.64)	1.48 (0.76-2.89)
Mechanism[b]			
Firearm	0.82 (0.33-2.03)	0.85 (0.34-2.11)	0.95 (0.38-2.40)
Vehicular	1.21 (0.10-14.5)	1.21 (0.10-14.8)	1.35 (0.10-19.0)
Severe Injury	1.36[c] (1.02-1.81)	1.34 (0.99-1.81)	1.27 (0.94-1.71)
Abbreviated Injury Scale	0.97 (0.88-1.06)	0.97 (0.88-1.07)	0.98 (0.89-1.08)
Debride Timing		1.10 (0.53-2.29)	1.13 (0.54-2.36)
Debride Frequency		0.79 (0.41-1.51)	0.75 (0.39-1.45)
NPWT		1.16 (0.84-1.60)	1.13 (0.81-1.57)
Wound Infection			2.02[c] (1.16-3.50)
Log Likelihood	-164.63	-164.04	-160.90[c]
Akaike Information Criteria	341.25	346.07	328.5

[a] Odds ratios for injury type are relative to blunt type injuries.
[b] Odds ratios for injury mechanism are relative to explosive mechanism.
[c] $P<.05$

odds of HO formation with 2 times greater odds compared to subjects who were not diagnosed with an infection. The model fit statistics favor the full model.

Comment

Across a broad population of extremity-injured subjects, 15% of subjects were diagnosed following injury with HO. Of 263 subjects further analyzed with open wounds associated with their extremity injury, 87 subjects (33%; 87/263) developed HO. Among subjects that were diagnosed with HO, 41% (36/87) were symptomatic. With only 36 out of the 263 subjects analyzed experiencing symptomatic HO, these data do support that HO is not abundantly problematic as a long-term outcome. This frequency is much lower than the frequencies reported in studies containing grade 3 open fracture and amputation patients only.[10,12]

Heterotopic bone is formed in traumatically injured tissues that are in a state of persistent inflammation, a state theoretically maintained by repeated handling of the tissues at frequent surgical settings.[2,11,15] A comparison of practices between deployed British and US surgeons suggested that certain devices used for high impulse irrigation, more frequent irrigations and debridements, and NPWT were more commonly associated with HO formation.[16] Each of these aspects of care represent ways that tissue is repeatedly traumatized in such a way that inflammation may persist. While the irrigation devices (high-pulsatile or other) used for the subjects' care in this cohort could not reliably be described by retrospective means, early debridement and irrigation frequency in this cohort was overall high and negative pressure wound therapy use common. However, these data did not support the hypothesis that particularly aggressive early wound care was associated with HO formation.

What is evident from these data is that when modeling several potential predictors of HO, the only predictor variable that was positively associated with increased odds of HO was infection. Infection is a recognized contributor to HO, presumably because of persistent inflammation associated with infection.[10,21] In a rat model of heterotopic ossification designed to mimic severe blast-related amputation, induced wound infection resulted in a greater volume of heterotopic bone volume.[22] Furthermore, local therapy with vancomycin in that same model reduces both infection and HO.[23] While HO has also been connected with infection in burn patients, this association is not described following extremity trauma or orthopaedic surgical patients outside of combat extremity injury.[24,25] This further reiterates the importance of the patient's inflammatory state and that multiple insults to the acute phase response are significant for HO risk.

Limitations to this study include limitations inherent to retrospective data collection. MOTR has an extensive quality assurance process for its data.[17,18] However, nuances of wound care, such as the irrigation device previously mentioned, is not reliably recorded for access via registry. The same can be assumed for details on injury severity and overall burden of injury (eg, TBI, burn, multisystem injury) which may contribute to the subjects' systemic inflammation magnitude and duration. Such details difficult to capture by retrospective means could under- or overestimate tested associations in regression modeling. The number of subjects who developed HO is also relatively small. This may make drawing conclusion on these associations challenging, warranting additional study such as in a case-control design.

This study provides a more comprehensive understanding of risk factors for HO in the military combat setting. By including multiple factors into this model, our data suggest that infection and resulting persistent inflammation is the primary risk factor for HO. While prior studies suggested that aggressive wound care practices and blast exposure may be primary factors associated

with HO, these data suggest that those relationships may be spurious due to common occurrence of infection with blast exposure and the common use of aggressive wound care practices in blast exposures with infection.

Acknowledgment

This work was funded by the Combat Casualty Care Research Program. The authors report no conflicts of interest related to the work.

References

1. Firoozabadi R, O'Mara TJ, Swenson A, Agel J, Beck JD, Routt M. Risk factors for the development of heterotopic ossification after acetabular fracture fixation. *Clin Orthop Relat Res*. 2014;472(11):3383-3388.
2. Yuasa M, Mignemi NA, Nyman JS, et al. Fibrinolysis is essential for fracture repair and prevention of heterotopic ossification. *J Clin Invest*. 2015;125(8):3117-3131.
3. Davis TA, O'Brien FP, Anam K, Grijalva S, Potter Bk, Elster EA. Heterotopic ossification in complex orthopaedic combat wounds: quantification and characterization of osteogenic precursor cell activity in traumatized muscle. *J Bone Joint Surg Am*. 2011;93(12):1122-1131.
4. Nauth A, Giles E, Potter BK, Nesti LJ, O'Brien FP, Bosse MJ. Heterotopic ossification in orthopaedic trauma. *J Orthop Trauma*. 2012;26(12):684-688.
5. Foruria AM, Augustin S, Morrey SF, Sanchez-Sotelo J. Heterotopic ossification after surgery for fractures and fracture-dislocations involving the proximal aspect of the radius or ulna. *J Bone Joint Surg Am*. 2013;95(10):e66.
6. Peterson JR, De La Rose S, Sun H, et al. Burn injury enhances bone formation in heterotopic ossification model. *Ann Surg*. 2014;259(5):993-998.
7. Dizdar D, Tiftik T, Kara M, Tunc H, Ersoz M, Akkus S. Risk factors for developing heterotopic ossification in patients with traumatic brain injury. *Brain Inj*. 2013;27(7-8):807-811.
8. Ohlmeier M, Suereo EM, Aach M, Meindl R, Schildhauer TA, Citak M. Muscle localization of heterotopic ossification following spinal cord injury. *Spine J*. 2017;17(10):1519-1522.
9. Alfieri K, Forsberg JA, Potter BK. Blast injuries and heterotopic ossification. *Bone Joint Res*. 2012;1(8):192-197.
10. Forsberg JS, Potter BK. Heterotopic ossification in wartime wounds. *J Surg Orthop Adv*. 2010;19(1):54-61.
11. Evans KN, Forsberg JA, Potter BK, et al. Inflammatory cytokine and chemokine expression is associated with heterotopic ossification high-energy penetrating war injuries. *J Orthop Trauma*. 2012;26(11):e204-e213.
12. Potter BK, Burns TC, Lacap AP, Granville RR, Gajewski DA. Heterotopic ossification following traumatic and combat-related amputations. Prevalence, risk factors, and preliminary results of excision. *J Bone Joint Surg Am*. 2007;89(3):476-486.
13. Tintle SM, Shawen SB, Forsberg JA, Gajewski DA, Keeling JJ, Andersen RC, Potter BK. Reoperation after combat-related major lower extremity amputations. *J Orthop Trauma*. 2014;28(4):232-237.
14. Tintle SM, Baechler MF, Nanos GP, Forsberg JA, Potter BK. Reoperations following combat-related upper-extremity amputations. *J Bone Joint Surg Am*. 2012;94(16):e1191-e1196.
15. Pavey GJ, Polfer EM, Nappo KE, Tintle SM, Forsberg JA, Potter BK. What risk factors predict recurrence of heterotopic ossification after excision in combat-related amputations?. *Clin Orthop Relat Res*. 2015;473(9):2814-2824.
16. Brown KV, Dharm-Datta S, Potter BK, Etherington J, Mistlin A, Hsu JR, Clasper JC. Comparison of development of heterotopic ossification in injured US and UK armed services personnel with combat-related amputations: preliminary findings and hypotheses regarding causality. *J Trauma*. 2010;69(suppl 1):S116-S122.
17. Rivera JC, Greer RM, Spott MA, Johnson AE. The Military Orthopaedic Trauma Registry: the potential of a specialty specific process improvement tool. *J Trauma Acute Care Surg*. 2016;81(5 suppl 2):S100-S103.
18. Rivera JC Greer RM, Wenke JC, Ficke JR, Johnson AE. Military Orthopaedic Trauma Registry: quality data now available. *J Surg Orthop Adv*. 2016;25(2):89-92.
19. Le TD, Orman JA, Stockinger ZT, et al. The Military Injury Severity Score (mISS): a better predictor of combat mortality than Injury Severity Score (ISS). *J Trauma Acute Care Surg*. 2016;81(1):114-121.
20. MacKenzie EJ, Bosse MJ, Kellam JF, et al. Characterization of patients with high-energy lower extremity trauma. *J Orthop Trauma*. 2000;14(7):455-466.
21. Forsber JA, Pepek JM, Wagne S, et al. Heterotopic ossification in high-energy wartime extremity injuries: prevalence and risk factors. *J Bone Joint Surg*. 2009;91:1094-1091.

22. Pavey GJ, Qureshi AT, Hope DN, Pavlicek RL, Potter BK, Forsberg JA, Davis TA. Bioburden increases heterotopic ossification formation in an established rate model. *Clin Orthop Relat Res*. 2015;473(9):2840-2847.

23. Seavey JG, Wheatly BM, Pavey GJ, et al. Early local delivery of vancomycin suppresses ectopic bone formation in a rate model of trauma-induced heterotopic ossification. *J Orthop Res*. 2017;35(11):2397-2406.

24. Orchard GR, Paratz, JD, Roberts JA. Risk factors in hospitalized patients with burn injuries for developing heterotopic ossification-a retrospective analysis. *J Burn Care Res*. 2015;36(4):465-470.

25. Thefenne L, de Brier G, Leclerc T, et al. Two new risk factors for heterotopic ossification development after severe burns. *PLoS One*. 2017;12(8):e0182303.

AUTHORS

Ms Juarez is affiliated with the US Army Institute of Surgical Research, Fort Sam Houston, Texas and the University of North Texas Health Science Center, Fort Worth, Texas.

Dr Pugh is affiliated with the University of Utah Health Science Center, Salt Lake City, Utah and South Texas Veterans Health Care System, San Antonio, Texas.

Dr Wenke is affiliated with the US Army Institute of Surgical Research, Fort Sam Houston, Texas.

When this study was conducted, MAJ Rivera was affiliated with the US Army Institute of Surgical Research, Fort Sam Houston, Texas.

Injury Mechanisms, Activities, and Limited Work Days in US Army Infantry Units

Michelle Canham-Chervak, PhD, MPH
Catherine Rappole, MPH
Tyson Grier, MS
Bruce H. Jones, MD, MPH

Abstract

Injuries are a leading health and readiness concern for the US Army. For effective prevention planning, details concerning circumstances associated with injuries are needed. Over 5,000 Soldiers were surveyed to collect demographic and injury details (type, body part, mechanism, activity, limited duty days); 874 reported an injury within 6 months of survey administration. The greatest proportion of limited duty time was associated with knee (19.2%), ankle (14.8%), and lower back injuries (12.9%). Overexertion was the leading injury mechanism (43.9%), followed by falls, jumps, trips, and slips (35.2%), which accounted for the highest average limited duty days per injury (42±43 days). Running was the leading activity associated overexertion injuries (39.3%) and falls (30.5%). Running also accounted for the greatest total limited duty days (5,844 days, 29.8%). For Army infantry units, results suggested a focus of prevention activities on running-related injuries resulting in overexertion or falls. Healthcare providers can facilitate injury prevention with contributions to initiatives providing details on injury mechanisms and activities associated with injuries.

The US Army is predominantly a young, physically active population, and as a result, injuries and musculoskeletal conditions are a significant health issue, resulting in over one million medical encounters among active duty Army personnel annually,[1] with an estimated 10 million restricted work days.[2] For effective injury prevention planning to occur, details concerning activities and mechanisms associated with injuries are necessary.[3-5] These critical elements of a minimum basic data set for injury surveillance have been recommended by the World Health Organization[4] and have also been specifically recommended to support US state health department[3,6] and military injury prevention efforts.[7,8] Yet, external cause of injury coding of medical data remains voluntary.[9]

Leading causes of injury often differ among Army units and organizations, given the varying missions, occupations, and geographic locations represented. Injuries have been most extensively studied in military trainee populations,[10] where leading activities associated with injury include physical training, road marching, and obstacle courses.[11] Few studies describe information on activities and mechanisms of injury beyond basic training, and existing studies focus on specific populations. In an Army airborne division, 75% of injuries were traumatic due to parachuting and other operational activities.[12] In a sample of infantry and Special Forces Soldiers, over 80% of injuries were attributed to physical training, road marching, or sports.[13] Among engineers and artillery Soldiers, half of injuries were attributed to physical training and road marching, while another 30% were related to occupational tasks such as equipment repair or carrying ammunition.[13] During deployment, injuries also vary according to the unit mission and environment; leading mechanisms have ranged from lifting and carrying and dismounted patrol[14] to weightlifting and sports.[15]

This article summarizes injury details from a large sample of Soldiers in an infantry division, including information not routinely available in the medical records such as activities, mechanisms, and limited duty days associated with injury. Injury risk factors in this and other infantry populations have been described elsewhere.[16-18] These details on activity and mechanism provide information necessary to prioritize and guide Army injury prevention activities.

Methods

Surveys were administered to active duty Army Soldiers in 3 infantry brigade combat teams between January 2011 and November 2012 as part of evaluations of physical training programs in those units. The projects were reviewed and approved as public health practice by the US Army Public Health Center Public Health Review Board. Demographic data collected by survey included gender, age, rank, brigade, and military occupational specialty (MOS). The MOSs were grouped into 13 specific occupational groups[16,19] and 3 broad categories

Table 1. Distribution by Injury Type and Limited Duty Days among Army Infantry Brigade Combat Team Soldiers.

Injury Type	Total Injuries (N=874) n_1 (%N)	Medical Care Not Sought n_2 (%n_1)	Medical Care Sought; No Profile Received n_3 (%n_1)	Medical Care Sought; Temporary Profile Received n_4 (%n_1)	Total Limited Duty Days (N=19,628) n_5 (%N)	Average Limited Duty Days n_6 (SD)
Strain	219 (25.1%)	51 (23.3%)	37 (16.9%)	128 (58.4%)	3,700 (18.9%)	30 (35)
Sprain	160 (18.3%)	39 (24.4%)	26 (16.3%)	94 (58.8%)	2,751 (14.0%)	31 (30)
Pain	150 (17.2%)	48 (32.0%)	29 (19.3%)	71 (47.3%)	2,384 (12.1%)	35 (36)
Fracture	76 (8.7%)	3 (3.9%)	11 (14.5%)	62 (81.6%)	3,373 (17.2%)	59 (47)
Tendonitis or bursitis	34 (3.9%)	5 (14.7%)	1 (2.9%)	28 (82.4%)	1,083 (5.5%)	42 (41)
Dislocation (joint)	30 (3.4%)	9 (30.0%)	2 (6.7%)	19 (63.3%)	1,420 (7.2%)	84 (67)
Nerve injury	28 (3.2%)	2 (7.1%)	5 (17.9%)	21 (75.0%)	1,108 (5.6%)	55 (31)
Bruise (contusion)	23 (2.6%)	4 (17.4%)	0	19 (82.6%)	552 (2.8%)	29 (41)
Cut/laceration/puncture	23 (2.6%)	3 (13.0%)	6 (26.1%)	13 (56.5%)	249 (1.3%)	21 (19)
Hernia	22 (2.5%)	4 (18.2%)	3 (13.6%)	15 (68.2%)	532 (2.7%)	41 (24)
Tear	15 (1.7%)	0	1 (6.7%)	14 (93.3%)	804 (4.1%)	57 (53)
Scrape/abrasion	11 (1.3%)	1 (9.1%)	5 (45.5%)	5 (45.5%)	314 (1.6%)	63 (74)
Concussion (TBI)	6 (0.7%)	1 (16.7%)	2 (33.3%)	3 (50.0%)	80 (0.4%)	27 (6)
Blister	5 (0.6%)	4 (80.0%)	1 (20.0%)	0	0	-
Burn	1 (0.1%)	0	1 (100%)	0	0	-
Multiple	4 (0.5%)	1 (25.0%)	1 (25.0%)	2 (50.0%)	40 (0.2%)	20 (14)
Other	34 (3.9%)	5 (14.7%)	4 (11.8%)	24 (70.6%)	1,037 (5.3%)	49 (44)
Unspecified	33 (3.8%)	7 (21.2%)	5 (15.2%)	11 (33.3%)	202 (1.0%)	NA
Totals	874 (100%)	187 (21.4%)	140 (16.0%)*	529 (60.5%)	19,628 (100%)	

*Information on medical care or profile was not provided for 18 injuries.
Note: TBI indicates traumatic brain injury; NA, not applicable.

(combat arms, combat support, and combat service support).[20] Combat arms included Soldiers who interact with enemy forces or provide battlefield capabilities, such as infantry and field artillery. Combat support included occupations with critical functions such as engineering, communications, and transportation. Combat service support occupations provide sustainment services such as paralegal, financial management, and medical.[20,21]

To ensure only injuries occurring while part of the infantry unit were included in the analysis, in-processing date and injury date were compared; only those with an injury occurring after in-processing with the unit were included. Survey date and injury date were compared to identify injuries occurring within 6 months of survey administration.

For each injury, the survey captured injury type, body part affected, mechanism of injury, activity associated with the injury, whether medical care was sought (yes/no), whether a profile was received (yes/no), and days of limited duty. Days of limited duty referred to the length of time a Soldier was on restricted activity (ie, temporary profile) as determined by a medical provider at the time of treatment and as reported on the survey. Consistent with *Army Regulation 40-501: Standards of Medical Fitness*,[22] the maximum number of limited duty days a Soldier could be given at one appointment with a medical provider was 365 days. Since the time frame for analysis was 6 months, reported values were limited to a maximum of 182.5 days.

Injury characteristics (injury type, body part, mechanism of injury, activity associated with the injury) are presented, along with the proportion reporting that medical care was sought and limited duty time was received. Total limited duty days and the average limited duty days per injury are reported by body part, injury type, mechanism of injury, and activity associated with the injury. Average limited duty days were calculated by dividing the total limited duty days in each category by the number of Soldiers reporting limited duty days in that category. Average limited duty days include the standard deviation to indicate the degree of variability. For injury type only, the number of encounters for which medical care was not sought is also reported. Analyses were conducted using SPSS Statistics, version 21 (IBM Corporation, Armonk, NY).

Results

Of the 5,102 active duty Army personnel surveyed in the 3 brigades, 93% were male, 63% were lower enlisted rank (E1 to E4), 55% were in a combat arms military occupation specialty, and the average age was 26 years

(±6 years). Nearly all Soldiers (99%) were Regular Army (ie, not part of the Army National Guard or Reserves). A total of 1,572 respondents (30%) reported an injury on the survey. Exclusion from further analysis occurred for the following reasons: missing survey date (n=5); missing injury date (n=250), injury occurred more than 6 months prior to the survey date (n=150), and injury occurred before in-processing with the brigade (n=293).

A total of 874 Soldiers reported an injury while serving in the infantry brigade and within a 6 month time period from survey administration. Among injured Soldiers, most were male (92%), with an average age of 27±6.4 years, a rank of E1 to E4 (59%), and were in combat arms occupations (49%), the most common of which was infantry (31%).

Sprains and strains were the most common injury type (43%), followed by pain (17%) and fractures (9%) (Table 1). Medical care was not sought for approximately one of 5 reported injuries (n=187, 21%). However, over 60% of reported injuries received medical care and limited duty days (n=529). Strains accounted for the greatest number of temporary profiles (25%), followed by sprains (18%), and pain (17%). Sprains contributed the greatest proportion of total limited duty days (20%), followed by fractures (17%). Average limited duty days were greatest for dislocations (84±67 days).

Table 2 displays the most commonly injured body parts. The knee was the most frequently reported injured body part (19%), followed by the ankle (15%), and lower back (13%). These body parts also contributed the greatest number of limited duty days (23%, 14%, and 12%, respectively). Average limited duty days were greatest for the wrist (67±60 days) and lower leg (56±56 days).

Reported mechanisms of injuries are shown in Table 3. Overexertion, strenuous or repetitive movements were reported as the mechanism resulting in the most injuries and limited duty (n=384, 44% of all injuries, 42% of injuries with limited duty days). Overexertion was the mechanism resulting in the most limited duty (42% of total limited duty days). Average limited duty days were greatest for the fall, jump, trip, or slip category (42±43 days).

Activities associated with reported injuries are listed in Table 4. Running for physical training was the most common activity associated with injuries (32%), followed by lifting or moving heavy objects (13%), and walking, hiking, or road marching (11%). Running was also associated with the greatest number of injuries with limited duty (31%) and resulted in over 5,000 total limited duty days (30% of all days). The highest average number of limited duty days was received for injuries due to military tasks and training (43±47 days).

Stratifying the top 3 mechanisms associated with injury by activity (Table 5) indicated that, among overexertion injuries, over one third (39%) were attributed to running, and another 20% were attributed to lifting or moving heavy objects. Among overexertion injuries, running was also associated with the greatest number of temporary profiles (41% of all overexertion injury profiles) and resulted in the greatest total limited duty days (39% of all limited duty days due to overexertion). The highest

Table 2. Injuries by Body Part and Limited Duty Days among Army Infantry Brigade Combat Team Soldiers.

Injured Body Part	Total Injuries (N=874) n (%N)	Medical Care Sought; Temporary Profile Received (N=529) n (%N)	Total Limited Duty Days (N=19,628) n (%N)	Average Limited Duty Days n (SD)
Knee	168 (19.2%)	109 (20.6%)	4,549 (23.2%)	43 (38)
Ankle	129 (14.8%)	82 (15.5%)	2,849 (14.5%)	38 (41)
Lower back	113 (12.9%)	74 (14.0%)	2,339 (11.9%)	32 (32)
Foot	72 (8.2%)	48 (9.1%)	1,497 (7.6%)	34 (31)
Shoulder	59 (6.8%)	33 (6.2%)	1,153 (5.9%)	44 (44)
Upper back	49 (5.6%)	36 (6.8%)	1,965 (10.0%)	55 (55)
Hand/Fingers	39 (4.5%)	22 (4.2%)	599 (3.1%)	30 (24)
Lower Leg (calf/shin)	36 (4.1%)	17 (3.2%)	897 (4.6%)	56 (56)
Hip	28 (3.2%)	17 (3.2%)	801 (4.1%)	53 (57)
Head/face	24 (2.7%)	12 (2.3%)	211 (1.1%)	19 (17)
Wrist	24 (2.7%)	13 (2.5%)	865 (4.4%)	67 (60)
Upper leg (thigh)	17 (1.9%)	10 (1.9%)	183 (0.9%)	18 (11)
Pelvic area	13 (1.5%)	6 (1.1%)	77 (0.4%)	13 (13)
Arm (upper or lower)	12 (1.4%)	7 (1.3%)	292 (1.5%)	49 (29)
Elbow	12 (1.4%)	6 (1.1%)	324 (1.7%)	54 (37)
Neck	11 (1.3%)	7 (1.3%)	130 (0.7%)	19 (20)
Chest	11 (1.3%)	6 (1.1%)	156 (0.8%)	26 (20)
Abdominal area	8 (0.9%)	5 (0.9%)	89 (0.5%)	18 (8)
Multiple	13 (1.5%)	5 (0.9%)	42 (0.2%)	14 (0)
Other	5 (0.6%)	5 (0.9%)	350 (1.8%)	88 (62)
Unspecified	31 (3.5%)	9 (1.7%)	261 (1.3%)	NA

Note: NA indicates not applicable.

average number of limited duty days received for overexertion injuries were attributed to walking, hiking, or road marching (46±36 days). Leading activities associated with fall, jump, trip, or slip injuries were running (n=94, 31% of all fall-related injuries), walking, hiking, or roach marching (n=55, 18%), and sports and recreation (n=44, 14%). Among fall, jump, trip, or slip injuries, running was also associated with the greatest number of temporary profiles (28% of fall, jump, trip, or slip profiles) and resulted in the greatest total limited duty days (25% of all limited duty days due to fall, jump, trip, or slips). The highest average number of limited duty days received for fall, jump, trip, or slip injuries was due to lifting or moving heavy objects (49±60 days). The leading activities due to being struck by or against a person or object were lifting or moving heavy objects (23%), sports and recreation (18%), repairing or maintaining equipment or vehicles (12%), and riding or driving in or on a motorized vehicle (12%). Among struck by/against injuries, injuries attributed to lifting or moving heavy objects had the greatest number of temporary profiles (23% of struck by/against profiles) and the greatest number of limited duty days (18% of all limited duty days due to struck by/against injuries). The highest average number of limited duty days received for struck by/against injuries was due to riding or driving in or on a motorized vehicle (33±33 days).

Table 3. Injuries and Limited Duty Days by Injury Mechanism among Army Infantry Brigade Combat Team Soldiers.

Injury Mechanism	Total Injuries (N=874) n (%N)	Medical Care Sought; Temporary Profile Received (N=529) n (%N)	Total Limited Duty Days (N=19,628) n (%N)	Average Limited Duty Days n (SD)
Overexertion, strenuous, or repetitive movements	384 (43.9%)	220 (41.6%)	8,275 (42.2%)	39 (39)
Fall, jump, trip, or slip	308 (35.2%)	211 (39.9%)	8,138 (41.5%)	42 (43)
Struck by/against	57 (6.5%)	35 (6.6%)	973 (5.0%)	29 (32)
Cut by a sharp instrument, tool, or object	13 (1.5%)	8 (1.5%)	128 (0.7%)	18 (20)
Fire, hot substance or object, or steam	1 (0.1%)	0	0	-
Environmental factors such as heat or cold	1 (0.1%)	1 (0.2%)	30 (0.2%)	-
Multiple	1 (0.1%)	0	0	-
Other	63 (7.2%)	35 (6.6%)	1,200 (6.1%)	37 (36)
Unspecified	46 (5.3%)	19 (3.6%)	885 (4.5%)	NA

Note: NA indicates not applicable.

Table 4. Injuries and Limited Duty Days by Injury Activity among Army Infantry Brigade Combat Team Soldiers.

Injury Activity	Total Injuries (N=874) n (%N)	Medical Care Sought; Temporary Profile Received (N=529) n (%N)	Total Limited Duty Days (N=19,628) n (%N)	Average Limited Duty Days n (SD)
Running	275 (31.5%)	163 (30.8%)	5,844 (29.8%)	38 (38)
Lifting or moving heavy objects	109 (12.5%)	67 (12.7%)	1,992 (10.1%)	34 (35)
Walking, hiking, or road marching	98 (11.2%)	58 (11.0%)	2,112 (10.8%)	40 (43)
Sports and Recreation	85 (9.7%)	45 (8.5%)	1,637 (8.3%)	42 (35)
Physical Training, not running	71 (8.1%)	41 (7.8%)	1,411 (7.2%)	35 (40)
Military tasks and training	42 (4.8%)	34 (6.4%)	1,423 (7.2%)	43 (47)
Stepping or climbing (stairs, ladder)	39 (4.5%)	31 (5.9%)	1,153 (5.9%)	37 (27)
Repairing or maintaining equipment or vehicles	24 (2.7%)	17 (3.2%)	674 (3.4%)	40 (47)
Riding or driving in or on a motorized vehicle	19 (2.2%)	16 (3.0%)	637 (3.2%)	42 (36)
Other	63 (7.2%)	40 (7.6%)	1,988 (10.1%)	51 (51)
Unspecified	49 (5.6%)	17 (3.2%)	759 (3.9%)	NA

Note: NA indicates not applicable.

Comment

This study provides a unique summary of injury details for active duty US Army personnel in a large infantry unit, including details not available from medical records but essential for the identification of the greatest contributors to injury occurrence and injury-related lost duty time. Among these Soldiers, sprains and strains were the most common injury type that accounted for the greatest proportion of total limited duty days. The knee was most often affected, followed by the ankle and lower back. Overexertion was the leading mechanism of injury, followed by falls, jumps, trips, and slips, which also accounted for the highest average limited duty days per injury. The leading activity associated with injury was running, which resulted in the greatest number of profiles and limited duty days. Among both overexertion and fall-related injuries, running was the leading activity.

Table 5. Top 3 Injury Mechanisms by Activity and Limited Duty Days among Army Infantry Brigade Combat Team Soldiers.

Top 3 Injury Mechanisms and Associated Activities	Total Injuries (N=749) n_1 (%n)	Medical Care Sought; Temporary Profile Received (N=466) n_2 (%n)	Total Limited Duty Days (N=17,387) n_3 (%n)	Average Limited Duty Days n_4 (SD)
Overexertion	n=384	n=220	n=8,275	
Running	151 (39.3%)	89 (40.5%)	3,256 (39.3%)	37 (34)
Lifting or moving heavy objects	75 (19.5%)	40 (18.2%)	1,133 (13.7%)	30 (24)
Physical training	53 (13.8%)	30 (13.6%)	1,143 (13.8%)	39 (45)
Walking, hiking, or road marching	35 (9.1%)	19 (8.6%)	789 (9.5%)	46 (36)
Sports and recreation	25 (6.5%)	11 (5.0%)	425 (5.1%)	39 (30)
Other activity	45 (11.7%)	31 (14.1%)	1,529 (18.5%)	51 (58)
Fall, jump, trip, or slip	n=308	n=211	n=8,139	
Running	94 (30.5%)	60 (28.4%)	2,057 (25.3%)	39 (44)
Walking, hiking, or road marching	55 (17.9%)	34 (16.1%)	1,247 (15.3%)	40 (49)
Sports and recreation	44 (14.3%)	28 (13.3%)	1,100 (13.5%)	46 (40)
Stepping or climbing (eg, stairs, ladder)	35 (11.4%)	27 (12.8%)	1,064 (13.1%)	39 (28)
Lifting or moving heavy objects	19 (6.2%)	17 (8.1%)	686 (8.4%)	49 (60)
Other activity	61 (19.8%)	45 (21.3%)	1,985 (24.4%)	46 (44)
Struck by/against	n=57	n=35	n=973	
Lifting or moving heavy objects	13 (22.8%)	8 (22.9%)	173 (17.8%)	25 (9)
Sports and recreation	10 (17.5%)	3 (8.6%)	80 (8.2%)	27 (15)
Repairing or maintaining equipment or vehicles	7 (12.3%)	4 (11.4%)	59 (6.1%)	15 (11)
Riding or driving in or on a motorized vehicle	7 (12.3%)	6 (17.1%)	163 (16.8%)	33 (33)
Running	4 (7.0%)	3 (8.6%)	45 (4.6%)	15 (17)
Other activity	16 (28.1%)	11 (31.4%)	453 (46.6%)	41 (48)

Other reviews of military medical surveillance and medical records have indicated that sprains and strains are leading injury types experienced by active duty personnel. A summary of over 500,000 outpatient visits for acute injuries among active duty US military personnel in 2006 found that 49% of all visits were due to sprains and strains.[7,23] Regarding limited duty and profile days, strains and sprains have been reported as accounting for the greatest proportion of limited duty days among airborne Soldiers, and overuse injuries (which included strains and sprains) accounted for the greatest total number of limited duty days among infantry, engineer, and artillery Soldiers.[12,13] In these populations, fractures and stress fractures also contributed significantly to limited duty.[12,13]

Knee injuries contributed the highest proportion of limited duty days and profiles in the infantry units of the study population, as well as the greatest number of total limited duty days, consistent with one other study of infantry Soldiers.[24] Another assessment of records of medical readiness in an infantry division showed that knee and leg injuries accounted for the greatest proportion of medically not ready (profiled) cases.[25]

Looking at mechanisms and activities associated with injury, overexertion has been previously identified as a leading mechanism of injury among US Army Soldiers,[1,26] but can be challenging to describe and mitigate since such injuries result from a wide variety of activities including repetitive movements, strenuous movements or load, and prolonged or strenuous static or awkward postures. In order to provide further evidence of where overexertion injuries were occurring, this analysis stratified mechanism by activity. In these units, overexertion injuries predominantly occurred while running, lifting or moving heavy objects, or during physical training. Falls have also been consistently identified as a leading mechanism of injury among Army Soldiers.[1,27] Further analysis by activity type indicated that, in these units, falls were most often related to running as well. For fall-related injuries, prior studies have shown that Army safety reports may serve as a source of additional details on circumstances, locations, and activities.[28,29]

The broad category of "physical training" has also been the leading activity associated with injury in basic training and infantry units.[11,13,18] However, when more specific categorization was available, running was cited as the leading activity.[24,30] A 2008 survey of over 3,000 US

Army personnel indicated that half (50.2%) of reported exercise and sports-related injuries were attributed to running.[31] In selected military populations (eg, airborne, engineer, artillery), studies have suggested that 30% or more of injuries are related to occupational tasks (eg, parachuting, repairing heavy vehicles, carrying shells, other military training),[12,13] demonstrating the importance of characterizing injury circumstances in different types of Army units.

Surveys are a tool that can provide details on injury activities and mechanisms, particularly in situations where electronic medical data are not readily available or when cause-coding of medical data is incomplete.[4] Work restrictions, or limited duty days, can also be obtained by survey and provide a measure of severity that is currently not captured completely in military electronic medical records.[2] In addition, surveys can provide information on injuries for which medical care was not sought. Surveys may be subject to recall bias related to injury details, though recall bias was minimized in this analysis by restricting to injuries occurring in the past 6 months. Soldier reporting of injuries within the past 6 months has been shown to be accurate when compared with medical records.[32] It is possible, however, that injuries for which medical care was received were more likely to be remembered and reported. Due to time restrictions, a limitation of this survey was that details on only one injury in the past 6 months were obtained. In the future, electronic surveys may provide the capability to collect details on all injuries during a specified time period. Finally, at the time of survey administration, the brigades were preparing for deployments to Afghanistan. Training activities during this time may differ from other time periods with less frequent deployments or deployments to a different location.

Ideally, activities and mechanisms associated with injury would be captured as part of an established surveillance system, given that surveillance offers the most cost-effective means of providing ongoing, systematic collection of data needed to quantify, prioritize, and track injury trends and intervention effects.[4,33,34] The capability to include external cause codes from the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) for each medical encounter for active duty military already exists. However, external cause coding has not been mandated in the Military Health System, though mandatory cause coding has been recommended by military safety and public health communities.[2,7,35] A number of US states have successfully established cause-coding of hospitalization and emergency department records; these states serve as examples of how it can be done.[34]

Clinician support of prevention is needed,[36,37] and military health care providers can contribute substantially to primary prevention and population health through contributions to injury cause coding of patient encounters or other efforts, such as surveys in specific populations, to capture detailed injury information. Data-driven prevention planning enables a focus on leading activities and mechanisms resulting in the greatest lost duty time, and thus more effective utilization of limited prevention resources. In addition, clinicians can lead efforts to design programs that address the most common injury activities and mechanisms, in partnership with leadership, supervisors, public health and safety professionals, and others responsible for injury prevention programs and planning. Through such partnerships and a systematic approach to injury prevention,[35,38] reduction of injuries among US Army Soldiers can occur.

References

1. Marshall S, Canham-Chervak M, Dada E, Jones B. Military Injuries. In: *The Burden of Musculoskeletal Diseases in the United States*. Rosemont, IL: United States Bone and Joint Initiative; 2013. Available at: http://www.boneandjointburden.org/2013-report/military-injuries/vi5. Accessed December 12, 2018.
2. Ruscio BA, Jones BH, Bullock SH, et al. A process to identify military injury prevention priorities based on injury type and limited duty days. *Am J Prev Med.* 2010;38(suppl 1):S19-S33.
3. National Center for Injury Prevention and Control. Recommended actions to improve external-cause-of-injury coding in state-based hospital discharge and emergency department data systems [internet]. Atlanta, GA: Centers for Disease Control and Prevention; December 2009. Available at: https://www.cdc.gov/injury/pdfs/ecode-a.pdf. Accessed December 12, 2018.
4. Holder Y, Peden M, Krug E, Lund J, Kobusingye O, eds. Injury Surveillance Guidelines. Geneva: World Health Organization; 2001. Available at: https://stacks.cdc.gov/view/cdc/6456. Accessed December 12, 2018.
5. Sleet DA, Moffett DB. Framing the problem: injuries and public health. *Fam Community Health.* 2009;32(2):88-97.
6. Injury Surveillance Workgroup. *Consensus Recommendations for Using Hospital Discharge Data for Injury Surveillance.* Marietta, GA: State and Territorial Injury Prevention Directors Association; 2003. Available at: https://stacks.cdc.gov/view/cdc/11518. Accessed December 12, 2018.
7. Jones BH, Canham-Chervak M, Canada S, Mitchener T, Moore S. Medical surveillance of injuries in the US military: descriptive epidemiology and recommendations for improvement. *Am J Prev Med.* 2010;38(suppl 1):S42-S60.

8. Hauret KG, Taylor BJ, Clemmons NS, Block SR, Jones BH. Frequency and causes of nonbattle injuries air evacuated from Operations Iraqi Freedom and Enduring Freedom, US Army, 2001-2006. *Am J Prev Med*. 2010;38(suppl 1):S94-S107.
9. Centers for Medicare and Medicaid Services and the National Center for Health Statistics. ICD-10-CM Official Guidelines for Coding and Reporting FY 2019 [internet]. Available at: https://www.cdc.gov/nchs/icd/data/10cmguidelines-FY2019-final.pdf. Accessed December 12, 2018.
10. Jones BH, Knapik JJ. Physical training and exercise-related injuries. Surveillance, research and injury prevention in military populations. *Sports Med*. 1999;27(2):111-125.
11. Knapik JJ, Graham BS, Rieger J, Steelman R, Pendergrass T. Activities associated with injuries in initial entry training. *Mil Med*. 2013;178(5):500-506.
12. Potter RN, Gardner JW, Deuster PA, Jenkins P, McKee K, Jr., Jones BH. Musculoskeletal injuries in an Army airborne population. *Mil Med*. 2002;167(12):1033-1040.
13. Reynolds K, Cosio-Lima L, Bovill M, Tharion W, Williams J, Hodges T. A comparison of injuries, limited-duty days, and injury risk factors in infantry, artillery, construction engineers, and special forces Soldiers. *Mil Med*. 2009;174(7):702-708.
14. Roy TC, Knapik JJ, Ritland BM, Murphy N, Sharp MA. Risk factors for musculoskeletal injuries for Soldiers deployed to Afghanistan. *Aviat Space Environ Med*. 2012;83(11):1060-1066.
15. Roy TC. Diagnoses and mechanisms of musculoskeletal injuries in an infantry brigade combat team deployed to Afghanistan evaluated by the brigade physical therapist. *Mil Med*. 2011;176(8):903-908.
16. Anderson MK, Grier T, Canham-Chervak M, Bushman TT, Jones BH. Occupation and other risk factors for injury among enlisted US Army Soldiers. *Public Health*. 2015;129(5):531-538.
17. Grier T, Canham-Chervak M, McNulty V, Jones BH. Extreme conditioning programs and injury risk in a US Army Brigade Combat Team. *US Army Med Dep J*. October-December 2013:36-47.
18. Tomlinson JP, Lednar WM, Jackson JD. Risk of injury in Soldiers. *Mil Med*. 1987;152(2):60-64.
19. Headquarters Department of the Army (DA). *DA Pamphlet 611-21: Military Occupational Classification and Structure*. Washington, DC: US Department of the Army; 2007.
20. Headquarters Department of the Army. *Field Manual 3-90: Tactics*. Washington DC: US Department of Army; 2001.
21. Headquarters Department of the Army. *Field Manual 7-21.13: The Soldier's Guide*. Washington DC: US Department of the Army; 2004.
22. Headquarters Department of the Army. *Army Regulation 40-501: Standards of Medical Fitness*. Washington, DC: US Department of the Army; 2008.
23. Hauret KG, Jones BH, Bullock SH, Canham-Chervak M, Canada S. Musculoskeletal injuries: Description of an under-recognized injury problem among military personnel. *Am J Prev Med*. 2010;38(suppl 1):S61-S70.
24. Smith TA, Cashman TM. The incidence of injury in light infantry Soldiers. *Mil Med*. 2002;167(2):104-108.
25. Malish RG, Arnett AD, Place RJ. Returning to duty from temporary disability in the US Army: observational data and commentary for commanders, providers, and Soldiers. *Mil Med*. 2014;179(11):1190-1197.
26. Canham-Chervak M, Steelman RA, Schuh A, Jones BH. Importance of external cause coding for injury surveillance: lessons from assessment of overexertion injuries among US Army Soldiers in 2014. *MSMR*. 2016;23(11):10-15.
27. Senier L, Bell NS, Yore MM, Amoroso PJ. Hospitalizations for fall-related injuries amond active-duty Army Soldiers, 1980-1998. *Work*. 2002;18:161-170.
28. Shuping E, Canham-Chervak M, Amoroso PJ, Jones BH. Identifying modifiable causes of fall-related injury: an analysis of US Army safety data. *Work*. 2009;33(1):23-34.
29. Hauschild VD, Schuh A, Taylor BJ, Canham-Chervak M, Jones BH. Identification of specific activities associated with fall-related injuries, active component, US Army, 2011. *MSMR*. 2016;23(6):2-9.
30. Knapik JJ, Jones SB, Darakjy S, et al. Injury rates and injury risk factors among US Army wheel vehicle mechanics. *Mil Med*. 2007;172(9):988-996.
31. Hauret KG, Bedno S, Loringer K, Kao TC, Mallon T, Jones BH. Epidemiology of exercise-and sports-related injuries in a population of young, physically active adults: A survey of military servicemembers. *Am J Sports Med*. 2015;43(11):2645-2653.
32. Schuh-Renner A, Canham-Chervak M, Grier TL, Jones BH. Accuracy of self-reported injuries compared to medical record data. *Musculoskelet Sci Pract*. 2018;39:39-44.
33. Chandran A, Hyder AA, Peek-Asa C. The global burden of unintentional injuries and an agenda for progress. *Epidemiol Rev*. 2010;32:110-120.
34. Annest JL, Fingerhut LA, Gallagher SS, et al. Strategies to improve external cause-of-injury coding in state-based hospital discharge and emergency department data systems. *MMWR Recomm Rep*. 2008;57(RR01):1-15.

35. Gunlicks JB, Patton JT, Miller SF, Atkins MG. Public health and risk management a hybridized approach to military injury prevention. *Am J Prev Med*. 2010;38(suppl 1):S214-S216.

36. Institute of Medicine. *Primary Care and Public Health: Exploring Integration to Improve Population Health*. Washington, DC: The National Academies Press; 2012. Available at: https://www.ncbi.nlm.nih.gov/pubmed/24851288. Accessed December 7, 2018.

37. Sullivan KJ, Wallace JG, Jr., O'Neil ME, et al. A vision for society: physical therapy as partners in the national health agenda. *Phys Ther.* 2011;91(11):1664-1672.

38. Jones BH, Canham-Chervak M, Sleet DA. An evidence-based public health approach to injury priorities and prevention recommendations for the U.S. Military. *Am J Prev Med*. 2010;38(suppl 1):S1-S10.

AUTHORS

The authors of this article are with the Injury Prevention Division, US Army Public Health Center, Aberdeen Proving Ground, Maryland.

Risk Factors for Sprains and Strains Among Physically Active Young Men: A US Army Study

Robyn C. Martin, MPH
Tyson Grier, MS
Michelle Canham-Chervak, PhD, MPH
Timothy T. Bushman, MS
Morgan K. Anderson, MPH, CPH
Esther O. Dada, MPH
Bruce H. Jones, MD, MPH

Abstract

This investigation aimed to identify risk factors for lower extremity sprain/strain injuries in physically active men. Lower extremity (LE) sprain/strain injuries are a significant source of morbidity among physically active populations. Data on and risk factors for injuries, including personal characteristics, and physical training and fitness were obtained from male Soldiers in an operational US Army division (N=6,865) by survey. Injury risks, risk ratios (RR), odds ratios (OR), and 95% confidence intervals (95% CI) were calculated. Multivariate analysis utilized logistic regression. Self-reported injury incidence for the prior 12 months was 43% (n=2,939), with 30% (n=878) of injuries attributed to LE sprains/strains. Lower extremity sprain/strain injuries were most commonly caused by falls, jumps, trips, or slips (49.4%), occurred while running (30.6%), and often resulted in limited duty profiles (64%). Higher risk of LE sprain/strain injury was independently associated with higher body mass index ($OR_{overweight/normal}$=1.2, 95% CI: 1.0-1.5), ($OR_{obese/normal}$=1.4, 95% CI: 1.1-1.9), lower aerobic endurance (from 2-mile run time) ($OR_{Quartile\ 2\ (Q2)/Quartile\ 4\ (Q4)}$=1.4, 95% CI: 1.0-1.8), ($OR_{Quartile\ 1\ (Q1)/Q4}$=1.6, 95% CI: 1.3-2.1), and lower core strength (sit-up repetitions) ($OR_{Q1/Q4}$=1.4, 95% CI: 1.1-1.8). Lower risk of LE sprain/strain injury was associated with performing unit resistance training 3 or more times per week ($OR_{3\ times/none}$=0.5, 95% CI: 0.3-0.8). LE sprain/strain injuries contribute a significant portion of injuries among US Army Soldiers. Emphasis on aerobic fitness, core strength, and resistance training may help reduce the risk of LE sprain/strain injury among physically active men.

Affecting almost 600,000 service members and resulting in over 2.1 million medical encounters annually, injuries represent a significant health care burden to the US military.[1] In 2011, more service members received medical care for mostly musculoskeletal injuries such as sprains, strains, fractures, Achilles tendonitis, and stress fractures than any other health condition.[1] Furthermore, it has been estimated that across the Department of Defense (DoD), acute and overuse injuries have been estimated to result in over 25 million days of limited duty.[2] Nationally, injuries are also a leading cause of mortality and morbidity. In 2007 alone, there were an estimated 34.3 million medically attended injury episodes among the US civilian, noninstitutionalized population.[3]

According to numerous studies of military and other physically active populations, injuries most commonly occur in the lower extremity (LE).[4-11] Injuries to the LE have been reported to account for up to 88% of all injuries in young, active, nonmilitary populations,[4-6] and up to 83% of injuries in military populations.[7-10,12] Among these injuries, sprains and strains are often the most common injury type. An analysis conducted for the DoD Military Injury Prevention Priorities Workgroup found that LE sprains and strains were the most frequently reported cause of outpatient visits, the third most frequently reported injury type resulting in hospitalization, and the fifth most common cause of limited duty days among active duty service members.[13] Another study found that 29% of all sports and physical training related injuries in US Army Soldiers resulting in hospitalization were due to sprains or strains and the most frequently injured anatomic locations were the knee and the ankle.[11]

Previous studies have reported a number of risk factors for musculoskeletal injury in military populations. These include younger (<20 years old) and older age (>27 years old), cigarette smoking, low aerobic endurance, low muscular endurance, high frequency and duration of exercise, and both high and low categories of body mass index (BMI) and flexibility.[7,10,14-19] To date, no analysis has been performed to assess risk factors specifically associated with LE sprains and strains. In addition, most prior studies were conducted among Soldiers in Basic Combat Training or Advanced Individual Training. The purpose of this study was to determine the risk factors for self-reported LE sprain and strain injuries among male US Army Soldiers in an operational

division. Risk factor categories examined included personal characteristics, physical training activities, and physical fitness.

Methods

Experimental Approach to the Problem

This investigation used a cross-sectional survey of US Army Soldiers to assess potential risk factors for sprains and strains of the LEs. Respondents were asked about personal characteristics, physical training, physical fitness, cigarette use, and injuries sustained in the 12 months prior to being surveyed. Potential injury risk factors were explored among Soldiers who self-reported sprains and strains of the LEs.

Subjects

A total of 6,865 male US Army light infantry division Soldiers stationed in the United States were surveyed. Soldiers who completed the survey were part of a larger evaluation investigating unit physical training programs. Project plans were reviewed and approved as public health practice by the institutional Public Health Review Board. Informed consent was received and the rights of all subjects were protected according to the approved study protocol.

Procedures

Surveys administered between September 2010 and October 2011 asked Soldiers about personal characteristics, unit and personal physical training, most recent Army Physical Fitness Test (APFT) results, injuries, limited duty days, and cigarette use during the previous 12 months. Injuries included traumatic and overuse injuries. Sprain and strain injuries were identified by asking the type of injury suffered. Sprains were described as injuries to ligaments or joints, and strains were described as injuries to tendons or muscles. Injuries to the LE were identified by asking what part of the body was injured. For the purpose of this investigation, LE injuries were defined as injuries to the knee, lower leg (calf/shin), ankle, or foot. Injury incidence (overall and LE) was calculated as the number of Soldiers with one or more self-reported injuries divided by the total number of Soldiers surveyed. The number of limited duty days was calculated for LE sprain and strain injuries.

The APFT consists of three events: a 2-minute maximal effort push-up event, a 2-minute maximal effort sit-up event, and a 2-mile run performed for time. Previous investigations have shown strong correlations between self-reported and unit-reported APFT scores.[20,21] The APFT variables (push-ups, sit-ups and 2-mile run) were converted into quartiles, where Q1=lowest performance and Q4=highest performance. Unit and personal training was assessed by the total distance run per week, and frequency of interval/sprint running, calisthenics, resistance training, agility training, and road marching.

Body mass index was calculated as weight in kilograms divided by height in meters squared (kg/m²) and grouped according to the Centers for Disease Control and Prevention categories (<18.5=underweight, 18.5-25=normal, 25-29.9=overweight, ≥30=obese).[22] Age categories were created by splitting the age variable into quartiles (Q1-Q4). Current smokers were defined as Soldiers who had smoked at least 100 cigarettes in their lifetime and had smoked at least one day or at least one cigarette in the past 30 days.

Statistical Analyses

The Statistical Package for the Social Sciences (SPSS), Version 21.0 (IBM, Armonk, NY) was used for all statistical analyses. Frequencies and percentages were calculated for personal characteristics, cigarette use, unit and personal training, physical fitness, and injury characteristics. Means and standard deviations were computed for age and BMI. Some subjects failed to respond to every survey question, resulting in unique denominators for each variable, as shown in Tables 1 and 2. Potential risk factors for strains and sprains of the LEs were explored using χ^2 tests. Risk ratios (RR) with 95% confidence intervals (95% CI) are reported. Variables from the univariate analysis with a 2-tailed statistical significance of $P<.05$ were further explored as potential independent risk factors for LE sprain and strain injuries using backward stepping multivariable logistic regression. Multivariate logistic regression only considers participants who had responses to every variable entered into the model (n=4,525). The variables that were included in the multivariable logistic regression were: age, BMI, total distance run per week during personal training, frequency of resistance training, APFT 2-mile run time, and APFT sit-up repetitions. Since APFT 2-mile run time and APFT sit-up repetitions were significantly correlated, two different multivariate models were compared. One model included 2-mile run time but not sit-ups and the other model included sit-up repetitions but not run time. Statistical significance of less than 0.1 was required for retention in the model. Multivariate odds ratios (ORs) and 95% CIs were calculated for each potential risk factor (independent variables). Results from multivariable logistic regression were considered significant if $P\leq.05$.

Results

Between September 2010 and October 2011, 6,865 male Soldiers completed the survey. Soldiers were an average of 26.6±5.9 years of age and had an average BMI of 26.1±3.6 kg/m.[2] Due to the small number of

underweight (BMI<18.5) Soldiers (n=58), underweight and normal weight Soldiers were combined into a single category (BMI<25). Overall self-reported injury incidence for the 12 months prior to survey completion was 43% (n=2,939 out of 6,865), with nearly half reporting sprains or strains (48%, n=1,416 out of 2,939). Sprains and strains were the most common injury type, with injury-associated pain (not otherwise classified) (11.2%; n=328 out of 2,939) and breaks/fractures (8.6%; n=253 out of 2,939) reported as the second and third most common injuries, respectively. Of those reporting sprains or strains, 62% (n=878 out of 1,416) were to the LEs. The ankle (36.3%, n=319 out of 878) and knee (35.8%, n=314 out of 878) were the most commonly sprained or strained LE anatomic locations. The LE sprain or strain injuries most commonly occurred while running (30.6%, n=269 of the 878 responses), performing "other exercise" (16.5%, n=145 of the 878 responses), or while walking, hiking, or marching with no load (15.3%, n=134 of the 878 responses). Sprain or strain injuries to the LE were most commonly caused by falls, jumps, trips, or slips (49.4%, n=410 of the 830 responses) or overexertion due to strenuous or repetitive movements (37%, n=307 of the 830 responses). Limited duty profiles were given to 64% of Soldiers (n=529 of the 833 responses) with LE sprain or strain injuries. Fifty injured Soldiers did not respond to the question about length of limited duty. Of the 479 responses, 48% (n=231) of the limited duty profiles were for less than 30 days, 32% (n=153) were for 30 to 60 days, and 20% (n=95) were for more than 60 days.

Table 1 displays the univariate logistic regression results for the survey variables. Soldiers who were over the age of 30, overweight (BMI 25-29.9) or obese (BMI≥30), had slower 2-mile run times, or had lower core muscular endurance (sit-ups) were at a significantly higher risk for a LE sprain or strain injury. Soldiers who ran over 16 miles per week during personal training or performed resistance training with their unit three or more times per week were at lower risk for a LE sprain or strain injury. There was no significant risk of sprain or strain injury associated with age, cigarette use, total distance run per week during unit training, APFT push-up repetitions, or frequency of calisthenics, agility training, or interval/sprint training per week during unit or personal training.

Table 2 displays the results of a multivariable backward stepping logistic regression for risk factors associated with LE sprain or strain injuries. Analysis showed that male soldiers who were overweight or obese had a 20% and 40% higher risk of a LE sprain or strain injury, respectively. Male soldiers who had slower APFT 2-mile run times had a 40% (Q2: 14.57-15.58 min) and 60% (Q1: 15.59+ min) higher risk of a LE sprain or strain injury, respectively. However, male soldiers who performed resistance training with their units 3 or more times per week were at 50% lower risk for a LE sprain or strain injury. Due to a significant correlation between APFT 2-mile run times and APFT sit-up repetitions, a second multivariable model (not shown) replacing 2-mile run time with sit-up repetitions was created. That model showed similar results to the model shown in Table 2, but revealed that Soldiers who performed fewer than 61 sit-ups have an increased risk of LE sprain or strain injury (OR 1.4, 95% CI 1.1-1.8, $P<.01$). Age and total distance run during personal training were not found to be independent risk factors for LE sprains and strains.

Comment

This investigation identified risk factors for self-reported LE sprain and strain injuries among male US Army Soldiers in an operational division. Forty-three percent of Soldiers were injured in the 12 months prior to survey completion. Studies performed on other military populations have shown similar overall injury rates (ranging from 31% to 61%).[14,16,19,23] The most common injury type was sprains and strains, with approximately 62% (n=878) of all sprains and strains occurring to the LE. Independent risk factors for LE sprains and strains included higher BMI and lower aerobic fitness (2-mile run time) and core strength (sit-up repetitions). Performing resistance training 3 or more times per week during unit training was found to protect Soldiers against LE sprains and strains.

In prior studies, the association between BMI and injury risk have produced inconsistent results. While several investigations of military populations have shown that overweight and obese Soldiers are at higher risk for injuries,[15,17,24-26] other studies have either reported no association between BMI and injury,[7,8] or bimodal associations between the lowest and highest BMI categories and injury.[14,15,27] These inconsistencies may be explained by differences in study population and tasks performed during training or normal duty.

The present study showed an increased risk of LE sprains and strains among Soldiers with higher BMIs. There is evidence that increased forces on body tissues during physical activity due to excess body weight may explain the association between high BMI and injury risk.[28] Furthermore, Wu et al suggest that greater step width and higher transversal friction demand in obese adults could contribute to slip-induced falls.[29] Body mass index is used as an indicator of body fat which has been shown to adversely affect performance on physically demanding military tasks.[30-33] Crawford et al found that Army Soldiers with 18% or less body fat

Table 1. Unadjusted risk factors for lower extremity sprain/strain injuries in male US Army Soldiers (N=6,865).

Variable	Variable Level	n	Reported LE Sprain/ Strain Injury (%n)	Risk Ratio (95% CI)	*P* Value
Age (years)	≤22	1857	11.6%	1.0	--
	23-25	1671	13.5%	1.2 (0.98, 1.4)	.09
	26-30	1741	12.5%	1.1 (0.9, 1.3)	.41
	>30	1482	14.2%	1.2 (1.0, 1.5)	.02
Body mass index	<25 (Normal)	2623	10.3%	1.0	--
	25-29.9 (Overweight)	3212	13.5%	1.3 (1.1, 1.5)	<.01
	30+ (Obese)	941	16.7%	1.6 (1.4, 1.9)	<.01
Cigarette Use	Nonsmoker	3420	13.0%	1.0	--
	Smoker	3106	12.5%	0.96 (0.8, 1.1)	.52
Years smoking for current smokers	Nonsmoker	3420	13.0%	1.0	--
	0-5	758	11.1%	0.9 (0.7, 1.1)	.15
	6-10	1032	12.3%	1.0 (0.8, 1.1)	.56
	11+	1246	13.3%	1.0 (0.9, 1.2)	.78
Total distance run per week (unit training)	≤7 miles	2526	12.1%	1.0	--
	7.01-16 miles	2817	13.0%	1.1 (0.9, 1.2)	.33
	16+ miles	510	15.1%	1.3 (1.0, 1.6)	.06
Total distance run per week (personal)	≤7 miles	5048	13.5%	1.0	--
	7.01-16 miles	1006	11.3%	0.8 (0.7, 1.0)	.06
	16+ miles	236	8.1%	0.6 (0.4, 0.9)	.02
Frequency of calisthenics per week (unit training)	No Calisthenics	862	11.9%	1.0	--
	1-2 times	2855	13.0%	1.1 (0.9, 1.3)	.42
	3+ times	2634	12.6%	1.1 (0.9, 1.3)	.63
Frequency of resistance training per week (unit training)	No Resistance Training	3362	13.7%	1.0	--
	1-2 times	2395	12.2%	0.9 (0.8, 1.0)	.10
	3+ times	562	8.5%	0.6 (0.5, 0.8)	<.01
Frequency of resistance training per week (personal)	No Resistance Training	1972	11.8%	1.0	--
	1-2 times	2117	13.7%	1.2 (0.98, 1.4)	.08
	3+ times	2206	13.2%	1.1 (0.95, 1.3)	.18
Frequency of agility training per week (unit training)	No Agility Training	3233	13.5%	1.0	--
	1-2 times	2478	12.0%	0.9 (0.78, 1.02)	.10
	3+ times	605	11.4%	0.9 (0.67, 1.1)	.17
Frequency of sprint or interval running per week (unit training)	No Sprint/Interval Training	922	13.8%	1.0	--
	1-2 times	4584	12.6%	0.9 (0.76, 1.1)	.31
	3+ times	837	11.8%	0.9 (0.66, 1.1)	.20
Frequency of sprint or interval running per week (personal)	No Sprint/Interval Training	4064	12.8%	1.0	--
	1-2 times	2244	12.9%	1.0 (0.87, 1.1)	.97
	3+ times	499	12.2%	0.95 (0.74, 1.2)	.70
Road march total distance per month (unit training)	No Road March	532	11.1%	1.0	--
	≤6 miles	4391	12.8%	1.2 (0.9, 1.5)	.26
	7+ miles	1331	12.8%	1.2 (0.88, 1.5)	.30
APFT 2 mile run time in minutes and seconds (quartiles)*	15.59+ (Q1)	1345	16.7%	1.6 (1.3, 1.9)	<.01
	14.57-15.58 (Q2)	1356	13.6%	1.3 (1.1, 1.6)	.01
	13.58-14.56 (Q3)	1353	11.3%	1.1 (0.87, 1.3)	.46
	≤13.57 (Q4)	1354	10.4%	1.0	--
APFT push-up repetitions (quartiles)*	≤55 (Q1)	1610	13.2%	1.1 (0.9, 1.3)	.43
	56-66 (Q2)	1652	14.0%	1.1 (0.96, 1.4)	.13
	67-75 (Q3)	1558	12.0%	1.0 (0.8, 1.2)	.85
	76+ (Q4)	1529	12.2%	1.0	--
APFT sit-up repetitions (quartiles)*	≤60 (Q1)	1829	14.7%	1.3 (1.1, 1.5)	<.01
	61-68 (Q2)	1492	13.2%	1.2 (0.96, 1.4)	.12
	69-77 (Q3)	1500	12.0%	1.1 (0.87, 1.3)	.58
	78+ (Q4)	1506	11.4%	1.0	--

*Q1 indicates low performance; Q4 indicates high performance; APFT indicates Army Physical Fitness Test.

had significantly better performance on 7 out of 10 fitness tests than Soldiers with body fat greater than 18%. Crawford et al suggest that Soldiers with excess body fat may have performed more poorly on fitness tests due to physiological fitness deficits that decrease muscular strength and aerobic endurance.[30] As fat mass is added, more energy is required to move body mass and overcome inertia during acceleration. The extra energy required to move excess total mass relative to lean mass may cause overweight Soldiers to fatigue more quickly than Soldiers in the low or normal BMI categories when performing similar exercises or tasks, leading to increased likelihood of injury.

Table 2. Multivariable logistic regression results for risk factors associated with lower extremity sprain/strain injuries in male US Army Soldiers (N=4,525).

Variable	Variable Level	n	Risk Ratio (95% CI)	*P* Value
Body mass index	<25 (normal)	1833	1.0	--
	25-29.9 (overweight)	2166	1.2 (1.0, 1.5)	.05
	30+ (obese)	526	1.4 (1.1, 1.9)	.02
2-mile run times in minutes and seconds (quartiles)	≤13.57 minutes (Q4)	1183	1.0	--
	13.58-14.56 minutes (Q3)	1153	1.2 (0.9, 1.6)	.18
	14.57-15.58 minutes (Q2)	1111	1.4 (1.0, 1.8)	.02
	15.59+ minutes (Q1)	1078	1.6 (1.3, 2.1)	<.01
Frequency of resistance training (unit training)	No resistance training	2315	1.0	--
	1-2 times per week	1814	0.9 (0.8, 1.1)	.27
	3+ times per week	396	0.5 (0.3, 0.8)	<.01

Q1 indicates low performance; Q4 indicates high performance; APFT indicates Army Physical Fitness Test.
Initial model variables: age, BMI, total distance run per week during personal training, frequency of resistance training during unit training, and APFT 2-mile run time.

As with this study, previous studies of military populations have also shown that Soldiers with lower aerobic fitness are at increased risk for injury.[7,16,17,26,34] Soldiers with slower 2-mile run times are more likely to have lower aerobic capacity.[7,35,36] Soldiers with low aerobic capacity will exercise at a high percentage of maximum aerobic capacity at any given amount of activity and will be expected to fatigue more quickly than Soldiers who are more aerobically fit. Several studies have shown that muscle fatigue causes changes in posture and gait leading to increased risk of falls,[37-40] a leading mechanism of sprain and strain injuries in this population. Parijat and Lockhart found that bilateral LE fatigue may increase the likelihood of slip-induced falls by significantly altering heel contact velocity, transitional acceleration in the forward direction, and friction demand.[39] Other studies have shown that fatigue can cause ligament laxity,[41] decrements in proprioception,[42] alterations to balance[43,44] and muscle activity,[42] and decreases in joint stability.[45,46]

Our finding that Soldiers who participated in resistance training 3 or more times per week were at decreased risk for LE sprain and strain injury is consistent with other literature. Research by Costain and Williams suggests that imbalances in the ratio of muscular strength between agonist and antagonist muscles across a joint (such as the quadriceps and hamstring) may increase injury risk.[47] Several studies suggest that improving muscle performance will aid in musculoskeletal alignment by promoting the growth and strength of muscles, tendons, ligaments, joint cartilage, tissue to bone connections, and connective tissue sheaths within the muscle.[48-50] Willson et al[51] and Leetun et al[52] suggest that due to the relationship between core trunk muscle activity and LE movement, improving core stability through strength training may decrease rates of back and LE injury. Concurrent with aerobic training, resistance training improves load bearing performance and heavy lifting tasks,[53,54] and increases both short and long term aerobic capacity.[55] To date, several studies have shown that neuromuscular training programs, including resistance training, may reduce injury risk in young athletes and Soldiers.[26,48,56-59] Unfortunately, it is difficult to compare these studies because programs were not standardized (eg, different length of exposure, different exercises) and were administered in different populations (eg, military members vs athletes). Most of the published studies combine neuromuscular, proprioceptive, and sensorimotor training methods to reduce injury, making it difficult to determine specific elements of the program that reduce injury.

One limitation of this project is that all data were collected via survey and personal characteristics, injuries, and physical training activities are self-reported, which may result in some recall bias. However, previous studies have shown that the validity of self-reported recall of injury among athletes is acceptable.[60,61] One study showed that within the past 12 months, recall was 80% accurate for body region injured and 61% accurate for number, body region, and exact diagnosis of each injury sustained.[60] Subjects were also asked to estimate how often they had performed specific tasks in the previous 6 months. In an environment where duty requirements and training patterns can vary from week to week, activity patterns may have fluctuated during a 6-month period. Some subjects also did not answer all of the survey questions. Another limitation is the restriction to only male subjects. While only 13.5% of active duty Army Soldiers were female in 2011,[62] future research on LE sprain and strain injury risk factors should include female subjects.

This is the first study to assess risk factors specific to LE sprain and strain injuries in a military population.

Although the findings of this study are most applicable to other military populations, we would expect the generalities of these results to be applicable to other young male populations engaged in varied physical training or occupational activities. While some activities may appear unique to the military, many have counterparts to those of civilian populations. General categories of activities include general physical fitness training, lifting and carrying objects, pushing and pulling, digging, and movement from one location to another on foot including running or walking with or without an external load. In the general population, it has been estimated that medical and physical therapy treatments for acute ankle sprains can range from $490 to $4,662 depending on the severity and time lost from work. Therefore, even a small reduction in LE sprains and strains could result in substantial savings to the Department of Defense.[63]

Conclusion

In a population of physically active young men, risk factors for LE sprain and strain injuries included higher BMI, and lower aerobic fitness and core strength. Resistance training performed 3 or more times per week during unit training was found to be protective against injury. Sprain and strain injuries, particularly to the LEs, are one of the most common, debilitating, and costly sources of injury in the military. Moreover, LE sprains and strains are a significant source of injury among physically fit young men across various sports, occupations, and recreational physical fitness activities. The identification of risk and protective factors for this leading injury type will inform the development of more effective, focused injury prevention programs for physically active adults. Future injury prevention programs should focus on (1) maintaining a healthy BMI, (2) improving aerobic fitness, (3) improving muscle strength, particularly core muscle strength, and (4) addition of resistance training to weekly training regimens. Although this study identifies several risk and protective factors for this leading injury type in active populations, continued research is warranted. Future research should focus on the effectiveness of existing injury prevention programs. Special attention should be shown to how interventions impact the physiological characteristics that lead to injury, the effectiveness of interventions across diverse groups (military versus civilian or men versus women), and how interventions may be specifically targeted to maximize injury reduction in each unique population.

Acknowledgments

This research was supported in part by an appointment to the Postgraduate Research Participation Program at the Army Public Health Center (APHC) administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the US Department of Energy and APHC. This study is approved for public release, distribution is unlimited. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the US Army or the Department of Defense.

References

1. Armed Forces Health Surveillance Center. Absolute and relative morbidity burdens attributable to various illnesses and injuries, US Armed Forces, 2011. *MSMR*. 2012;19(4):4-9.
2. Ruscio B, Smith J, Amoroso P, et al. *DoD Military Injury Prevention Priorities Working Group: Leading Injuries, Causes, and Mitigation Recommendations*. Washington DC: Office of the Assistant Secretary of Defense for Health Affairs; 2006.
3. Chen LH, Warner M, Fingerhut L, et al. *Injury Episodes and Circumstances: National Health Interview Survey, 1997-2007*. Hyattsville, MD: National Center for Health Statistics; 2009.
4. Murphy DF, Connolly DA, Beynnon BD. Risk factors for lower extremity injury: a review of the literature. *Br J Sports Med*. 2003;37(1):13-29.
5. Seil R, Rupp S, Tempelhof S, et al. Sports injuries in team handball. A one-year prospective study of sixteen men's senior teams of a superior nonprofessional level. *Am J Sports Med*. 1998;26(5):681-687.
6. Ekstrand J, Gillquist J, Moller M, et al. Incidence of soccer injuries and their relation to training and team success. *Am J Sports Med*. 1983;11(2):63-67.
7. Knapik JJ, Sharp MA, Canham-Chervak M, et al. Risk factors for training-related injuries among men and women in basic combat training. *Med Sci Sports Exerc*. 2001;33(6):946-954.
8. Jones BH, Cowan DN, Tomlinson JP, et al. Epidemiology of injuries associated with physical training among young men in the Army. *Med Sci Sports Exerc*. 1993;25(2):197-203.
9. Dada-Laseinde E, Canham-Chervak M, Jones B. *US Army Annual Injury Epidemiology Report 2008*. Aberdeen Proving Ground, MD: US Army Public Health Command; 2009.
10. Almeida SA, Williams KM, Shaffer RA, et al. Epidemiological patterns of musculoskeletal injuries and physical training. *Med Sci Sports Exerc*. 1999;31(8):1176-1182.
11. Lauder TD, Baker SP, Smith GS, et al. Sports and physical training injury hospitalizations in the army. *Am J Prev Med*. 2000;18(suppl 3):118-128.
12. Davidson PL, Chalmers DJ, Wilson BD, et al. Lower limb injuries in New Zealand Defence Force personnel: descriptive epidemiology. *Aust N Z J Public Health*. 2008;32(2):167-173.

13. Ruscio BA, Jones BH, Bullock SH, et al. A process to identify military injury prevention priorities based on injury type and limited duty days. *Am J Prev Med*. 2010;38(suppl 1):S19-S33.
14. Jones BH, Bovee MW, Harris JM 3rd, et al. Intrinsic risk factors for exercise-related injuries among male and female Army trainees. *Am J Sports Med*. 1993;21(5):705-710.
15. Knapik J, Jones SB, Sharp MA, et al. *A Prospective Study of Injuries and Injury Risk Factors Among Army Wheel Vehicle Mechanics*. Aberdeen Proving Ground, MD: US Army Center for Health Promotion and Preventive Medicine; 2006.
16. Knapik J, Ang P, Reynolds K, et al. Physical fitness, age, and injury incidence in infantry soldiers. *J Occup Med* 1993;35(6):598-603.
17. Reynolds K, Cosio-Lima L, Bovill M, et al. A comparison of injuries, limited-duty days, and injury risk factors in infantry, artillery, construction engineers, and special forces soldiers. *Mil Med*. 2009;174(7):702-708.
18. Kaufman KR, Brodine S, Shaffer R. Military training-related injuries: surveillance, research, and prevention. *Am J Prev Med* 2000;18(suppl 3):54-63.
19. Grier T, Morrison S, Knapik J, et al. *Injury Incidence and Injury Risk Factors Among Soldiers in the United States Army Ordnance School*. Aberdeen Proving Ground, MD: US Army Center for Health Promotion and Preventive Medicine; 2009.
20. Jones SB, Knapik JJ, Sharp MA, et al. The validity of self-reported physical fitness test scores. *Mil Med*. 2007;172(2):115-120.
21. Martin RC, Grier T, Canham-Chervak M, et al. Validity of self-reported physical fitness and body mass index in a military population. *J Strength Cond Res*. 2016;30(1):26-32.
22. Centers for Disease Control and Prevention. Healthy Weight-it's not a diet, it's a lifestyle [internet]; 2015. Available at: https://www.cdc.gov/media/subtopic/matte/pdf/031210-Healthy-Weight.pdf. Accessed January 20, 2015.
23. Piantanida NA, Knapik JJ, Brannen S, et al. Injuries during Marine Corps officer basic training. *Mil Med*. 2000;165(7):515-520.
24. Reynolds K, Cosio-Lima L, Creedon J, et al. Injury occurrence and risk factors in construction engineers and combat artillery soldiers. *Mil Med*. 2002;167(12):971-977.
25. Billings CE. Epidemiology of injuries and illnesses during the United States Air Force Academy 2002 Basic Cadet Training program: documenting the need for prevention. *Mil Med*. 2004;169(8):664-670.
26. Grier T, Canham-Chervak M, McNulty V, et al. Extreme conditioning programs and injury risk in a US Army brigade combat team. *US Army Med Dep J*. October-December 2013:36-47.
27. Knapik JJ, Graham B, Cobbs J, Thompson D, Steelman R, Jones BH. A prospective investigation of injury incidence and risk factors among army recruits in combat engineer training. *J Occup Med Toxicol*. 2013;8(1):5.
28. Browning RC, Kram R. Effects of obesity on the biomechanics of walking at different speeds. *Med Sci Sports Exerc*. 2007;39(9):1632-1641.
29. Wu X, Lockhart TE, Yeoh HT. Effects of obesity on slip-induced fall risks among young male adults. *J Biomech*. 2012;45(6):1042-1047.
30. Crawford K, Fleishman K, Abt JP, et al. Less body fat improves physical and physiological performance in army soldiers. *Mil Med*. 2011;176(1):35-43.
31. Mattila VM, Tallroth K, Marttinen M, et al. Physical fitness and performance. Body composition by DEXA and its association with physical fitness in 140 conscripts. *Med Sci Sports Exerc*. 2007;39(12):2242-2247.
32. Bohnker BK, Sack DM, Wedierhold L, et al. Navy physical readiness test scores and body mass index (Spring 2002 cycle). *Mil Med*. 2005;170(10):851-854.
33. Vogel JA. Obesity and its relation to physical fitness in the US military. *Armed Forces & Society*. 1992;18(4):497-513.
34. Knapik JJ, Sharp MA, Canham ML, Hauret K, Cuthie J. *Injury Incidence and Injury Risk Factors Among U.S. Army Basic Trainees at Ft. Jackson SC, 1998 (Including Fitness Training Unit Personnel, Discharges, and Newstarts)*. Aberdeen Proving Ground, MD: US Army Center for Health Promotion and Preventive Medicine, 1999. Available at: https://apps.dtic.mil/dtic/tr/fulltext/u2/a367596.pdf. Accessed November 14, 2018.
35. Knapik J. The Army Physical Fitness Test (APFT): a review of the literature. *Mil Med*. 1989;154(6):326-329.
36. Mello RP, Murphy MM, Vogel JA. Relationship between a two mile run for time and maximal oxygen uptake. *J Strength Cond Res*. 1988;2(1):9-12.
37. Granacher U, Wolf I, Wehrle A, et al. Effects of muscle fatigue on gait characteristics under single and dual-task conditions in young and older adults. *J Neuroeng Rehabil*. 2010;7:56.
38. Vuillerme N, Forestier N, Nougier V. Attentional demands and postural sway: the effect of the calf muscles fatigue. *Med Sci Sports Exerc*. 2002;34(12):1907-1912.
39. Parijat P, Lockhart TE. Effects of lower extremity muscle fatigue on the outcomes of slip-induced falls. *Ergonomics*. 2008;51(12):1873-1884.
40. Le Bris R, Billat V, Auvinet B, et al. Effect of fatigue on stride pattern continuously measured by an accelerometric gait recorder in middle distance runners. *J Sports Med Phys Fitness*. 2006;46(2):227-231.

41. Sakai H, Tanaka S, Kurosawa H, et al. The effect of exercise on anterior knee laxity in female basketball players. *Int J Sports Med*. 1992;13(7):552-554.

42. Rozzi SL, Lephart SM, Fu FH. Effects of muscular fatigue on knee joint laxity and neuromuscular characteristics of male and female athletes. *J Athl Train*. 1999;34(2):106-114.

43. Johnston RB, 3rd, Howard ME, Cawley PW, et al. Effect of lower extremity muscular fatigue on motor control performance. *Med Sci Sports Exerc*. 1998;30(12):1703-1707.

44. Dickin DC, Doan JB. Postural stability in altered and unaltered sensory environments following fatiguing exercise of lower extremity joints. *Scand J Med Sci Sports*. 2008;18(6):765-772.

45. Ortiz A, Olson SL, Etnyre B, et al. Fatigue effects on knee joint stability during two jump tasks in women. *J Strength Cond Res*. 2010;24(4):1019-1027.

46. Melnyk M, Gollhofer A. Submaximal fatigue of the hamstrings impairs specific reflex components and knee stability. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(5):525-532.

47. Costain R, Williams AK. lsokinetic quadriceps and hamstring torque levels of adolescent, female soccer players. *J Orthop Sports Phys Ther*. 1984;5(4):196-200.

48. Fleck SJ, Falkel JE. Value of resistance training for the reduction of sports injuries. *Sports Med*. 1986;3(1):61-68.

49. Woo SL, Ritter MA, Amiel D, et al. The biomechanical and biochemical properties of swine tendons -- long term effects of exercise on the digital extensors. *Connect Tissue Res*. 1980;7(3):177-183.

50. LaStayo PC, Woolf JM, Lewek MD, et al. Eccentric muscle contractions: their contribution to injury, prevention, rehabilitation, and sport. *J Orthop Sports Phys Ther*. 2003;33(10):557-571.

51. Willson JD, Dougherty CP, Ireland ML, et al. Core stability and its relationship to lower extremity function and injury. *J Am Acad Orthop Surg*. 2005;13(5):316-325.

52. Leetun DT, Ireland ML, Willson JD, et al. Core stability measures as risk factors for lower extremity injury in athletes. *Med Sci Sports Exerc*. 2004;36(6):926-934.

53. Kraemer WJ, Vescovi JD, Volek JS, et al. Effects of concurrent resistance and aerobic training on load-bearing performance and the Army physical fitness test. *Mil Med*. 2004;169(12):994-999.

54. Kraemer WJ, Vogel JA, Patton JF, Dziados JE, Reynolds KL. *The Effects of Various Physical Training Programs on Short Duration, High Intensity Load Bearing Performance and the Army Physical Fitness Test*. 1987. Available at: http://www.dtic.mil/docs/citations/ADA185473. Accessed November 14, 2018.

55. Reynolds KL, Harman EA, Worsham RE, et al. Injuries in women associated with a periodized strength training and running program. *J Strength Cond Res*. 2001;15(1):136-143.

56. Hubscher M, Zech A, Pfeifer K, et al. Neuromuscular training for sports injury prevention: a systematic review. *Med Sci Sports Exerc*. 2010;42(3):413-421.

57. Olsen OE, Myklebust G, Engebretsen L, et al. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. *BMJ*. 2005;330(7489):449.

58. Grooms DR, Palmer T, Onate JA, et al. Soccer-specific warm-up and lower extremity injury rates in collegiate male soccer players. *J Athl Train*. 2013;48(6):782-789.

59. Walden M, Atroshi I, Magnusson H, et al. Prevention of acute knee injuries in adolescent female football players: cluster randomised controlled trial. *BMJ*. 2012;344:e3042.

60. Gabbe BJ, Finch CF, Bennell KL, et al. How valid is a self reported 12 month sports injury history? *Br J Sports Med*. 2003;37(6):545-547.

61. Valuri G, Stevenson M, Finch C, et al. The validity of a four week self-recall of sports injuries. *Inj Prev*. 2005;11(3):135-137.

62. United States Department of Defense. 2011 Demographics Profile of the Military Community, 2011.

63. Bielska IA, Pickett W, Brison R, Brouwer B, Johnson AP. Health care resource utilization after acute ankle sprains. *Zdrowie Publiczne i Zarządzanie*. 2012;10(2):106-110. Abstract available at: http://www.ejournals.eu/Zdrowie-Publiczne-i-Zarzadzanie/Tom-10-2012/Tom-10-zeszyt-2/art/2148/. Accessed November 14, 2018.

Authors

The authors of this article are with the Injury Prevention Division, Army Public Health Center, Aberdeen Proving Ground, Maryland.

The Etiology of Injuries in US Army Initial Entry Training

Veronique D. Hauschild, MPH
Stephen Barnes, MPH
Keith Hauret, PT
Terrence Lee, PhD, MPH
Lanna Forrest, PhD
Bruce H. Jones, MD, MPH

Abstract

Background: US Army initial entry training (IET) trainees engage in intense physical activities for 10 or more weeks prior to their assignment to operational units. Many trainees succumb to injury during IET. Injuries to the lower extremities and back have historically been the most common, and thus have been the focus of routine health surveillance.

Objectives: The primary goal of this analysis was to verify the training-related injuries of greatest concern and to update the clinical diagnostic codes (ICD-10-CM) used in surveillance. The investigation also aimed to develop a sense of the financial magnitude of these injuries.

Methods: The distribution of all IET injuries was determined using a comprehensive injury taxonomy. Injuries were categorized based on causal energy source (mechanical, thermal, radiant, nuclear, chemical, or electrical). Mechanical energy transfers included acute trauma and cumulative microtrauma ("overuse"). Injury ICD-10-CM codes were identified in calendar year 2016 IET trainees' electronic healthcare records. Injury frequencies were reported for gender, body region, and injury type. Costs were calculated from medical encounters and estimated lost training time using the most frequently injured anatomical site as a baseline.

Results: Among 106,367 trainees, 65,026 separate injuries were identified. Mechanical energy transfers to lower extremities caused 75% of all injuries; most (65%) were cumulative microtraumatic. The most frequently injured anatomical site (the knee, 20% of injuries), is estimated to have cost over $39 million.

Conclusions: Lower extremity injuries, followed by those of the low back continue to be leading "training-related injuries." This suggests the need to ensure distances and/or frequencies of weight-bearing activities (running, foot-marching) are not increased too rapidly or too excessively, and that trainees' fitness prior to IET is adequate. Medical costs and lost training time should be included in future monitoring.

United States military basic training, officially called initial entry training (IET) and informally called "boot camp," prepares recruits and other newly entering men and women for the physical, mental, and emotional elements of military service.[1-3] Each of the armed services has its own tailored version of the IET program.[1] For each service, the IET program involves intense physical activities in sometimes austere environments for several weeks. During IET, trainees engage in activities such as weapons use, land navigation, combatives (a form of martial arts), medical aid, and obstacle course drills.[1,2,4] Trainees seek medical evaluation for a variety of physical injuries including foot blisters,[4-6] exertional heat injuries,[7-8] and numerous musculoskeletal diagnoses.[3,4,9-16] Because the trainees experience known exposure conditions and a relatively standardized set of activities, they are frequently the subject of epidemiological studies.[3,16]

The US Army's IET program is the primary component of its overall initial military training process designed to produce disciplined, motivated, and physically fit enlisted Soldiers.[2] Army enlistees must successfully graduate from IET prior to assignment to an operational unit within the Active Army, Reserve, or National Guard. The IET begins with a 10-week Basic Combat Training (BCT) program, followed by additional weeks of specific occupational training (Advanced Initial Training) at a different location. In certain combat occupations, the full IET program is combined at one location as One Station Unit Training (OSUT). After successful completion of the third phase of IET (graduation from BCT or 10th week of OSUT), trainees are officially authorized to be referred to as "Soldiers."[2] Prior to this authorization, the trainees are often referred to as "basic trainees."

Army basic trainees and Soldiers spend a substantial portion of their training time on their feet conducting vigorous weight-bearing activities such as running, patrolling, and ruck marching.[2,4] These weight-bearing activities are fundamental military skills that increase individual fitness, yet are also the primary cause of military overuse injuries.[3,4,13-21] The literature has consistently described the lower extremities as the most commonly injured body region among Army basic trainees and Soldiers.[3,4,16,22-24] To address this, the Army officially implemented the Physical Readiness Training (PRT)

regimen in 2010[25] to reduce the volume (distance and frequency) of running in training programs as part of an evidence-based injury reduction strategy.[3,16,26,27] Although the PRT may have reduced some injuries among basic trainees, lower extremity overuse injuries continue to be problematic. For example, it is estimated that such injuries account for 80% of the disability-related discharges among Army basic trainees.[28] While not fully characterized in past studies, the fiscal impact of these injuries, including direct medical treatment costs as well as the indirect costs associated with lost or restricted training time, is thought to be enormous.[3,28] The Army's loss of investment to these "training-related injuries" is a tremendous burden that has been described as "the single most significant medical impediment to military readiness."[28]

The US Army routinely monitors training-related injuries using the International Classification of Disease (ICD) clinical diagnosis codes in basic trainees' electronic healthcare records (EHR).[14,15,29,30] These analyses are provided as training-related injury reports (TRIRs) to IET unit leadership to help identify injury problems.[14] Instead of describing all potential injuries attributed to training activities, the TRIR focuses exclusively on those injuries considered to be of the greatest magnitude, specifically those to the lower extremities and lower back.[14,15] The ICD codes selected for the initial TRIR over a decade ago were from the ICD Version 9 Clinical Modification (ICD-9-CM). Since then, not only have the codes used in the EHR been expanded and updated to ICD-10-CM,[29] there have also been changes to training procedures and basic trainee demographics.[25,29,30]

This analysis verifies the magnitude of the lower extremity and back injuries in the context of all injuries currently experienced by Army basic trainees by applying a comprehensive injury taxonomy to the ICD-10-CM codes now used in basic trainees' EHR. The selected set of ICD-10-CM codes updates the Army's definition of "training-related injuries." This investigation also proposes an approach to estimate the financial effect of these injuries.

Methods

This project was a descriptive epidemiologic analysis of one year (2016) of Army trainee medical records approved as public health monitoring by the Public Health Review Board of the US Army Public Health Center. Injuries were determined using a comprehensive list of ICD-10-CM "injury codes"in trainees' EHR.[29] The ICD codes were categorized using an injury taxonomy that grouped injuries based on the type of causal energy exposure (ie, mechanical, thermal, radiant, electrical, chemical, biological, and nuclear/radiological).[29] Exposure groups were further grouped and subcategorized. For example, mechanical energy injuries were grouped into acute traumatic injuries resulting from a single high intensity force and cumulative microtraumatic (overuse) injuries from repeated lower intensity forces. These were further subcategorized to those affecting the musculoskeletal (MSK) system or other (non-MSK) system. Nonmechanical energies were subdivided in environmental, poisons, nonenvironmental, and other categories. Environmental exposures included injuries resulting from thermal and radiant energy (ie, heat stroke and heat exhaustion).[29]

This study defined each "training-related injury" as the first or incident occurrence of an injury ICD-10-CM code documented as a primary diagnosis in an IET trainee's EHR during calendar year (CY) 16. Trainees may have multiple medical encounters for the same injury during the IET program. If not otherwise specified, after an individual's first medical encounter with a specified ICD-10-CM code, 30 days had to lapse before it could again be counted as an "incident injury."

The population included 106,367 trainees who were enrolled in either the BCT or OSUT Army IET program at any time during the CY 2016, based on the Army Training Requirements and Resources System. Advanced Initial Training trainees were not included due to difficulties identifying rosters. For purposes of the investigation, the trainees are referred to as IET basic trainees. Electronic health care records (hospitalized/emergency room and outpatient clinic visits) were retrieved from the Defense Medical Surveillance System (DMSS). The Armed Forces Health Surveillance Branch (AFHSB) linked the identified trainees' training dates to their medical encounter data. Incident injuries were calculated for all IET basic trainees and for both genders. Descriptive results were organized as incident injury frequencies by energy exposure category, general and specific body region, and injury type.[30]

Direct medical costs were extracted from the Military Health System Data Repository files using the Military Health System Mart interface. The direct costs included the total paid by the military healthcare system (provider costs, diagnostics and lab costs, medicines) for the trainees' initial injury encounters and any CY 2016 follow-up and sequelae visits. Given the resources available, the scope was limited to the extraction of primary ICD-10-CM diagnoses for only the most frequently injured anatomical site. Indirect costs were calculated as the total incident injuries for that anatomical site, multiplied by the average salary for the lowest paid basic

Table 1. Distribution of Total Injuries* (N=65,025) by Type of Energy Transfer, Army CY 2016 IET (BCT/OSUT) Trainees.

Exposure Type: Energy Category	Energy Subcategory	Body System	No. of Injuries	% Total Injuries (%N)	No. of Trainees Injured	Men		Women	
						No. of Injuries	No. of Injured	No. of Injuries	No. of Injured
Mechanical	All		62,672	96	33,005	41,635	22,990	21,037	10,015
	Acute Trauma	All	10,567	16	8,435	6,795	5,524	3,772	2,911
		Non-MSK	4,007	6.2	3,577	2,825	2,541	1,182	1,036
		MSK	6,560	10	5,273	3,970	3,206	2,590	2,067
	Cumulative Microtrauma	All	52,105	80	29,294	34,840	20,250	17,265	9,044
		Non-MSK	3,432	5.3	3,014	1,954	1,755	1,478	1,259
		MSK	48,673	75	27,478	32,886	19,105	15,787	8,373
Environmental	All		1,574	2.4	1,339	1,025	854	549	485
	Thermal/Radiant		1,542	2.4	1,308	1,006	835	536	473
	Pressure		0	0.0	0	0	0	0	0
	Cold		32	0.0	32	19	19	13	13
	Electrical		0	0.0	0	0	0	0	0
Poisons	All		154	0.2	124	109	90	45	34
	Drugs		51	0.1	37	27	20	24	17
	Chemicals		41	0.1	30	27	20	14	10
	Toxins		62	0.1	59	55	52	7	7
Nonenvironmental	All		97	0.1	87	71	64	26	23
	Nuclear/Radiation		0	0.0	0	0	0	0	0
	Thermal (burns)		97	0.1	87	71	64	26	23
	Electrical		0	0.0	0	0	0	0	0
Other	All		528	0.8	490	348	320	180	170
	Operative/Medical Accidents		0	0.0	0	0	0	0	0
	Operative/Medical Complications		33	0.1	33	22	22	11	11
	Unspecified/Multiple Injuries		176	0.3	174	110	110	66	64
	Lack of Essential Element(s)		71	0.1	69	43	42	28	27
	Abuse /Intentional		48	0.1	47	27	26	21	21
	Other Foreign Body/Food		25	0.0	13	23	11	2	2
	Other Reaction to External Cause		175	0.3	158	123	113	52	45
Total Injuries			65,025	100	35,045	43,188	24,318	21,837	10,727

*Initial encounters (up to sixth digit, 30-day gap rule); data from DMSS, January 2, 2018; prepared by AFHSB.

trainee (E1 rank and less than 4 months of service, $103/day)[31] multiplied by a 30-day lost duty or training time (LTT) estimate. The 30-day LTT is a low end conservative estimate based on the 30 to 120 days of the lost duty for various mechanical energy injuries described by Ruscio et al,[24] and a more recent average estimate of 39 limited duty days per injury.[32]

Results

There were 65,025 incident injuries among the 106,367 Army basic trainees (21,273 women and 85,094 men). This means an average 61 injuries occurred per 100 trainees. The incidence was higher among women than men (82 versus 54 injuries per 100 trainees). The 65,025 incident injuries occurred among only one third of the trainees (35,045/106,367). On average, each injured trainee sought medical evaluation for approximately 2 separate injuries during CY 2016 (1.9 all, 1.8 men, and 2.0 women).

The vast majority of the basic trainee injuries (96%) were the result of a mechanical energy transfer with 75% from cumulative microtraumatic damage to the MSK system (Table 1). Most injuries (75%, Table 2) occurred to a lower extremity, most frequently the knee (19.5% of all injuries), followed by the hip (14%), the ankle (12%), and the foot/toe (12%). The highest percentage of acute injuries occurred to the ankle (3.7%). Aside from the lower extremities, some notable injuries involved the lower back (4.3% cumulative microtraumatic; 0.4% acute trauma), followed by the shoulder (3.5% cumulative microtraumatic; 0.9% acute trauma).

The largest portion of injuries were in the injury-type category of "MSK Tissue Damage, Other" (Table 3). Diagnoses in this category included specific overuse injuries (ie, iliotibial band syndrome (leg), patellar tendinitis (knee), chondromalacia (knee), and plantar fascial fibromatosis (foot), but the largest portion (>90%) were for

Table 2. Injuries from Mechanical Energy Transfer[a] by Body Regions, Army CY 2016 IET (BCT/OSUT) Trainees.

General Body Region	% Total Injuries (%N)[b]	% Acute Traumatic (%N)	% Nontraumatic (%N)	Specific Anatomical Site	% Total Injuries (%N)[b]	% Acute Traumatic (%N)	% Cumulative Microtraumatic (%N)	Rank
Head and Neck	2.0	2.0	0.0	Traumatic Brain Injury	0.2	0.2	0.0	
				Other head	0.9	0.9	0.0	
				Face	0.3	0.3	0.0	
				Eye	0.3	0.3	0.0	
				Ear	0.3	0.1	0.0	
				Neck	0.1	0.1	0.0	
				Head/Neck, Other	0.0	0.0	0.0	
Spine and Back	7.3	0.4	6.9	Back, Upper	0.6	0.0	0.5	
				Back, Middle	0.5	0.0	0.5	
				Back, Lower	4.5	0.4	4.2	5
				Back, Other	1.7	0.0	1.7	
Torso	1.6	0.9	0.6	Chest	0.6	0.5	0.0	
				Abdomen	0.1	0.1	0.0	
				Pelvis	0.9	0.3	0.6	
				Trunk, Other	0.0	0.0	0.0	
Upper Extremity	10	3.7	6.4	Shoulder	4.4	0.9	3.5	6
				Arm, Upper	0.3	0.2	0.1	
				Elbow	0.9	0.3	0.6	
				Arm, Lower	0.4	0.3	0.1	
				Wrist	1.1	0.3	0.9	10
				Hand, Finger	2.5	1.7	0.9	9
				Arm, Other	0.4	0.0	0.3	
Lower Extremity	75	9.3	65	Hip	14.0	0.8	13.0	2
				Leg, Upper	3.6	0.7	2.9	8
				Knee[c]	20.0	1.3	18.0	1
				Leg, Lower	9.8	2.1	7.7	4
				Ankle	12.0	3.4	8.7	3
				Foot, Toe	12.0	1.0	11.0	3
				Leg, Other	3.9	<0	3.9	7
Other	1.2	--		System-wide	<0	0.0	<0	
				Multisystem	0.3	<0	0.3	
				Unspecified	0.9	0	0.9	

[a] Initial encounters (up to sixth digit, 30-day gap rule); data from DMSS, January 2, 2018; prepared by AFHSB.

[b] Percentage of total injury values are calculated on total injuries (N=65,025), rounded to 2 significant digits. After rounding, the sum of percentage values is approximately the proportion of total injuries from mechanical energy transfer (n= 62,672, 95.8% N).

[c] Knee is anatomical site with largest portion of overall injuries and cumulative microtraumatic injuries but was fourth in acute injuries after ankle; lower leg; hand, finger.

nonspecific pain syndromes to specific anatomical sites such as "pain in knee," pain in back," etc.

Approximately 20% of the basic trainees CY 2016 incident injuries were to the knee (12,706 knee incident injuries/65,025 all incident injuries). These injuries were experienced by approximately 13% of the trainees (n=13,889/106,367), who required a total of 36,875 knee-related medical encounters during CY 2016. Less than 1% of these were inpatient encounters. The total direct cost for these knee-related medical encounters was $4,989,869. Eighty percent of these costs ($4,017,626) were due to cumulative microtraumatic injuries. Based on the proposed methodology, an estimate of indirect costs attributed to these knee injuries is $39,261,540 (12,706 incident injuries×30 days LTT×$103/day).

Comment

Injury Types

For the first time, all injuries clinically diagnosed among Army IET basic trainees have been identified in categories that demonstrate the different causes of injuries. Categories include: mechanical energy acute traumatic injuries (eg, sprained or fractured ankles, dislocated shoulders, broken teeth); mechanical energy cumulative microtraumatic overuse injuries (eg, knee and back pain syndromes, plantar fasciitis, stress fractures);

Table 3. Injuries from Mechanical Energy Transfer[a] by Injury Type, Army CY 2016 IET (BCT/OSUT) Trainees.

Primary System Affected	Injury Type	% Total Injuries (%N)[b]	% of Cumulative Microtraumatic Injuries Within Type of Injury	Primary Injury Diagnoses
MSK System	Fracture	4.7	67	Stress fractures (ie, leg, hip, pelvis)
	Dislocation	0.3	<0	Shoulder
	Sprain/Joint Damage	4.5	1.0	Sprained ankle
	Strain/Tear	3.2	0.3	Strained muscle or tendon
	MSK Tissue Damage, Other	72	99	Pain in knee, hip, leg, foot, ankle low back Dorsalgia Iliotibial band syndrome Patellar tendinitis Chondromalacia Plantar fascial fibromatosis Cervicalgia
	Amputation and Crush	0.1	0	Fingers
Non-MSK or Multisystem	Internal Organ and Blood Vessel	0.3	0	Traumatic Brain Injury
	Open Wound	1.0	0	Head and neck Hands
	Nerve	0.3	80	Brachial plexus disorders Carpal tunnel syndrome Sciatica
	Contusion/Superficial	8.8	55	Foot blisters
	Tissue Damage, Other	0.8	0.5	Tinnitus & Hearing loss Teeth Other/unspecified

[a] Initial encounters (up to sixth digit, 30-day gap rule); data from DMSS, January 2, 2018; prepared by AFHSB.
[b] Percentage of total injury values are calculated on total injuries (N=65,025), rounded to 2 significant digits. After rounding, the sum of percentage values is approximately the proportion of total injuries from mechanical energy transfer (n= 62,672, 95.8% N).

environmental injuries (eg, heat stroke, frost bite), poisonings; nonenvironmental injuries; and other injuries from external causes.[29,30]

The results clearly highlight the primary source of the Army's injury problem during IET: 96% of the injuries resulted from mechanical energy transfers. The next most substantial cause (environmental heat-related energy transfers) was responsible for only 2.4% of the overall injuries. The vast majority of mechanical injuries are to the MSK system (85%), of which most (75%) are cumulative microtraumatic injuries caused by repeated low intensity forces. Whereas minor damage caused by these forces can stimulate the remodeling and strengthening of muscle, skin, and bone tissues, the damage will accumulate if the magnitude and/or frequency is excessive.[33] This results in an overuse injury for which the tissues cannot heal without a recovery period.

Body Regions Injured

Consistent with previous studies, this study also found that the majority (75%) of Army IET mechanical energy injuries are to the lower extremities. This includes the top 5 injured anatomical sites: knees (1), hip (2), ankles and feet (3, tied), and lower legs (4). This makes physiological sense since trainees spend so much time on their feet conducting weight-bearing activities such as running and ruck marching.[4,14,30] Injuries and pain syndrome in the lower back region (4.5%) may be partially explained by the energy transferred from the ground through the lower extremities. The shoulder (4.4%), the next most commonly injured region, would likely not be explained by these body weight-bearing activities. The donning or doffing of ruck sacks and other lifting or pulling training activities that might cause such injuries require further evaluation.

The most common injury diagnoses among the Army IET trainees were nonspecific pain syndromes in a specific anatomical site, ie, "pain in knee." While trainees are expected to experience some muscle soreness as they adapt to new physical stress, when the pain hinders normal activity and requires medical evaluation it is an injury.[34] It is recognized, however, that not all IET trainees will seek medical evaluation for pain, even when a specific injury is evident.[19,20]

Costs

Injuries to the knee alone represented approximately 20% of the CY 2016 IET (BCT/OSUT) injuries. The total direct and estimated indirect costs for these knee injuries were over $40 million. Over 80% of these costs were attributed to outpatient overuse injuries, which required an average of 2 medical encounters. Because the

indirect cost is largely influenced by the LTT incurred by those injured, we used a low end, conservative 30-day LTT and the lowest rank to determine pay. Though the amount of lost or limited duty can vary substantially depending on the type of injury, the 30-day estimate is below the estimated average time lost to injuries. Ruscio et al[24] found a range of 30 to 120 days of lost or limited duty for different types of mechanical injuries. More recently, Army survey data found that, on average, an injury was attributed to 39 days of limited duty. The data described a range of 17 to 135 days attributable to mechanical injuries compared to 3 to 11 days lost to heat and cold injuries.[32] Among acute injuries, fractures may limit duty for 73 to 120 days, strains/sprains for 18 to 30 days, dislocations for 35 days, tears or ruptures for up to 61 days, and bruises/contusions for 17 days.[24,32] Lost duty or training time estimates attributed to overuse injuries include 19 days for tendonitis, 30 days for blisters, 46 days for unspecified pain, 69 days for fasciitis, up to 135 days for bursitis.[32] Basic trainees who experience these injuries are typically removed from training into a rehabilitation program for recovery until such time as they can "recycle" back into the BCT/OSUT program.[2]

Injury cost estimates are primarily attributed to indirect costs. Since the 30-day LTT is a conservative estimate for mechanical injuries, the calculated cost of knee injuries ($40 million, 20% of all injuries) can be used to estimate the cost of the other 80% of trainees' mechanical energy injuries. Based on this assumption, injuries to basic trainees cost the Army over $200 million annually, and most of this ($150 million) is due to lower extremity injuries. These are low-end estimates and do not include less frequent but extremely costly injuries (eg, pelvic, hip, and lower-extremity stress fractures) among trainees that sometimes even result in separation and long term medical compensation.[3,35] Though they represent a substantial loss to the Army's investment, the cost of injuries may not be adequately recognized by unit leaders.

Conclusion

Injuries among IET trainees not only cost the Army millions of dollars annually, they detract from both training efficiency and force strength. The use of a standardized injury taxonomy refines the operational definition of "training-related injuries" to promote the comparability of future surveillance and intervention investigations. Of particular value, the taxonomy provides the causative source of the energy exchange, a critically important aspect of understanding the etiology of injuries in a population. This helps set priorities and focus on energy transfers that are the most important to prevent. Based on this investigation's application of the taxonomy, the Army should continue focusing its monitoring on lower extremity and low back MSK injuries, which are the most common injuries. Injury interventions may include modifications to intrinsic or individual factors as well as extrinsic measures (changes to training activities, equipment).[17,36]

Though this study did not assess the personal characteristics of injured IET trainees, prior studies have attributed higher risk of injury to certain modifiable conditions or behaviors. For example, Jones et al[36] summarizes Army studies that demonstrate the relationship of higher injury risks with poor aerobic fitness (cardiovascular endurance), extremely high as well as extremely low body mass index, sedentary lifestyle prior to IET, and tobacco use. In addition, trainees may develop a more serious injury if they ignore early signs of an injury for a number of reasons, ranging from high-motivation to leadership use of additional physical activity such as running or push-ups as a disciplinary action.

Though the Army has already doctrinally decreased the volume of running required for physical training,[3,25] this study shows that lower extremity overuse injuries are continuing to impede the effectiveness of Army basic training. Further attention on the amount (distances, weights), intensity (speed), and frequency of weight-bearing activities conducted by trainees is warranted. For example, distance running and ruck marching training activities should not be conducted on consecutive days, and/or marches may need to be reduced in distance or frequency.[17,20] Unit leaders and drill sergeants should be encouraged to monitor injury rates and adjust the frequency and duration (volume) of running and ruck marching to continuously reduce injury risks. Changes to training activities designed to reduce lower extremity injuries, however, must be balanced to avoid increasing injuries to other body regions such as the lower back or shoulders.

References

1. McCrary JE. Overview of Accessions. In: Dekoning BL, senior ed. *Recruit Medicine*. Fort Sam Houston, Texas: Borden Institute; 2006:29-44.
2. Department of the Army. *TRADOC Regulation 350-6, Enlisted Initial Entry Training Polices and Administration*. Fort Eustis, Virginia: US Army Training and Doctrine Command; March 20, 2017: chap 1, 2; append G, H. Available at: http://adminpubs.tradoc.army.mil/regulations/TR350-6withChange1.pdf. Accessed October 30, 2018.

3. Molloy JM, Feltwell DN, Scott SJ, Niebuhr DW. Physical training injuries and interventions for military recruits. *Mil Med.* 2012;177(5):553-558. Available at: https://doi.org/10.7205/MILMED-D-11-00329.
4. Knapik JJ, Graham BS, Rieger J, Steelman R, Pendergrass T. Activities associated with injuries in initial entry training. *Mil Med*. 2013; 178(5):500-506.
5. Knapik JJ. Prevention of foot blisters. *J Spec Oper Med*. 2014;14(2):95-97.
6. US Army Public Health Center. Injury Prevention Fact Sheet No. 12-001-0915: Blister Prevention [internet]. 2015. Available at: https://phc.amedd.army.mil/PHC%20Resource%20Library/BlisterPrevention_FS_12-001-0915.pdf. Accessed June 11, 2018.
7. Carter R, Cheuvront SN, Williams JO, Kolka MA, Stephenson LA; Sawka MN, Amoroso PJ. Epidemiology of Hospitalizations and Deaths from Heat Illness in Soldiers. *Med Sci Sports Exec*. 2005;37(8):1338-1344.
8. US Army Public Health Center. Injury Prevention Fact Sheet No. 12-005-0316: Heat Illness [internet]. 2016. Available at: https://phc.amedd.army.mil/PHC%20Resource%20Library/HeatIllness_FS_12-005-0316.pdf. Accessed June 11, 2018.
9. Jones BH, Cowan DN, Tomlinson JP, Robinson JR, Polly DW, Frykman PN. Epidemiology of injuries associated with physical training among young men in the army. *Med Sci Sports Exec*. 1993;2:197-203.
10. Jones BH, Amoroso P, Canham M, Weyandt M, Schmitt J. Atlas of injuries in the US Armed Forces. *Mil Med*. 1999;164(suppl 8):1-14,11-25,19-25.
11. Kaufman KR, Brodine S, Shaffer R. Military training-related injuries: surveillance, research, and prevention. *Am J Prev Med.* 2000;18(suppl 3):54-63.
12. Jones BH, Thacker SB, Gilchrist J, Kimsey CD, Sosin DC. Prevention of lower extremity stress fractures in athletes and soldiers: a systematic review. *Epidemiol Rev*. 2002;24(2):228-247.
13. Rauh MJ, Macera CA, Trone DW, Shaffer RA, Brodine SK. Epidemiology of stress fracture and lower-extremity overuse injury in female recruits. *Med Sci Sports Exec.* 2006;38(9):1571-1577.
14. Knapik JJ, Hauret KG, Jones BH. Primary Prevention of Injuries in Initial Entry Training. In: Dekoning BL, senior ed. *Recruit Medicine*. Fort Sam Houston, Texas: Borden Institute; 2006:125-146.
15. Hauret KG, Jones BH, Bullock SH, Canham-Chervak M, Canada S. Musculoskeletal injuries: description of an under-recognized injury problem among military personnel. *Am J Prev Med*. 2010;38(1):S61-S70.
16. Jones BH, Hauschild VD. Physical training, fitness, and injuries: lessons learned from military studies. *J Strength Cond Res*. 2015;29(suppl 11):S57-S64.
17. Bullock SH, Jones BH, Gilchrist J, Marshall SW. Prevention of physical training-related injuries: recommendations for the military and other active populations based on expedited systematic reviews. *Am J Prev Med.* 2010;38(1):S156-S181.
18. US Army Public Health Center. PHR No. S.0023151 Injury Prevention Survey: Army Awareness Assessment and Needs Analysis, 9 July-26 August 2014. 2015. Available at: http://www.dtic.mil/docs/citations/ADA623021. Accessed October 30, 2018.
19. Hauschild VH. Schuh A, Jones BH. What Soldiers know and want to know about preventing injuries: a needs survey regarding a key threat to readiness. *US Army Med Dep J*. January-February 2016; 10-19.
20. US Army Public Health Center. Technical Information Paper (TIP) No. 12-054-0616: Foot Marching, Load Carriage, and Injury Risk [internet]. 2016. Available at: http://www.dtic.mil/get-tr-doc/pdf?AD=AD1010939. Accessed June 11, 2018.
21. Schuh-Renner A, Grier T, Canham-Chervak M, Hauschild VD, Roy TC, Fletcher J, Jones BH. Risk factors for injury associated with low, moderate, and high road marching in a US Army infantry brigade. *J Sci Med Sport*. 2017;20(suppl 4):S28-S33.
22. Bell NS, Mangione TW, Hemenway D, Amoroso PJ, Jones BH: High injury rates among female army trainees: a function of gender?. *Am J Prev Med*. 2000;18(3):141-146.
23. Blacker SD, Wilkinson DM, Bilzon JL, Rayson MP. Risk factors for training injuries among British Army recruits. *Mil Med*. 2008;173(3):278-286.
24. Ruscio BA, Jones BH, Bullock SH, et al. A process to identify military injury prevention priorities based on injury type and limited duty days. *Am J Prev Med.* 2010;38(suppl 1):S19-S33.
25. Department of the Army. Training Circular (TC) 3-22.20, Army Physical Readiness Training. Headquarters US Army, Washington DC; 2010.
26. US Army Center for Health Promotion and Preventive Medicine (USACHPPM). USACHPPM Project No. 12-Hf-5772B-04. Evaluation of Two Army Fitness Programs: The TRADOC Standardized Physical Training Program for Basic Combat Training and the Fitness Assessment Program. Aberdeen Proving Ground, MD: USACHPM; 2004.
27. Knapik JJ. Evaluation of a standardized physical training program for basic combat training. *J Strength Cond Res.* 2005;19:246-253.

28. National Research Council. *Assessing Fitness for Military Enlistment: Physical, Medical, and Mental Health Standards*. Washington, DC: The National Academies Press; 2006.
29. US Army Public Health Center. Public Health Information Paper No. 12-01-0717: A Taxonomy of Injuries for Public Health Monitoring & Reporting [internet]. July 2017 [Addendums 1 & 2, December 2017]. Available at: http://www.dtic.mil/docs/citations/AD1039481.
30. US Army Public Health Center. Public Health Information Paper No. 12-01-0118: Application of the Taxonomy of Injuries: Analyses of Army Recruit Injuries, CY 2016 [internet]. January 2018. Available at: http://www.dtic.mil/docs/citations/AD1049222.
31. Defense Financial Accounting System. CY 2016 Military Pay Tables. Available at https://www.dfas.mil/militarymembers/payentitlements/military-pay-charts.html. Accessed June 18, 2018.
32. Schuh-Renner A, Canham-Chervak M, Jones BH. *Technical Report S.0030637-17: Survey of Injuries and Injury Risk Factors in the 2nd Brigade Combat Team, 3rd Infantry Division, November 2014-January 2015*. Aberdeen Proving Ground, MD: US Army Public Health Center; July 2017.
33. Fredericson M, Jennings F, Beaulieu C, Matheson GO. Stress fractures in athletes. *Top Magn Reson Imaging*. 2006;17(5):309-325.
34. Morris, D. Brief and Narrative: Pain Defined. *The Scientist* [serial online]. March 2005. Available at: https://www.the-scientist.com/?articles.view/articleNo/16332/title/Belief-and-Narrative/. Accessed June 18, 2018.
35. Chalupa RL, Aberle C, Johnson AE. Observed rates of lower extremity stress fractures after implementation of the Army Physical Readiness Training Program at JBSA Fort Sam Houston. *US Army Med Dep J*. January-March 2016:6-9.
36. Jones BH, Chervak-Canham M, Hauschild VD. Musculoskeletal injury prevention in the US Army: Evolution of the science and the public health approach. *J Sci Med Sport*. In press 2018. Available at: http://www.jsams.org/article/S1440-2440(18)30063-X/fulltext. Accessed September 5, 2018.

AUTHORS

Ms Hauschild, Mr Barnes, Dr Forrest, Mr Hauret, and Dr Jones are with the US Army Public Health Center, Aberdeen Proving Ground, Maryland.

At the time this study was conducted, Dr Lee was a contract public health consultant with the Armed Forces Health Surveillance Branch, Defense Health Agency.

Human Papillomavirus Incidence and Sexually Transmitted Coinfections Among US Military Recruits (2009-2015)

COL Paul O. Kwon, MC, USA
Jenny Lay, MPH
David Hrncir, MD, MPH
Lynn Levin, PhD, MPH

Sexually transmitted infections (STIs) remain significant diseases of major concern to the US military due to the serious postinfectious complications that diminish readiness and health protection.[1] Among US military personnel during the period 2007-2016, *Chlamydia trachomatis* (chlamydia) was the most commonly diagnosed STI, followed in descending frequency by genital human papillomavirus (HPV), *Neisseria gonorhoeae* (gonorrhea), herpes simplex virus (HSV), and syphilis.[2] In the United States, one in 4 persons are infected with at least one type of HPV.[3] The majority of cancers caused by HPV involve one of 2 types: 16 or 18.[4,5] Of all cancers, cervical cancer is most commonly linked to HPV and is the second leading cause of mortality among women between the ages 20 to 39.[6] Although the Food and Drug Administration (FDA) approved an HPV vaccine that is also recommended by the Advisory Committee on Immunization Practices (ACIP),[7] HPV vaccine uptake rates remain consistently below[6-8] *Healthy People 2020* goals of 80%.[9] Further, Department of Defense Instruction 1010.10[10] and the President's Cancer Panel[11] support these goals which are committed to reducing any missed opportunities for cancer prevention. These statistics underscore the need for improved HPV vaccine uptake as a primary prevention tool among military recruit populations.

Although most STIs remain undiagnosed, genital HPV infection is very prevalent[12] with an estimated 79 million persons infected within the United States.[3] Almost half of all new infections occur among adolescents aged 15-24 years.[12] From 2003-2006, HPV prevalence was as high as 42.5% among females aged 14-59 years,[13] with the majority of cases between ages 20-24 years (53.8%).[14] Studies have revealed that HPV infection will occur within a few years of becoming sexually active.[15] It should be noted that detection of HPV deoxyribonucleic acid (DNA) is only adequate at indicating a current infection and provides no insight into prior infections that have cleared.

Transmission of HPV is primarily through genital contact by sexual intercourse or other intimate contact (eg, oral-genital or genital-genital).[15-19] Nonsexual routes of genital HPV transmission are less common (eg, intrapartum transmission).[20] Of note, most data on the natural history of HPV are obtained from cervical infection studies. Further, the most consistent predictors of infection have been measures of sexual activity (eg, number of sex partners).[21-24] However, even one lifetime sex partner may be a risk factor for infection. For example, one prevalence study found that HPV infection was 14.3% among women aged 18-25 years who had one lifetime sex partner, 22.3% among women with 2 lifetime partners, and 31.5% among those with 3 or more partners.[24]

Interestingly, studies have demonstrated that HPV seroprevalence is actually low (1% to 8%) in late adolescence, but increases with age, reaching 15% to 35% seroprevalence by age 40.[25] The cumulative incidence among men has been reported to be as high as 62.4%.[26] Although men seem to have a relatively constant incidence, women display increased risks for HPV acquisition as age increases until a peak in the early 20s.[27] However, acquisition of HPV may be accelerated in populations with a higher proportion of sexually active individuals such as in young, military populations.[28,29] Among active duty (AD) females, HPV seroprevalence has been reported to be as high as 45% to 51%.[29] Among AD men, it has been reported that more than one-third of service members seroconverted to one or more of the HPV serotypes.[25]

Most infections are transient and asymptomatic such that 70% of individuals will clear HPV infection within one year, while up to 90% will clear infections within 2 years, especially in younger age groups.[21,30-32] Median duration of new infections can extend up to 8 months.[18,21,27,32] Oral HPV infections are less common, but time to clearance appears to be similar.[33,34] However, immunocompromised individuals (such as those with HIV infections) display higher rates of HPV acquisition and progression to disease.[35]

Genital HPV is also associated with genital warts (GW), a comorbidity that significantly contributes to the burden of health care costs. Alarmingly, more than 300,000 cases of GWs occur in the United States yearly with a combined estimated cost of $8 billion.[36] Similarly, HPV is one of the most common viral STI detected among US service members.[37] During the period 2007-2016, the incidence rate of genital HPV infections was 37.2/10,000 person-years (p-yrs) among women and 199.6/10,000 p-yrs among men.[2] To put this in perspective, the number of health care visits due to HPV alone among AD service members was greater than gonorrhea and chlamydia combined.[25] Given the morbidity and mortality associated with HPV, prevention offers a very real and relevant benefit. It has been reported that prevention of GWs and cancers resulting from HPV infection decreased health care system burdens and associated long-term healthcare costs.[36] Yet, there is a paucity of data describing the incidence of HPV with STI coinfections among military recruit trainees who may be at risk for this vaccine-preventable disease. In this study, we aim to describe the incidence rate of HPV infection and characterize STI coinfections during recruit training in order to illustrate potential comorbid risks and yearly trends within this unique at-risk population.

Methods

A retrospective cohort analysis was performed using data from the Defense Medical Surveillance System (DMSS), the Armed Forces Health Surveillance Branch (AFHSB), Defense Health Agency, Silver Spring, Maryland (2009 to 2015; data released May 23, 2016). The DMSS data is derived and managed by the AFHSB, which links several military data sources including electronic medical encounters, reportable medical events, demographic, and service records for US military service members. Personnel records were used to identify recruits entering recruit training from October 1, 2009 to September 16, 2015. Recruits were defined as new members of the Army (ranks E1-E4), and Navy, Air Force, or Marine Corps (ranks E1-E3) who served at one of 9 basic training locations during a service-specific training period. Demographic and military service data (age, sex, marital status, and race/ethnicity) were obtained from DMSS for each recruit. Depending on the service, recruit training ranged from 56 to 63 days. Information on several demographic characteristics of the recruit trainees was also obtained.

Reportable medical events and medical encounter data from October 1, 2009 to September 16, 2015 among recruits during their recruit training period were used to identify diagnoses of HPV; the surveillance period for STI diagnoses was extended until September 30, 2015. The cases of documented STI coinfections were identified by the ICD-9 CM diagnoses:

- HPV – ICD-9 CM: 078.11, 079.4, 795.05, 795.09, 795.15, 796.75, 796.79
- chlamydia – ICD-9 CM: 099.41, 099.5
- genital HSV – ICD-9 CM: 054.1
- acute gonorrhea – ICD-9 CM: 098.0x, 098.1x, 098.4x, 098.8x
- primary syphilis – ICD-9 CM: 091.x

An incident case of HPV was defined as a first occurrence of an ICD-9 CM code consistent with HPV infection recorded in either the first or second diagnostic position in a medical record of an outpatient encounter. Incidence rates of HPV infection per 1000 p-yrs were calculated and summarized by service and demographic characteristics. A subanalysis was conducted to determine the calculation of HPV incidence rates for specific DNA testing codes (ICD-9 CM codes: 795.05, 795.15, 795.09, 796.75, and 796.79) in conjunction with Papanicolaou test. This subanalysis was undertaken to allow comparisons by sex and branch of service of HPV incidence rates in cases based on confirmation of DNA testing versus HPV incidence rates in cases without laboratory confirmation. For each HPV case, diagnoses of chlamydia, genital HSV, gonorrhea, and primary syphilis coinfections, occurring within the 14-day window before and after the incident HPV diagnosis date, were obtained. The number and proportion of STI coinfections among incident HPV cases was defined as the number of a STI coinfection (numerator) over the total number of HPV cases (denominator). The number and percentage of incident HPV cases with a STI coinfection was stratified by demographic characteristics and specific branch of service.

Results

The majority of recruits were below the age of 25 years (90.6%), single (90.0%), white non-Hispanic (58.1%), and male (83.6%) (Table 1). The overall incidence of HPV infection was 4.1 per 1,000 p-yrs among all military recruits during the study period, 2009-2015 (Table 2). The older age groups had higher HPV incidence rates reaching a peak of 42.5/1,000 p-yrs in the 35-39 age group. The highest incidence of HPV infection was noted among married recruits (6.3 per 1,000 p-yrs) compared to the single or other marital status categories, among black non-Hispanic recruits (6.4 per 1,000 p-yrs) compared with other race/ethnic groups, and among females (19.0 per 1,000 p-yrs) (Table 2). When comparing incidence rates of HPV among military services, the Navy (14.4 per 1,000 p-yrs) demonstrated the highest rates while the Air Force (0.7 per 1,000 p-yrs) had the lowest.

The Navy had an unusually high HPV incidence rate among those aged 30-39 years (150.0 per 1,000 p-yrs). Upon stratification by calendar year for the period 2009-2016, HPV incidence rates overall did not show a consistent pattern or apparent trend, with rates ranging from 2.52 to 5.95 per 1,000 p-yrs, and with the highest rates in the Navy (Table 3).

Overall HPV incidence rates by calendar year based on ICD-9 CM DNA testing codes revealed similar findings to rates based on all HPV ICD-9 CM codes, although these rates declined after 2012 (Table 4). This decreasing trend was also observed among females. Incident cases of HPV that were not based on laboratory confirmation (ICD-9 CM: 078.11, 079.4) did not show a clear trend by calendar year or among females (Table 5).

Counts of STI coinfections among military recruits diagnosed with incident HPV were extremely low (Table 6). Among all HPV cases within each branch of service, the Navy displayed 2 of 3 chlamydia cases, 1 of the 4 HSV cases, and 3 of the 3 gonorrhea cases (Table 6). Notably, no STI coinfections were identified among Air Force recruits, and there were no cases of syphilis diagnosed in any branch of service within this study. The rates of HIV were not examined in this study due to the mandatory screening at accessions and the corresponding low incidence rates among the military recruit population.[38]

Comment

In this study, we determined the HPV incidence rates and the STI coinfection counts among military active component recruits. Among this young, healthy, adult population within which an HPV vaccination "catch-up" schedule is recommended, these data indicate similar incidence rates compared to recent studies involving total active component service members. The overall incidence of HPV infection was 4.1 per 1,000 p-yrs among all military recruits. In a recent study, covering the period 2007-2016, the overall HPV incidence rate among active component service members was 60.1 per 10,000 p-yrs, with rates dropping dramatically to a low of 31.1 cases/10,000 p-yrs in 2016.[2] However, this study included an additional 2012 ICD-9-CM diagnosis code of "other abnormal Papanicolaou smear of vagina and vaginal HPV" (795.19) which could have captured more cases. It is likely that HPV incidence rates are underestimated in the recruit population compared with rates among all active components, as detection and diagnoses of HPV cases mostly occur post-basic training, when service members are assigned to duty stations.

Table 1. Demographic characteristics of active component military recruits.

	All Services	Army	Navy	Air Force	Marine Corps
Total	159,852	61,545	34,259	25,743	38,305
Age					
<20	105,552	36,531	20,872	16,798	31,351
20-24	39,324	16,635	9,488	7,251	5,951
25-29	11,851	6,147	3,046	1,659	999
30-34	2,465	1,744	690	27	4
35-39	565	397	160	8	0
40-44	94	91	3	0	0
Sex					
Male	133,704	51,723	26,300	20,787	34,894
Female	26,148	9,823	7,959	4,956	3,411
Marital Status					
Married	15,231	9,446	2,537	2,491	757
Single	143,897	51,535	31,722	23,174	37,466
Other	724	564	0	77	82
Race/ethnicity					
White, non-Hispanic	92,912	36,142	15,671	16,331	24,768
Black, non-Hispanic	26,078	13,228	5,528	3,674	3,648
Hispanic	24,101	8,147	5,624	3,295	7,035
Asian/Pacific Islander	5,839	3,069	1,231	63	1,475
Other	10,922	959	6,205	2,378	1,379

Table 2. Incidence rates of HPV infection (per 1,000 p-yrs) among military recruits.

	All Services	Army	Navy	Air Force	Marine Corps
Total	4.1	1.2	14.4	0.7	1.8
Age					
<20	1.3	0.7	3.5	0.4	1.0
20-24	8.2	2.5	25.2	1.5	4.9
25-29	7.0	1.0	22.7	0.0	8.0
30-34	35.7	0.6	126.1	0.0	0.0
35-39	42.5	0.0	150.0	0.0	0.0
40-44	0.0	0.0	0.0	0.0	0.0
Sex					
Male	1.2	1.0	2.0	0.4	1.2
Female	19.0	1.9	55.4	2.0	7.9
Marital Status					
Married	6.3	1.3	33.1	0.0	0.0
Single	3.8	1.2	12.8	0.8	1.8
Other	4.2	1.8	0.0	0.0	0.0
Race/ethnicity					
White, non-Hispanic	2.8	1.0	11.1	0.6	1.6
Black, non-Hispanic	6.4	1.8	22.8	1.9	3.0
Hispanic	4.8	1.4	16.5	0.3	1.4
Asian/Pacific Islander	3.6	0.3	0.0	47.3	11.5
Other	8.2	1.0	0.2	1.3	45.0

Table 3. Total counts and HPV incidence rates (per 1000 p-yrs) by calendar year among military recruits.

Calendar Year	All Years	2009	2010	2011	2012	2013	2014	2015
Total Count (rate)	652 (4.1)	19 (3.5)	163 (6.0)	120 (4.5)	123 (4.5)	79 (2.7)	62 (2.5)	86 (4.6)
Service								
Army	73 (1.2)	4 (1.8)	21 (1.9)	16 (1.6)	11 (1.1)	13 (1.1)	7 (0.7)	1 (0.2)
Navy	493 (14.4)	10 (8.4)	114 (21.4)	93 (17.1)	95 (15.7)	57 (8.9)	45 (8.1)	79 (18.7)
Air Force	18 (0.7)	2 (1.9)	4 (0.9)	2 (0.4)	3 (0.7)	4 (0.9)	0 (0.0)	3 (1.1)
Marines	68 (1.8)	3 (3.0)	24 (3.9)	9 (1.4)	14 (2.1)	5 (0.7)	10 (1.7)	3 (0.6)
Age								
<20	136 (1.3)	6 (1.9)	56 (3.3)	29 (1.7)	19 (1.0)	15 (0.7)	5 (0.3)	6 (0.5)
20-24	321 (8.2)	10 (6.4)	64 (8.9)	55 (8.2)	68 (10.1)	43 (6.0)	31 (5.4)	50 (11.8)
25-29	83 (7.0)	1 (1.9)	10 (4.4)	18 (8.7)	15 (7.5)	14 (6.8)	12 (7.1)	13 (10.6)
30-34	88 (35.7)	2 (15.0)	27 (50.7)	14 (31.7)	16 (40.9)	7 (17.4)	8 (23.8)	14 (61.3)
35-39	24 (42.5)	0 (0.0)	6 (27.3)	4 (27.0)	5 (121.9)	0 (0.0)	6 (194.4)	3 (102.6)
40-44	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sex								
Male	155 (1.2)	11 (2.4)	30 (1.3)	30 (1.3)	31 (1.3)	27 (1.1)	17 (0.8)	9 (0.6)
Female	497 (19.0)	8 (8.8)	133 (29.9)	90 (21.4)	92 (21.0)	52 (11.0)	45 (10.7)	77 (23.5)
Marital Status								
Married	96 (6.3)	2 (2.7)	17 (5.3)	21 (7.6)	25 (10.1)	8 (3.2)	12 (5.8)	11 (7.7)
Single	553 (3.8)	17 (3.6)	146 (6.1)	99 (4.2)	98 (3.9)	71 (2.7)	49 (2.2)	73 (4.2)
Other	3 (4.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (12.0)	2 (36.0)
Race/ethnicity								
White, non-Hispanic	259 (2.8)	8 (2.4)	67 (4.0)	48 (3.0)	39 (2.4)	41 (2.5)	27 (2.0)	29 (2.8)
Black, non-Hispanic	168 (6.4)	6 (6.9)	37 (9.3)	26 (6.5)	36 (8.3)	18 (3.5)	16 (3.6)	29 (8.7)
Hispanic	115 (4.8)	1 (1.5)	35 (9.8)	24 (6.3)	26 (6.4)	9 (2.0)	10 (2.4)	10 (3.0)
Asian/Pacific Islander	21 (3.6)	0 (0.0)	5 (5.7)	2 (2.4)	3 (3.2)	1 (0.9)	5 (4.8)	5 (5.9)
Other	89 (8.2)	4 (9.0)	19 (9.0)	20 (10.1)	19 (9.1)	10 (5.1)	4 (2.9)	13 (13.2)

The calculated incidence rates among the various armed service branches allowed for a standardized comparison of trends by calendar year. During the study period, there were no specific changes to DoD guidelines (changes in policy) for HPV screening in any of the services. In 2012, however, there were significant changes in HPV screening guidelines among the US Preventive Services Task Force, American College of Obstetricians and Gynecologists, and the American Cancer Society. Specifically, it was recommended that HPV co-testing with cytology not be conducted among individuals less than 30 years of age.[39] This change may account for the noted decline in HPV incident cases diagnosed by DNA testing in our data after 2012 (Table 4). Additionally, the comparative subanalysis of rates by calendar year was proportionally consistent among the various armed service components through the calendar years. To note, the high HPV incidence rates found among the Navy military recruits may warrant further research.

The counts of STI coinfections were very low in this population, indicating primary HPV diagnoses during medical encounters are not commonly associated with chlamydia, gonorrhea, syphilis, or HSV, at least during the recruit training period. Identification of STI coinfections also may be underestimated because of the variable latency period of HPV diagnosis and probable asymptomatic STIs. Nonetheless, the data indicate an opportunity to identify and improve HPV vaccination uptake among this at-risk population for disease and cancer prevention.

There are several limitations that must be taken into consideration to carefully interpret these results. First, the ICD-9 CM codes were obtained from administrative records from outpatient encounters and some codes may not reflect a confirmatory lab result or clinically-validated information. Also, ICD-9 CM codes may result in incorrect disease classification based on other similar conditions. Some clinicians, for example, may code probable cases based on symptoms alone such as "dysuria" or "urethritis" which may not accurately capture the STI diagnoses until follow-up care. Symptoms for these particular infections may range from indolent, asymptomatic to skin lesions, dysuria, back pain, discharge and inguinal and abdominal discomfort. Thus, it is difficult to accurately estimate prevalence of STIs since the symptoms and time to diagnosis may vary.

Table 4. Counts and incidence rates (per 1000 p-yrs) of HPV by DNA testing* among military recruits.

Calendar Year	All Years	2009	2010	2011	2012	2013	2014	2015
Total Count (rate)	271 (1.7)	2 (0.4)	93 (3.4)	60 (2.3)	71 (2.6)	31 (1.1)	11 (0.5)	3 (0.2)
Service								
Army	3 (0.1)	0 (0.0)	2 (0.2)	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Navy	246 (7.2)	2 (1.7)	76 (14.3)	59 (10.8)	71 (11.8)	31 (4.8)	6 (1.1)	1 (0.2)
Air Force	2 (0.1)	0 (0.0)	2 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Marines	20 (0.5)	0 (0.0)	13 (2.1)	0 (0.0)	0 (0.0)	0 (0.0)	5 (0.9)	2 (0.4)
Age								
<20	43 (0.4)	0 (0.0)	33 (1.9)	7 (0.4)	3 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)
20-24	140 (3.6)	2 (1.3)	36 (5.0)	31 (4.6)	43 (6.4)	22 (3.1)	4 (0.7)	2 (0.5)
25-29	37 (3.1)	0 (0.0)	5 (2.0)	9 (4.3)	12 (6.0)	7 (3.4)	4 (2.4)	0 (0.0)
30-34	41 (16.6)	0 (0.0)	16 (30.1)	10 (22.7)	10 (25.5)	2 (5.0)	2 (6.0)	1 (4.4)
35-39	10 (17.7)	0 (0.0)	3 (13.7)	3 (20.2)	3 (73.1)	0 (0.0)	1 (32.4)	0 (0.0)
40-44	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sex								
Male	1 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Female	270 (10.3)	2 (2.2)	92 (20.7)	60 (14.3)	71 (16.2)	31 (6.6)	11 (2.6)	3 (0.9)
Marital Status								
Married	41 (2.7)	1 (1.4)	10 (3.1)	8 (2.9)	14 (5.6)	6 (2.4)	2 (1.0)	0 (0.0)
Single	230 (1.6)	1 (0.2)	83 (3.5)	52 (2.2)	57 (2.3)	25 (0.9)	9 (0.4)	3 (0.2)
Other	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Race/ethnicity								
White, non-Hispanic	97 (1.0)	0 (0.0)	31 (1.8)	24 (1.5)	20 (1.2)	15 (0.9)	6 (0.4)	1 (0.1)
Black, non-Hispanic	67 (2.6)	1 (1.2)	22 (5.5)	15 (3.8)	21 (4.8)	6 (1.2)	1 (0.2)	1 (0.3)
Hispanic	60 (2.5)	0 (0.0)	27 (7.6)	10 (2.6)	16 (3.9)	5 (1.1)	2 (0.5)	0 (0.0)
Asian/Pacific Islander	7 (1.2)	0 (0.0)	2 (2.3)	2 (2.4)	1 (1.1)	1 (0.9)	0 (0.0)	7 (8.3)
Other	40 (3.7)	1 (2.3)	11 (5.2)	9 (4.5)	13 (6.3)	4 (2.1)	1 (0.7)	1 (1.0)

*ICD-9 CM codes: 795.05, 795.15, 795.09, 796.75, and 796.79

There are other possible gaps in reporting of medical encounters captured in electronic military medical records that should to be considered. Individuals who otherwise are eligible to obtain medical care in the Military Health System may choose to access a nonmilitary facility such as the local public health department for STI treatment. The nonmilitary facility would diagnose and treat STIs among military recruit populations; however, the data would not necessarily be transferred to the military medical databases. Therefore, the true estimation of HPV and STI coinfections among this at-risk population are likely underestimated.

Conclusion

Human papillomavirus and other common STI coinfections affect force health protection and military readiness. Although common STIs such as chlamydia and gonorrhea may garner more attention during a clinic visit, there still remains an important possibility of missed opportunities for HPV vaccination for those at risk in this setting. The current HPV vaccine prevents both HPV infections and cancer and is readily accessible to service members. The US military recruit populations provide a "catch-up" target population wherein missed opportunities are identified. Within this study, the overall characterization of STI coinfections among incident HPV cases helped define the most likely at-risk population of missed opportunities for HPV vaccination uptake and target future policies within the DoD towards a healthier Armed Forces consistent with *Healthy People 2020* [9] goals.

Acknowledgments

We thank the technical staff from the Armed Forces Health Surveillance Branch for data acquisition and data quality control measures. We also thank Ms Janice Gary at the Walter Reed Army Institute of Research who was essential to the organization and management of this research.

Table 5. Counts and incidence rates (per 1000 p-yrs) of HPV by non-DNA testing* among military recruits.

Calendar Year	All Years	2009	2010	2011	2012	2013	2014	2015
Total Count (rate)	381 (2.4)	17 (3.1)	70 (2.6)	60 (2.3)	52 (1.9)	48 (1.6)	51 (2.1)	83 (4.4)
Service								
Army	70 (1.1)	4 (1.8)	19 (1.7)	15 (1.5)	11 (1.1)	13 (1.1)	7 (0.7)	1 (0.2)
Navy	247 (7.2)	8 (6.7)	38 (7.1)	34 (6.2)	24 (4.0)	26 (4.0)	39 (7.0)	78 (18.4)
Air Force	16 (0.6)	2 (1.9)	2 (0.4)	2 (0.4)	3 (0.7)	4 (0.9)	0 (0.0)	3 (1.1)
Marines	48 (1.3)	3 (3.0)	11 (1.8)	9 (1.4)	14 (2.1)	5 (0.7)	5 (0.9)	1 (0.2)
Age								
<20	93 (0.9)	6 (1.9)	23 (1.3)	22 (1.3)	16 (0.9)	15 (0.8)	5 (0.3)	6 (0.5)
20-24	181 (4.6)	8 (5.1)	28 (3.9)	24 (3.6)	25 (3.7)	21 (3.0)	27 (4.7)	48 (11.4)
25-29	46 (3.9)	1 (1.9)	5 (2.2)	9 (4.3)	3 (1.5)	7 (3.4)	8 (4.7)	13 (10.6)
30-34	47 (19.1)	2 (15.0)	11 (20.7)	4 (9.1)	6 (15.3)	5 (12.4)	6 (17.9)	13 (56.9)
35-39	14 (24.8)	0 (0.0)	3 (13.7)	1 (6.7)	2 (48.7)	0 (0.0)	5 (162.0)	3 (102.6)
40-44	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sex								
Male	154 (1.2)	11 (2.4)	29 (1.3)	30 (1.3)	31 (1.3)	27 (1.1)	17 (0.8)	9 (0.6)
Female	227 (8.7)	6 (6.6)	41 (9.2)	30 (7.2)	21 (4.8)	21 (4.4)	34 (8.1)	74 (22.6)
Marital Status								
Married	55 (3.6)	1 (1.4)	7 (2.2)	13 (4.7)	11 (4.4)	2 (0.8)	10 (4.9)	11 (7.7)
Single	323 (2.2)	16 (3.4)	63 (2.6)	47 (2.0)	41 (1.6)	46 (1.7)	40 (1.8)	70 (4.1)
Other	3 (4.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (12.0)	2 (36.0)
Race/ethnicity								
White, non-Hispanic	162 (1.7)	8 (2.4)	36 (2.1)	24 (1.5)	19 (1.2)	26 (1.6)	21 (1.5)	28 (2.7)
Black, non-Hispanic	101 (3.9)	5 (5.7)	15 (3.7)	11 (2.8)	15 (3.4)	12 (2.4)	15 (3.4)	28 (8.4)
Hispanic	55 (2.3)	1 (1.5)	8 (2.2)	14 (3.7)	10 (2.5)	4 (0.9)	8 (2.0)	10 (3.0)
Asian/Pacific Islander	14 (2.4)	0 (0.0)	3 (3.4)	0 (0.0)	2 (2.2)	0 (0.0)	4 (3.8)	5 (5.9)
Other	49 (4.5)	3 (6.8)	8 (3.8)	11 (5.6)	6 (2.9)	9 (3.1)	3 (2.2)	12 (12.2)

*ICD-9 CM codes: 078.11, 079.4

References

1. Armed Forces Health Surveillance Center. Sexually transmitted infections, active component, U.S. Armed Forces, 2000-2012. *MSMR*. 2013;20(2):5-10.
2. Stahlman S, Oetting AA.Sexually transmitted infections, active component, U.S. Armed Forces, 2007-2016. *MSMR*. 2017;24(9):15-22.
3. Satterwhite CL, Torrone E, Meites E, et al. Sexually transmitted infections among US women and men: prevalence and incidence estimates, 2008. *Sex Transm Dis*. 2013;40(3):187-193.
4. Wheeler CM, Hunt WC, Schiffman M, et al. Human papillomavirus genotypes and the cumulative 2-year risk of cervical precancer. *J Infect Dis*. 2006;194:1291-1299.
5. Moscicki AB, Schiffman M, Kjaer S, Villa LL. Updating the natural history of HPV and anogenital cancer. *Vaccine*. 2006;24:42-51.
6. Siegel RL, Miller KD, Jemal A. Cancer Statistics, 2017. *CA Cancer J Clin*. 2017;67:7-30.
7. Petrosky E, Bocchini JA, Hariri S, et al. Use of 9-valent human papillomavirus (HPV) vaccine: updated HPV vaccination recommendations of the Advisory Committee on Immunization Practices. *MMWR Morb Mortal Wkly Rep*. 2015;64:300-304.
8. Maktabi H, Ludwig SL, Eick-Cost A, et al. Quadrivalent human papillomavirus vaccine initiation, coverage, and compliance among U.S. active component service women, 2006-2011. *MSMR*. 2012;19:16.
9. US Department of Health and Human Services. Objective IID-11.4: Increase the vaccination coverage level of 3 doses of human papillomavirus (HPV) vaccine for female by age 13 to 15 years [internet]. Immunization and Infectious Diseases page, HealthyPeople.gov website. Available at: https://healthypeople.gov/2020/topics-objectives/topic/immunization-and-infectious-diseases/objectives. Accessed Februrary 28, 2018.
10. *DoD Instruction 1010.10: Health Promotion and Disease Prevention*. Washington, DC: US Department of Defense; April 28, 2014. Available at: http://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/101010p.PDF?ver=2018-01-12-113645-193. Accessed Februrary 23, 2018.
11. *Accelerating HPV vaccine uptake: Urgency for action to prevent cancer. A report to the President of the United States from the President's Cancer Panel*. Bethesda, MD: National Cancer Institute; 2014. Available at: https://deainfo.nci.nih.gov/advisory/pcp/annualreports/HPV/PDF/PCP_Annual_Report_2012-2013.pdf. Accessed February 23, 2018.

Table 6. Counts of STI coinfections among incident HPV diagnosis of military recruits.

	Chlamydia	HSV	Gonorrhea	Syphilis
Total	3	4	3	0
Service				
Army	0	2	0	0
Navy	2	1	3	0
Air Force	0	0	0	0
Marines	1	1	0	0
Age				
<20	0	2	1	0
20-24	2	1	2	0
25-29	0	0	0	0
30-34	1	1	0	0
35-39	0	0	0	0
40-44	0	0	0	0
Sex				
Male	0	2	0	0
Female	3	2	3	0
Marital Status				
Married	0	0	0	0
Single	2	4	3	0
Other	0	0	0	0
Race/ethnicity				
White, non-Hispanic	0	4	0	0
Black, non-Hispanic	1	0	1	0
Hispanic	1	0	0	0
Asian/Pacific Islander	1	0	0	0
Other	0	0	1	0

12. Markowitz LE, Dunne EE, Saraiya M, et al. Human papillomavirus vaccination: recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Morb Mortal Wkly Rep*. 2014;63:1-30.

13. Hariri S, Unger ER, Sternberg M, et al. Prevalence of genital human papillomavirus among females in the United States, the National Health and Nutrition Examination Survey, 2003-2006. *J Infect Dis*. 2011;204:566-573.

14. Dunne EF, Sternberg M, Markowitz LE, et al. Human papillomavirus (HPV) 6, 11, 16, and 18 prevalence among females in the United States--The National Health and Nutrition Examination Survey, 2003-2006: opportunity to measure HPV vaccine impact?. *J Infect Dis*. 2011;204:562-565.

15. Winer RL, Lee SK, Hughes JP, Adam DE, Kiviat NB, Koutsky LA. Genital human papillomavirus infection: incidence and risk factors in a cohort of female university students. *Am J Epidemiol*. 2003;157:218-226.

16. Fairley CK, Gay NJ, Forbes A, Abramson M, Garland SM. Hand-genital transmission of genital warts - an analysis of prevalence data. *Epidemiol Infect*. 1995;115:169-176.

17. Marrazzo JM, Stine K, Koutsky LA. Genital human papillomavirus infection in women who have sex with women: a review. *Am J Obstetr Gynecol*. 2000;183:770-774.

18. Moscicki AB, Schiffman M, Burchell A, et al. Updating the Natural History of Human Papillomavirus and Anogenital Cancers. *Vaccine*. 2012;30:F24-F33.

19. Shew ML, Weaver B, Tu WZ, Tong Y, Fortenberry JD, Brown DR. High frequency of human papillomavirus detection in the vagina before first vaginal intercourse among females enrolled in a longitudinal cohort study. *J Infect Dis*. 2013;207:1012-1015.

20. Watts DH, Koutsky LA, Holmes KK, et al. Low risk of perinatal transmission of human papillomavirus: Results from a prospective cohort study. *Am J Obstetr Gynecol*. 1998;178:365-373.

21. Ho GYF, Bierman R, Beardsley L, Chang CJ, Burk RD. Natural history of cervicovaginal papillomavirus infection in young women. *N Engl J Med*. 1998;338:423-428.

22. Moscicki AB, Hills N, Shiboski S, et al. Risks for incident human papillomavirus infection and low-grade squamous intraepithelial lesion development in young females. *JAMA*. 2001;285:2995-3002.

23. Peyton CL, Gravitt PE, Hunt WC, et al. Determinants of genital human papillomavirus detection in a US population. *J Infect Dis*. 2001;183:1554-1564.

24. Manhart LE, Holmes KK, Koutsky LA, et al. Human papillomavirus infection among sexually active young women in the United States: implications for developing a vaccination strategy. *Sex Trans Dis*. 2006;33:502-508.

25. Agan BK, Macalino GE, Nsouli-Maktabi H, et al. Human papillomavirus seroprevalence among men entering military service and seroincidence after ten years of service. *MSMR*. 2013;20:21-24.

26. Partridge JM, Hughes JP, Feng QH, et al. Genital human papillomavirus infection in men: incidence and risk factors in a cohort of university students. *J Infect Dis*. 2007;196:1128-1136.

27. Giuliano AR, Lee JH, Fulp W, et al. Incidence and clearance of genital human papillomavirus infection in men (HIM): a cohort study. *Lancet*. 2011;377:932-940.

28. Goyal V, Mattocks KM, Sadler AG. High-risk behavior and sexually transmitted infections among U.S. active duty servicewomen and veterans. *J Womens Health*. 2012;21:1155-1169.

29. Shah KV, Daniel RW, Tennant MK, et al. Diagnosis of human papillomavirus infection by dry vaginal swabs in military women. *Sex Transm Infect*. 2001;77:260-264.

30. Moscicki AB. Genital infections with human papillomavirus (HPV). *Ped Infect Dis J*. 1998;17:651-652.

31. Franco EL, Villa LL, Sobrinho JP, et al. Epidemiology of acquisition and clearance of cervical human papillomavirus infection in women from a high-risk area for cervical cancer. *J Infect Dis*. 1999;180:1415-1423.

32. Molano M, van den Brule A, Plummer M, et al. Determinants of clearance of human papillomavirus infections in Colombian women with normal cytology: a population-based, 5-year follow-up study. *Am J Epidemiol*. 2003;158:486-494.

33. Gillison ML, Broutian T, Pickard RKL, et al. Prevalence of oral HPV infection in the United States, 2009-2010. *J Am Med Assoc*. 2012;307:693-703.

34. Kreimer AR, Campbell CMP, Lin HY, et al. Incidence and clearance of oral human papillomavirus infection in men: the HIM cohort study. *Lancet*. 2013;382:877-887.

35. Chin-Hong PV, Palefsky JM. Natural history and clinical management of anal human papillomavirus disease in men and women infected with human immunodeficiency. *Clin Inf Dis*. 2002;35:1127-1134.

36. Chesson HW, Ekwueme DU, Saraiya M, Watson M, Lowy DR, Markowitz LE. Estimates of the annual direct medical costs of the prevention and treatment of disease associated with human papillomavirus in the United States. *Vaccine*. 2012;30:6016-6019.

37. Nsouli-Maktabi H, Ludwig SL, Yerubandi UD, Gaydos JC. Incidence of genital warts among U.S. service members before and after the introduction of the quadrivalent human papillomavirus vaccine. *MSMR*. 2013;20:17-20.

38. Okulicz JF, Beckett CG, Blaylock JM, et al. Review of the U.S. military's human immunodeficiency virus program: a legacy of progress and a future of promise. *MSMR*. 2017;24:2-7.

39. Centers of Disease Control and Prevention. Cervical Cancer Screeening Guidelines for Average-Risk Women [internet]. U.S. Preventive Services Task Force. 2012. Available at: https://www.cdc.gov/cancer/cervical/pdf/guidelines.pdf. Accessed February 24, 2018.

AUTHORS

COL Kwon is Director, US Medical Research Directorate-Georgia, Walter Reed Institute of Research, Silver Spring, Maryland.

Ms Lay is Chief, Department of Health Systems, Preventive Medicine Branch, Walter Reed Institute of Research, Silver Spring, Maryland.

Dr Hrncir is Regional Medical Director, Immunizations Healthcare Branch, Defense Health Agency, Joint Base San Antonio-Lackland, San Antonio, Texas.

Dr Levin is Senior Epidemiologist, Department of Epidemiology, Preventive Medicine Branch, Walter Reed Institute of Research, Silver Spring, Maryland.

Evaluation of NU-FlexSIV Socket Performance for Military Service Members with Transfemoral Amputation

Starr E. Brown, MSc
Elizabeth Russell Esposito, PhD
Andrea J. Ikeda, MS, CP
Jason M. Wilken, PT, PhD
Stefania Fatone, PhD

Abstract

Ischial containment sockets are the current standard of care for military service members with transfemoral amputation. However, they fit intimately with the ischium, which may limit hip motion and contribute to proximal socket discomfort, a common complaint among prosthesis users. Subischial sockets, such as the newly described Northwestern University Flexible Subischial Vacuum (NU-FlexSIV) Socket technique, do not interact with the ischium, potentially increasing hip motion and improving comfort.

Purpose: To transfer the NU-FlexSIV Socket technique to military prosthetists and evaluate performance among military service members with transfemoral amputation.

Study design: case series.

Methods: Four of the 11 enrolled subjects completed the study protocol comparing the NU-FlexSIV Socket to the ischial containment socket. Gait kinematics (over ground and on stairs), physical performance measures (Four-Square Step Test, T-test of Agility, and an obstacle course), limb-socket motion, and socket comfort were assessed after accommodation time in each socket.

Results: While wearing the NU-FlexSIV Socket, sagittal plane hip motion generally increased while coronal plane trunk motion and walking speed remained largely unaffected during over ground walking. During stair ascent, sagittal plane hip motion increased while wearing the NU-FlexSIV Socket, with minimal changes in walking speed for all subjects. Pre- and post-walking fluoroscopy measures suggest fit of the NU-FlexSIV Socket was less affected by activity. Most subjects reported that the NU-FlexSIV Socket was more comfortable for sitting but some found it less comfortable for walking and running. Performance measure results were mixed. Although attempts were made to consistently implement the NU-FlexSIV Socket technique, some challenges were experienced.

Conclusions: The NU-FlexSIV Socket provided greater hip motion across a variety of tasks without adversely affecting other movement mechanics but did not consistently improve socket comfort. Variability in the liners and socket materials used may have contributed to variability in results. Overall, the design was a viable alternative to traditional ischial containment sockets for some individuals with transfemoral amputation.

It is estimated that persons with transfemoral (TF) amputation represent approximately 20% of the overall population with amputations[1]; however, the proportion is greater (31%) among service members who have sustained limb amputation as a result of recent military conflicts.[2] Furthermore, service members with traumatic amputation present different challenges than their dysvascular counterparts as they are typically younger, with excellent premorbid health, and have higher functional expectations postamputation.[3]

Current standard of care TF prosthetic sockets, such as the ischial containment (IC) socket,[4] are designed to fit intimately with the ischium and greater trochanter, stabilizing the socket on the residual limb and supporting body weight.[5-7] However, it has been acknowledged that the proximal brim of the IC socket may limit hip range of motion (ROM) and contribute to socket discomfort, the most common complaint of prosthesis users.[8-12]

Subischial or brimless sockets have been proposed to shift the proximal brim of the socket below the ischium to decrease impingement between the socket and pelvis and potentially increase hip ROM and comfort.[13-16] While early reports suggest subischial sockets are functionally feasible,[13,14,16] only the Northwestern University Flexible Subischial Vacuum (NU-FlexSIV) Socket technique has been described in detail such that others may replicate its fabrication.[15,17]

The NU-FlexSIV Socket combines flexible, lower socket trim lines with vacuum-assisted suspension (VAS) and has been reported to improve comfort.[15,16] Vacuum-assisted suspension uses an active pump rather than relying on passive suction as is common with IC sockets.[18,19] While VAS has been used with transtibial prostheses, application in TF prostheses is less common.[14] By incorporating VAS, the NU-FlexSIV Socket may not only increase hip ROM and comfort, but also reduce pistoning between the socket and limb by stabilizing residual limb fluid volume fluctuations as reported in other applications of VAS.[14,20]

The stability of the residual limb within the socket is an important consideration when determining the appropriate socket for a TF prosthesis user.[21] When coronal plane stability of the limb within the socket is poor, TF prosthesis users often increase lateral trunk displacement and step width.[21] A lower socket trim line results in less socket surface area to stabilize the residual limb but neither Kahle and Highsmith[13] nor Fatone and Caldwell[16] observed gait adaptations associated with coronal plane instability when comparing subischial and IC sockets.

A series of papers describing the fabrication technique for the NU-FlexSIV Socket have been published,[15-17] but additional research on its application to various patient populations is critical for understanding utility. Therefore, the purpose of this study was to transfer the NU-FlexSIV Socket technique to military prosthetists and compare performance among military service members with TF amputation. It was hypothesized that the NU-FlexSIV Socket technique would improve hip ROM, suspension, and comfort, without negatively affecting other movement mechanics such as coronal plane stability.

This study was approved by the Brooke Army Medical Center Institutional Review Board.

Methods

Subjects

Eleven male service members (aged 18-45 years, who had a unilateral TF amputation, were K4 level ambulators, and had not previously used VAS) were enrolled in this study.

Intervention

Two socket systems were assessed. The first was the subjects' standard of care IC socket with passive suction suspension, which represented the design used daily prior to participation in the study. The second was the NU-FlexSIV Socket[15] incorporating VAS. For the study, only the socket systems were changed; the prosthetic knee and foot remained consistent. In order to learn to fit and fabricate the NU-FlexSIV Socket, study prosthetists were provided in-person training, a multimedia instruction manual, and ongoing consultation from the NU-FlexSIV Socket developers. Subjects were expected to have an 8-week accommodation time to wear the definitive version of the NU-FlexSIV Socket.

Protocol

When possible, subjects were first tested in the IC socket followed by the NU-FlexSIV Socket (Figure 1). The order was not randomized and subjects were first tested in the socket to which they were already accustomed to avoid the additional accommodation time that would otherwise be required. Biomechanical data were collected as subjects walked over level ground at a self-selected speed, as well as when walking up a 16-step staircase at a self-selected cadence. Handrail use and stair stepping patterns (step-over-step or step-to-step) were noted. Biomechanical data were captured using a 26-camera motion capture system (Motion Analysis, Santa Clara, CA) with a 6-degree of freedom marker set using 57 markers to define 13 body segments.[22,23] A digitization pointer was used to identify 20 bilateral anatomical landmarks (C-Motion, Inc, Germantown, MD). The position of the ankle joint center was mirrored from the intact ankle, resulting in comparable anterior/posterior, superior/inferior, and medial/lateral positioning. The knee joint center was determined using digitized points on the medial and lateral aspects of the prosthetic knee axis of rotation.

Functional performance was assessed using 3 measures:

1. The Four-Square Step Test, which required subjects to change directions and step over a one-inch obstacle[24]: this test was performed 3 times and the fastest time recorded.
2. The T-test of Agility, which is a timed test that requires running forward and backward, and side-shuffling, and has been used previously to assess individuals with TF amputation[16]: this test was performed twice and the fastest time recorded.
3. An obstacle course which was created for this study to assess agility, balance, and mobility: The course was set up over 20 m and involved starting from a seated position, weaving through cones, stepping on and over a box, making a 180° turn, performing narrow and wide steps inside and outside of pipes, respectively, and stepping over 6-inch hurdles. This test was performed twice and the fastest time recorded.

Medial-lateral digital fluoroscopy (Dynamic Motion X-ray system, VF-Works, Inc, Palm Harbor, FL) of the

residual limb within the socket was recorded before and after level walking on a treadmill for 10 minutes at a standardized speed based on leg length.[25] Using methods similar to those of Darter et al,[26] subjects stood on a force platform (AMTI Inc, Watertown, MA) and applied vertical loads of 0% and 100% of body weight through their prosthetic limb, while minimizing shear forces to less than 2.5% body weight. A radiopaque ruler was taped to the socket to ensure consistent scaling of all image measurements. Three trials of medial-lateral digital fluoroscopy were collected in each loading condition before and after activity.

Figure 1. Ischial containment socket (left) and NU-FlexSIV Socket (right) illustrating the difference in proximal socket shape/height and different valves for passive versus active suction. Remaining components were standardized.

Socket comfort scores[27] were collected at the end of data collection in each socket condition using a scale from 0 (most uncomfortable) to 10 (most comfortable) for sitting, standing, walking, and running activities. Additionally, the study prosthetist recorded informal interviews with each subject at the end of their study participation to solicit feedback regarding their experiences using the NU-FlexSIV Socket. Interviews were conducted regardless of whether subjects completed the entire study protocol, given that information from such subjects was assumed to be equally informative of socket performance. Exit interviews were conducted by one of 3 investigators using a standard set of questions based as applicable on items in the Patient Assessment Validation Evaluation Test (Hanger Orthopedic Group, Inc), Prosthesis Evaluation Questionnaire,[28] Questionnaire for Persons with Transfemoral Amputation,[29] and Trinity Amputation and Prosthesis Experience Scales.[30] Additional questions were asked as necessary by the interviewer for clarification or to solicit more information.

Data Analysis

Using Visual 3D software (C-Motion Inc, Germantown, MD), marker data were filtered with 2nd order Butterworth low-pass filters using cutoff frequencies of 6 Hz and 50 Hz, respectively. Three-dimensional lower extremity kinematics were computed using an Euler angle approach and normalized to 100% of the gait cycle. Peak joint angles and ROMs were identified using a custom Matlab program (Mathworks, Inc, Natick, MA).

A single representative fluoroscopy image subjectively determined to have the best contrast, orientation, and visualization of the limb was selected from each fluoroscopy trial. The average distance from the distal point of the femur and the top of the socket attachment plate was determined for both loading conditions (Media Cybernetics, Inc, Rockville, MD). Fluoroscopic assessments of bone-socket motion have been previously shown to be reliable in persons with TF amputation.[31]

In this case series, descriptive statistics were used to compare results between sockets with regards to walking speed, hip motion (sagittal plane hip ROM and maximal hip extension), socket stability (coronal plane trunk ROM), suspension (difference in pre- and post-walking limb-socket displacement upon full loading), comfort (socket comfort scores), and functional performance (Four-Square Step Test, T-Test of Agility, and the obstacle course). Differences between sockets for the following variables were compared using minimal detectable change (MDC) values reported in the literature: over ground sagittal plane hip ROM,[23] over ground coronal plane trunk ROM,[23] T-Test of Agility,[32] Four-Square Step Test,[33] and Socket Comfort Score.[34] Minimal detectable

change values were not available for stair ascent, sagittal plane hip ROM, or the obstacle course.

Results

Four subjects completed testing in both sockets (Table 1). Feedback from 9 of the 11 subjects (P01-P11) regarding experience with the NU-FlexSIV Socket were recorded as part of the exit interview.

Gait Biomechanics (Table 2)

Walking speeds over level ground and stair ascent were consistent between sockets with differences of 0.06 m/s or less, with the exception of P11 who walked 0.31 m/s faster over ground in the IC socket.

Sagittal plane hip ROM during over ground walking increased for 3 subjects (P02, P08, P09) while wearing the NU-FlexSIV Socket (differences: 14.21°, 4.22°, 5.00°, respectively). The exception was P11 for whom hip ROM was 2.71° less in the NU-FlexSIV Socket (Figure 2). The increase in hip ROM during over ground walking for the 3 subjects was greater than the MDC of 3.21°,[23] while the decrease in hip ROM for P11 was less than the MDC. Sagittal plane hip ROM during stair ascent increased for all subjects (differences: 3.83°, 5.10°, 5.22°, 5.86°). More specifically, hip extension during both over ground walking and stair ascent increased for all subjects in the NU-FlexSIV Socket (Figure 2). The increase in hip extension during over ground walking for P02 and P11 (differences: 9.67°, 5.37°, respectively) exceeded the MDC of 4.69°.[23]

Coronal plane trunk ROM during over ground walking increased for 3 subjects (P02, P08, P11) while wearing the NU-FlexSIV Socket (differences: 0.93°, 1.08°, 3.75°, respectively) (Figure 2), however, the increase was only greater than the MDC of 1.14°[23] for P11. Trunk ROM during stair ascent was not assessed due to handrail use by 3 subjects for one or both sockets.

Fluoroscopy (Figure 3)

Three subjects (P02, P08, P11) had less difference in pre- and post-walking limb-socket displacement while wearing the NU-FlexSIV Socket (0.30 cm, -0.06cm, -0.16 cm, respectively) compared to the IC socket (1.27 cm, 1.04 cm, -0.59 cm, respectively). Socket displacement

Table 1. Subject demographics and NU-FlexSIV Socket accommodation time or reason for dropping out for all subjects enrolled in the study.

Subject	Age (years)	Height (m)	Mass (kg)	Accommodation Time (Fluoroscopy/Biomechanics) or Discontinuation	Prosthetist	Liner used with NU-FlexSIV socket	NU-FlexSIV inner flexible socket material
P01	28	1.89	83	Relocation	A, B	medi Relax 3C Cushion	No definitive socket made
P02	35	1.86	95	8 weeks/8 weeks	A, B	medi Relax 3C Cushion	Polytol
P03	40	1.85	98	Refused to return to IC socket for testing	A, B	medi Relax 3C Cushion	Polytol
P04	31	1.81	82	Relocation	B	medi Relax 3C Cushion	No definitive socket made
P05	24	1.75	92	Discontinued NU-FlexSIV socket	A, C	Össur Iceross Seal-In X TF	Northvane
P06[a]	33	1.82	102	Discontinued NU-FlexSIV socket: neuroma surgery and relocation	A, C	Össur Iceross Seal-In X TF	First definitive: medi Flex EVA Second definitive: Northvane
P07	32	1.70	103	Discontinued NU-FlexSIV check socket	A, C	Össur Iceross Seal-In X TF	No definitive socket made
P08	33	1.72	77	0 days/3 days[b]	B	Össur Iceross Seal-In X TF	Northvane
P09	30	1.85	94	9 weeks/9 weeks	B	Össur Iceross Seal-In X TF	Northvane
P10	36	1.68	96	Discontinued NU-FlexSIV check socket	B	Össur Iceross Seal-In X TF	No definitive socket made
P11	31	1.72	80 (91[c])	9 weeks/3 weeks[c]	D	Össur Iceross Seal-In X TF	Northvane

Notes:

Shaded rows indicate subjects who completed the study. The order of testing for all subjects who completed the study was ischial containment socket followed by the NU-FlexSIV Socket. Four prosthetists (labeled A-D) were involved. Prosthetist A was a member of the development team of the NU-FlexSIV Socket.

[a] Search for new definitive socket material meant that this subject spent longer in different sockets than planned.

[b] Subject returned to duty station earlier than expected after receiving the NU-FlexSIV Socket, shortening the accommodation time.

[c] Subject gained mass between fluoroscopy and biomechanics testing sessions, which required a second definitive socket to be made. Accommodation time represents the time in this new socket. Biomechanics testing was performed 13 weeks after fluoroscopy testing due to subject scheduling conflicts and experiencing low back pain for unspecified reasons.

Table 2. Individual subject data for hip and trunk kinematics, socket comfort score, and performance measures in the Ischial Containment (IC) and NU-FlexSIV Sockets for subjects who completed testing.

Measurement	P02		P08		P09		P11	
	IC	NU-FlexSIV	IC	NU-FlexSIV	IC	NU-FlexSIV	IC	NU-FlexSIV
Self-selected walking speed OG (m/s)	1.23	1.18	1.24	1.18	1.42	1.39	1.61	1.30
Self-selected walking speed STA (m/s)	0.33	0.32	0.38	0.40	0.45	0.40	0.44	0.44
Sagittal plane hip range of motion OG (degrees)	40.83	55.04	53.75	57.97	53.54	58.54	58.33	55.62
Sagittal plane hip range of motion STA (degrees)	65.17	69.00	67.59	72.69	60.40	65.62	64.20	70.06
Sagittal plane hip extension OG (degrees)	4.77	-4.90	-16.67	-18.54	-16.28	-18.08	-9.06	-14.43
Sagittal plane hip extension STA (degrees)	17.54	13.63	12.40	5.83	16.06	9.76	10.96	7.24
Coronal plane trunk range of motion OG (degrees)	5.03	5.96	9.12	10.20	10.53	9.97	3.86	7.61
Socket comfort score sitting	4	8	9	8	6.50	8	7	8
Socket comfort score standing	5	8	9	4	8	5	5	6
Socket comfort score walking	2	8	9	6	7.50	4	5	4
Socket comfort score running	1	7	5	0	6.50	0.50	7	4
Four Square Step Test (seconds)	7.52	8.02	10.16	8.69	7.35	7.47	7.43	6.16
T-Test (seconds)	25.22	21.17	22.94	30.13	19.08	20.25	18.47	18.79
Obstacle course (seconds)	15.85	15.16	22.25	15.69	14.34	16.56	13.78	13.56

OG indicates over ground; STA, stair ascent.
P02 and P09 used handrails with both sockets and P08 used handrails with the NU-FlexSIV Socket during STA.
All subjects performed STA step-over-step.
Socket comfort scores are from 0 (most uncomfortable) to 10 (most comfortable).

assessed independently from walking did not show a clear result.

Functional Performance Measures (Table 2)

Functional performance measures showed mixed results. Three subjects (P08, P09, P11) performed the T-Test of Agility more slowly (by 7.19 seconds, 1.17 seconds, 0.32 seconds, respectively) while wearing the NU-FlexSIV Socket, two of which exceeded the MDC of 0.91.[32] Three subjects (P02, P08, P11) performed the obstacle course faster (by 0.69 seconds, 6.56 seconds, 0.22 seconds, respectively) while wearing the NU-FlexSIV Socket. Improved performance in the Four-Square Step Test was divided between sockets; however, only the faster time by subject P08 in the NU-FlexSIV Socket exceeded the MDC of 1.41.[33]

Socket Comfort Score (Table 2)

Subject P02 was the only subject who rated the NU-FlexSIV Socket more comfortable for all activities (sitting, standing, walking, running) with the difference in scores exceeding the MDC of 2.73[34] for all activities. Of the remaining 3 subjects, differences for sitting comfort did not exceed the MDC of 2.73.[34] All 3 subjects (P08, P09, P11) rated the NU-FlexSIV Socket less comfortable for walking (differences: 3, 3.5, 1, respectively) and running (differences: 5, 6, 3, respectively) with most of these changes exceeding the MDC of 2.73.[34] Improved socket comfort during standing was inconsistent across subjects, with two preferring the NU-FlexSIV Socket (P02, P11; differences: 3, 1) and two preferring the IC socket (P08, P09; differences: 5, 3): most of the changes exceeded the MDC of 2.73.[34]

Exit Interviews

Nine subjects were interviewed following their accommodation time in the NU-FlexSIV Socket, regardless of the length of accommodation time or completion of testing (four completed the study and five dropped out (Table 1)). All subjects were asked the same standard set of questions with the exception of 2 subjects, P07 and P10, who were asked fewer questions because some were not applicable as the NU-FlexSIV Socket was worn for less than a day. The 2 subjects who were not interviewed, P01 and P04, moved out of the area and did not complete the study.

Subject interviews confirmed that, compared to the IC socket, the NU-FlexSIV Socket had better comfort when sitting, including when driving. Regarding the NU-FlexSIV Socket trim lines, subject P03 suggested making them even lower, while subjects P06 and P11 thought they should be a little higher. Subjects P02 and P09 described that they liked the NU-FlexSIV Socket for cycling, squats, and bending over, however subjects P03 and P11 described losing suction (between the limb and liner) when cycling. Subject P09 observed that the NU-FlexSIV Socket required more muscular utilization than the IC socket, was less stable, and not as good for running or agility. Regarding donning the NU-FlexSIV Socket: subjects P05 and P11 liked that the alcohol spray they used with their IC sockets was not required for the NU-FlexSIV Socket; however, subject P10 disliked that donning the NU-FlexSIV Socket required more time. Four subjects (P05, P07, P09, P10) were unable to discern a difference between the VAS used with the NU-FlexSIV Socket and the passive suction used with the

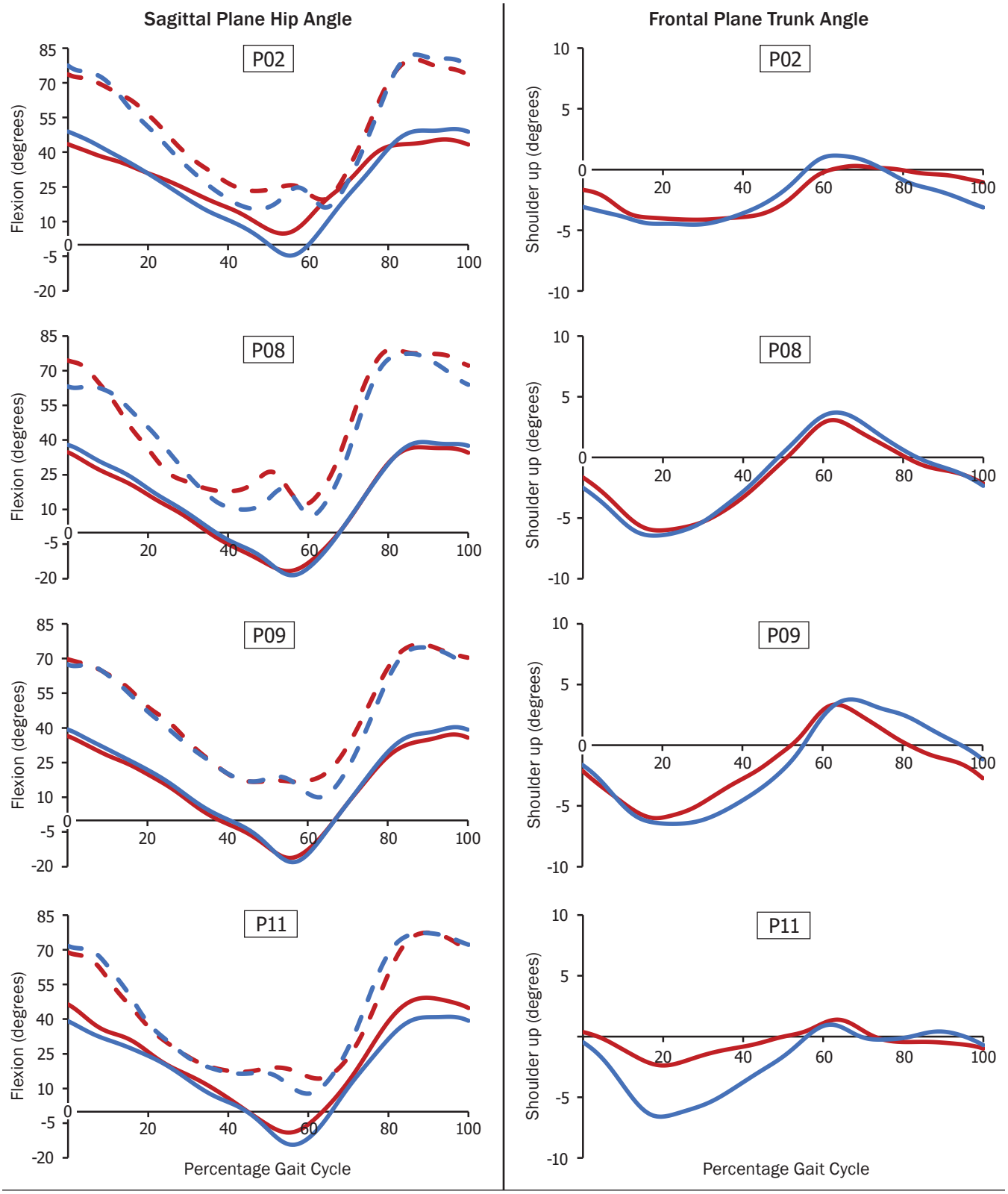


Figure 2. Representative sagittal plane hip and trunk angles for subjects P02, P08, P09, and P11 during:
over ground walking wearing Ischial Containment Socket ——— wearing Nu-FlexSIV Socket ———
stair ascent wearing Ischial Containment Socket — — wearing Nu-FlexSIV Socket — —
Data were normalized to 100% of the gait cycle.

IC socket. However, subject P11 felt a big difference between the two with a strong preference for the VAS. Residual limb volume fluctuation and sweating in the NU-FlexSIV Socket were not an issue for 4 subjects (P02, P03, P08, P09); while 3 subjects (P05, P06, P11) commented that volume fluctuation affected socket fit.

Comment

This study provided the NU-FlexSIV Socket technique to military prosthetists and evaluated socket performance in military service members with TF amputation by comparing it to the current standard of care IC socket. Generally, our results indicated that the NU-FlexSIV Socket increased hip ROM without compromising walking speed and lateral trunk motion. This finding supports that of previous studies [13,16] and suggests coronal plane socket stability with lower socket trim lines is possible. However, stability was not perceived by all subjects and it is possible that stability varied due to variability in the liners and socket materials used. For example, the medi Relax 3C Cushion liner (Össur Americas, Foothill Ranch, CA) has very high compressive resistance compared to Össur silicone liners (www.linerassist.org), with the greatest potential to create stability and facilitate transfer of limb motion to the socket. Similarly, both Polytol (Ottobock gmbh, Duderstadt, Germany) and medi Flex EVA (Össur Americas) are more firm and supportive than Northvane (North Sea Plastics, Ltd, Glasgow, UK). The 2 subjects (P02, P03) who strongly preferred the NU-FlexSIV Socket were the only ones who wore the medi liner with Polytol socket (Table 2). By contrast, subjects P09 and P11, who perceived instability, wore the less supportive combination of Össur liner with Nothvane for the full accommodation period. While the developers recommend the medi liner and socket material for use with the NU-FlexSIV Socket,[35] future research could more systematically explore the effect of material properties and choices on socket performance, especially for highly active users.

Digital fluoroscopy was a useful tool for examining limb-socket displacement in the NU-FlexSIV Socket. We found less difference in pre- and post-walking limb-socket displacement for 3 subjects while wearing the NU-FlexSIV Socket, suggesting the fit of the NU-FlexSIV Socket was not affected by walking. Limb-socket displacement is posited to affect the volume of the residual limb with greater displacement resulting in greater volume loss.[36] The ability of the NU-FlexSIV Socket to reduce displacement after activity is consistent with previous suggestions that volume fluctuations are reduced when VAS is used,[36,37] but perhaps surprising given the way each socket supports body weight. The IC socket supports body weight in part through the pelvis and gluteals during midstance (a position similar to the static weight bearing position in this test) and might therefore be expected to experience less variability in longitudinal displacement. By comparison, the NU-FlexSIV Socket supports body weight exclusively on soft tissues of the thigh yet demonstrated less variability in displacement. Limb-socket displacement independent of activity showed mixed results, although it was less variable while wearing the NU-FlexSIV Socket compared to the IC socket. The lack of clear overall reduction in limb-socket displacement independent of activity with a VAS compared to passive suction is not consistent with transtibial socket studies that found a reduction in limb-socket displacement independent of exercise when using a VAS.[20] Research on a greater number of subjects is required to study this phenomenon in more detail.

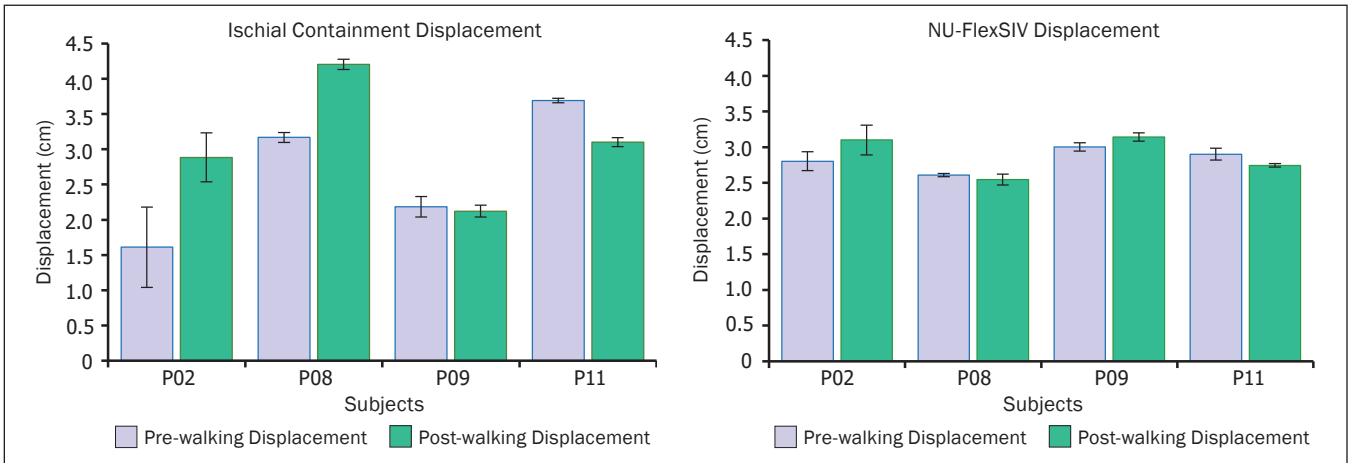


Figure 3. Mean (SD) limb-socket displacement data for subjects P02, P08, P08, and P11. Total displacement (0% and 100% body weight) is presented for the pre- and post-walking (10 minutes of treadmill walking) tests in the ischial containment and NU-FlexSIV sockets respectively.

Most subjects reported that the NU-FlexSIV Socket was more comfortable for sitting but less comfortable for walking and running, which does not fully accomplish the main goal of the NU-FlexSIV Socket to improve comfort. However, when considering the socket comfort and hip ROM results along with comments from the exit interviews, the functional performance results seem reasonable. Most subjects performed the T-Test of Agility more slowly and the obstacle course faster while wearing the NU-FlexSIV Socket. The T-Test of Agility is largely based on running while the obstacle course started from a sitting position and consisted of maneuvering through obstacles (eg, a step and hurdles), which required increased hip ROM. Future investigation into use of the NU-FlexSIV Socket for activity-specific prostheses may be especially beneficial to service members and Veterans.

Although attempts were made to consistently implement the NU-FlexSIV Socket technique, the following challenges were noted: several different materials were used for the flexible inner socket (with some issues resulting from discontinuation of material by the manufacturer during the course of the study); various gel liners were used; the type of socket worn during accommodation (hard socket or flexible proximal trim line) was not consistent; the amount of time a subject wore the test and definitive sockets during the study varied; and multiple prosthetists were involved. These differences in socket implementation are consistent with a dynamic clinical environment but may have contributed to some of the variability in results across subjects.

This variability in implementation was one of several study limitations. For example, only a small number of subjects were able to complete the study. The required accommodation time of 8 weeks in the NU-FlexSIV Socket likely contributed to the large number of dropouts in this population of service members who encountered conflicting active duty demands during study participation. This requirement was so challenging that it was waived for latter subjects such as subject P08 who was tested after only 3 days wearing the NU-FlexSIV Socket. Also, we deviated in the testing order for subject P03, first testing in the NU-FlexSIV Socket, because after experiencing the NU-FlexSIV Socket, the subject developed such a strong preference that he would not return to the IC socket for testing. It is important to highlight the successes and pitfalls of new technology on an individual level. Not every socket design will meet the fit and functional needs of every individual, but if new designs can provide a benefit to some prosthesis users, they are a viable and potentially advantageous alternative. In addition, as osseointegration becomes more widely available, exposure to alternative socket designs such as the one described here is increasingly important, as a current condition for receiving this invasive surgery is failed socket attempts.

Conclusion

The NU-FlexSIV Socket provided greater hip ROM across a variety of tasks without adversely affecting other movement mechanics, but did not consistently improve socket comfort for these highly active military service members. Variability in the combination of liners and socket materials used may have contributed to variability in results. Overall, this design was a viable alternative to traditional IC sockets for some individuals with TF amputation.

Acknowledgment

Funding for this study (Award #W81XWH-10-1-0744) was awarded and administered by the US Army Medical Research and Materiel Command Acquisition Activity, 820 Chandler 10 Street, Fort Detrick, MD 21702-5014. The content of this article does not necessarily reflect the position or the policy of the Government, and no official endorsement should be inferred.

References

1. Owings MF, Kozak LJ. Ambulatory and inpatient procedures in the United States, 1996. *Vital Health Stat*. 1998;13(139):1-119.
2. Stansbury L, Lalliss S, Branstetter J, Bagg M, Holcomb J. Amputations in U.S. military personnel in the current conflicts in Afghanistan and Iraq. *J Orthop Trauma*. 2008;22(1):43-46.
3. Pasquina PF, Fitzpatrick KF. The Walter Reed experience: current issues in the care of the traumatic amputee. *J Prosthet Orthot*. 2006;18(6):119-122.
4. Schuch CM, Pritham CH. Current transfemoral sockets. *Clin Orthop Relat Res*. 1999;361:48-54.
5. Sabolich J. Contoured adducted trochanteric-controlled alignment method (CAT-CAM): introduction and basic principles. *Clin Prosthet Orthot*. 1985;9:15-26.
6. Hoyt C, Littig D, Lundt J, Staats T. *The Ischial Containment Above-Knee Prosthesis*. Los Angeles, CA: UCLA Prosthetics Education and Research Program; 1987.
7. Pritham CH. Biomechanics and shape of the above-knee socket considered in light of the ischial containment concept. *Prosthet Orthot Int*. 1990;14(1):9-21.
8. Hagberg K, Haggstrom E, Uden M, Branemark R. Socket versus bone-anchored trans-femoral prostheses: hip range of motion and sitting comfort. *Prosthet Orthot Int*. 2005;29(2):153-163.

9. Smith D. The Transfemoral Amputation Level, Part 4: Great prosthetic components are good, but a good socket is great. *inMotion*. 2004;14:56-61. Available at: https://www.amputee-coalition.org/wp-content/uploads/2015/05/transfemoral4.pdf. Accessed September 26, 2018.
10. Dillingham TR, Pezzin LE, MacKenzie EJ, Burgess AR. Use and satisfaction with prosthetic devices among persons with trauma-related amputations: a long-term outcome study. *Am J Phys Med Rehabil*. 2001;80(8):563-571.
11. Pezzin LE, Dillingham TR, Mackenzie EJ, Ephraim P, Rossbach P. Use and satisfaction with prosthetic limb devices and related services. *Arch Phys Med Rehabil*. 2004;85(5):723-729.
12. Berke GM, Fergason J, Milani JR, et al. Comparison of satisfaction with current prosthetic care in veterans and servicemembers from Vietnam and OIF/OEF conflicts with major traumatic limb loss. *J Rehabil Res Dev*. 2010;47(4):361-371.
13. Kahle JT, Highsmith MJ. Transfemoral interfaces with vacuum assisted suspension comparison of gait, balance, and subjective analysis: ischial containment versus brimless. *Gait Posture*. 2014;40(2):315-320.
14. Kahle JT, Orriola JJ, Johnston W, Highsmith MJ. The effects of vacuum-assisted suspension on residual limb physiology, wound healing, and function: a systematic review. *Technol Innov*. 2014;15(4):333-341.
15. Fatone S, Caldwell R. Northwestern university flexible subischial vacuum socket for persons with transfemoral amputation: part 1 description of technique. *Prosthet Orthot Int*. 2017;41(3):237-245.
16. Fatone S, Caldwell R. Northwestern University flexible subischial vacuum socket for persons with transfemoral amputation: part 2 preliminary evaluation. *Prosthet Orthot Int*. 2017;41(3):246-250.
17. Fatone S, Johnson W, Tran L, Tucker K, Mowrer C, Caldwell R. Quantification of rectifications for Northwestern University flexible subischial vacuum (NU-FlexSIV) socket. *Prosthet Orthot Int*. 2017;41(3):251-257.
18. Kapp S. Suspension systems for prostheses. *Clin Orthop Relat Res*. 1999;361:55-62.
19. Kapp SL. Transfemoral socket design and suspension options. *Phys Med Rehabil Clin N Am*. 2000;11(3):569-583.
20. Darter BJ, Sinitski K, Wilken JM. Axial bone–socket displacement for persons with a traumatic transtibial amputation: The effect of elevated vacuum suspension at progressive body-weight loads. *Prosthet Orthot Int*. 2016;40(5):552-557.
21. Fatone S, Dillon M, Stine R, Tillges R. Coronal plane socket stability during gait in persons with unilateral transfemoral amputation: pilot study. *J Rehabil Res Dev*. 2015;51(8):1217-1228.
22. Kaufman K, Miller E, Kingsbury T, et al. Reliability of 3D gait data across multiple laboratories. *Gait Posture*. 2016;49:375-381.
23. Wilken JM, Rodriguez KM, Brawner M, Darter BJ. Reliability and minimal detectible change values for gait kinematics and kinetics in healthy adults. *Gait Posture*. 2012;35(2):301-307.
24. Dite W, Connor HJ, Curtis HC. Clinical identification of multiple fall risk early after unilateral transtibial amputation. *Arch Phys Med Rehabil*. 2007;88(1):109-114.
25. Vaughan CL, O'Malley MJ. Froude and the contribution of naval architecture to our understanding of bipedal locomotion. *Gait Posture*. 2005;21(3):350-362.
26. Darter BJ, Sinitski K, Wilken JM. Axial bone-socket displacement for persons with a traumatic transtibial amputation: the effect of elevated vacuum suspension at progressive body-weight loads. *Prosthet Orthot Int*. 2016;40(5):552-557.
27. Hanspal RS, Fisher K, Nieveen R. Prosthetic socket fit comfort score. *Disabil Rehabil*. 2003;25(22):1278-1280.
28. Legro MW, Reiber GD, Smith DG, del Aguila M, Larsen J, Boone D. Prosthesis evaluation questionnaire for persons with lower limb amputations: assessing prosthesis-related quality of life. *Arch Phy Med Rehabil*. 1998;79(8):931-938.
29. Hagberg K, Branemark R, Hagg O. Questionnaire for Persons with a Transfemoral Amputation (Q-TFA): initial validity and reliability of a new outcome measure. *J Rehabil Res Dev*. 2004;41(5):695-705.
30. Gallagher P, Maclachlan M. The Trinity Amputation and Prosthesis Experience Scales and quality of life in people with lower-limb amputation. *Arch Phy Med Rehabil*. 2004;85(5):730-736.
31. Werner KM, Linberg AA, Wolf EJ. Reliability of digital fluoroscopic video for assessing axial and mediolateral movement of the femur during weight bearing in individuals with transfemoral amputations. *Prosthet Orthot Int*. 2007;25:64-67.
32. Gailey RS, Gaunaurd IA, Raya MA, et al. Development and reliability testing of the Comprehensive High-Level Activity Mobility Predictor (CHAMP) in male servicemembers with traumatic lower-limb loss. *J Rehabil Res Dev*. 2013;50(7):905-918.
33. Wilken JM, Darter BJ, Goffar SL, et al. Physical performance assessment in military service members. *J Am Acad Orthop Surg*. 2012;20(suppl 1):S42-S47.

34. Hafner BJ, Morgan SJ, Askew RL, Salem R. Psychometric evaluation of self-report outcome measures for prosthetic applications. *J Rehabil Res Dev*. 2016;53(6):797-811.

35. Fatone S, Caldwell R. Northwestern University flexible subischial vacuum socket for persons with transfemoral amputation: part 2 description and preliminary evaluation. *Prosthet Orthot Int*. 2017;41(3):246-250.

36. Board WJ, Street GM, Caspers C. A comparison of trans-tibial amputee suction and vacuum socket conditions. *Prosthet Orthot Int*. 2001;25(3):202-209.

37. Gerschutz MJ, Denune JA, Colvin JM, Schober G. Elevated vacuum suspension influence on lower limb amputee's residual limb volume at different vacuum pressure settings. *J Prosthet Orthot*. 2010;22(4):252-256.

Authors

Ms Brown is with the Center for the Intrepid, San Antonio Military Medical Center, Joint Base San Antonio (JBSA) Fort Sam Houston, Texas.

Dr Russell Esposito is with the Center for Limb Loss and Mobility at the VA Puget Sound and is affiliated with the Center for the Intrepid, San Antonio Military Medical Center JBSA Fort Sam Houston, Texas, and the DoD-VA Extremity Trauma and Amputation Center of Excellence.

Ms Ikeda is with the Center for the Intrepid, San Antonio Military Medical Center, JBSA Fort Sam Houston, Texas, and affiliated with the DoD-VA Extremity Trauma and Amputation Center of Excellence.

Dr Wilken is with the Department of Physical Therapy & Rehabilitation Science, University of Iowa, and affiliated with the Center for the Intrepid, San Antonio Military Medical Center JBSA Fort Sam Houston, Texas, and the DoD-VA Extremity Trauma and Amputation Center of Excellence.

Dr Fatone is with the Department of Physical Medicine and Rehabilitation, Northwestern University Feinberg School of Medicine, Chicago, Illinois.

Motivational Guest Speaker Presentation as an Anti-Stigma Intervention for US Army Soldiers

MAJ Rohul Amin, MC, USA
CPT Sarah C. McLeroy, MC, USA
MAJ Victor M. Johnson, SP, USA

Abstract

Stigma towards mental illness represents a significant challenge. No specific anti-stigma military training curricula currently exists. An infantry division sought to reduce stigma by inviting 2 guest speakers to address Soldiers. The intervention was designed on social contact theory and executed as a quality improvement project. The intervention was speakers self-disclosing their own mental health struggles and having the audience contact with persons from the stigmatized group. Postintervention evaluation (N=361) demonstrated significant reduction in stigma scores (t=8.128, df=329, P<.001, 2-tailed, d=0.3), and effect size was greatest (d=1.17) among those with greater baseline stigma scores. Soldiers also reported positive perceptions of help-seeking behaviors. Given these findings, other units could conduct these type of training events to target stigma toward mental illness.

Medical readiness of a military unit entails physical, mental, and spiritual readiness. Among these concerns, mental health carries a significant weight. Over the course of a 9-year period, mental illness was the leading cause among female US service members and the fourth leading cause among male US service members for medical evacuations from the US Central Command area of operations in Iraq and Afghanistan.[1] Mental illness has significant implications for suicidal death with studies showing most Soldiers (79.3%) who died by suicide had a previously identified mental health disorder.[2] In 2013, self-inflicted deaths (28.5%) were second only to accidental deaths (32.3%) among US service members.[3] During this same time period, death by suicide occurred with 3 times the frequency of combat-related deaths.[3] Despite the importance of ensuring service members are treated for mental illness, significant challenges exist. We attempted to target stigma towards seeking mental health care as a Quality Improvement Project (QI).

Background

A 2014 study showed that only 23% to 40% of a military cohort who met strict criteria for any mental health problem a decade prior had received professional help.[4] One explanation for this gap is the stigma and barriers associated with seeking mental health services among military members. The US Army has attempted to tackle these challenges through programmatic changes to the way mental health care is delivered.[5] Perhaps due to some of these interventions, there have been positive results. Surveys and behavioral health utilization data show that stigma has decreased while behavioral health utilization has increased over time.[6] Despite these gains, the author reported that approximately 6 of every 10 Soldiers meeting self-reported criteria for posttraumatic stress disorder or major depressive disorder were not using mental health services.[6] A possible explanation may be that symptoms of mental illness appear to have positive correlation with stigma and perceived barriers to care.[7] Those who need the mental health services often experience the greatest amount of stigma.

Researchers have asserted stigma to be fourth highest ranked barrier to help-seeking among general population.[8] Central to many service members' reluctance to pursue help for mental health related challenges—particularly those related to depression and suicidality—are fears pertaining to the consequences of being identified, or self-identifying with stigma. These fears may be more befittingly recognized as fear related to appearing weak, compromising the experience of unit comradery or peer esteem, and possible harm done to one's future career. In review of the literature, stigma has been specifically linked in conflict with a number of attributes deemed desirable within the armed forces, namely toughness, self-sufficiency, and combat readiness.[9]

While the negative effects of stigma on mental illness are widely accepted, interventions to target and reduce stigma are lacking. At the time of our intervention, only one anti-stigma toolkit was reported in the literature, but generalization of the training to our unit needs was not possible.[10] A study by Stuart provides a thorough review of stigma reduction programs.[11] These interventions

typically entail actions targeting one or more of the following areas: literacy programs, awareness raising, protest, advocacy, and social contact with those with mental illness. Among adult populations, the best outcomes have been noted in social contact-based interventions.[12] The principle concept is that greater social contact with the stigmatized group may challenge faulty perceptions and generalizations.

The US Army has recognized the importance of reducing stigma and perceived barriers to mental illness. This organizational intent can be found in its suicide prevention guidelines for commanders.[13] The majority of guidance suggests development of a supportive climate, policies, and procedures that reduce barriers to receiving help for mental health, advocacy, and increased awareness. Official guidance is not prescriptive and therefore there are significant heterogeneities in suicide prevention programs among various organizations. Military commanders and suicide prevention program managers (SPPM) often rely on intuition without the aid of explicit and evidence-based interventions to target stigma.

Based on the described concerns and challenges, the author (R.A.), while serving as the SPPM for his unit, wanted to target stigma towards mental health in the infantry division. As part of Suicide Prevention Month in September 2017, 2 speakers were invited to share their personal struggles with mental health. This command training event was executed as a QI project using the Plan, Do, Study, and Act cycle. In the Study cycle, the immediate effects on the audience of active duty Soldiers regarding attitudes towards help-seeking behaviors and stigma were measured. Herein the authors describe the intervention and their findings from its evaluation and assert it can easily be emulated by units across the Army to target stigma.

Methods

Planning Phase

The intervention was part of the unit's annual suicide prevention month efforts. Each year, commanders at various levels implement specific training requirements in addition to the Army-wide prevention training and interventions. As the SPPM for his unit (an Army infantry division), the author (R.A.) recommended anti-stigma training to the commander who approved and directed the event. To meet the commander's intent, background review on the topic was conducted. Four articles[7,11,12,14] were selected to help inform the planning phase based on qualitative relevance of these articles to the topic.

The decision to invite 2 guest speakers to address the unit was based on literature review[12] which identified the strongest evidence for meaningful outcomes in social contact-based intervention. A standard operational order was published to provide place and time for the training event. Each subordinate unit within the organization was tasked to ensure approximately 10% of their population was present.

The Aim Statements for the QI were: (1) achieve a statistically significant ($P<.005$, CI=95%) improvement in stigma scores with an effect size of 0.3 or more immediately following the training; (2) increase perceived help-seeking behaviors by at-least 30% immediately following the training.

Guest Speakers

The first guest speaker (A) was a prominent, recently retired, leader in the US Army. His biography includes being the most senior enlisted leader (command sergeant major) in a high-level Army-command post. Speaker A was already a public advocate for seeking help for mental health challenges and had previously self-disclosed receiving care for behavioral health in a newspaper article. The second guest speaker (B) was a junior noncommissioned officer who had attempted but aborted suicide resulting in psychiatric hospitalization. He had ultimately made significant recovery including promotion to the next rank—highlighting a resiliency and success story.

Measurements of Quality Improvement

Outcome Measures: Primary outcomes were immediate, statistically significant ($P<.05$, CI=95%), intrasubject, reduction in pre- vs post-training stigma scores stigma scale items using a paired-samples *t* test. The secondary outcomes were at least 30% increase of perceived positive help-seeking behaviors on the 3 scale items. Details of the survey items and planning are provided below.

Process Measures: (1) Return rate of the surveys with goal of 70% completed surveys, (2) satisfaction with each guest speaker's presentation.

Balancing Measures: The same measures as outcome measures were used but to look for reversed effect of increased stigma scores post-training. An additional comment section was provided on the survey to capture any unforeseen balancing measures.

Survey: During review of pre-existing literature, no studies were found supporting guest speaker-based intervention in reduction of mental health stigma at an organizational level. We planned to evaluate the event's efficacy by measuring 4 validated stigma items[15] in our active duty Army audience before and immediately

after the training. Data from prior surveys conducted in our unit had these same 4 stigma items. We conducted reliability and construct validity tests on the prior data using SPSS (IBM Corporation, Armonk, NY). It had shown good reliability (Crohnbach $\alpha = 0.946$) and construct validity with these same 4 items with a single component explaining 86% variance.

An additional 3 items were added in accordance with survey design recommendations in the literature.[16] These were added to measure the impact of the training on perceptions of help-seeking behaviors. These items were modified for vocabulary and syntax based on 5 interviews with Soldiers to reduce language ambiguity and improve question precision. The stem for these items asked the audience member to select all that apply with a checkbox next to each of the three items. The options to check included:

- Due to today's training event, I am more likely to seek mental health services for myself in the near future.
- Due to today's training event, I am more likely to have greater empathy for other Soldiers that are receiving mental health services.
- Due to today's training event, I am more likely to encourage other Soldiers who are struggling to seek mental health services.

There was also a "none of the above" option.

The survey was a single 8 by 11 inch sheet of paper with the top two-thirds of the page containing "Before Training" and "After Training" sections in 2 columns. While both columns had the same 4 stigma items, the order was reversed. The bottom one-third of the sheet contained the 3 additional help-seeking items. Overall satisfaction was also measured with each of the 2 speaker's presentations. Satisfaction with presentation ranged from 1 (least satisfied) to 5 (most satisfied) on a Likert scale. Additional space for comments was also available.

Doing Phase

Approximately 1,400 Soldiers participated in the training which was conducted in an auditorium. Due to the size of the audience, the same intervention was delivered twice during the same day in a large auditorium in October 2017.

Guest Speakers

Each speaker received a copy of the postintervention survey and were informed that the objective of the training event was to reduce stigma scores on 4 distinct items and to increase perceptions of help-seeking behaviors listed on the survey. Author R.A. also coached guest speaker B on presentation skills based on techniques used by the popular TED Talks,[17] but the content was determined by the speaker himself. Each guest speaker spent approximately 40 minutes to deliver their talks.

Data Collection

Two hundred surveys were randomly distributed during each session (morning and afternoon) with the goal of sampling 20% of the audience in each group. Prior to the guest speaker presentation, audience members were asked to complete the 4 "Before Training" items on the survey and then put the survey away. Upon completion of the event, the audience was asked to complete the remainder of the survey. Surveys were completed anonymously, and participation and submission were entirely voluntary.

Studying Phase

Data Collection and Analysis

All data from collected surveys was entered manually into a spreadsheet and imported into SPSS. A paired-samples t test was conducted on stigma scale data with before and after training values. A Cohen's d was calculated for each of the 4 stigma items and total means of all 4 items. The Cohen's d was calculated as (M2-M1)/(pooled standard deviation). A subanalysis was done to compare the effect size difference between the group in upper and lower quartile population of baseline total stigma scores. The percentage totals of the audience were calculated for each of the 3 help-seeking behaviors questions. Satisfaction scores for each guest speaker on a Likert scale of 1-5 were calculated and the means were compared.

Results

A total of 361 (90%) surveys were returned representing approximately 26% of the audience. The demographics evaluation demonstrated predominantly younger and lower-ranking enlisted Soldiers (Table 1). The before and after training scale items showed good reliability. The Crohnbach α for the 4 stigma items on before training and after training were 0.942 and 0.959 respectively. The data was analyzed by means of principal component analysis. All 4 stigma items loaded onto a single component with an eigenvalue of greater than 1.0; the scree plot also indicated only a single component, explaining 85.18% of the variance.

Results indicated significant reduction in stigma scores following the guest speaker training. A paired-samples t test showed the difference between before and after training was significant with a small effect size ($t = 8.128$, $df = 329$, $P < .001$, 2-tailed, $d = 0.3$). The baseline level of stigma scores had significant effect on the effect size. Analysis revealed scores for lower quartile population (lowest baseline stigma scores) were not significantly

different. Whereas in the top quartile population (highest baseline stigma scores), a paired *t* test showed that the difference between before and after training was significant and the effect size was large (t=7.825, df=76, P<.001, 2-tailed, d=1.17). Paired *t* tests of each individual item on the scale also showed significant reduction in stigma scores (Table 2).

Evaluation showed that a majority of Soldiers (76%) perceived that the training event increased their likelihood of encouraging other struggling Soldiers to seek mental health services. Results also showed 67% of participants reported increased likelihood of demonstrating greater empathy for Soldiers who are receiving mental health services. Finally, results found 43% of participants reported they would be more likely to seek mental health service for personal needs in the near future.

Table 1. Demographics of survey respondents (N=361).

		Respondents	%n
Age (years) (n=343[a])	18-20	65	19.0
	21-25	145	42.3
	26-35	102	29.7
	36-45	30	8.8
	46 and older	1	0.3
Rank[b] (n=344[a])	E1-E4	228	66.3
	E5-E6	88	25.6
	E7-E9	9	2.6
	O1-O3	12	3.5
	O4-O10	3	0.9
	WO1-WO5	4	1.2

[a] The total of respondents for each category (Age, n=343; Rank, n=344) does not equal the number of surveys returned (N=361) due to no selections in these areas by some respondents.

[b] Military rank structure:
E1-E4, lower enlisted ranks
E5-E6, junior noncommissioned officers
E7-E9, senior noncommisioned officers
O1-O3, company grade commissioned officers
O4-O10, field grade and general officers
WO1-WO5, warrant officers

Table 2. Stigma scores before and after guest speaker anti-stigma presentation.

Stigma Item	N[a]	Mean	SD	SE (mean)	*t*	Significance (2-tailed)	Effect Size
Members of my unit might have less confidence in me.					5.284	*P*<.001	0.23
Before Training	343	2.21	1.478	0.08			
After Training	343	1.89	1.29	0.07			
Unit leadership might treat me differently.					7.635	*P*<.001	0.31
Before Training	346	2.3	1.491	0.08			
After Training	346	1.88	1.253	0.067			
I would be seen as weak.					6.02	*P*<.001	0.26
Before Training	342	2.24	1.515	0.082			
After Training	342	1.88	1.28	0.069			
It would harm my career.					6.985	*P*<.001	0.32
Before Training	340	2.3	1.518	0.082			
After Training	340	1.86	1.27	0.069			
Total Scores					8.128	*P*<.001	0.3
Before Training	330	2.248	1.397	0.077			
After Training	330	1.86	1.197	0.066			
Lower Quartile Baseline Stigma					-1.902	*P*=.059	0.3
Before Training	139	1	0	0			
After Training	139	1.0414	0.256	0.0218			
Upper Quartile Baseline Stigma					7.825	*P*<.001	1.17
Before Training	77	4.377	0.583	0.066			
After Training	77	3.334	1.195	0.136			

[a] N values presented for a given Stigma Item correspond to the number of responses completed for that item from surveys returned and do not equal the total of returned surveys (361).

The audience reported higher level of overall satisfaction with the presentation of guest speaker A (M=4.53, SD=0.850, t(2)=99.0, P<.001) when compared to guest speaker B (M=4.16, SD=1.049, t(2)=73.23, P<.001).

Act Phase

Results of the training outcomes were reviewed with commanders. Feedback showed that the duration of the event was too long. The audience recommended only one guest speaker. As a result, the video of the event was edited and only the presentation by guest speaker A was disseminated throughout the division, given that he received higher satisfaction scores when compared to guest speaker B. The unit intends to use the video in future training events.

Comment

Military units nest various types of prevention and intervention to directly or indirectly reduce the rate of suicide and associated negative outcomes such as failed suicide attempts and untreated mental illness. An important pillar of these efforts is timely and effective access to mental health services. The US Army has expended significant resources to this end.[5] However, stigma and perceived barriers to mental health continue to be a challenge despite the reported overall reduction.[6] The US Army has developed specific training materials for areas such as suicide awareness and education under the Ask, Care, Escort curriculum. It also relies on commercial products such as Applied Suicide Intervention Skills Training for its primary and secondary gatekeepers. However, no specific instructional anti-stigma materials existed at the time of the event.

The meta-analysis by Corrigan et al[12] identifies social contact as the approach with greatest potential for reducing stigma. We designed our anti-stigma training informed by these concepts. The effect sizes reported by Corrigan et al are large (Cohen's $d=0.63$). Our results showed Cohen's $d=0.3$, a smaller effect size; however, when we compared Soldiers in the upper quartile of baseline stigma scores versus the lowest quartile, data showed a large effect size ($d=1.17$) for those in the upper quartile. What this suggests is that targeted intervention in a group of Soldiers with higher baseline stigma is of higher value than intervening universally. Number needed to treat in other prevention programs tend to be much lower for targeted prevention when compared to universal prevention.[18,19] This highlights the need for units to conduct behavioral needs surveys and do targeted prevention and interventions whenever possible to obtain better effect sizes. Our results support the use of the 4-item stigma survey[15] with excellent reliability and construct validity in this population.

While the observations from our intervention are supportive of guest speaker events in a military unit, a number of questions still remain which highlight the limitations of our current understandings. First, these observations are from a QI to help develop training curriculum and not a formal research trial. The stigma outcomes were measured immediately following the event. It is unclear what happens to these reported changed attitudes and beliefs over time. Stigma tends to be higher among persons with greater psychiatric symptoms.[7] We did not measure psychiatric symptoms among our audience which would have allowed for assessing differences in response among those with high versus low psychiatric symptoms. The audience reported positive and productive perceived behaviors but it is unclear to what extent this translates to enacted behaviors. Interestingly, more participants reported positive perceived behaviors towards helping others to seek help as opposed to their own future help-seeking behaviors.

Additionally, there were 2 guest speakers, with guest speaker A receiving higher level of audience satisfaction compared to guest speaker B. It is unclear whether the positive outcomes resulted from collective contact with both speakers, or from unequal proportions with one speaker contributing greater effect to the results noted. Although we intended the intervention to predominantly affect the audience through social contact theory, there were other components of anti-stigma theory which were incorporated into the event including awareness and advocacy. It is unclear which training content and delivery yields the greatest effect and feasibility for future military training events.

This training event only reached approximately 10% of the unit members. Based on the small effect size in this universal intervention design, it is unclear whether this is clinically relevant at the population level. Lastly, our audience was predominantly infantry and it is unclear if occupational specialty correlates with response to anti-stigma interventions. We intend to provide video recordings of the event to the remaining Soldiers in the unit, although video-based interventions tend to be less effective than in-person interventions.[12] The effect of using videos from such events is currently not known.

Recently, there was a report of training designed to increase support toward military personnel with mental health problems.[20] The strengths of the study are using implicit association testing and both immediate and 3-month follow-up. However, given the academic nature of this particular study, external validity of the training and accessibility for a typical commander in the field is unclear. More research is needed in the area of anti-stigma intervention, both in the general population and the military. This includes a more systematic evaluation of various educational content including head-to-head comparisons to identify the best approach for reducing stigma among military service members.

Despite these limitations and the QI nature of our observations, our findings highlight a potential simple and inexpensive intervention that is unobtrusive and reached approximately 1,400 Soldiers very quickly. A targeted approach would have likely yielded better results with greater effect sizes. Future interventions should be unobtrusive to unit training schedules, inexpensive, reproducible, accessible and easily implemented in large populations in military organizations.

Conclusion

Guest speakers willing to self-disclose their mental illness and help-seeking behaviors appear to reduce immediate stigma scores among a large audience of active duty Soldiers. This type of event also appears to improve perceived attitudes and beliefs about help-seeking behaviors and increase empathy towards the stigmatized group.

References

1. Armed Forces Health Surveillance Center. Causes of medical evacuations from Operations Iraqi Freedom (OIF), New Dawn (OND) and Enduring Freedom (OEF), active and reserve components, US Armed Forces, October 2001-September 2010. *MSMR*. 2011;18(2):2-7.

2. Nock MK, Dempsey CL, Aliaga PA, et al. Psychological autopsy study comparing suicide decedents, suicide ideators, and propensity score matched controls: results from the study to assess risk and resilience in service members (Army STARRS). *Psychol Med*. 2017;47(15):2663-2674. doi:10.1017/S0033291717001179.

3. Armed Forces Health Surveillance Center. Surveillance snapshot: Manner and cause of death, active component, US Armed Forces, 1998-2013. *MSMR*. 2014;21(10):21.

4. Lazar SG. The mental health needs of military service members and veterans. *Psychodyn Psychiatry*. 2014;42(3):459-478. doi:10.1521/pdps.2014.42.3.459.

5. Hoge CW, Ivany CG, Brusher EA, et al. Transformation of mental health care for U.S. Soldiers and Families during the Iraq and Afghanistan wars: where science and politics intersect. *Am J Psychiatry*. 2016;173(4):334-343. doi:10.1176/appi.ajp.2015.15040553.

6. Quartana PJ, Wilk JE, Thomas JL, et al. Trends in mental health services utilization and stigma in U.S. soldiers from 2002 to 2011. *Am J Public Health*. 2014;104(9):1671-1679. doi:10.2105/AJPH.2014.301971.

7. Hoge CW, Castro CA, Messer SC, McGurk D, Cotting DI, Koffman RL. Combat duty in Iraq and Afghanistan, mental health problems, and barriers to care. *N Engl J Med*. 2004;351(1):13-22. doi:10.1056/NEJMoa040603

8. Clement S, Schauman O, Graham T, et al. What is the impact of mental health-related stigma on help-seeking? A systematic review of quantitative and qualitative studies. *Psychol Med*. 2015;45(1):11-27. doi:10.1017/S0033291714000129

9. Dunt D. *Review of Mental Health Care in the ADF and Transition through Discharge*. Canberra, AU: Australia Department of Defence; 2009. Available at: https://trove.nla.gov.au/version/49038606. Accessed November 20, 2018.

10. Hurtado SL, Simon-Arndt CM, McAnany J, Crain JA. Acceptability of mental health stigma-reduction training and initial effects on awareness among military personnel. *SpringerPlus*. 2015;4:606. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4628072/. Accessed November 20, 2018.

11. Stuart H. Reducing the stigma of mental illness. *Glob Ment Health* (Camb). 2016;3:e17. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5314742/. Accessed November 20, 2018.

12. Corrigan PW, Morris SB, Michaels PJ, Rafacz JD, Rüsch N. Challenging the public stigma of mental illness: a meta-analysis of outcome studies. *Psychiatr Serv*. 2012;63(10):963-973. doi:10.1176/appi.ps.201100529.

13. Department of the Army. *Pamphlet 600-24 Health Promotion, Risk Reduction, and Suicide Prevention*. Washington, DC: US Department of the Army; 2015:9. Available at: https://www.army.mil/e2/downloads/rv7/r2/policydocs/p600_24.pdf. Accessed February 21, 2018.

14. Wright KM, Cabrera OA, Bliese PD, Adler AB, Hoge CW, Castro CA. Stigma and barriers to care in soldiers postcombat. *Psychol Serv*. 2009;6(2):108-116. Available at: https://www.researchgate.net/publication/232506970_Stigma_and_Barriers_to_Care_in_Soldiers_Postcombat. Accessed November 20, 2018.

15. Britt TW. The stigma of psychological problems in a work environment: evidence from the screening of service members returning from Bosnia. *J Appl Soc Psychol*. 2000;30(8):1599-1618. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1559-1816.2000.tb02457.x. Accessed November 20, 2018.

16. Gehlbach H, Brinkworth ME. Measure twice, cut down error: A process for enhancing the validity of survey scales. *Rev Gen Psychol*. 2011;15(4):380-387. doi:10.1037/a0025704

17. Anderson, C. How to Give a Killer Presentation. *Harvard Business Review*. June 2013. Available at: https://hbr.org/2013/06/how-to-give-a-killer-presentation. Accessed February 22, 2018.

18. Baigent C, Blackwell L, Collins R, et al, for the Antithrombotic Trialists' (ATT) Collaboration. Aspirin in the primary and secondary prevention of vascular disease: collaborative meta-analysis of individual participant data from randomised trials. *Lancet*. 2009;373(9678):1849-1860. doi:10.1016/S0140-6736(09)60503-1.

19. Antithrombotic Trialists' Collaboration. Collaborative meta-analysis of randomised trials of antiplatelet therapy for prevention of death, myocardial infarction, and stroke in high risk patients. *BMJ*. 2002;324(7329):71-86.

20. Britt TW, Black KJ, Cheung JH, Pury CLS, Zinzow HM. Unit training to increase support for military personnel with mental health problems. *Work Stress*. 2018;32(3):281-296. doi:10.1080/02678373.2018.1445671.

Authors

MAJ Amin is Chief, Addictions Residential Treatment Facility, Fort Belvoir Community Hospital, Fort Belvoir, Virginia.

CPT McLeroy is an internal medicine/psychiatry resident at Walter Reed National Medical Medical Center, Bethesda, Maryland.

MAJ Johnson is Behavioral Health Officer, 3 Brigade Combat Team, 82nd Airborne Division, Fort Bragg, North Carolina.

Lessons Learned: Military Screening for Posttraumatic Stress Disorder

Tiffany L. Schweitzer, PhD, MHA, RT(R)
Earla J. White, PhD, MEd, RHIA
Ronald P. Hudak, JD, PhD

ABSTRACT

The purpose of this study was to assist military communities of interest to more accurately identify service members who may have emotional and behavior disorders. Specifically, this study identifies service members' perceptions of the Department of Defense Post-Deployment Health Reassessment (PDHRA) screening instrument for posttraumatic stress disorder (PTSD). Findings were that responses to the PDHRA were related to how it was administered and the respondents' perceptions of how the PTSD diagnosis could affect the ability to obtain jobs and obtain promotions. Recommendations include implementing a screening environment free of distractions, involving family members, and assuring a confidential PTSD diagnosis.

The purpose of this study was to assist military communities to more accurately identify service members who may have emotional and behavior disorders. Specifically, this study identified respondents' perceptions of a screening process for posttraumatic stress disorder (PTSD).

Psychological injuries of warfare include PTSD, a highly comorbid condition associated with increased suicide risk among military and veteran populations.[1] Veterans often report mental anguish, guilt, and disconcerting thoughts about actions taken during war.[2] The Department of Defense (DoD) Post-Deployment Health Reassessment (PDHRA) is required for all members of the Marine Corps (hereinafter referred to as Marines) to identify any health consequences from deployment.[3] As discussed by Wisco et al,[4] effective screening tools are integral to the diagnosis and treatments for PTSD. Findings from a study by Aralis et al[5] were indicative of the PDHRA producing an underestimated prevalence of postdeployment health concerns.

Marines displayed increased symptoms of PTSD after experiencing combat deployments.[2] Symptoms of PTSD were common occurrences for service members returning from Operations Iraqi Freedom and Enduring Freedom.[6] In addition, Aralis et al[5] found that redeployment as well as prolonged combat exposure and engagement have placed Marines at an increased risk for developing signs and symptoms of PTSD.

Veterans have experienced difficulty with self-efficacy and the meaning of life with PTSD and depression. A study by Blackburn and Owens[7] indicates that an understanding of self-efficacy can help with overcoming stressful situations resulting from PTSD. Bush et al[8] found that self-monitoring and reporting of mood through mobile applications has helped to increase awareness of symptoms among military personnel experiencing PTSD.

The culture of the Marines embodies standards of honor and fortitude. Marines must always be physically prepared to perform their military tasks.[9] Difficulty in maintaining this standard can cause stress and unwanted anxiety among Marines. According to Hart,[10] this Marine standard conflicts with the associated stigma of debilitating PTSD symptoms such as depression and suicidal ideation.

Comprehensive screening can help inform treatment planning.[2] Veterans have delayed and avoided seeking treatment for PTSD symptoms because of self-stigma and social stigma associated with PTSD. Likewise, public stereotypes of PTSD have dissuaded some service members from seeking help.[11] In addition, PTSD diagnoses may be missed if Marines taking the PDHRA are not forthright in their responses because they fear the stigma and ramifications of being identified with PTSD.[5]

Research about Marine veterans' perceptions of the PDHRA screening process is limited or missing from the literature. Exploration of Marines' perceptions in this area may assist the DoD and health professionals to develop a screening tool that results in accurate diagnoses, effective treatment, and less stigma. The purpose of this study was to identify postdeployment Marine veterans' perceptions of the DoD PDHRA screening process for PTSD.

Method

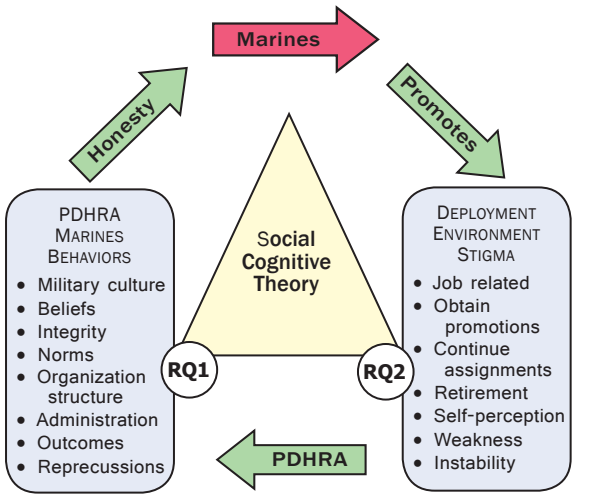
We conducted a qualitative phenomenological study by interviewing postdeployment Marine veterans who resided in a community near the Marine Corps Recruit Depot Parris Island, South Carolina. The study was guided by 2 research questions (RQ):

- RQ1: What are the perceptions of Marines about the PTSD screening process?
- RQ2: How does the potential stigma surrounding PTSD hinder the decision of Marines to report PTSD symptoms while completing the PDHRA?

Bandura's social cognitive theory (SCT), which captures a triadic relationship among person, environment, and behavior, served as the theoretical framework to ground the study.[12] A pilot study with 2 Marines validated 13 open-ended interview questions developed from the 2 research questions. Next, a convenience-based sample of 10 participants developed from Marines who volunteered after seeing a solicitation flyer in the local Veterans of Foreign Wars hall. Flyers were distributed to Marines who met the inclusion criteria of postdeployment Marine male veterans who experienced the PDHRA and spoke English. The interviews were conducted face-to-face on an individual basis in a private library setting.

Results

Study findings were incorporated in the SCT framework of personal factors, environmental factors, and behavioral factors, as shown in the Figure. The personal factors related to interpersonal characteristics included age, rank, number of years in the military, the number of times deployed, and references to family life. The environmental factors related to external factors included deployment and experiences during deployment. The behavioral factors referred to PTSD-related behaviors and symptoms.



Study findings were incorporated in the SCT framework of personal factors, environmental factors, and behavioral factors.

Interview Questions and Responses

The 13 interview questions (IQs) aligned with the research questions in order to address Marines' perceptions and responses to the PDHRA process for PTSD. Each of the 10 Marines (n=10) answered all of the questions.

Research Question 1

To answer the first research question, "what are the perceptions of Marines about the PTSD screening process?", the SCT aligned with IQ1 through IQ7 and explored areas of behavior, environment, and Marine participant perceptions.

Specifically, IQ1 through IQ5 allowed for investigation into the characteristics of each Marine along with his rank, age, gender, years of service, and number of deployments outside the United States, presented as demographic data in the Table.

Interview question 6 examined each Marine's experience with taking the PDHRA. Eight participants felt it was a waste of time, another 3 thought it was helpful for future junior Marines, and 3 felt the PDHRA was not anonymous.

Interview question 7 explored any difficulties the Marines experience with taking the PDHRA. Six Marines reported the assessment questions were clear. Seven Marines felt the assessment questions were redundant, and all 10 Marines felt the assessment was too long and time-consuming.

Research Question 2

The second research question, "how does the potential stigma surrounding PTSD hinder the decision of Marines to report PTSD symptoms while completing the PDHRA?", was addressed by IQ8 through IQ13. Interview question 8 examined sections of the PDHRA for which the Marine might not be forthcoming with honest answers. Eight of the Marines reported that they might not be forthcoming in responding to questions about alcohol and drug use. Nine Marines indicated they would not reply honestly to questions about having trouble falling asleep or staying asleep. Seven Marines would not admit to having reported disturbing dreams. Finally, 6 Marines would not admit to feeling bad about themselves.

Interview question 9 examined factors that might adversely affect the Marine's future status after completing the PDHRA. Eight Marines reported that there may be a stigma attached to them. All 10 Marines felt that promotion might be negatively affected. Six Marines felt that favorable assignments might be at risk. Finally, 9 Marines felt that they would not be able to complete a 20-year career into retirement.

Demographic characteristics of participants.

Participant	Rank	Age	Gender	Years of Service	Number of Deployments
Participant 1	First Sergeant	41	Male	22	1
Participant 2	Chief Warrant Officer 3	43	Male	25	4
Participant 3	Major	42	Male	20	3
Participant 4	Major	44	Male	24	6
Participant 5	Chief Warrant Officer 4	52	Male	22	7
Participant 6	Chief Warrant Officer 2	48	Male	20	5
Participant 7	Gunnery Sergeant	56	Male	20	2
Participant 8	Staff Sergeant	38	Male	18	5
Participant 9	Staff Sergeant	36	Male	16	2
Participant 10	Staff Sergeant	47	Male	20	5

Interview question 10 examined reasons why the Marines felt uncomfortable with taking the assessment. All 10 Marines reported that the assessment was administered in an inappropriate environment because other individuals were in the room. While taking the assessment, 8 Marines were conscious of the possibility of repercussions after completing the assessment. For example, 8 Marines were concerned about being referred to a medical evaluation. Six Marines questioned the value of the assessment. All 10 participants were aware they may be perceived as weak after the assessment was evaluated.

Interview question 11 examined negative stigma that may be attached to PTSD within the Marine Corps. Six of the Marines reported that PTSD does influence job-related issues. Eight Marines felt that a PTSD diagnosis would lower their self-perception.

Interview question 12 was designed to confirm responses to IQ9 and IQ10 regarding the effect of negative stigma on Marines' answers on the assessment. Responses to IQ12 confirmed that all 10 Marines believed that a negative stigma is attached to PTSD and taking the PDHRA.

Interview question 13 was the last question and was the foundation for our recommendations because it explored ways that may assist the Marines to be honest while answering the questions on the PDHRA. For example, 9 Marines reported that the assessment environment should be changed. All 10 Marines wanted to ensure anonymity was maintained. All 10 also wanted to remove the repercussions associated with responses that indicate PTSD symptoms, especially those related to career (military and postmilitary) and use the results to provide help to Marines. Finally, 3 Marines want to involve the family when possible.

Perceptions of Stigma Attached to PTSD

A number of themes emerged from the data regarding the Marines' perceptions of PTSD and attached stigma. These themes were military culture, repercussions, and career. Within these themes were the following subthemes: beliefs, customs, norms, rules, structure, integrity, concerns, impacts, and professional growth.

Military culture refers to military beliefs, customs, norms, rules, and organizational structure that affect perceptions of PTSD and may influence the integrity of assessment responses. Repercussions refer to an awareness or concern about consequences for Marines that may occur from the PDHRA assessment results. The repercussions might range from being barred from carrying a weapon to loss of security clearance. Career refers to perceived effects of PTSD diagnosis or assessment responses on a respondent's career (remaining in service, promotion, and retirement) or ability to perform job-related tasks.

Military culture and privacy appeared to be an important part of the experiences of Marines. This was evident by a participant's statement:

> I think surveys are just a check in the box, but, if you have to sit down with a healthcare worker, it will be easy to tie a connection. The healthcare worker should understand what the unit went through on deployment and the healthcare worker will get a better idea if the Marine is answering the questions truthfully or not. Put an individual in a private atmosphere where they feel comfortable and not sitting behind a computer punching several buttons in a classroom setting. I would suggest taking the PDHRA in the home, but the majority of Marines that experience this sort of stuff live in the barracks. Therefore, home to that young man or woman is many miles away from where they live. Home in their mind is where the Marine comes from a year or two years ago rather than where they are at now.

Another example was the belief that Marines needed to be tough and should not display weakness or admit to needing help for current alcohol issues. This was evident in a participant's statement:

> We know there are consequences if we disclose that we drink more than a couple glasses of alcohol. The administration denies this, but they send Marines to medical for alcohol treatment if they disclose drinking more than a couple of drinks per week. Also, if they do not complete the treatment it will result in termination from the Marine Corps. Marines should understand the benefit of answering this question honestly. I would suggest revising the PDHRA and promote its importance and benefits to ensure Marines are getting the best care possible.

This theme is also evident in another participant's statement:

> Most people are worried about their careers and promotion so they are going to lie on the PDHRA. After Marines put in retirement papers they can tell the truth and not face being portrayed weak from fellow Marines.

Repercussion was an important theme as well. The evidence was seen when a participant stated:

> I would not answer the night sweats question on the PDHRA truthfully in fear of repercussions such as my weapon being taken away and security clearance being revoked if I answered I experienced night sweats.

Another participant's statement exposed the theme of career:

> Most people are worried about their careers and if you have been in 10 or 15 years, you know you are still looking at getting promoted. You are still worried about your career and you are going to lie. Most Marines say that when you put in the retirement papers is when they start going to the doctor and telling the truth because they know the need for additional medical benefits after retiring.

One Marine expressed that he was honest on the PDHRA because he wanted to help others that assumed his role. He gave in-depth detail about his night terrors and waking up holding his wife in a choke hold position. The experiences led to sleeping on the couch for 2 years. Sleeping on the couch was not because of a lack of love for his wife and the desire to sleep with her, but to protect his wife from his involuntary actions that occurred as the result of PTSD.

Comment

This study's findings are suggestive of the need for changing perceptions of PTSD among Marines and developing revisions for an effective PTSD screening. The findings were validated through the Marines' answers to this study's research questions. Marine participants in this study reported that administration, outcomes, questions, and repercussions are all related to the PDHRA and the promotion of an effective PTSD assessment.

The participants reported that attached stigma resulting from the diagnosis of PTSD could affect the ability to obtain or continue assignments, complete a job, obtain promotions, and retire. Likewise, the self-perception of the attached stigma affected how the Marines viewed themselves and how other individuals or Marines may see them as weak or mentally unstable.

The first recommendation was to validate these findings with surveys of participants with different demographic characteristics. This includes exploring female and younger, more diverse Marines. In addition, surveys should be also conducted at the Marine Corps Recruit Depot, San Diego, to determine whether there are differences based on location and command climate.

The second recommendation was to ensure that the diagnosis of PTSD remains private throughout their diagnosis and treatment, as noted by the participants. The Marines suggested not informing their superiors and others of their diagnosis and to ensure that access to a Marine's PTSD diagnosis was only authorized for healthcare providers. The Marines felt that if superiors knew their diagnosis, they would be treated differently.

The third recommendation was to implement changes to the environment in which the Marines take the assessment. Specifically, instead of a room full of Marines and computers, the assessment should occur in a private setting with no distractions or having a feeling of being rushed to return to their duties. Also, they should be assured that no one within their chain of command was present.

The fourth recommendation was to involve family members when taking the PTSD assessment. At times, Marines may not reveal or even realize their behaviors are abnormal. A family member can speak to the actions and uncover behaviors that normally are not presented if the Marine took the assessment privately.

The fifth recommendation was to remove adverse repercussions after the Marines' responses indicate PTSD symptoms. These repercussions relate to the Marines' careers in the military and postmilitary jobs. Eliminating repercussions should allow the Marine to answer the questions more honestly. This will alleviate concerns of the Marines for such matters as fearing the loss of access to assigned weapons, not being selected for promotion, or missing duty by having to attend numerous medical appointments. The eliminated repercussions should allow the Marines to take the assessment with an open mind and not fear adverse consequences for their answers.

The final recommendation was to ensure that it is evident to each Marine that the PDHRA will contribute to helping other Marines. The Marines suggested that there should not be a perception that the PDHRA is simply one component of the process to push them through the assessment system. Instead, they wish to ensure that their answers will aid others with the same issues. In addition, Marines recommend healthcare providers look at the bigger picture, see that Marines' lives matter, provide them with positive reinforcement, and not take away what makes them a Marine.

Conclusion

The findings of this study should assist military healthcare providers in the more accurate identification of individuals who may have emotional and behavior disorders by taking into account an individual's perceptions of a screening process for PTSD. Specifically, this study contributes to the understanding of how Marines perceive and respond to the PDHRA. Findings of this study are indicative that PTSD and associated stigma have a significant effect on the personal and professional lives of the Marines. Equally noteworthy was that the Marines indicated that they were not forthcoming with their answers on the PDHRA. The first research question revealed Marines' concerns for administration, outcomes, questions, and repercussions. The second research question revealed Marines' concerns for career, job-related issues, self-perceptions, personal factors, and military culture.

The Marines' responses to their experiences may contribute to revised diagnostic instruments with which healthcare providers can more definitively recognize PTSD earlier and provide treatment based on accurate responses to the PDHRA. Thus, these results may give insight on how to assess Marines who may have PTSD and to expedite treatment and services to optimize their personal, interpersonal, and professional well-being.

References

1. Institute of Medicine. Treatment for posttraumatic stress disorder in military and veteran populations' final assessment. Report Brief June 2014. Available at: http://www.nationalacademies.org/hmd/~/media/Files/Report%20Files/2014/PTSD-II/PTSD-II-RB.pdf. Accessed February 10, 2018.
2. US Department of Veterans Affairs. Treatment of PTSD. National Center for PTSD web page. 2018. Available at: https://www.ptsd.va.gov/understand_tx/tx_basics.asp. Accessed December 4, 2018.
3. Execution guidance for required deployment health assessments. Official U.S. Marine Corps Website. May 12, 2011. Available at: https://www.marines.mil/News/Messages/Messages-Display/Article/888176/execution-guidance-for-required-deployment-health-assessments/. Accessed February 18, 2018.
4. Wisco B, Marx B, Keane T. Screening, diagnosis, and treatment of post-traumatic stress disorder. *Mil Med*. 2012;177(suppl 8):7-13. doi:10.7205/MILMED-D-12-00111.
5. Aralis HJ, Macera CA, Rauh MJ, Macgregor AJ. Traumatic brain injury and PTSD screening efforts evaluated using latent class analysis. *Rehabilitation Psychology,* 2014;59(1):68-78. doi:10.1037/a0035263.
6. Macera C, Aralis H, Rauh M, MacGregor AJ. Do sleep problems mediate the relationship between traumatic brain injury and development of mental health symptoms after deployment?. *Sleep*. 2013;36(1):83-90. doi:10.5665/sleep.2306.
7. Blackburn L, Owens G. The effect of self-efficacy and meaning in life on posttraumatic stress disorder and depression severity among veterans. *J Clin Psychol*. 2015;71(3):219-228. doi:10.1002/jclp.22133.
8. Bush N, Ouellette G, Kinn J. Utility of T2 mood tracker mobile application among Army warrior transition unit service members. *Mil Med*. 2014;179(12):1453-1457. doi:10.7205/MILMED-D-14-00271.
9. Bartlett JL, Phillips J, Galarneau MR. A descriptive study of the U.S. Marine Corps fitness tests (2000–2012). *Mil Med*. 2015;180(5):513-517. doi:10.7205/MILMED-D-14-00490.
10. Hart N. Veterans battling PTSD: know the triggers, recognize the symptoms. *N C Med J*. 2015;76(5):308-309. doi:10.18043/ncm.76.5.308.
11. Mittal D, Drummond KL, Blevins D, Curran G, Corrigan P, Sullivan G. Stigma associated with PTSD: perceptions of treatment seeking combat veterans. *Psychiatr Rehabil J*. 2013;36(2):86-92. doi:10.1037/h0094976.
12. Oppong S. Between Bandura and Giddens: structuration theory in social psychological research?. *Psychol Thought*. 2014;7(2):111-123. doi:10.5964/psyct.v7i2.104.

Authors

Dr Schweitzer is with the Walden University School of Health Services, Minneapolis, Minnesota.

Dr White is with the Department of Public Health, A. T. Still University School of Osteopathic Medicine in Arizona, Mesa, Arizona.

Dr Hudak is with the United States Defense Health Agency, Falls Church, Virginia.

Military Medicine Implements In-home Virtual Health in Europe

Steven M. Cain, MPAS, PA-C
LTC Robert J. Cornfeld, MC, USA
COL Kirk H. Waibel, MC, USA
Kendra L. Jorgensen-Wagers, PhD
Ronald S. Keen, RN
Capt Jennifer N. Brown, USAF, RD
Hunter A. Hearn, MD
Ashley L. Jack, PA-C
Irma Black
Edwin Ortiz-Rosado

Abstract

Objective: This report outlines a multispecialty implementation effort which included 12 specialty practices and 28 clinicians within Regional Health Command Europe (RHCE) and Landstuhl Regional Medical Center (LRMC) to pilot an in-home virtual health (VH) program using existing resources.

Methods and Materials: Synchronous VH encounters were performed using an Acano desktop conferencing client (Cisco Systems, Inc, San Jose, CA) and a USB web camera at the provider (distant) site and the patient's own computer or device in the home. A web real-time conferencing (Web RTC) server provided the connections.

Results: Between October 2016 and May 2018, 310 synchronous VH appointments to patients' homes in 23 geographic locations in 9 countries on 3 different continents were completed; 28 skill type I and II specialty providers at LRMC, SHAPE Belgium Army Health Clinic (AHC), and Vilseck AHC, Germany Primary Care Clinic participated. The providers represented 9 distinct specialties and primary care. Appointment types were as follows: 85 (39%) follow-up type appointments; 70 (32%) group type appointments; 65 (30%) initial specialty care appointments. The 3 most active clinics were Pediatric Gastroenterology with 88 (28%), the Nutrition Clinic with 82 (26%), and the Traumatic Brain Injury Clinic with 63 (20%) encounters. Full audio and video connectivity rate was 97%, excluding reconnects after dropped calls which occasionally occurred. Patient satisfaction scores were high 16/17 (94%) with 5% of patients surveyed.

Conclusion: Low complexity synchronous VH appointments were successfully accomplished across a broad spectrum of health care services and appointment types. Landstuhl RMC specialists received consults from sites across a vast geographic area including Europe, the Middle East, and Africa. An in-home VH option gives providers a special tool to extend services far beyond traditional boundaries. This pilot project helped RHCE and LRMC providers gain valuable experience extending care to the home and will provide foundational knowledge for future VH efforts targeting groups and outcomes.

Background

In April 2016, the Army Surgeon General signed Operation Order 16-50 (Telehealth to the Patients Location).[1] This operation order outlined in broad terms the implementation of a 3-year enterprise virtual health effort to provide a platform for Army providers to reach beneficiaries wherever they may be. The "home" became an authorized "originating site" or place to deliver care. It was made clear that acquisition and implementation would be accomplished centrally through the Military Health System (MHS). However, the operation order did allow Army regions to pilot in-home programs with Army Medical Command (MEDCOM) approval.

Subsequent to the issuance of Operation Order 16-50, the FY17 National Defense Authorization Act (NDAA)[2] was signed into law on December 23, 2016. For the first time, NDAA legislation contained language about military virtual health services, including guidance to gather information from the MHS about its virtual health service activities, as well as recommendations about what kinds of digital services the MHS should seek to provide. Section 718 of the FY17 NDAA states the MHS should:

> Allow health care providers, through video conference, telephone or tablet applications, or home health monitoring devices—(i) to assess and evaluate disease signs and symptoms; (ii) to diagnose diseases; (iii) to supervise treatments; and (iv) to monitor health outcomes.

The FY17 NDAA language advances the idea that technology should be leveraged to provide some medical services at the patient's location. This progressive statement gives credence to the idea that we need to rethink how we deliver care. Requiring patients to travel to

a fixed facility for every type of encounter is an antiquated model for the delivery of many types of health care services. Additionally, rethinking the standard of care paradigm offers new ideas regarding resourcing of clinical staff and provisioning of clinics which could ultimately result in improved metrics for healthcare utilization and return on investment.

In 2015, Regional Health Command Europe and the Regional VH Group purchased a web real-time conferencing (Web RTC) server to provide conferencing capability. The progressive thought process in choosing a Web RTC server was to provide flexibility for connectivity and to synchronize a variety of VTC signals across the spectrum of generic conferencing needs, as well as to provide a capability for connectivity from outside the military network. Web-based connectivity would be beneficial in connecting to a wide range of groups such as US embassies and remote NATO and other operational units spread across a vast geographic footprint. The Web-RTC server would provide for standard video conferencing functions and allow virtual health activities to "piggy-back" on the server. No new network outlays for connectivity would be required specifically for VH activities. This connectivity arrangement functioned well within the RHCE virtual network connection, providing a bridge for both functions. The one additional outlay needed for VH to be successful is people on the bridge to actively manage calls. Testing and coordinating patients dialing in from their own home computers represented a big challenge to the RHCE VH Team. The RHCE VH Team made the decision in October 2016 to pursue, in expectation of future enterprise VH programs to the patient location, a pilot program to establish an in-home virtual health capability.

Overview

This report outlines a multispecialty in-home virtual health pilot conducted between October 2016 and May 2018. This effort focused on clinicians within the Regional Health Command Europe military health care delivery system. These encounters were with beneficiaries within the direct care system or who were in remote areas where gaps in care existed in the Tricare Network. Virtual health encounters to the homes were to patients in which the specialists had received consultation and for which the reviewer of consults felt there would be some benefit either clinically, logistically, or both. The next group of military beneficiaries examined for in-home care were in the primary care space. At this stage, we chose not to perform acute care assessments via in-home virtual health, focusing rather on routine, stable patient encounters, follow-ups, and group appointments. That said, there are a number of use cases in primary care which could be safely managed in the same manner, and will be part of future efforts. Most of the patients we surveyed also told us that they would like to have visits with their Primary Care doctors.

The chief aim of this effort was to evaluate the in-home modality with a select number of specialties in order to gain knowledge and experience within the RHCE Army medicine community. Based on previous surveys, patient acceptance of VH programs has been very positive.[3,4] The challenge was in coordination of VH care, thoughtfully selecting patients in a safe manner so that all parties including the providers would have clinically relevant and satisfying encounters.

Methods and Equipment

With requisite regulatory approvals in place, the RHCE virtual health team set about organizing select clinics to establish an in-home virtual health capability. The first specialty care clinics which sought approval for in-home VH pilots were Sleep Medicine, Pediatric subspecialties, Nutrition, and Traumatic Brain Injury (TBI) clinics. Others were added later. All of these clinics had robust VH programs and experience within the Army's European VH network connecting outlying clinics with LRMC.

This new process required a change in thinking about the originating site which in traditional VH is a clinical access station which has a nurse running the station with dedicated appointment times. Providing an in-home option for patients meant that the patient would be logging in at a set time in the middle of a busy providers clinic. We employed a tried and true method employed in our Region for new virtual health programs, dividing planning into preappointment activities, day of appointment activities, and post-visit activities. The VH Team met first with individual clinic leaders to develop VH appointing guidelines, review patient safety, consent, and other VH attendant provision of care items. We added VH appointing guidelines and processes as an addendum to their existing VH standard operating procedures.

Encounter types included initial specialty care, follow-up, screenings, and educational class encounters. Landstuhl RMC specialists received consults from a large area of responsibility (AOR). Virtual health to the patient's location would also be used as care coordination tool to gather pertinent information, history, and review of systems to determine if a patient should travel to LRMC. If a VH care coordination visit to the patient's home resulted in the need for travel, coordination of the care prior to travel could be accomplished. This type of encounter is typically a face-to-face verbal exchange of information and usually does not require a physical exam or collection of vital signs.

Additionally, we built a back-up safety plan for the appointing process by making sure the physical address of the patient was in the appointing system and readily available and obvious for the provider at the time of appointment. There exists the theoretical risk of a patient who is alone in their house having a seizure which would mandate that the witnessing doctor, physican assistant (PA), or nurse at the distant end activate the emergency medical system. Procedures were established and taught to clinic support staff.

Synchronous VH encounters were performed using the Acano desktop conferencing system (Cisco Systems, Inc, San Jose, CA) and a USB web camera (web cam) on the provider's (distant) desktop monitor (Figure 1). The patients used their own internet connection in their home and typically used their laptop computer or tablet with an embedded web cam. Connectivity was accomplished using the internet via a secure, actively managed Web RTC connection.

Results

This pilot produced the Army's very first in-home virtual health visit in October 2016 by author R.J.C., a LRMC pediatrician. Between October 2016 and May 2018, 310 synchronous VH appointments to patients' homes were completed by 28 providers representing 12 distinct specialties (Figure 2). These skill type I and II providers were located at Landstuhl Regional Medical Center, SHAPE Belgium Army Health Clinic (AHC), and Vilseck AHC Germany Primary Care Clinic. Appointment types consisted of future or follow-up appointments (41%), group type appointments (36%), and routine encounters (3%). Three clinics accounted for 75% of all visits: the Pediatric Gastroenterology Clinic with 88 (28%) encounters; the Nutrition Medicine Clinic with 82 (26%) encounters; and the TBI Clinic with 63 (20%) encounters. The average number of encounters seen by providers was 11.0. The patient locations mirrored the locations from where LRMC receives consults and represented 18 different geographic locations (Figure 3), the majority being in Germany with others including remote locations such as France, Spain, and locations in Africa and the Middle East. Six (2%) appointments could not be accomplished due to connectivity issues and 2 visits were audio only. This was mostly related to low-bandwidth problems at the originating site. Full audio and video connectivity rate for scheduled visits was 97.5%, excluding reconnects after dropped calls, which occurred occasionally. All patient calls were actively managed by

Figure 1. Author LTC Cornfeld conducts the US Army's first in-home virtual health appointment in October 2016.

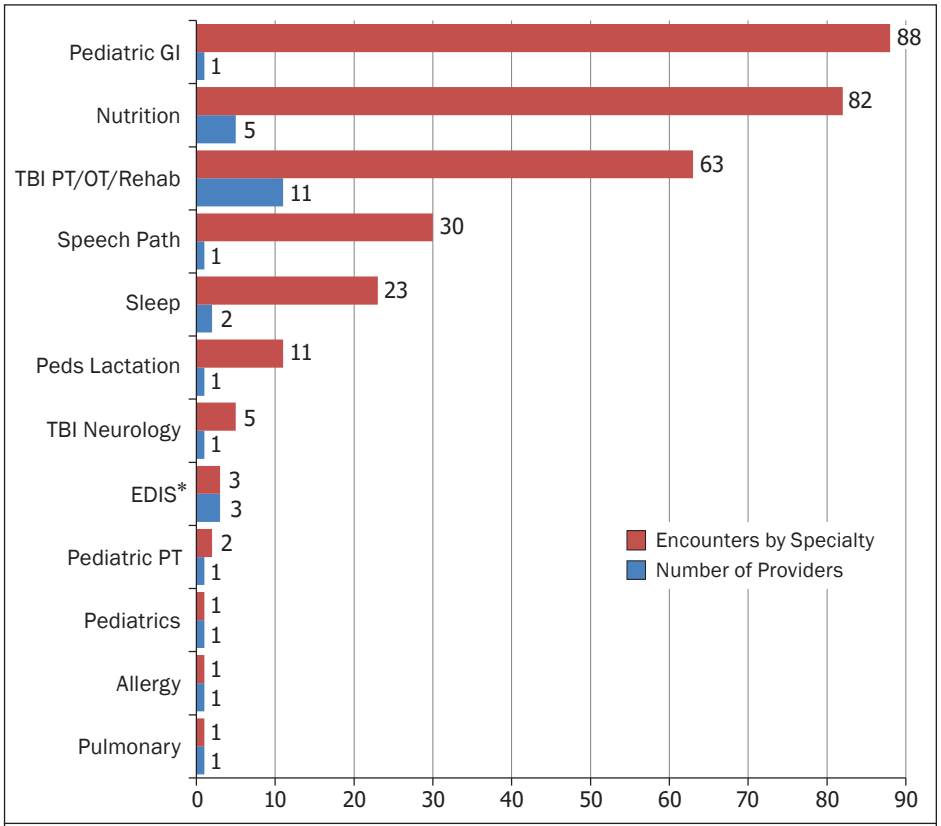


Figure 2. In-home virtual health encounters by specialty and the number of healthcare providers involved. *EDIS indicates Education and Developmental Intervention Services.

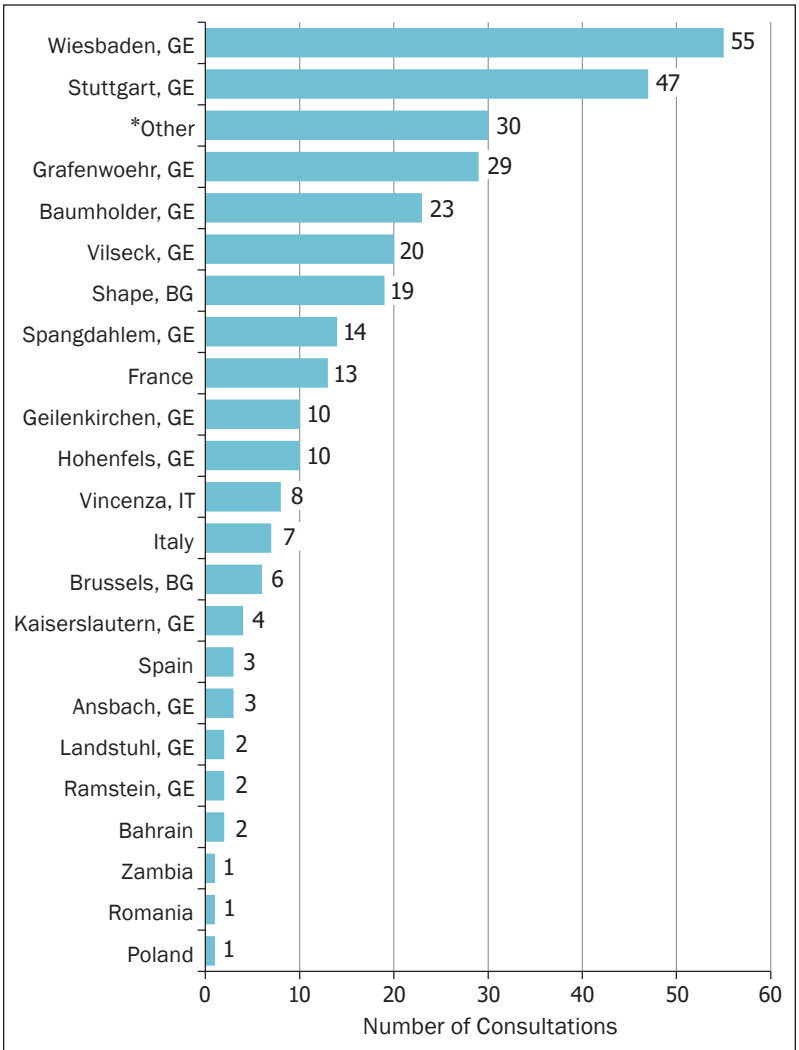


Figure 3. Geographic locations of patients originating in-home virtual health consultations.

RHCE bridge managers by quality checking audio and video with originating and distant sites, and assignment of a unique 4-digit PIN number to create a 2-level log-in security. The VH group conducted a small telephonic survey of 12 patients who had completed in-home visits and asked some simple satisfaction questions based on a 5-point Likert Scale. Patient satisfaction data with care was independently evaluated by the TBI clinic querying 5 patients using the Neuro-Rehabilitation Patient Satisfaction Survey with a 4 question Likert scale. Total number of surveyed patients was 17 (5%).

Of patients surveyed, 16/17 (94%) were satisfied with their in-home visits. All 12 telephonic survey patients agreed or strongly agreed with the statement recommending an in-home visit to other patients. Nine of twelve (75%) respondents answered positively that they would like to have an in-home visits with their primary care provider. Regarding whether the "the in-home VH appointment was easy to set up," patient responses were somewhat mixed with 25% either neutral or negative.

Comment

This in-home VH Pilot demonstrated that with few resources and the right kind of equipment, an in-home VH program can be implemented in a cost effective manner. Key elements are in place within RHCE which allow innovative VH programs to proliferate. Those key elements include (1) Region and LRMC leadership commitment to VH combined with dedicated staff and providers, (2) a flexible platform with WEB-RTC technology, and (3) a functioning virtual network connection with technical staff dedicated to VH.

The providers themselves decided which patients to see or follow-up, and therefore understood the clinical context in which they were seeing the patients. For some services, this modality provided a method to reach out to a large AOR to collect first-hand clinical information directly from the patient or patient's family. Virtual health to the patient's location provided a stressless way to follow-up with a patient who did not necessarily need another clinic screening or in-person visit to perform a simple, uncomplicated follow-up or participate in a class. Interestingly, not only patients who lived far away participated. Many patients within the hospital's own community elelcted to participate. Several patients who lived within just one or 2 kilometers chose an in-home visit over the stress of dealing with driving, parking, and waiting rooms.

In the case of the TBI Clinic, this new modality was viewed as potentially transformational in terms of a stronger rapid response time from head injury to acute management and treatment. The LRMC TBI Clinic's 11 providers constitute a true multidisciplinary care model. Nearly all providers participated in evaluating in-home VH patients including physical medicine and rehabilitation, occupational therapy, physical therapy, psychology, neuropsychology, 2 primary care providers, (nurse practitioner and PA), and nurse case management. A future research trial validating the use of emerging technology and the telehealth platform is planned for the very near future. Connecting with a patient with a known concussive event in their environment to perform a TBI screening could save significant time and put the patient into

the TBI care and support community faster and more efficiently.

The Web RTC server functioned very well, providing excellent connectivity with a high rate of success over a geographically very broad, multicontinent AOR. According to bridge managers, this rate of connectivity (97%) remains solid as home internet connectivity in European countries for most families demonstrates sufficient requisite upload and download speeds and low latency. The Web RTC server used for this pilot was acquired in 2015 and had undergone Department of Defense (DoD) Information Assurance Certification and Accreditation Process, a risk management assessment certification addressing issues such as cybersecurity with expiration in 2018. However, 4 months into our pilot, Army MEDCOM requested a pause to "outside" dial-ins in order to perform a more current and rigorous certification and accreditation process called risk management framework which certifies DoD information systems that operate on DoD networks. This process required 5 to 6 months between February and July

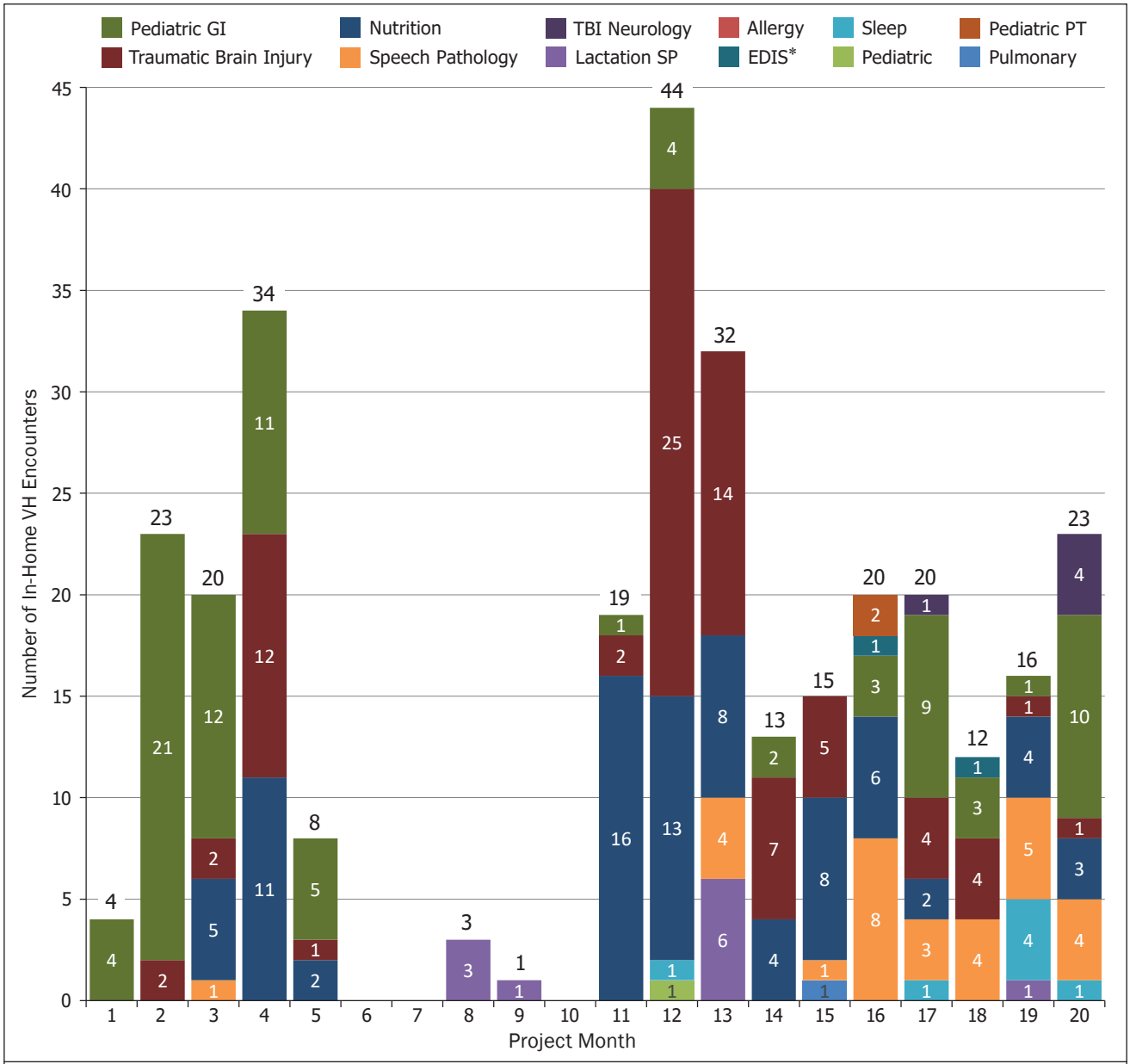


Figure 4. Monthly in-home virtual health encounters during the Regional Health Command Europe pilot project from October 2016 (month 1) through May 2018 (month 20). The reduced encounter activity beginning in month 5 and continuing through month 10 was necessitated by the risk management framework certification and accreditation process required for all DoD information systems operating on DoD networks. *EDIS indicates Education and Developmental Intervention Services.

2017. The downturn in monthly activity is shown in Figure 4 beginning after month 4 (January) and continuing through month 10 (July). Following accreditation of the Web RTC server, the pilot resumed in August 2017 and continues to the present.

Conclusions and Recommendations

Regional Health Command Europe and LRMC providers care for Army, Navy, and Air Force patients and their families across a large AOR, both in garrison and remote and operational settings. The expectation that patients must travel to a clinic or hospital, no matter how far, to see a provider seems an antiquated model for the delivery of care in the 21st century. When thoughtfully employed, in-home VH is a valuable tool to mitigate the cost and expense of travel to and from the medical facility, as well as force multiplier to maintain a ready military force. Patient satisfaction appears to be very high when we bring services to patients in their space and environment. With modest investment in resources using a Web-RTC server as a simple method of connection, a dedicated team of providers are ready to expand in-home care efforts. This initial effort may also serve as a model for other military health systems and regions interested in piloting in-home VH programs. All military beneficiaries can and should have an in-home option for routine, low risk care. Against the backdrop of increasingly "VH literate" communities and culture, expanding in-home VH including primary care and behavioral health with a focus on access, safety, and outcomes should be pursued. The vision is to give providers and patients within our care delivery systems an in-home VH option to augment the already excellent in-person care to improve access and outcomes for the benefit of both patients and healthcare providers.

The DoD should critically assess direct-to-consumer models which still have some lingering quality and cost concerns when treating acute care patients.[5] Antibiotic prescribing rates for VH vs in-person visits, for example, have been shown to be significantly higher for UTI and sinusitis.[6] The ultimate aim is to thoughtfully integrate an in-home VH option as part of the normal care beneficiaries receive. Access to care and patient and provider satisfaction should be closely linked to clinical outcomes. In-home behavioral health (BH) is another area for which stable, low risk patients can benefit. Although behavioral health was not a part of this effort, both clinical effectiveness and economic benefits can be achieved when BH patients possess requisite computing hardware and internet access at home.[7,8]

References

1. US Army Medical Command Operation Order 16-50, Telehealth to the Patient's Location. Fort Sam Houston, Texas: Headquarters, US Army Medical Command. April 2016.
2. Fiscal Year 2017 National Defense Authorization Act (FY17 NDAA). Available at: http://www.dtic.mil/congressional_budget/pdfs/FY2017_pdfs/HASC/HASC_Report-CRPT-114hrpt537.pdf Accessed November 24, 2017.
3. Mair F, Whitten P. Systematic review of studies of patient satisfaction with telemedicine. *BMJ*. 2000;320(7248):1517-1520.
4. Kruse CS, Krowski N, Rodriguez B, Tran L, Vela J, Brooks M. Telehealth and patient satisfaction: a systematic review and narrative analysis. *BMJ Open*. 2017;7(8). doi: 10.1136/bmjopen-2017-016242.
5. Kirkner, RM. Some thumbs up, some down, on telehealth quality of care. *Manag Care*. 2017;26(4):23-25.
6. Ashwood JS, Mehrotra A, Cowling D, Uscher-Pines L. Direct-to-consumer telehealth may increase access to care but does not decrease spending. *Health Aff* (Millwood). 2017;36(3):485-491.
7. Bounthavong M, Pruitt LD, Smolenski DJ, Gahm GA, Bansal A, Hansen RN. Economic evaluation of in-home telehealth compared to in-person treatment delivery for depression. *J Telemed Telecare*. 2018;24(2):84-92.
8. Luxton DD, Pruitt LD, Wagner A, Smolenski DJ, Jenkins-Guarnieri MA, Gahm G. Randomized clinical trial of home-based telebehavioral health treatment of depression for U.S. military personnel and veterans. *J Consult Clin Psychol*. 2016;84(11),923-934. doi:10.1037/ccp0000135.

Authors

When this article was written, Mr Cain was Deputy Chief, European Regional Virtual Health, RHCE.

LTC Cornfield is a pediatric gastroenterologist at LRMC.

COL Waibel is with Brooke Army Medical Center, Fort Sam Houston, Texas.

Dr Jorgensen-Wagers is a TBI researcher at LRMC.

Mr Keen is Director, Virtual Health, RHCE.

Capt Brown is Chief, Medical Nutrition Therapy, LRMC.

Dr Hearn is a sleep medicine physician, Fort Hood, Texas.

Ms Jack is with the TBI Clinic, LRMC.

Ms Black is with clinical operations, RHCE Virtual Health.

When this article was written, Mr Ortiz-Rosado was with clinical operations, RHCE Virtual Health.

Sexual Dimorphic Features Associated with Femoroacetabular Impingement

CPT Victoria B. Okpala, MC
COL (Ret) Anthony E. Johnson, MC
MAJ David J. Tennent, MC
LTC Matthew R. Schmitz, MC

Abstract

Sexual dimorphism describes differences in biologic response between males and females due to inherent chromosomal differences. These differences similarly affect orthopaedic-related injuries and treatment outcomes as seen with femoroacetabular impingement, an abnormal hip morphology where females have shown worse hip function scores than male counterparts before and after surgery. Potential dimorphic factors that increase susceptibility of females to injury and/or worse outcomes may include joint laxity, hip morphology, and osseous biology. This article reviews the relevant literature of prevalence, presentation, management, and outcomes that characterize sexual dimorphism as it relates to femoroacetabular impingement.

Sexual dimorphism describes differences in biologic response between males and females due to inherent chromosomal differences.[1] Though often used to describe anthropomorphic differences between sexes, the term can be extended to include specific anatomic, physiologic, psychological, and behavioral differences.[2]

Thus, sexual dimorphism similarly affects orthopaedic-related injuries and treatment outcomes as seen with shoulder instability, ACL injuries, stress fractures, and femoroacetabular impingement.[3] Dimorphic factors that have been shown to increase the susceptibility of females to musculoskeletal injuries and/or worse outcomes may include joint laxity, hip morphology, and osseous biology.[4]

Femoroacetabular impingement (FAI) is an abnormal hip morphology resulting in an abutment between the proximal femur and acetabular rim.[5] These abnormalities of the acetabulum and/or femur ultimately lead to damage within the joint.[6] Seen most frequently in active adolescents and young adults, FAI is widely recognized in the athletic patient population.[7,8] The 2 most common types of FAI include cam-type, most prevalent in young males, and pincer-type, most frequently seen in middle-aged females.[5,8-12] While the clinical presentations are similar for both types of FAI, treatment outcomes have differed between sexes. The purpose of this article is to review the relevant literature to characterize sexual dimorphism as it relates to FAI.

What is FAI?

The 2016 Warwick Agreement defines FAI as a syndrome of a motion-related clinical disorder of the hip with a triad of symptoms, clinical signs, and imaging findings.[13] It represents symptomatic premature contact between the proximal femur and the acetabulum.[13] There are 2 main morphologies described for FAI syndrome: cam-type and pincer-type. In cam-type morphology, the proximal femur osseous morphology is characterized by an aspherical cartilage extension at the anterosuperior head-neck junction that abuts against the acetabular rim with flexion and internal rotation of the hip.[14-18] In pincer-type morphology, the abnormal acetabular rim produces relative overcoverage of the femoral head leading to a decrease in motion between the femoral head-neck junction and acetabulum.[5,6] Over time, these changes can cause significant pain, chondral delamination, and labral dysfunction, ultimately leading to degenerative changes in the hip and premature osteoarthritis.[9,18-21] As pathologic changes rarely occur independently of one another, a mixed cam and pincer-type morphology is the most common type of FAI syndrome seen in the general population.[5,22]

Prevalence, Clinical and Diagnostic Presentation

The prevalence of FAI syndrome is estimated to be between 10% and 15% of the general population and is predominantly seen in active adolescents and young adults involved in impact sports such as collegiate football and basketball.[19,23-25] Moreover, there is a high prevalence of asymptomatic abnormal radiographic impingement morphology in the adolescent population.[26] Consequently, due to the wide spectrum of normal variance, using hard-set static radiographic parameters when weighing surgical management should be used cautiously in patients with FAI syndrome.[26]

Typically, FAI syndrome presents as an insidious onset of poorly characterized deep groin pain or discomfort. However, there can be wide variation in the location, nature, radiation, severity, and precipitating factors that characterize this pain. While most patients report pain in the groin or hip, pain is also reported in the lateral hip,

anterior thigh, buttock, knee, lower back, lateral or posterior thigh.[27] This pain is aggravated with activity and active hip motion.[28] In females, FAI syndrome can present with significantly more disability, despite generally having less severe deformities and less intra-articular disease in comparison to their male counterparts.[29] Furthermore, although FAI is most commonly associated with developmental morphogenic changes, a high index of suspicion should also be maintained for patients with clinical signs of impingement secondary to trauma or previous surgeries undertaken for correction of developmental hip pathology.

The most commonly tested and the most sensitive clinical examination finding suggestive of impingement of anterior impingement is the flexion, adduction, and internal rotation test (FADIR).[19,30] In the FADIR test, the hip is flexed to 90° and forcibly adducted and internally rotated.[31] If anterior impingement is present, the patient will describe reproduction of their pain with a sensitivity of 0.99.[30]

The cam-type morphology is most prevalent in young and athletic males.[8,18,32] It is theorized that due to intense sports participation in male adolescents, there is an increased risk of developing cam-type morphology in this population.[33] Schmitz et al compared anteroposterior pelvic radiographs made with EOS imaging in asymptomatic adolescents, demonstrating that 92.8% of participants demonstrated at least one parameter suggesting impingement morphology.[26] These findings demonstrate that the emphasis for surgical management should be tailored towards physical examination findings in conjunction with the radiographic findings, and not radiographic findings alone.

Within the US adult population, the ratio of asymptomatic cam-type morphology is 2:1 when comparing males to females.[22] Furthermore, the prevalence of cam-type morphologies in asymptomatic adults has been reported to be as high as 24% in males and 5.4% of females with alpha angles parameters greater than 50.5°.[34] The Copenhagen Osteoarthritis Study reported a similar prevalence of abnormal alpha angle finding with 17% in males and 4% in female adults on anteroposterior pelvis radiographs.[35]

Diagnostic radiographic findings in cam-type impingements include the alpha angle, pistol grip deformity, and the femoral head-neck offset (Figure 1).[14,18,36] Specifically, the pistol grip deformity is more common in males, with a prevalence of 19.6% compared to 5.2% in females. Similar findings were reported by Laborie and colleagues with a prevalence of 21.5% in males and 3.3% in females.[32] Moreover, alpha angles are significantly decreased among females at 47.8° in comparison to males at 63.6°.[21,37] The lower symptomatic alpha angles in females tend to be more shallow, have a lower

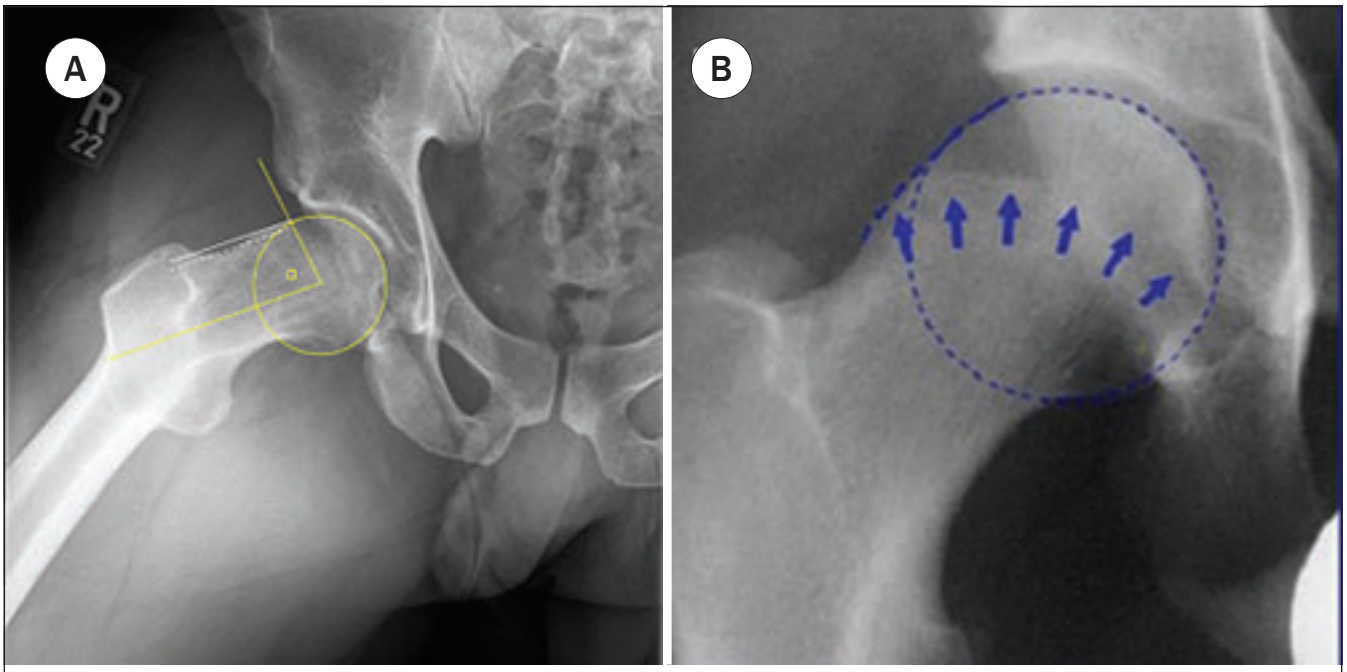


Figure 1. Panel A: Lateral view of the right hip showing increased alpha angle (yellow lines with normal being less than 50°). Also with decrease in femoral head neck offset (the difference between the solid white and dashed white lines (normal 8 mm).
Panel B: Anterior posterior view of the right hip showing the pistol grip deformity of the proximal femur with abnormal extension of the epiphysis down the proximal femoral neck.

total volume (males 433±471 mm^3; females 89±124 mm^3), and are more symptomatic with alpha angles less than 50°.[37,38] Additionally, these subtle symptomatic cam-type morphologies in females tend to be in an atypical location and smaller in size, thereby suggesting that radiographic parameters may be modified based on the above sexual dimorphic features to improve potential surgical decision-making.[5,37]

Pincer-type morphologies are most prevalent in middle aged active females and are more predominantly associated with anterior acetabular wall over coverage.[5,9-12,39] Population-based studies have shown males to have a significantly decreased focal and global acetabular version compared with females, where focal acetabular version in the 1-o'clock position was 15.5° and 18.3°; 21.5° and 24.0° in the 2-o'clock position; and 20.2° and 24.3° in the 3-o'clock position for males and females respectively.[39] While Tannebaum et al found no statistical difference between sexes when assessing true acetabular version (males: 19.1°, females 22.2°), males were shown to have a posterior wall deficiency contributing to a related acetabular retroversion.[39] These findings lead one to consider the relevance of dynamic factors that contribute to the prevalence of pincer-type morphologies in females, such as increased joint laxity that facilitates greater extremes of motion and increased pelvic tilt, or forward tilt from weaker core musculature.[40,41] Understanding these differences between sexes in the presentation of FAI syndrome is important for establishing accurate diagnostic algorithms for treatment and decision-making.[42]

Diagnostic radiographic findings for the pincer morphologies include the crossover sign, posterior wall sign, ischial spine sign, coxa profunda, protrusio acetabuli, and lateral center-edge (LCE) (Figure 2). Schmitz et al showed a significantly higher prevalence of coxa profunda in females compared with males, 87.8% and 75.6% respectively.[26] Furthermore, their data on asymptomatic adolescents also suggest that the upper limit of normal for LCE angle may be as high as 44° based on normative values from their study.[26] The high prevalence of coxa profunda illustrated above suggests that this pincer-type morphology may be a variant of normal rather than abnormal morphology, particularly among females. As such, coxa profunda morphology in isolation of other pathology may not represent true impingement pathology in all cases and additional studies should be considered. There was no significant difference detected among other signs of acetabular overcoverage.[26]

Treatments

Currently, there are no data to suggest a sex difference in conservative treatment modalities.[43] As such, the goal of first-line conservative management for FAI syndrome includes education, activity modification, NSAIDs, and core strengthening exercises. Although the above conservative therapies improve hip function and reduce pain, the overall hip range of motion of the symptomatic extremity does not improve in comparison to the unaffected extremity.[43] Once conservative measures have been exhausted, surgical management is often explored. However, due to the vague insidious symptoms of FAI syndrome and overlap with other musculoskeletal conditions of the hip, pelvis, and lumbar spine, definitive diagnosis and surgical management of symptomatic FAI syndrome is often delayed with average symptom duration of 3.1 years and an average of 4.2 (±2.9) healthcare providers seen before eventual diagnosis.[44] Moreover, surgical management that is excessively delayed can place a patient at risk for an accelerated degenerative disease and end-stage arthritic changes that may ultimately require total hip arthroplasty. This postponed diagnosis is attributed to under-recognition of symptomatic FAI syndrome as a cause of hip pain secondary to the degree of education and training among the various healthcare providers regarding FAI syndrome.[43]

Current surgical interventions to manage FAI syndrome include hip arthroscopy, a combined arthroscopic and open approach, mini-open approach, surgical hip dislocation, and anteverting periacetabular osteotomy (PAO). However, few studies focusing on the surgical management of open and arthroscopic techniques have shown a large influence of sex in determining outcomes in the surgical treatment for FAI syndrome.[7] Clohisy et al[45] examined the rate of surgically treated FAI syndrome and found that females were more likely to undergo surgical treatment for symptomatic FAI syndrome than males. Multiple studies have shown both open and arthroscopic hip approaches were effective in pain relief and improvement in function with short-term (2 years or less) and midterm (2 to 5 years) follow-up for both male and females.[46] Arthroscopy has shown equivalent functional outcomes, using various functional outcome measures, with a lower rate of major complications that include osteonecrosis, deep infection, femoral neck fracture, loss of fixation, and trochanteric nonunion when compared to mini-open approaches and surgical hip dislocation techniques.[47,48] Furthermore, hip arthroscopy yields meaningful improvements in hip function, as validated with a mean difference before and after surgery exceeding the minimal clinically important difference of the iHOT-33 in majority of patients, regardless of sex.[49-51]

An alternative form of surgical management is the PAO surgical technique often used for pincer-type impingement to reduce acetabular retroversion, and is one of

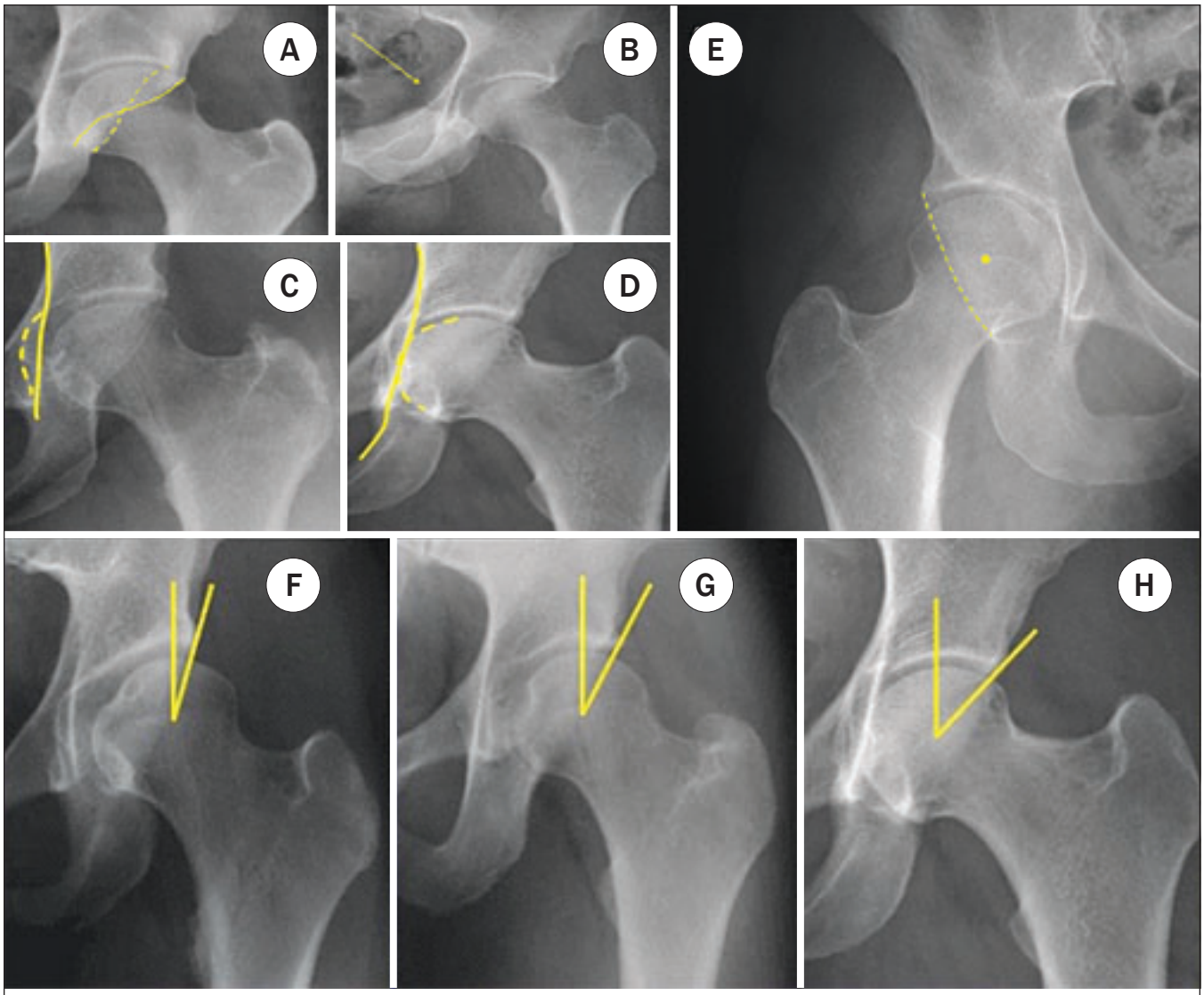


Figure 2. Panel A: Crossover sign with the anterior acetabular wall (solid line) crossing over the posterior wall (dashed line) indicating focal anterior over coverage.
Panel B: Ischial spine sign indicated by the arrow with the ischial spine projecting into the true pelvis, indicative of global acetabular retroversion.
Panel C: Coxa profunda on the left with the acetabular depth (dashed line) projecting medial to the ilioischial line (solid line).
Panel D: Coxa protrusio on the right with the femoral head (dashed line) projecting medial to the ilioischial line (solid line).
Panel E: Posterior wall signs with the posterior wall (dashed line) lateral to the center of the femoral head indicated by a circle. This represents posterior overcoverage or relative anteversion of the acetabulum.
Panel F: Decreased lateral center edge (LCE) angle of less than 25° demonstrating dysplasia.
Panel G: Normal LCE shown with LCE between 25° and 39°.
Panel H: Increased LCE shown with overcoverage greater than 40°.

the few surgical approaches to have an association as a sex-specific treatment secondary to the increased prevalence of pincer-type morphology in the female population.[37] The anterosuperior quadrant of the acetabulum is a primary weight-bearing area and removal potentiates a high amount of stress during weight bearing. Thus, performing preoperative hip version analyses with axial CT or MR imaging should be considered to assess for the smaller subtle cam morphologies found in females prior to anterosuperior and superolateral acetabulum rim trimming to avoid increasing contact stresses at weight-bearing areas that may accelerate hip degeneration.[6,37]

We are unaware of any studies comparing PAO surgical outcomes for acetabular retroversion between sexes; however, Ziebarth et al demonstrated males presented

with a high postoperative rate of clinical signs of FAI syndrome after PAO for developmental dysplasia of the hip compared to the female population.[52]

Outcomes

Frank et al showed that older female patients have significantly lower hip function scores than male counterparts before and after surgery.[50] Furthermore, females have a greater overall improvement of quality of life scores after surgery with short-term (2 years or less) follow-up, suggesting that females undergo surgery when they are more highly disabled compared to males and may have more to gain in terms of quality of life after surgery.[50,53,54] These sex differences observed in outcome measures are multifactorial and may include a component of perception where females perceive pain as more limiting to function, whereas males may over-estimate pain relief and functional performance.[55]

However a study by Byrd et al showed no meaningful difference in long-term outcomes based on impingement morphology or between male and female patients within a 2- to 10-year period after arthroscopic surgery in a population consisting of young athletes with ages ranging from 12 to 17 years.[56] In comparison, a study by Philippon et al demonstrated contrary findings in a smaller prospective study of 60 active adolescents, with female patients reporting significantly poorer hip function than their male counterparts with midterm (2 to 5 years) follow-up after arthroscopic surgery in adolescent population aged 11 to 16 years.[57] This suggests that females may have worse functional outcomes when compared to males with short to midterm follow-up. Continued research following surgical outcomes with variances of duration of follow-up may narrow the clinical outcome differences amongst sexes.

Outcome measurements are an effective tool for evaluating surgical functional outcomes for FAI syndrome pre- and postoperatively. The most common functional outcomes measurements reported to assess FAI syndrome are the Harris Hip Score (HHS), Nonarthritic Hip Scale, range of motion, pain scores, and patient satisfaction (on visual analogue scales).[58] Other primary clinical outcomes cited in the literature to assess postoperative outcomes include the use of the anterior impingement test (flexion, adduction, internal rotation), modified HHS, Short Form 12, Hip Outcome Score—activities of daily living, and/or Hip Outcome Score—sport-specific.[58] The aforementioned measures are not validated in patients with FAI syndrome but for labral tears, nor are they applicable to the nonadult population (less than 23 years old). Interestingly, Impellizerri et al compared the validity, reproducibility, and responsiveness of the Oxford Hip Score (OHS) and Hip Outcome Score measurements in patients undergoing surgery for FAI syndrome and concluded that the OHS was an appropriate instrument for pain and function assessment in those status post arthroscopic FAI surgery (47% male and 53% female patients).[59] Despite the promise of these outcome measures, evaluating and validating them in all populations, particularly between males and females, will be important for global use and assessing clinical difference amongst various populations.[58]

Patient satisfaction has been suggested as an important domain for functional outcome assessment with preoperative expectations and the fulfillment of those expectations influencing postoperative satisfaction more than functional outcomes.[60] A review by Kahlenberg et al found that the quality of studies reporting patient satisfaction after FAI surgery are low due to several discrepancies in the reporting, including failure to gauge patients' initial expectations before the operative procedure, and further distinguishing expectations of outcomes versus process of care satisfaction. Failure to define patient expectations before the operative procedure may inaccurately assume that the functional outcome of care is assessed rather than the process of care.[61] These discrepancies may factor into the worse reported functional outcomes in females after undergoing arthroscopy for FAI syndrome. There is currently no standardized means for reporting patient satisfaction. With hip arthroscopy being increasingly used to address FAI syndrome, little is known about the state of patient satisfaction reporting after the treatment of FAI syndrome as well as the relation of patient satisfaction to overall outcome.[60] Delineating satisfaction relating to delivery of care versus outcome of care plays an increasingly larger role in defining the value of emerging orthopaedic interventions, particularly with surgical management of FAI syndrome which has consistently shown worse patient reported functional outcomes when comparing males to females.[62]

Sexual dimorphisms in hip morphology, soft tissue laxity, muscle mass, increased pelvic tilt, and dynamic joint stabilization have been proposed as causes of the reported outcome differences between males and females with nonarthritic hip pain.[41,49] In a 2014 study by Frank et al, hip capsular volumes of 97 patients were analyzed using magnetic resonance arthrograms.[63] Interestingly, female patients were found to have a larger ratio of capsular volume to femoral head volume compared with male patients, providing a possible explanation for the known prevalence of hip joint hypermobility in female patients compared with male patients. Pontiff et al examined the differences in perceived function and quality

of life outcomes in females with and without generalized joint laxity (GJL) prior to and 6 months following hip arthroscopy for FAI syndrome.[64] Differences in self-reported hip function were not identified preoperatively or 6 months postoperatively, suggesting that GJL has no effect on worse self-reported hip function and quality of life outcomes perioperatively for arthroscopic treatment of FAI syndrome in the female population.[64] This is the first prospective study to examine the effect of laxity on patients who undergo surgical treatment for intra-articular hip pathology.[64] While little data exists, the lack of differences in group outcome scores may be attributed to limitations of having a single postoperative follow-up and the use of a laxity score index not specific to the hip joint.[64] Identification of variables such as generalized joint laxity should continue to be explored, along with adjusting the course of postoperative care to modulate improved outcomes in females after hip arthroscopy for FAI syndrome.[64]

Female sex was also shown by Lee et al[49] to be predictive of a longer recovery time after arthroscopic hip surgery for the treatment of common hip disorders. This correlates with a study by Boyd et al,[65] which showed that longer durations of follow-up increased recovery time and ultimately offset differences between sexes in functional outcomes postoperatively from arthroscopic hip surgery. As such, further reducing recovery time may optimize functional outcomes with short-term follow-up and more emphasis directed toward rehabilitation protocols within a specified time interval should be considered. Likewise, Joseph et al demonstrated that functional improvements plateaued 6 months after hip arthroscopic surgery.[49] A greater understanding of physical impairments and activity limitations may aid in the effects of future physical therapy protocols and potentially minimize the discrepancy in hip functional outcomes when comparing males to females after hip arthroscopy for FAI syndrome.[66]

Future Domains of Research

Sexual dimorphic features associated with FAI treatment and outcomes are multifactorial and include factors such as hip morphology, management including conservative and surgical options, and patient-reported outcomes. Future domains of research should include randomized control trials that examine treatment effects on FAI syndrome and consider whether conservative treatments are a viable and/or a preferable alternative to surgical interventions.[66] Current evidence supporting surgical and conservative interventions for FAI syndrome is based on low-level research. Moreover, multicenter randomized controlled trials are needed to help establish the value of these interventions in the management of FAI syndrome. Such trials will also help define appropriate clinical pathways to further differentiate sex-specific treatments and ultimately improve functional outcomes.[67,68]

References

1. Gehrig LM, Bismarck SH. *Sex in Your Orthopaedic Practice*. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2013. Available at: https://www.aaos.org/cc_files/aaosorg/about/whiab/whiab_sexinyourpractice.pdf. Accessed October 2, 2018.
2. Gaulin SJC, Lassek WD. Sexual dimorphism. In: Whelehan P, Bolin A, eds-in-chief. *The International Encyclopedia of Human Sexuality*. Hoboken, NJ: John Wiley & Sons, Ltd; 2015:1115-1354. Available at: http://onlinelibrary.wiley.com/doi/10.1002/9781118896877.wbiehs450/abstract. Accessed October 2, 2018.
3. Gehrig LM, Baker MM, Carter CW, et al. Sex Based Considerations in Caring for Common Sports Injuries [internet]. AAOS Women's Health Issues Advisory Board. 2016. Available at: https://www.aaos.org/uploadedFiles/PreProduction/Research/Research_Tools/documents/_2016%20WHIAB%20Scientific%20Exhibit.pdf. Accessed October 2, 2018.
4. Wolf JM, Cannada L, Van Heest AE, O'Connor MI, Ladd AL. Male and female differences in musculoskeletal disease. *J Am Acad Orthop Surg*. 2015;23(6):339-347.
5. Banerjee P, McLean CR. Femoroacetabular impingement: a review of diagnosis and management. *Curr Rev Musculoskelet Med*. 2011;4(1):23-32.
6. Agricola R, Weinans H. What is femoroacetabular impingement? *Br J Sports Med*. 2016;50(4):196-197.
7. Halim A, Badrinath R, Carter CW. The importance of sex of patient in the management of femoroacetabular impingement. *Am J Orthop (Belle Mead NJ)*. 2015;44(4):172-175.
8. Nho SJ, Magennis EM, Singh CK, Kelly BT. Outcomes after the arthroscopic treatment of femoroacetabular impingement in a mixed group of high-level athletes. *Am J Sports Med*. 2011;39(suppl):14S-19S.
9. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip: an integrated mechanical concept. *Clin Orthop Relat Res*. 2008;466(2):264-272.
10. Pfirrmann CW, Mengiardi B, Dora C, Kalberer F, Zanetti M, Hodler J. Cam and pincer femoroacetabular impingement: characteristic MR arthrographic findings in 50 patients. *Radiology*. 2006;240(3):778-785. Erratum in: *Radiology*. 2007;244(2):626.

11. Leunig M, Jüni P, Werlen S, et al. Prevalence of cam and pincer-type deformities on hip MRI in an asymptomatic young Swiss female population: a cross-sectional study. *Osteoarthritis Cartilage*. 2013;21(4):544-550.
12. Gosvig KK, Jacobsen S, Sonne-Holm S, Gebuhr P. The prevalence of cam-type deformity of the hip joint: a survey of 4151 subjects of the Copenhagen Osteoarthritis Study. *Acta Radiol*. 2008;49(4):436-441.
13. Griffin DR, Dickenson EJ, O'Donnell J, et al. The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. *Br J Sports Med*. 2016;50(19):1169-1176.
14. Ito K, Minka MA II, Leunig M, Werlen S, Ganz R. Femoroacetabular impingement and the cam-effect. A MRI-based quantitative anatomical study of the femoral head-neck offset. *J Bone Joint Surg Br*. 2001;83(2):171-176.
15. Beaulé PE, Zaragoza E, Motamedi K, Copelan N, Dorey FJ. Three-dimensional computed tomography of the hip in the assessment of femoroacetabular impingement. *J Orthop Res*. 2005;23(6):1286-1292.
16. Reynolds D, Lucas J, Klaue K. Retroversion of the acetabulum. A cause of hip pain. *J Bone Joint Surg Br*. 1999;81(2):281-288.
17. Klaue K, Durnin CW, Ganz R. The acetabular rim syndrome. A clinical presentation of dysplasia of the hip. *J Bone Joint Surg Br*. 1991;73(3):423-429.
18. Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis--what the radiologist should know. *AJR Am J Roentgenol*. 2007;188(6):1540-1552.
19. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res*. 2003;(417):112-120.
20. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br*. 2005;87(7):1012-1018.
21. Gosvig KK, Jacobsen S, Sonne-Holm S, Palm H, Troelsen A. Prevalence of malformations of the hip joint and their relationship to sex, groin pain, and risk of osteoarthritis: a population-based survey. *J Bone Joint Surg Am*. 2010;92(5):1162-1169.
22. Jung KA, Restrepo C, Hellman M, AbdelSalam H, Morrison W, Parvizi J. The prevalence of cam-type femoroacetabular deformity in asymptomatic adults. *J Bone Joint Surg Br*. 2011;93(10):1303-1307. Erratum in: *J Bone Joint Surg Br*. 2011;93(12):1679.
23. Leunig M, Ganz R. Femoroacetabular impingement. A common cause of hip complaints leading to arthrosis [in German]. *Unfallchirurg*. 2005;108(1):9-10, 12-17.
24. Kapron AL, Anderson AE, Aoki SK, et al. Radiographic prevalence of femoroacetabular impingement in collegiate football players: AAOS Exhibit Selection. *J Bone Joint Surg Am*. 2011;93(19):e111(1-10).
25. Siebenrock KA, Ferner F, Noble PC, Santore RF, Werlen S, Mamisch TC. The cam-type deformity of the proximal femur arises in childhood in response to vigorous sporting activity. *Clin Orthop Relat Res*. 2011;469(11):3229-3240.
26. Schmitz MR, Bittersohl B, Zaps D, Bomar JD, Pennock AT, Hosalkar HS. Spectrum of radiographic femoroacetabular impingement morphology in adolescents and young adults: an EOS-based double-cohort study. *J Bone Joint Surg Am*. 2013;95(13):e90.
27. Griffin DR, Dickenson EJ, O'Donnell J, et al. The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. *Br J Sports Med*. 2016;50(19):1169-1176.
28. Philippon MJ, Maxwell RB, Johnston TL, Schenker M, Briggs KK. Clinical presentation of femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(8):1041-1047.
29. Nepple JJ, Riggs CN, Ross JR, Clohisy JC. Clinical presentation and disease characteristics of femoroacetabular impingement are sex-dependent. *J Bone Joint Surg Am*. 2014;96(20):1683-1689.
30. Reiman MP, Mather RC III, Cook CE. Physical examination tests for hip dysfunction and injury. *Br J Sports Med*. 2015;49(6):357-361.
31. Khan M, Bedi A, Fu F, Karlsson J, Ayeni OR, Bhandari M. New perspectives on femoroacetabular impingement syndrome. *Nat Rev Rheumatol*. 2016;12(5):303-310.
32. Laborie LB, Lehmann TG, Engesæter IØ, Eastwood DM, Engesæter LB, Rosendahl K. Prevalence of radiographic findings thought to be associated with femoroacetabular impingement in a population-based cohort of 2081 healthy young adults. *Radiology*. 2011;260(2):494-502.
33. Li Y, Helvie P, Mead M, Gagnier J, Hammer MR, Jong N. Prevalence of femoroacetabular impingement morphology in asymptomatic adolescents. *J Pediatr Orthop*. 2017;37(2):121-126.
34. Hack K, Di Primio G, Rakhra K, Beaulé PE. Prevalence of cam-type femoroacetabular impingement morphology in asymptomatic volunteers. *J Bone Joint Surg Am*. 2010;92(14):2436-2444.

35. Gosvig KK, Jacobsen S, Palm H, Sonne-Holm S, Magnusson E. A new radiological index for assessing asphericity of the femoral head in cam impingement. *J Bone Joint Surg Br*. 2007;89(10):1309-1316.

36. Nötzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg Br*. 2002;84(4):556-560.

37. Hetsroni I, Dela Torre K, Duke G, Lyman S, Kelly BT. Sex differences of hip morphology in young adults with hip pain and labral tears. *Arthroscopy*. 2013;29(1):54-63.

38. Yanke AB, Khair MM, Stanley R, et al. Sex differences in patients with CAM deformities with femoroacetabular impingement: 3-dimensional computed tomographic quantification. *Arthroscopy*. 2015;31(12):2301-2306. Erratum in: *Arthroscopy*. 2016;32(2):404.

39. Tannenbaum EP, Zhang P, Maratt JD, et al. A computed tomography study of gender differences in acetabular version and morphology: implications for femoroacetabular impingement. *Arthroscopy*. 2015;31(7):1247-1254.

40. Kolo FC, Charbonnier C, Pfirrmann CW, et al. Extreme hip motion in professional ballet dancers: dynamic and morphological evaluation based on magnetic resonance imaging. *Skeletal Radiol*. 2013;42(5):689-698.

41. Ross J, Nepple J, Philippon M, et al. The influence of pelvic tilt on common acetabular parameters and range of motion in patients with femoroacetabular impingement (FAI). *Arthroscopy*. 2013;29(12)(suppl):e203.

42. Crawford JR, Villar RN. Current concepts in the management of femoroacetabular impingement. *J Bone Joint Surg Br*. 2005;87(11):1459-1462.

43. Emara K, Samir W, Motasem el H, Ghafar KA. Conservative treatment for mild femoroacetabular impingement. *J Orthop Surg (Hong Kong)*. 2011;19(1):41-45.

44. Clohisy JC, Knaus ER, Hunt DM, Lesher JM, Harris-Hayes M, Prather H. Clinical presentation of patients with symptomatic anterior hip impingement. *Clin Orthop Relat Res*. 2009;467(3):638-644.

45. Clohisy JC, Baca G, Beaulé PE, et al; ANCHOR Study Group. Descriptive epidemiology of femoroacetabular impingement: a North American cohort of patients undergoing surgery. *Am J Sports Med*. 2013;41(6):1348-1356.

46. Hellman MD, Riff AJ, Frank RM, Haughom BD, Nho SJ. Operative treatment of femoroacetabular impingement. *Phys Sportsmed*. 2014;42(3):112-119.

47. Ng VY, Arora N, Best TM, Pan X, Ellis TJ. Efficacy of surgery for femoroacetabular impingement: a systematic review. *Am J Sports Med*. 2010;38(11):2337-2345.

48. Matsuda DK, Carlisle JC, Arthurs SC, Wierks CH, Philippon MJ. Comparative systematic review of the open dislocation, mini-open, and arthroscopic surgeries for femoroacetabular impingement. *Arthroscopy*. 2011;27(2):252-269.

49. Joseph R, Pan X, Cenkus K, Brown L, Ellis T, Di Stasi S. Sex differences in self-reported hip function up to 2 years after arthroscopic surgery for femoroacetabular impingement. *Am J Sports Med*. 2016;44(1):54-59.

50. Frank RM, Lee S, Bush-Joseph CA, Salata MJ, Mather RC III, Nho SJ. Outcomes for hip arthroscopy according to sex and age: a comparative matched-group analysis. *J Bone Joint Surg Am*. 2016;98(10):797-804.

51. Mohtadi NG, Griffin DR, Pedersen ME, et al; Multicenter Arthroscopy of the Hip Outcomes Research Network. The development and validation of a self-administered quality-of-life outcome measure for young, active patients with symptomatic hip disease: the International Hip Outcome Tool (iHOT-33). *Arthroscopy*. 2012;28(5):595-605.

52. Ziebarth K, Balakumar J, Domayer S, Kim YJ, Millis MB. Bernese periacetabular osteotomy in males: is there an increased risk of femoroacetabular impingement (FAI) after Bernese periacetabular osteotomy? *Clin Orthop Relat Res*. 2011;469(2):447-453.

53. Malviya A, Stafford GH, Villar RN. Impact of arthroscopy of the hip for femoroacetabular impingement on quality of life at a mean follow-up of 3.2 years. *J Bone Joint Surg Br*. 2012;94(4):466-470.

54. Impellizzeri FM, Mannion AF, Naal FD, Hersche O, Leunig M. The early outcome of surgical treatment for femoroacetabular impingement: success depends on how you measure it. *Osteoarthritis Cartilage*. 2012;20:638-645.

55. Katz JN, Wright EA, Guadagnoli E, Liang MH, Karlson EW, Cleary PD. Differences between men and women undergoing major orthopedic surgery for degenerative arthritis. *Arthritis Rheum*. 1994;37(5):687-694.

56. Byrd JW, Jones KS, Gwathmey FW. Femoroacetabular impingement in adolescent athletes: outcomes of arthroscopic management. *Am J Sports Med*. 2016;44(8):2106-2111.

57. Philippon MJ, Ejnisman L, Ellis HB, Briggs KK. Outcomes 2 and 5 years following hip arthroscopy for femoroacetabular impingement in the patient aged 11 to 16 years. *Arthroscopy*. 2012;28:1255- 1261.

58. Ayeni OR, Sansone M, de Sa D, et al. Femoro-acetabular impingement clinical research: is a composite outcome the answer?. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(1):295-301.

59. Impellizzeri FM, Mannion AF, Naal FD, Leunig M. Validity, reproducibility, and responsiveness of the oxford hip score in patients undergoing surgery for femoroacetabular impingement. *Arthroscopy*. 2015;31(1):42-50.

60. Montgomery SR, Ngo SS, Hobson T, et al. Trends and demographics in hip arthroscopy in the United States. *Arthroscopy*. 2013;29(4):661-665.

61. Kahlenberg CA, Nwachukwu BU, Schairer WW, McCormick F, Ranawat AS. Patient satisfaction reporting for the treatment of femoroacetabular impingement. *Arthroscopy*. 2016;32(8):1693-1699.

62. Graham B, Green A, James M, Katz J, Swiontkowski M. Measuring patient satisfaction in orthopaedic surgery. *J Bone Joint Surg Am*. 2015;97(1):80-84.

63. Frank JM, Lee S, McCormick FM, et al. Quantification and correlation of hip capsular volume to demographic and radiographic predictors. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(6):2009-2015.

64. Pontiff M, Ithurburn MP, Ellis T, Cenkus K, Stasi SD. Pre- and post-operative self-reported function and quality of life in women with and without generalized joint laxity undergoing hip arthroscopy for femoroacetabular impingement. *Int J Sports Phys Ther*. 2016;11(3):378-387.

65. Lee HH, Klika AK, Bershadsky B, Krebs VE, Barsoum WK. Factors affecting recovery after arthroscopic labral debridement of the hip. *Arthroscopy*. 2010;26(3):328-334.

66. Diamond LE, Dobson FL, Bennell KL, Wrigley TV, Hodges PW, Hinman RS. Physical impairments and activity limitations in people with femoroacetabular impingement: a systematic review. *Br J Sports Med*. 2015;49(4):230-242.

67. FIRST Investigators. A multi-centre randomized controlled trial comparing arthroscopic osteochondroplasty and lavage with arthroscopic lavage alone on patient important outcomes and quality of life in the treatment of young adult (18-50) femoroacetabular impingement. *BMC Musculoskelet Disord*. 2015;16:64. Available at: https://bmcmusculoskeletdisord.biomedcentral.com/articles/10.1186/s12891-015-0500-y. Accessed October 2, 2018.

68. Mansell NS, Rhon DI, Marchant BG, Slevin JM, Meyer JL. Two-year outcomes after arthroscopic surgery compared to physical therapy for femoracetabular impingement: a protocol for a randomized clinical trial. *BMC Musculoskelet Disord*. 2016;17:60. Available at: https://bmcmusculoskeletdisord.biomedcentral.com/articles/10.1186/s12891-016-0914-1. Accessed October 2, 2018.

AUTHORS

CPT Okpala is a Field Surgeon with the 3rd Cavalry Regiment, Fort Hood, Texas.

MAJ Tennent is an Orthopaedic Surgeon at the Keller Army Community Hospital, US Military Academy, West Point, New York.

When this article was written, COL Johnson was Chairman, Department of Orthopaedic Surgery, San Antonio Military Medical Center, Joint Base San Antonio-Fort Sam Houston, Texas.

LTC Schmitz is with the Department of Orthopaedics, San Antonio Miltary Medical Center, Joint Base San Antonio-Fort Sam Houston, Texas.

Case Report: Unilateral Paresis of the Abdominal Wall with Associated Thoraco-Lumbar Pain

Maria Francisca Elgueta, MD
Nina Nan Wang, MD
Gaurav Gupta, MD, FRCPC
LCol Markus Besemann, MD, FRCPC

A 53-year-old male with unremarkable past medical history presented with a new onset left lower abdominal wall swelling and pain. The pain radiated from his back, into the left iliac crest, groin, and testicle region. Patient reported a history of performing heavy physical work 2 weeks prior to presentation, and felt an unusual sensation in the left thorocolumbar region when lifting a stone. The pain progressively worsened over time and was exacerbated with weight-bearing activities such as standing and walking. Valsalva maneuver also increased the pain intensity, while traction relieved it. Patient's sleep was interrupted due to pain and symptoms were worse in the left lateral decubitus position. Aside from nausea with standing, there were no other gastrointestinal, urologic, neurological, inflammatory, or constitutional symptoms.

Physical examination revealed a sizeable left lower abdominal quadrant bulge/prominence which disappeared when recumbent and when extending to the right posterior quadrant (Figure 1). There was restricted range of motion in flexion and left lateral bending. There was significant left paralumbar muscle spasm extending to the thoraco-lumbar junction and tenderness over the iliac crest and posterior superior iliac spine. There was no specific tenderness to any one particular spinal segment. No neurological abnormalities could be detected, sensation over the left lower abdominal region was normal.

Upon initial presentation to the emergency room, the principle diagnosis was left inguinal hernia and mechanical low back strain for which he was referred to both general surgery and physiotherapy. Attempts at spinal manipulation did not relieve the pain; however, intramuscular stimulation helped ease the muscle spasm. The pain was controlled with ibuprofen 400 mg po tid prn and hydromorphone 1 mg po q4h prn.

Ultrasound of the left lower abdominal wall showed absence of inguinal hernia. An electromyographic study of the left lower abdominal wall was negative for signs of axonal denervation. An MRI of the lumbar spine showed a large disc herniation/sequestered disc fragment within the left lateral recess and left foraminal region at L1-L2, with significant narrowing of the left neural foramen and impingement on the exiting left L1 nerve root (Figure 2).

His pain resolved over a period of 3 weeks, and 3 months later his abdominal herniation disappeared. Spinal decompression surgery was not deemed necessary given the clinical improvement.

True abdominal hernias are the result of the protrusion of abdominal cavity contents through an opening, tear, or weakness in the abdominal wall musculature.[1] Abdominal wall bulging is the result of segmental denervation of abdominal muscles that can mimic a true abdominal hernia, and the patient could be exposed to unnecessary surgery.

Abdominal muscles such as rectus abdominis, oblique, and tranversus abdominis, are innervated by the lower 6 thoracic nerves iliohypogastric and ilio-inguinal nerves. Any pathology that affects these nerves could cause abdominal wall pain and bulging of the abdominal wall, mimicking a true abdominal hernia. In our case, the patient had a L1 nerve root compression, the ventral ramus of L1 divides into iliohyoogastric and ilioinguinal nerves,

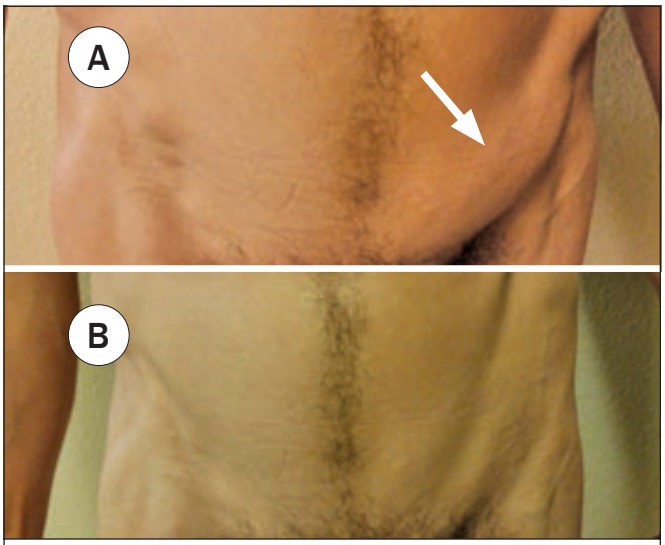


Figure 1. Panel A shows the left lower quadrant bulge (arrow). Panel B shows reduction of the bulge in lumbar extension/right side bending.

both in charge of supplying the innervation of the lower segments of the transversus abdominis and the internal and external oblique muscle.[2] Thus, a far lateral lumbar disc herniation at L1-L2 can also present with abdominal pain and weakness causing abdominal wall paresis and bulge.[3] To our knowledge, there is only one previous cases report of abdominal wall bulging in a patient with a L1-L2 herniation.[4] Upper lumbar disc herniation most commonly presents with anterior thigh and or groin pain, not unilateral paresis of the abdominal wall.[5]

There are other entities that should also be considered as part of differential diagnosis of abdominal hernia. These can also involve damage to intercostal or upper lumbar nerves. For example, diabetic truncal radiculopathy can also present with unilateral abdominal wall herniation. The patient population consists of middle-aged or elderly diabetic men usually accompanied by a severe weight loss. The muscle bulging and pain resolve after 3-12 months.[6] In the literature, there are also a few case reports of abdominal muscle paralysis associated with herpes zoster, the incidence of abdominal muscle weakness varies between 0% and 6%. The most common presentation of herpes zoster is in the thoracic area; however, herpes zoster localized to the face and limbs are associated with motor complications.[7]

Other rare entities such as Lyme's disease[8] and thoracic syringomelia[9] can be associated with abdominal wall pain and paresis.

In conclusion, this case clearly illustrates that not all clinical presentation of inguinal masses are caused by abdominal/inguinal hernia subtypes. Other differential diagnosis such as acquired neurogenic abdominal wall weakness should be suspected when a unilateral bulging of the abdominal wall musculature is accompanied with position related spinal pain, and negative imaging tests for hernia. With a high index of suspicion for these clinical entities in mind during evaluation, unnecessary surgery can be prevented and appropriate work up and treatment can be provided.

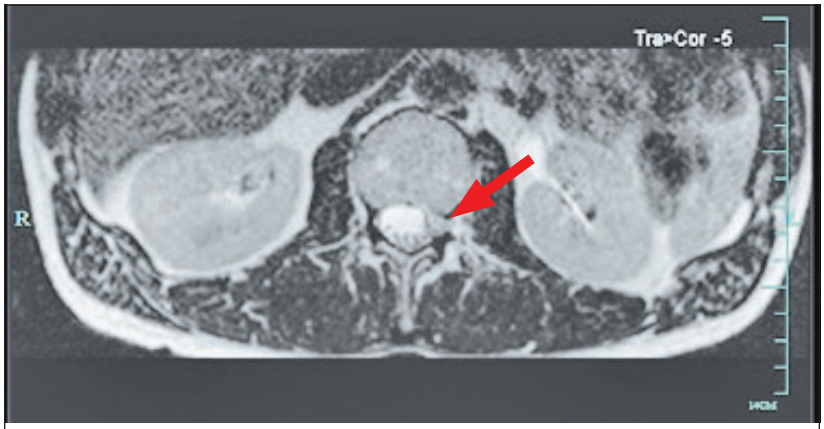


Figure 2. Left L1 nerve root compression from disc herniation (arrow). (MRI T2 weighted axial slice).

References

1. Schwartz SI, Shires GT, Spencer FC, Storer EH. *Principles of Surgery*. 3rd ed. New York, NY: McGraw Hill Book Company; 1979.
2. Moore KL, Agur AMR, Dalley AF. *Essential Clinical Anatomy*. 7th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2013.
3. Bartolomei L, Carbonin C, Cagnin G, Toso V. Unilateral swelling of the lower abdominal wall. Unusual clinical manifestation of an upper lumbar disc herniation. *Acta Neurochir* (Wien). 1992;117(1-2):78-79.
4. Billet FP, Ponssen H, Veenhuizen Q. Unilateral paresis of the abdominal wall: a radicular syndrome caused by herniation of the L1-2 disc?. *J Neurol Neurosurg Psychiatry*. 1989;52:678.
5. Sanderson SP, Houten J, Errico T, et al. The unique characteristics of "upper" lumbar disc herniations. *Neurosurgery*. 2004;55:385-389.
6. Chaudhuri KR, Wren DR, Werring D, Watkins PJ. Unilateral abdominal muscle herniation with pain: a distinctive variant of diabetic radiculopathy. *Diabet Med*. 1997;14(9):803-807.
7. Gottschau P, Trojaborg W. Abdominal muscle paralysis associated with herpes zoster. *Acta Neurol Scand*. 1991;84(4):344-347.
8. Daffner KR, Saver JL, Biber MP. Lyme polyradiculoneuropathy presenting as increasing abdominal girth. *Neurology*. 1990;40(2):373-375.
9. Coleman RJ, Ingram DA. Abdominal wall weakness due to thoracic syringomyelia. *Neurology*. 1991;41(10):1689-1691.

Authors

Dr Elgueta is a Research Fellow in the Department of Anesthesia, Montreal General Hospital, and affiliated with the Pontificia Universidad Catolica de Chile, Santiago.

Dr Wang is a Resident in the Department of Anesthesia, Montreal General Hospital.

Dr Gupta, a physiatrist, works with the Canadian Forces Health Centre-Ottawa and the Alan Edwards Pain Management Unit of the Department of Anesthesia, Montreal General Hospital. He is also an adjunct professor at Mc-Gill University in Montreal, Quebec.

LCol Besemann, a physiatrist, is head of the Canadian Forces physical rehabilitation program at the Canadian Forces Health Services Group Headquarters in Ottawa. He also works at the Canadian Forces Health Centre and is a lecturer at the University of Ottawa.

Application of High Energy Extracorporeal Shockwave Therapy on Musculoskeletal Conditions in US Military Medical Facilities

CPT Sally Corey, MC, USA
LTC Terry Mueller, MC, USA
COL (Ret) John Bojescul, MC, USA
Craig Cameron, DO

Abstract

Outcomes of extracorporeal shockwave therapy (ESWT) vary due to the heterogeneity of application protocols and patient characteristics. United States military medical facilities offer a unique environment to study the effects of ESWT due to the large use, consistent protocol, and ability to care for young active individuals. A retrospective review was conducted from November 2008 to March 2015 to assess types of musculoskeletal conditions treated by ESWT in US military medical treatment facilities, the demographics of patients treated with ESWT (age and gender), the trend throughout the time in question, and the protocols implemented. A literature review was performed to compare the use in US military facilities to reported data. In this study we report how US military medical facilities are using ESWT to treat musculoskeletal conditions and outcomes reported in literature. The purpose of our research is to raise awareness of this treatment modality and areas for further research within the US military medical facilities.

High energy extracorporeal shockwave therapy (ESWT) is FDA approved for lateral epicondylitis and plantar fasciitis; however, there are several other off-label uses.[1] Objective results are difficult to assess due to the variety of outcomes reported and protocols used in treating patients. United States military medical facilities treat young adult athletes with various musculoskeletal conditions. The goal of this study is to assess how US military medical facilities are using high energy extracorporeal shockwave therapy on musculoskeletal conditions in comparison to those reported in the literature in order to find areas for future research and utilization.

Materials and Methods

Approval was obtained from the Eisenhower Amy Medical Center institutional review board prior to the performance of this study. All data was de-identified of patient identifiable information by an outside source prior to analysis. From November 2008 to March 2015, all applications of high energy extracorporeal shock wave therapy (ESWT) produced by an electrohydraulic device, OssaTron (High Medical Technology, Alpharetta, GA), were recorded. Data was collected from 22 different medical treatment facilities within the US military including Army, Air Force, and Navy bases. Although a specific treatment method was not described by each facility included in this study, the method used by the authors of this article is illustrated in Figure 1. The treatment area of maximal tenderness on each patient was marked in the preoperative holding area. The patient underwent conscious sedation performed by the anesthesia staff. Hearing protection was placed on the patient as well as all others in the operating room. Ultrasound gel was applied to the patients marked extremity. The area was held under the OssaTron applicator and rotated slightly to apply even treatment to the entire area. The patient was awakened from anesthesia and discharged with instructions to abstain from strenuous activities of the treated extremity and to avoid ice and anti-inflammatory medications for 4 to 6 weeks.

Data was collected including the indication for ESWT treatment, laterality, patient demographics (age and gender), and the protocol used. The data was analyzed for the most common indications treated, typical protocol used for each indication described by kilovolts (kV) and number of shocks, and patient demographics associated with each indication. Descriptive statistics were performed using Microsoft Excel, 2013. A literature review was conducted using PubMed by searching for "extracorporeal shockwave therapy" and musculoskeletal conditions, such as "lateral epicondylitis," "plantar fasciitis," etc. Results were compared to data collected in US military medical facilities.

Results

United States military medical facilities performed 4,766 applications of high energy during the period studied.

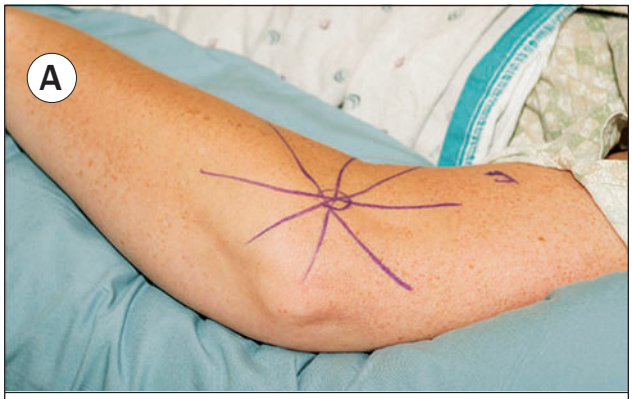
The facility where this research was synthesized performed 806 applications of ESWT by 4 different orthopedic providers and 2 different podiatric providers, who performed the majority of the procedures. The majority of patients treated at US military medical facilities were male (64%) with an average age of 40.5 years (range 15 to 87, median=40.1). Fifty-four different indications were described by the treating providers; however, not all indications are defined by ICD-9 or ICD-10 codes. Some indications were grouped together for ease of trending data (eg, "plantar fasciitis" and "arch tendonitis" were categorized as "plantar fasciitis"). The trend of applications is increasing as illustrated in Figure 2. Most patients were treated with 1,500 shocks at 18 kV.

The most common indication for high energy ESWT was plantar fasciitis (78% of all applications). Although almost 70% of patients were treated with 1,500 shocks at 18 kV, many other protocols were implemented in the treatment of plantar fasciitis. The average age of patients treated for plantar fasciitis was 40.4 years.

The next most common condition treated was achilles tendonitis, which included 13% of applications. The most common protocol performed was 1,500 shocks at 18 kV (420 of 605 applications); however, 88 patients were treated with 2,000 shocks at 24 kV. Ninety-two percent of the patients were aged 20 to 60 years, with an average age of 42.1.

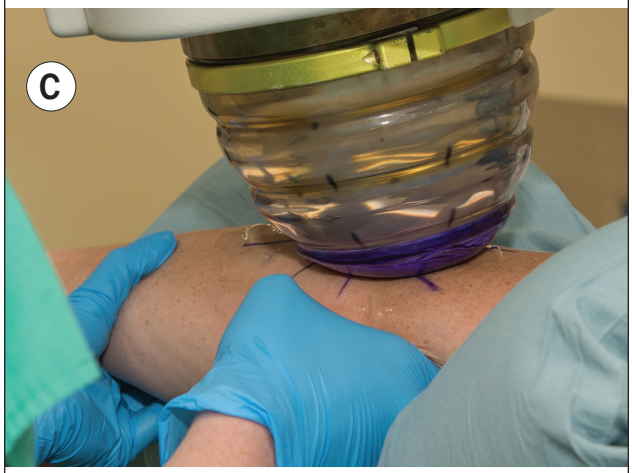
Lateral epicondylitis was the third most common indication for high energy ESWT, involving 3% of the patients included in this study. The average age of the patients was 45.6 years. Patellar tendonitis represented 2% of patients treated in US military medical facilities. Most of those patients (92%) were aged between 20 to 50 years, with an average age of 32.3.

Additional indications treated were grouped as ankle tendonitis, sesamoiditis, metatarsalgia, delayed union/non-unions, neuromas, and other. The widest variety of protocols utilized was described in the treatment of fracture non-unions and included 1,000 to 8,000 shocks at 15 kV to 28 kV. Most ankle tendonitis was treated with 2,000 shocks at 24 kV. Seven out of the 12 patients with neuromas were treated with 2,000 shocks at 24 kV. Although the most common protocol utilized for the other indications treated was 1,500 shocks at 18 kV, the less commonly treated indications had a wider variety in treatment protocols.



The area of maximal tenderness is marked in the preoperative holding area while the patient is awake.

The patient undergoes conscious sedation. The patient, operator, and anesthesia provider wear ear protection. Ultrasound gel is applied to the marked area.



The marked area is held to the OssaTron device and rotated slightly to apply treatment to the entire marked area.

Figure 1. The normal treatment method for high energy extracororeal shock wave therapy used by the authors at the Eisenhower Army Medical Center. The method is representative of procedures used at other US military medical facilities.

Comment

The effects of ultrasonic shockwaves on the human body were originally discovered during submarine warfare in

World War II. Its use in medicine began in 1971 to disintegrate kidney stones, known as lithotripsy. Research on orthopedic applications began in 1985 and in 1988 shock wave treatment was first applied for non-unions and delayed unions. The OssaTron was developed in 1993 to expand the indications of extracorporeal shockwave use to other musculoskeletal conditions.[2]

Shockwaves are generated 3 ways: electrohydraulic, electromagnetic, and piezoelectric. All 3 methods of creating shockwaves have the same general principals. Acoustic waves are generated, propagated through water, and transferred to the human body through a contact medium.[3] The exact effect on tissues of the human body is still unknown. Theories propose that ESWT induces the release of growth factors to promote angiogenesis and differentiation of mesenchymal stem cells, and provides hyper-stimulation analgesia.[4]

A literature review yields plantar fasciitis as the most reviewed indication for ESWT application. Most studies indicate that shockwave therapy improves symptoms of plantar fasciitis in comparison to placebo.[5-17] Despite many reports on the benefits of ESWT, adverse effects also occur. Haake et al found no significant improvement in symptoms between patients treated with ESWT and a control group. In addition, the treatment group had more side effects including skin reddening, pain, hematoma, local swelling, hair loss, nausea, dizziness, and sleep loss.[18] A systematic review by Thomson et al had similar conclusions.[19]

Previously reported results may not be applicable to patients treated in US military medical facilities due to various protocols and techniques used for application. The most relevant literature pertaining to the population in this study includes research performed by Ogden et al,[5,13] Wang et al,[16] Alvarez,[17] and Weil et al,[20] as they also used the OssaTron to deliver ESWT. In 2001, Ogden reported 56% improved symptoms in comparison to placebo, which led to FDA approval of ESWT application to chronic plantar fasciitis.[5] Wang found that the benefits of ESWT can last as long as 60 to 72 months.[16]

All of the studies cited above involved use of a local anesthetic in addition to or instead of general anesthesia. However, not all US military medical facilities use local anesthesia as allowed under current protocol. Since plantar fasciitis is the most commonly treated condition in US military medical facilities, future studies on outcomes could indicate if patients have improved immediate outcomes with local anesthetic compared to general anesthesia. Results of such study could greatly decrease the cost of using ESWT.

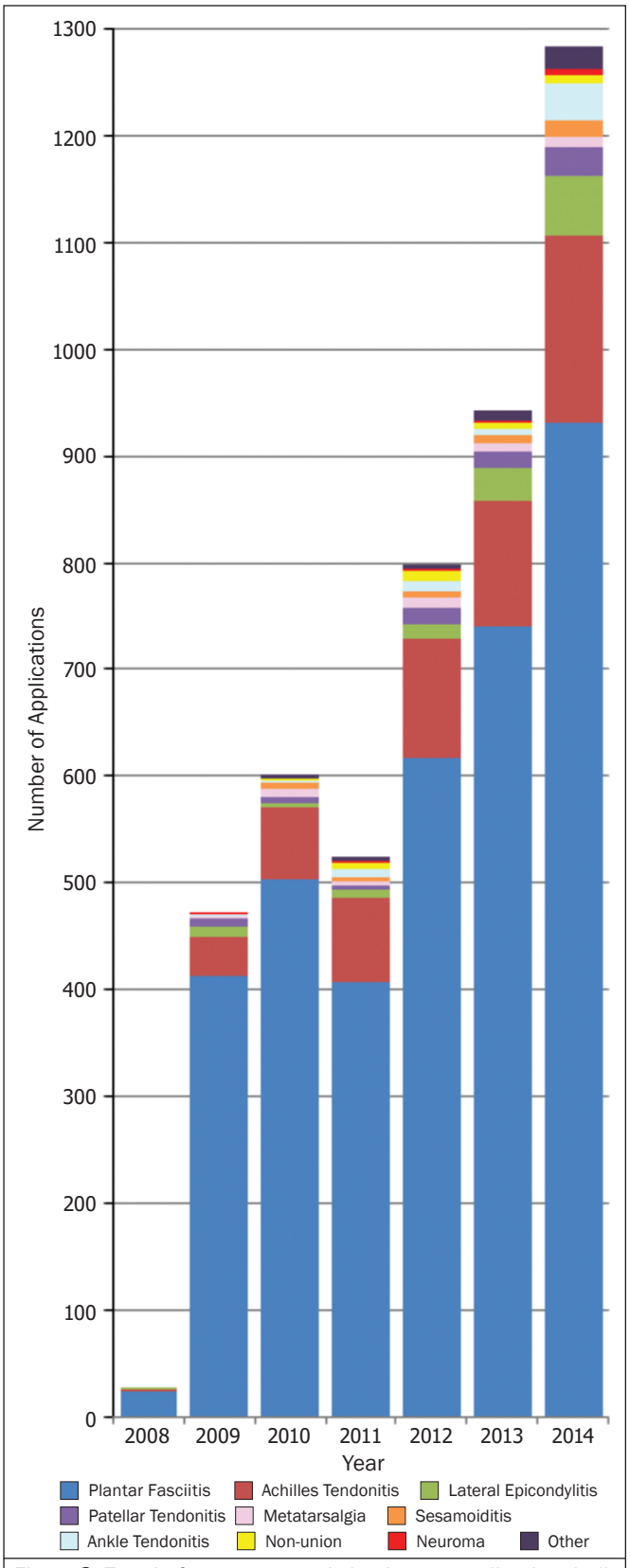


Figure 2. Trend of extracorporeal shockwave application. Indications listed in decreasing order (left to right).

The next most prevalent indication for ESWT application in our study was achilles tendonitis. Most studies on the application of low-energy ESWT for achilles tendonitis support its use.[21-24] Chen et al found that low-energy ESWT promotes TGF-ß1, and IGF-1 to improve healing of the achilles tendon.[25] A literature review found no previous studies on the use of the OssaTron for achilles tendonitis, however some research exists on the use of other high energy ESWT devices. In 1998, a study by Rompe et al found that high energy therapy greater than 0.28mJ/mm² may actually cause damage to tendons; however, that study was performed on rabbits and may not be applicable to humans.[26] Studies by Furia[27,28] on the use of high-energy ESWT in treating insertional and non-insertional achilles tendinopathy found improvement in outcomes after one year. These studies used electromagnetic generation of shock waves.[27,28] Costa et al[29] also used electromagnetic shock waves and found contradicting data in their randomized control trial with no improvement in pain and 2 cases of tendon ruptures.[29] Overall, data on ESWT for Achilles tendonitis remains inconclusive, and no studies have been performed using the same technique as used in US military medical facilities.

The second largest amount of research on the effects of ESWT was focused on lateral epicondylitis. In 2009, Buchbinder et al, conducted a systematic review analyzing 9 different randomized controlled trials on the use of ESWT for lateral epicondylitis and found no significant difference between symptoms after ESWT and placebo, and increased adverse effects with the use of ESWT. All studies included in their paper had various protocols, devices, and follow-up.[30] Results of other studies have been inconclusive or shown to have no effect.[31-36] Most of those studies used low-energy ESWT.

Studies using electrohydraulic high-energy shockwave have shown more positive results. Collins, Hildreth, and Jafarnia[37] performed a randomized controlled trial investigating the results of the OssaTron on lateral epicondylitis. The treatment group received a Bier block followed by ESWT with 1,500 shocks at 18 kV. After 8 weeks, 40% of patients in the treatment group met criteria of "success" compared to 21% in the placebo group.[37] Studies performed using the OssaTron for lateral epicondylitis were also performed by Wang and Chen[38] and Ko and Chen,[39] with improvement of symptoms with no long-term complications. A systematic review performed by Stasinopoulos and Johnson[40] concluded that the treatment of lateral epicondylitis with ESWT may be dose dependent and the optimal treatment protocol has not yet been determined.

Another common indication for ESWT in US military medical facilities is patellar tendonitis. Wang et al[41] provide the only literature on high energy electrohydraulic ESWT and found excellent results in 43% of patients 2 to 3 years after treatment in the ESWT group, whereas no excellent results were found in the control group. Zwerver et al[42] performed an interesting study looking specifically at the results of high energy ESWT in athletes during the competitive season. They found no long-term benefits to ESWT; however, there was a significant difference favoring the treatment group at one-week follow-up. Most other studies describe improvement in symptoms after treatment with ESWT.[43-45] A systematic review performed by van Leeuwen et al[46] concluded that although ESWT is effective in treating patellar tendonitis, the most effective protocol has not been determined.[46]

In our review, treatment of non-unions showed the most variation in ESWT protocols. Several studies have looked at the effects of various ESWT dosages and timing of treatment in the management of non-unions with satisfactory results.[47-50] A study by Alkhawashki[51] described the use of the OssaTron in the treatment of non-unions. By performing 3000-4000 shocks at 26 kV for large bones and 2000-3000 shocks at 26 kV for small bones, healing occurred in 37 of 49 patients at 10.2 months follow-up.[51] ESWT has been shown to have better results on hypertrophic non-union with a 76% union rate compared to a 29% union rate in atrophic non-unions.[52] Despite these findings, Kuo et al[53] performed a retrospective review on 22 patients with atrophic non-union of femoral shaft fractures after intramedullary fixation was performed and found a 100% union rate at 12 months after ESWT if ESWT was performed within 12 months after the initial surgery compared to 43% union rate when ESWT was performed greater than 12 months after the initial surgery. They concluded that the timing of ESWT application may matter.[53]

ESWT is most commonly used to treat conditions of tendons and bone; however, it has also been described to treat neuromas. Fridman et al[54] describe using the OssaTron to treat Morton's neuromas with 2,000 shocks at 21 kV. Patients treated with ESWT had a 92% improvement in pain 12 weeks after treatment in comparison to 76% in the control group.[54] United States military facilities also applied ESWT on neuromas; however, they used 2,000 shocks at 24 kV. Outcome measures could further describe the optimal intensity of treatment.

Other conditions treated with ESWT by US military medical facilities include several types of tendinopathy in the ankle, metatarsalgia, and sesamoiditis. To our

knowledge, there is no literature available describing treatment of these areas.

Evidence exists describing the use of ESWT on multiple other musculoskeletal conditions, such as avascular necrosis of the femoral head,[55,56] anterior cruciate ligament reconstruction,[57] chronic foot ulcers,[58] knee osteoarthritis,[59] and complex regional pain syndrome.[60] Some, though not all, of these conditions have been treated with ESWT in US military medical facilities. Most outcomes in the literature on these indications illustrate that this treatment modality may be beneficial to expedite healing and prolong or even decrease the need for surgery in these conditions.

Several studies describe the use of ESWT on the shoulder including calcific tendonitis and rotator cuff arthropathies with good results.[61-71] Only 3 applications of ESWT to the shoulder were recorded in US military medical facilities.

Reports on treatment outcomes vary regarding the effectiveness of ESWT. Although electromagnetic, piezoelectric, and electrohydraulic ESWT have the same general principles, differences exist in the amount and way of energy creation and transmission to the body.[1,72,73] Research on ESWT differentiates between focused and unfocused and between high, medium, and low energy shockwaves. These differences may help explain the variability in outcomes observed through the literature.

US military medical facilities offer a solution to the inconsistency of treatment protocols. In 2008, the OssaTron became the sole device to provide high energy ESWT on musculoskeletal conditions in US military medical facilities, which improves the uniformity of treatment protocols.

United States military medical facilities service a large population of generally athletic individuals who frequently encounter overuse injuries and would benefit from an expedited return to duty. Future studies are needed to assess the most efficacious protocol and validate results previously described.

Several limitations exist to this study. First, not all indications as described by providers were represented as an ICD-9 or 10 diagnosis code. Although the technique of application of ESWT is assumed to be consistent among providers, variations certainly exist. Providers performing ESWT in this study included orthopedic surgeons and podiatrists, which may overestimate use on foot and ankle conditions. The final limitation of this study is that it does not include outcomes, but suggests areas in which future research on the outcomes of ESWT can be performed in US military medical facilities.

Conclusion

US military medical facilities perform ESWT on indications not previously described in the literature. Due to the large use of ESWT and homogeneity of patient populations and protocols within the US military facilities, there exists great potential for future prospective studies on the outcomes of ESWT application on musculoskeletal conditions to determine effective protocols for active individuals and to expand the indications for ESWT application in the literature. Encouraging the application of ESWT in US military medical facilities on indications supported by literature may improve healing and decrease the need for surgery in certain conditions.

References

1. Wang CJ. Extracorporeal shockwave therapy in musculoskeletal disorders. *J Orthop Surg Res*. 2012;7:1-8.
2. Shrivastava S. Shock wave treatment in medicine. *J Biosci*. 2005;30(2):269-275.
3. Ogden JA, Tóth-Kischkat A, Schultheiss R. Principles of shock wave therapy. *Clin Orthop*. 2001;387:8-17.
4. Notarnicola A, Moretti B. The biological effects of extracorporeal shock wave therapy (eswt) on tendon tissue. *Muscles Ligaments Tendons J*. 2012;2(1):33-37.
5. Ogden JA, Alvarez R, Levitt R, Cross GL, Marlow M. Shock wave therapy for chronic proximal plantar fasciitis. *Clin Orthop Relat Res*. 2001;387:47-59.
6. Aqil A, Siddiqui MR, Solan M, Redfern DJ, Gulati V, Cobb JP. Extracorporeal shock wave therapy is effective in treating chronic plantar fasciitis: a meta-analysis of RCTs. *Clin Orthop Relat Res*. 2013;471(11):3645-3652.
7. Chang KV, Chen SY, Chen WS, Tu YK, Chien KL. Comparative effectiveness of focused shock wave therapy of different intensity levels and radial shock wave therapy for treating plantar fasciitis: a systematic review and network meta-analysis. *Arch Phys Med Rehabil*. 2012;93(7):1259-1268.
8. Gollwitzer H, Diehl P, von Korff A, Rahlfs VW, Gerdesmeyer L. Extracorporeal shock wave therapy for chronic painful heel syndrome: a prospective, double blind, randomized trial assessing the efficacy of a new electromagnetic shock wave device. *J Foot Ankle Surg*. 2007;46(5):348-357.
9. Gollwitzer H, Saxena A, DiDomenico LA, et al. Clinically relevant effectiveness of focused extracorporeal shock wave therapy in the treatment of chronic plantar fasciitis: A randomized, controlled multicenter study. *J Bone Joint Surg Am*. 2015;97(9):701-708.

10. Hsu WH, Lai LJ, Chang HY, Hsu RW. Effect of shockwave therapy on plantar fasciopathy. A biomechanical prospective. *Bone Joint J*. 2013;95(8):1088-1093.

11. Kudo P, Dainty K, Clarfield M, Coughlin L, Lavoie P, Lebrun C. Randomized, placebo-controlled, double-blind clinical trial evaluating the treatment of plantar fasciitis with an extracoporeal shockwave therapy (ESWT) device: a North American confirmatory study. *J Orthop Res*. 2006;24(2):115-123.

12. Metzner G, Dohnalek C, Aigner E. High-energy extracorporeal shock-wave therapy (ESWT) for the treatment of chronic plantar fasciitis. *Foot Ankle Int*. 2010;31(9):790-796.

13. Ogden JA, Alvarez RG, Levitt RL, Johnson JE, Marlow ME. Electrohydraulic high-energy shock-wave treatment for chronic plantar fasciitis. *J Bone Joint Surg Am*. 2004;86(10):2216-2228.

14. Rompe JD, Decking J, Schoellner C, Nafe B. Shock wave application for chronic plantar fasciitis in running athletes. A prospective, randomized, placebo-controlled trial. *Am J Sports Med*. 2003;31(2):268-275.

15. Theodore GH, Buch M, Amendola A, Bachmann C, Fleming LL, Zingas C. Extracorporeal shock wave therapy for the treatment of plantar fasciitis. *Foot Ankle Int*. 2004;25(5):290-297.

16. Wang CJ, Wang FS, Yang KD, Weng LH, Ko JY. Long-term results of extracorporeal shockwave treatment for plantar fasciitis. *Am J Sports Med*. 2006;34(4):592-596.

17. Alvarez R. Preliminary results on the safety and efficacy of the OssaTron for treatment of plantar fasciitis. *Foot Ankle Int*. 2002;23(3):197-203.

18. Haake M, Buch M, Schoellner C, et al. Extracorporeal shock wave therapy for plantar fasciitis: randomised controlled multicentre trial. *BMJ*. 2003;327(7406):75.

19. Thomson CE, Crawford F, Murray GD. The effectiveness of extra corporeal shock wave therapy for plantar heel pain: a systematic review and meta-analysis. *BMC Musculoskelet Disord*. 2005;6:19.

20. Weil LS Jr, Roukis TS, Weil LS, Borrelli AH. Extracorporeal shock wave therapy for the treatment of chronic plantar fasciitis: indications, protocol, intermediate results, and a comparison of results to fasciotomy. *J Foot Ankle Surg*. 2002;41(3):166-172.

21. Al-Abbad H, Simon JV. The effectiveness of extracorporeal shock wave therapy on chronic achilles tendinopathy: a systematic review. *Foot Ankle Int*. 2013;34(1):33-41.

22. Rasmussen S, Christensen M, Mathiesen I, Simonson O. Shockwave therapy for chronic achilles tendinopathy: a double-blind, randomized clinical trial of efficacy. *Acta Orthop*. 2008;79(2):249-256.

23. Rompe JD, Nafe B, Furia JP, Maffulli N. Eccentric loading, shock-wave treatment, or a wait-and-see policy for tendinopathy of the main body of tendo achillis: a randomized controlled trial. *Am J Sports Med*. 2007;35(3):374-383.

24. Rompe JD, Furia J, Maffulli N. Eccentric loading compared with shock wave treatment for chronic insertional achilles tendinopathy. A randomized, controlled trial. *J Bone Joint Surg Am*. 2008;90(1):52-61.

25. Chen YJ, Wang CJ, Yang KD, et al. Extracorporeal shock waves promote healing of collagenase-induced achilles tendinitis and increase TGF-beta1 and IGF-I expression. *J Orthop Res*. 2004;22(4):854-861.

26. Rompe JD, Kirkpatrick CJ, Küllmer K, Schwitalle M, Krischek O. Dose-related effects of shock waves on rabbit tendo achillis. A sonographic and histological study. *J Bone Joint Surg Br*. 1998;80(3):546-552.

27. Furia JP. High-energy extracorporeal shock wave therapy as a treatment for chronic noninsertional achilles tendinopathy. *Am J Sports Med*. 2008;36(3):502-508.

28. Furia JP. High-energy extracorporeal shock wave therapy as a treatment for insertional achilles tendinopathy. *Am J Sports Med*. 2006;34(5):733-740.

29. Costa ML, Shepstone L, Donell ST, Thomas TL. Shock wave therapy for chronic achilles tendon pain: a randomized placebo-controlled trial. *Clin Orthop Relat Res*. 2005;440:199-204.

30. Buchbinder R, Green SE, Youd JM, Assendelft WJ, Barnsley L, Smidt N. Shock wave therapy for lateral elbow pain. *Cochrane Database Syst Rev*. 2005;4(4):1-76.

31. Bisset L, Paungmali A, Vicenzino B, Beller E. A systematic review and meta-analysis of clinical trials on physical interventions for lateral epicondylalgia. *Br J Sports Med*. 2005;39(7):411-422; discussion 411-422.

32. Chung B, Wiley JP. Effectiveness of extracorporeal shock wave therapy in the treatment of previously untreated lateral epicondylitis: a randomized controlled trial. *Am J Sports Med*. 2004;32(7):1660-1667.

33. Dingemanse R, Randsdorp M, Koes BW, Huisstede BM. Evidence for the effectiveness of electrophysical modalities for treatment of medial and lateral epicondylitis: a systematic review. *Br J Sports Med*. 2014;48(12):957-965.

34. Haake M, Konig IR, Decker T, et al. Extracorporeal shock wave therapy in the treatment of lateral epicondylitis : A randomized multicenter trial. *J Bone Joint Surg Am*. 2002;84(11):1982-1991.

35. Speed CA, Nichols D, Richards C, et al. Extracorporeal shock wave therapy for lateral epicondylitis--a double blind randomized controlled trial. *J Orthop Res*. 2002;20(5):895-898.

36. Staples MP, Forbes A, Ptasznik R, Gordon J, Buchbinder R. A randomized controlled trial of extracorporeal shock wave therapy for lateral epicondylitis (tennis elbow). *J Rheumatol*. 2008;35(10):2038-2046.

37. Collins ED, Hildreth DH, Jafarnia KK. A clinical study of extracorporeal shock waves (ESW) for treatment of chronic lateral epicondylitis. *Curr Orthop Pract*. 2011;22(2):185-192.

38. Wang CJ, Chen HS. Shock wave therapy for patients with lateral epicondylitis of the elbow: a one- to two-year follow-up study. *Am J Sports Med*. 2002;30(3):422-425.

39. Ko JY, Chen HS, Chen LM. Treatment of lateral epicondylitis of the elbow with shock waves. *Clin Orthop Relat Res*. 2001;387:60-67.

40. Stasinopoulos D, Johnson MI. Effectiveness of extracorporeal shock wave therapy for tennis elbow (lateral epicondylitis). *Br J Sports Med*. 2005;39(3):132-136.

41. Wang CJ, Ko JY, Chan YS, Weng LH, Hsu SL. Extracorporeal shockwave for chronic patellar tendinopathy. *Am J Sports Med*. 2007;35(6):972-978.

42. Zwerver J, Hartgens F, Verhagen E, van der Worp H, van den Akker-Scheek I, Diercks RL. No effect of extracorporeal shockwave therapy on patellar tendinopathy in jumping athletes during the competitive season: a randomized clinical trial. *Am J Sports Med*. 2011;39(6):1191-1199.

43. Peers KH, Lysens RJ, Brys P, Bellemans J. Cross-sectional outcome analysis of athletes with chronic patellar tendinopathy treated surgically and by extracorporeal shock wave therapy. *Clin J Sport Med*. 2003;13(2):79-83.

44. Taunton K, Taunton J, Khan K. Treatment of patellar tendinopathy with extracorporeal shock wave therapy. *B C Med J*. 2003;45(10):500-507.

45. Vulpiani MC, Vetrano M, Savoia V, Di Pangrazio E, Trischitta D, Ferretti A. Jumper's knee treatment with extracorporeal shock wave therapy: a long-term follow-up observational study. *J Sports Med Phys Fitness*. 2007;47(3):323-328.

46. van Leeuwen MT, Zwerver J, van den Akker-Scheek I. Extracorporeal shockwave therapy for patellar tendinopathy: a review of the literature. *Br J Sports Med*. 2009;43(3):163-168.

47. Cacchio A, Giordano L, Colafarina O, et al. Extracorporeal shock-wave therapy compared with surgery for hypertrophic long-bone nonunions. *J Bone Joint Surg Am*. 2009;91(11):2589-2597.

48. Rompe JD, Rosendahl T, Schollner C, Theis C. High-energy extracorporeal shock wave treatment of nonunions. *Clin Orthop Relat Res*. 2001;387:102-111.

49. Tamma R, dell'Endice S, Notarnicola A, et al. Extracorporeal shock waves stimulate osteoblast activities. *Ultrasound Med Biol*. 2009;35(12):2093-2100.

50. Vulpiani MC, Vetrano M, Conforti F, et al. Effects of extracorporeal shock wave therapy on fracture nonunions. *Am J Orthop (Belle Mead NJ)*. 2012;41(9):E122-E127.

51. Alkhawashki HM. Shock wave therapy of fracture nonunion. *Injury*. 2015;46(11):2248-2252.

52. Zelle BA, Gollwitzer H, Zlowodzki M, Buhren V. Extracorporeal shock wave therapy: current evidence. *J Orthop Trauma*. 2010;24:S66-S70.

53. Kuo SJ, Su IC, Wang CJ, Ko JY. Extracorporeal shockwave therapy (ESWT) in the treatment of atrophic non-unions of femoral shaft fractures. *Int J Surg*. 2015;24(Pt B):131-134.

54. Fridman R, Cain JD, Weil L. Extracorporeal shockwave therapy for interdigital neuroma. *J Am Podiatr Med Assoc*. 2009;99(3):191-193.

55. Ludwig J, Lauber S, Lauber HJ, Dreisilker U, Raedel R, Hotzinger H. High-energy shock wave treatment of femoral head necrosis in adults. *Clin Orthop Relat Res*. 2001;(387):119-126.

56. Wang CJ, Wang FS, Huang CC, Yang KD, Weng LH, Huang HY. Treatment for osteonecrosis of the femoral head: comparison of extracorporeal shock waves with core decompression and bone-grafting. *J Bone Joint Surg Am*. 2005;87(11):2380-2387.

57. Wang C, Ko J, Chou W, et al. Shockwave therapy improves anterior cruciate ligament reconstruction. *J Surg Res*. 2014;188(1):110-118.

58. Wang C, Wu C, Yang Y, Liu R, Kuo Y. Long-term outcomes of extracorporeal shockwave therapy for chronic foot ulcers. *J Surg Res*. 2014;189(2):366-372.

59. Zhao Z, Jing R, Shi Z, Zhao B, Ai Q, Xing G. Efficacy of extracorporeal shockwave therapy for knee osteoarthritis: a randomized controlled trial. *J Surg Res*. 2013;185(2):661-666.

60. Notarnicola A, Moretti L, Tafuri S, et al. Shockwave therapy in the management of complex regional pain syndrome in medial femoral condyle of the knee. *Ultrasound Med Biol*. 2010;36(6):874-879.

61. Albert JD, Meadeb J, Guggenbuhl P, et al. High-energy extracorporeal shock-wave therapy for calcifying tendinitis of the rotator cuff: A randomised trial. *J Bone Joint Surg Br*. 2007;89(3):335-341.

62. Bannuru RR, Flavin NE, Vaysbrot E, Harvey W, McAlindon T. High-energy extracorporeal shock-wave therapy for treating chronic calcific tendinitis of the shoulder: A systematic review. *Ann Intern Med*. 2014;160(8):542-549.

63. Chen CY, Hu CC, Weng PW, et al. Extracorporeal shockwave therapy improves short-term functional outcomes of shoulder adhesive capsulitis. *J Shoulder Elbow Surg*. 2014;23(12):1843-1851.

64. Daecke W, Loew M. Long-term effects of extracorporeal shockwave therapy in chronic calcific tendinitis of the shoulder. *J Shoulder Elbow Surg*. 2002;11(5):476-480.

65. Gerdesmeyer L, Wagenpfeil S, Haake M, et al. Extracorporeal shock wave therapy for the treatment of chronic calcifying tendonitis of the rotator cuff: a randomized controlled trial. *JAMA*. 2003;290(19):2573-2580.

66. Hsu CJ, Wang DY, Tseng KF, Fong YC, Hsu HC, Jim YF. Extracorporeal shock wave therapy for calcifying tendinitis of the shoulder. *J Shoulder Elbow Surg*. 2008;17(1):55-59.

67. Huisstede BM, Gebremariam L, van der Sande R, Hay EM, Koes BW. Evidence for effectiveness of extracorporal shock-wave therapy (ESWT) to treat calcific and non-calcific rotator cuff tendinosis--a systematic review. *Man Ther*. 2011;16(5):419-433.

68. Lee SY, Cheng B, Grimmer-Somers K. The midterm effectiveness of extracorporeal shock-wave therapy in the management of chronic calcific shoulder tendinitis. *J Shoulder Elbow Surg*. 2011;20(5):845-854.

69. Loew M, Daecke W, Kusnierczak D, Rahmanzadeh M, Ewerbeck V. Shock-wave therapy is effective for chronic calcifying tendinitis of the shoulder. *J Bone Joint Surg Br*. 1999;81(5):863-867.

70. Rompe JD, Burger R, Hopf C, Eysel P. Shoulder function after extracorporal shock wave therapy for calcific tendinitis. *J Shoulder Elbow Surg*. 1998;7(5):505-509.

71. Verstraelen FU, In den Kleef NJ, Jansen L, Morrenhof JW. High-energy versus low-energy extracorporeal shock wave therapy for calcifying tendinitis of the shoulder: which is superior? A meta-analysis. *Clin Orthop Relat Res*. 2014;472(9):2816-2825.

72. Ogden JA, Alvarez RG, Levitt R, Marlow M. Shock wave therapy (Orthotripsy) in musculoskeletal disorders. *Clin Orthop Relat Res*. 2001;387:22-40.

73. Sems A, Dimeff R, Iannotti JP. Extracorporeal shock wave therapy in the treatment of chronic tendinopathies. *J Am Acad Orthop Surg*. 2006;14(4):195-204.

Authors

CPT Corey, LTC Mueller, and Dr Cameron are with the Department of Orthopaedic Surgery, Dwight D. Eisenhower Army Medical Center, Fort Gordon, Georgia.

COL (Ret) Bojescul is with Augusta Orthopedic and Sports Medicine Specialists, Augusta, Georgia.

Animal Derived Thiol Induced Work Exacerbated Asthma: A Brief Case Report of a Unique Workplace Hazard

LTC John W. Downs, MC, USA
Joshua M. Renshaw, MS

Abstract

A 33 year old female healthcare worker with a history of cough variant asthma presented with 2 weeks of dyspnea and cough that she believed to be due to recurring exposure to skunk spray in her work environment. The employee was working in a temporary structure outside the primary hospital campus. During the preceding 2 weeks, at least one striped skunk was observed multiple times by staff members to be crawling under the structure. The employee's symptoms were not initially considered serious by her supervisors who felt that the appreciable "skunk smell" was merely a nuisance odor. Repeated pre- and postexposure spirometry noted a 350 mL and 11% reduction in forced expiratory volume at one second (FEV1). A review of organic chemistry literature found that 2 thiols, also known as mercaptans, produced in striped skunk spray are structurally related to 1-butanethiol, a chemical workplace hazard and known respiratory irritant with established occupational exposure limits. The observation of the chemical similarities between these skunk-derived thiols and workplace thiols was the key factor in getting the employee temporarily removed from a hazardous, albeit unique, working environment.

Case Report

A 33 year old female healthcare worker with a history of cough variant asthma presented to the occupational health clinic with 2 weeks of dyspnea and cough that she believed to be due to recurring exposure to skunk spray. The patient reported that her asthma was typically well controlled requiring use of a short acting bronchodilator only twice per year for the past 6 years. Two weeks prior to presentation, she and coworkers began noticing the distinct odor of skunk spray in the temporary clinic building in which they were presently working while their usual location in the main hospital facility underwent renovations. They also witnessed at least one striped skunk traveling under the structure. Repeated attempts by pest control authorities to trap and remove the animal(s) had been unsuccessful. Several coworkers had experienced eye irritation, nausea, and headaches after working in the building, but no others experienced respiratory effects.

The patient's initial physical examination at presentation was remarkable for witnessed conversational dyspnea, but without any obvious adventitious sounds on lung auscultation. Initial spirometry showed a forced expiratory volume at one second (FEV1) of 2.97 L (92% of predicted NHANES III reference values); however, the patient had used her levalbuterol bronchodilator shortly before presenting for evaluation. The patient opted to take a day of sick leave before the weekend, which allowed her to have 3 days away from work. The following Monday, she presented for follow-up evaluation. She reported resolution of symptoms within 12 hours of leaving the temporary clinic, and denied any use of bronchodilators over the weekend. Before this visit, she had worked for less than an hour in the area where the skunk odor persisted. Spirometry at this time noted an FEV1 of 2.62 L (81% predicted). Based on this objective reduction in respiratory function, we recommended to her supervisors that she be temporarily removed from the current work environment, at least until the reported skunks could be captured and removed. Unfortunately, this did not occur immediately and the patient continued to complain daily of cough and dyspnea beginning within one hour of starting work in the temporary clinic building. She managed to work through the day with 3 to 4 bronchodilator administrations each day. The upcoming weekend included a holiday, and the patient spent 4 days away from work over a holiday weekend.

In the interim, occupational health and industrial hygiene conducted a review of organic chemistry literature to better understand what, if any, possible respiratory or mucus membranes irritants were contained within striped skunk spray that might explain the patient's presentation. This review found that 2 thiols, (E)-2-butene-1-thiol and 3-methyl-1-butanethiol, are primarily responsible for the odor of striped skunk spray.[1,2] Thiols are organic compounds containing a carbon-bonded

sulfhydryl (R-SH) group that were historically known as mercaptans.[1] The structurally related thiol 1-butanethiol (also known as 1-butyl-mercaptan) is known to have a potent skunk-like odor with a low detection threshold, and was once believed to have been the primary thiol in skunk spray.[1,3] As such, it has found use as an additive to natural gas to provide the putrid odor for leak detection, and may also be used as an industrial solvent.[4] 1-butanethiol has established occupational exposure limits by both the Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health and is a known mucus membrane and respiratory irritant.[5] Researchers from the California Environmental Protection Agency had also previously hypothesized that the release of butyl mercaptan, a known degradation product of cotton defoliants, may have contributed to an increased proportion of respiratory-related mortality in cotton-growing areas of the San Joaquin Valley.[6]

The patient returned for follow-up and pre-exposure spirometry following her 4-day absence from the temporary clinic. At this visit, she reported again cessation of symptoms after 12 hours outside the clinic, but stated she had return of cough and subjective dyspnea for about one hour after passing through skunk odor while driving in a rural area. She required no bronchodilator use during this 4-day absence from the temporary clinic. Pre-exposure spirometry was obtained, and the patient was noted to have an FEV1 of 2.97 L (92% predicted) again. She then returned to work in the temporary clinic. Within one hour of exposure, the previously reported developed cough and subjective dyspnea resumed. She then returned, as instructed, to the occupational health clinic after approximately 4 hours of work and before using her bronchodilator. A repeat postexposure spirometry found the FEV1 to be at 2.62 L (81% predicted), again noting a 350 mL and 11% reduction in FEV1. After this second documented detriment in FEV1 following presumed exposure to the noted skunk odor, we obtained permission from the patient to discuss the findings with her supervisors in order to help them understand why the patient was becoming ill at work. We informed the patient's supervisors that she displayed objective evidence of respiratory decline upon returning to the temporary clinic environment, and that we had determined that components of the skunk spray were very likely to cause respiratory irritation at sufficient concentrations. After providing this information, management agreed to relocate the patient to an alternate clinic area until either the skunk(s) could be trapped or until the clinic moved back into its permanent location inside the main hospital facility. Respiratory protection was considered with organic vapor cartridges, but this was rapidly dismissed as unfeasible due to the potential for alarming clinic patients with its appearance, and the reduced ability to communicate. Upon being moved to the alternate clinic facility, the patient again noted cessation of dyspnea, cough, and bronchodilator use within 12 hours after removal from the skunk odor. Pest control efforts continued in the coming weeks at trapping and removal of the skunk(s), but were apparently not successful.

A follow-up visit after working in an alternate clinic for one week found the patient's FEV1 to be 2.90 L (90% predicted) and she had not required bronchodilator use in 6 days. She continued to report no recurrence of cough or dyspnea since no longer being exposed to the skunk odor. Six weeks later, she returned to working with her primary clinic when it was moved back to its location within the main hospital. Symptoms have not returned in the months since return to the primary clinic location.

Comment

Work-exacerbated asthma has been reported to occur in up to 25% of working persons with asthma.[7] Healthcare workers are a recognized occupation at risk for work-exacerbated asthma, traditionally due to the use of compounds such latex, formaldehyde, glutaraldehyde, chlorhexidine, antibiotics, and detergent enzymes in healthcare.[7,8] Thiols would not generally be expected to contribute to work-exacerbated asthma in healthcare workers. However, in this case, we postulate that given the structural similarities among the thiols associated with industrial use and the thiols created in skunk spray, it is likely that the patient experienced thiol-induced respiratory irritation which exacerbated her underlying asthma, initiated symptoms of cough and dyspnea, and induced mild airway obstruction.

Available literature on the specific toxic effects of striped skunk spray in humans is very rare, aside from the expected anecdotal comments about its repulsive odor and resultant success as a deterrent. One physician in rural 19th century Virginia reported a single instance of a schoolboy prank gone wrong when 2 students held down another student, and forced him to inhale from a bottle of "perfume from the skunk or pole-cat."[9] The physician related that the forced inhalational exposure of skunk musk resulted in "A total unconsciousness, relaxation of muscular system, extremities cool, pupils natural, breathing normal, pulse 65, temperature 91°; in which condition he remained for one hour." Indeed, 1-butanethiol is also recognized as a central nervous system depressant.[3] The veterinary literature suggests that at least canines may be susceptible to a skunk thiol induced hemolytic anemia, but no similar reports are noted in the human medical literature.[10]

We believe this to be the only reported case of skunk thiol irritant-induced, work-exacerbated asthma. Although this is a likely an exceedingly rare occurrence and possibly unique to this particular patient, we felt it appropriate to report this observation as both management and coworkers initially found it difficult to take the patient's respiratory complaints seriously. They believed that the odor was "just a bad smell" and could not possibly have deleterious health effects on workers. It is possible that similar effects could be observed in occupations with greater likelihood of skunk exposure, such as pest control or wildlife management authorities. Our observation of the chemical similarities between skunk-associated thiols and thiols that are known occupational chemical hazards was a key factor in getting the patient removed from what we believed to be a hazardous, albeit unique, working environment for this patient. This case is also a reminder that the investigation of potential causes of occupational asthma or work-exacerbated asthma may require a multidisciplinary approach with occupational medicine, industrial hygiene, safety officers, and pulmonary medicine.

References

1. Wood WF. The history of skunk defensive secretion research. *Chem Educat*. 2000;4(2):44-50.
2. Wood WF. New components in defensive secretion of the striped skunk, *Mephitis mephitis*. *J Chem Ecol*. 1990;16(6):2057-2065.
3. Occupational Safety and Health Administration. Chemical Sampling Information: Butyl mercaptan [internet]. Available at: https://www.osha.gov/dts/chemicalsampling/data/CH_223600.html. Accessed October 2, 2018.
4. Haz-Map: Occupational Hazards Database [database online]. Bethesda, MD: National Library of Medicine. Last updated October 2018. Available at: https://hazmap.nlm.nih.gov/. Accessed October 2, 2018.
5. National Institute for Occupational Safety and Health (NIOSH). n-Butyl mercaptan. *NIOSH Pocket Guide to Chemical Hazards*. Available at: http://www.cdc.gov/niosh/npg/npgd0083.html. Accessed October 2, 2018.
6. Ames RG, Gregson J. Mortality following cotton defoliation: San Joaquin Valley, California, 1970-1990. *J Occup Environ Med*. 1995;37(7):812-819.
7. Tarlo SM, Lemiere C. Occupational asthma. *N Engl J Med*. 2014;370(7):640-649.
8. Szema AM. Work-exacerbated asthma. *Clin Chest Med*. 2012;33(4):617-624.
9. Conway WB. A new anaesthetic. *Virginia Medical Monthly*. July 28 1881;8:359.
10. Zaks KL, Tan EO, Thrall MA. Heinz body anemia in a dog that had been sprayed with skunk musk. *J Am Vet Med Assoc*. 2005;226(9):1516-1518, 1500.

Authors

When this report was prepared, LTC Downs was with the Department of Preventive Medicine, Blanchfield Community Hospital, Fort Campbell, Kentucky.

Mr Renshaw is Chief, Industrial Hygiene Service, Department of Preventive Medicine, Blanchfield Community Hospital, Fort Campbell, Kentucky.

Institution of Military Working Dog Physical Profile Record to Clarify Medical Readiness Category Status

CPT Sean P. Curry, VC, USA
CPT Jeremy W. Lewis, VC, USA

Abstract

The current medical readiness category (CAT) status system used for military working dogs (MWDs) simply outlines the deployability of an MWD. This system, however, does not detail any other restrictions or the reason for assigning the current CAT status. The question is often raised as to whether the MWD can continue to work and perform everyday duties despite not being a CAT I. Using the Physical Profile Record system established for human providers, a system was adapted for MWDs. This system will allow Veterinary Corps Officers (VCOs) to give specific instructions to the handler and owning unit about the nature, progression, and details of injury or dysfunction beyond the CAT status. Furthermore, the ability to track chronic conditions and duration of illness will increase overall readiness of a kennel.

The purpose of this project is to further expand the current medical readiness category (CAT) status policy as outlined in the DOD mem... Deployment Guidelines for Military Worki... memorandum outlines the CA... ing deployability of the ... of treatment for medical ... memorandum does not al... (VCOs) to expand upon t... tations to the MWD's wo... of the MWD often wants ... is during the evaluation and treatment process that miscommunication can occur between the VCO and owning unit. Does CAT III mean no work at all? Can the MWD perform specific duties (limited searches, physical preference/deterrence, etc.)? Can the MWD negotiate the obstacle course? The proposed MWD Physical Profile Record shown in the Figure provides a two-page document in which the VCO can clearly outline the injury, permanent or temporary profile, limitations of work, treatment, and expected return to duty while providing a deeper insight to the assignment of CAT status. The document also provides for tracking of days where physical restrictions exist, potentially highlighting the need for deeper inquiry or initiation of the disposition process.

The goal in the development of this MWD Physical Profile Record is worldwide integration into the MWD record. The MWD Physical Profile Record will provide a physical form to which both the VCO and owning unit can refer that is more readily understood by commanders. Integration will expedite return to duty and increase overall readiness of a kennel. Furthermore, it will provide a physical document in the MWD record that can be referenced for historical problems, especially ... of the MWD Physical Profile ... inst its human model and ... integrate it.

... ith integrating the MWD ... e MWD record. Training ... s currently accomplished ... s using both online and ... ing for this system can be adapted from the human system outlined in *Army Regulation 40-501: Standards of Medical Fitness*. Explanation of use of the form will be required to ensure understanding by VCOs. This can be accomplished through the use of teleconferences and in-person seminars. The VCOs can then instruct the MWD owning units of its use.

Summary

There is currently a lapse in understanding between VCOs and MWD owning units as to the limitations of the CAT status system. The CAT statuses do not fully explain what an MWD can and cannot do while on any status other than CAT I. As a result, miscommunications often occur, which can delay or even cause regression in a treatment plan. The MWD Physical Profile Record will fill that gap and improve communication through the use of a physical form to which both the VCO and owning unit can refer. Implementation will increase return to duty and overall readiness of a kennel.

Authors

When this article was written, CPT Curry and CPT Lewis were with the Fort Bragg Veterinary Center, Fort Bragg, North Carolina.

*Internal military document not readily accessible by the general public.

INSTITUTION OF MILITARY WORKING DOG PHYSICAL PROFILE RECORD
TO CLARIFY MEDICAL READINESS CATEGORY STATUS

MWD PHYSICAL PROFILE RECORD									
SECTION 1: MWD/UNIT INFORMATION									
1. MWD NAME		2. TATTOO				3. AGENCY/BRANCH			
4. UNIT, ORG, STATION						5. CERTIFICATION			
SECTION 2: PERMANENT PROFILE									
6. REASON FOR PROFILE						8. VCO	9. APPROVING AUTHORITY	10. DATE	
7.	P	U	L	E	S				
Combined PULES							11. CAT STATUS (Circle ONE) 1 2 3 4		
SECTION 3: ACTIVE TEMPORARY PROFILE(S) AS OF:									
12. REASON FOR PROFILE	13. SEVERITY	14. MECHANISM OF INJURY/ ILLNESS	15. EXPECTED RETURN DATE	16. DAYS ON PROFILE	17. VCO				
18. TOTAL DAYS ON TE 12 MONTHS ___ DATE:_____						S (Circle ONE) 3 4			
20. INDICATE THOSE A APPROPRIATE COLUM						G AN “N” IN THE SECTION 2.			
							P	T	
a. Physically able to walk without assistance?									
b. Physically able to walk or run without evident pain?									
c. Physically able to hup or jump into and out of vehicles unassisted?									
d. Mentally and/or physically able to function without medication?									
e. Able to perform daily duties outside kennel without heat stress?									
f. Live and function, without any restrictions in any geographic or climate area without worsening?									
21. ADDITIONAL PHYSICAL RESTRICTIONS:									

Proposed Military Working Dog Physical Profile Record (1 of 3, continued).

SECTION 5: MEDICAL INSTRUCTIONS TO UNIT (Permanent instructions highlighted)
22. MEDICATIONS, PHYSICAL THERAPY PLAN, KENNEL CARE, ETC.

SECTION 6: MWD PHYSICAL TRAINING AND DETECTION				
	PERMANENT		TEMPORARY	
23. EVENT	YES	NO	YES	NO
OB COURSE	[ ]	[ ]	[ ]	[ ]
BITE WORK	[ ]	[ ]	[ ]	[ ]
DETECTION	[ ]	[ ]	[ ]	[ ]

SECTION 7: MWD PHYSICAL TRAINING AND DETECTION CAPABILITIES
(Any marked "NO" in Section 6 require explanation)

24. ANNOTATE SPECIF

OB COURSE (Certain

BITE WORK:

DETECTION:

DEPLOYABILITY:

TDY STATUS/ABILITY (Based on CAT status):

OTHER NOTES BY PROVIDER:

25. HANDLER/KENNEL REP (Rank, Last, First)	SIGNATURE	DATE
26. VCO NAME (Rank, Last, First)	SIGNATURE	DATE

Proposed Military Working Dog Physical Profile Record (2 of 3, continued).

INSTITUTION OF MILITARY WORKING DOG PHYSICAL PROFILE RECORD
TO CLARIFY MEDICAL READINESS CATEGORY STATUS

Instructions for Each Block

Section 1: MWD/Unit Information

1. Military Working Dog's (MWD) full name printed.
2. MWD's Tattoo number.
3. Branch of Service/Agency Name.
4. MWD's Unit, Organization, and Station location.
5. All certifications the MWD holds such as patrol, explosive, etc.

Section 2: Permanent Profile

(Only to be completed if needed - skip this section if temporary)

6. Reason or injury leading to profile.
7. P- physical, U- front limb, L- hind limb, E- eyes, S- behavior: Mark each section with a CAT status indicating the region of dysfunction. Example, MWD on Ritalin for behavior issues w
8. Printed name of
9. Who is authorizi other than VCO)
10. Date profile was
11. CAT Status for t

Section 3: Active Ten

(If permanent, skip this section and fill out section 2)

12. Reason or injury leading to profile.
13. Mild, moderate, or severe based on how debilitated the MWD presents.
14. How the injury occurred Ex. On patrol, OB course, etc.
15. Expected return date to full active duty or permanent profile status with no restrictions.
16. Days on profile to today (filling out of current profile).
17. VCO printed name.
18. Historical account taken from previous MWD Physical Profile Records or MWD's record: fill in total days in last 12 and 24 months, write today's date.
19. CAT status for the temporary profile.

Section 4: Functional Activities

20. Fill out letters a-f by placing an "N" in either the Permanent (P) or Temporary (T) column. If an "N" is placed in the P column then section 2 must be completed.
21. Additional restrictions the VCO feels are relevant to injury or profile not already outlined above.

Section 5: Medical Instructions to Unit

22. Write anything important to completion of the profile such as; any medications to include dose and frequency, physical therapy plan VCO has explained to handler, any special kennel care requirements such as wearing a cone at all times.

Section 6: MWD Physical Training and Detection

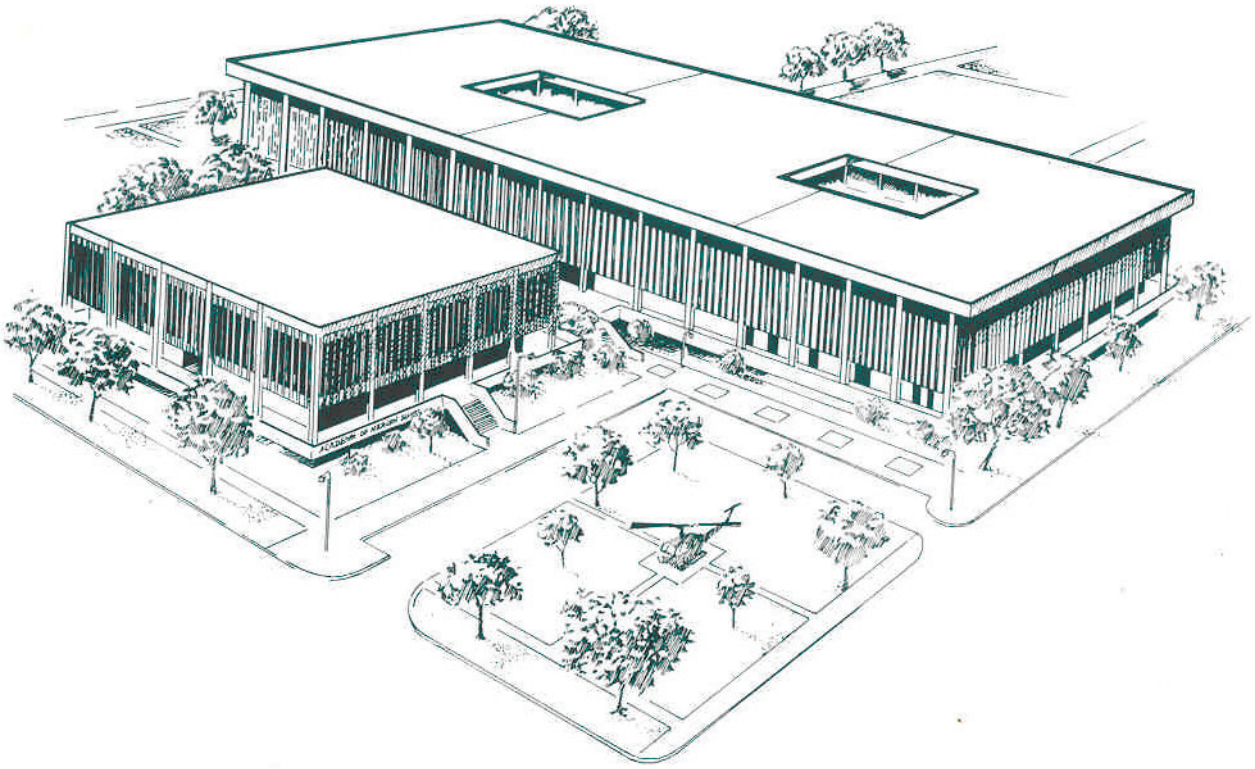
23. Place an "x" in the box indicating the MWD's perform the given task ach event will have both mporary marked in either

Training and abilities

plain any event that was marked "No." For example, if the OB Course was marked "No" in the temporary column, explain why and if it all or just some of the obstacles that are a "No." Use this section to explain the limitations of the MWD's profile and fill out all sections that are relevant. Is the MWD not deployable, but still able to go TDY?

25. Handler or Kennel Representative printed rank, last name, and first name, signature, and date.
26. VCO printed rank, last name, and first name, signature, and date.

Proposed Military Working Dog Physical Profile Record (3 of 3).



The US Army Health Readiness Center of Excellence

The Army Medical Department Center and School

Envision, Design, Train, Educate, Inspire

Joint Base San Antonio-Fort Sam Houston, Texas

This Page Intentionally Left Blank

Submission of Manuscripts to the *Army Medical Department Journal*

The *United States Army Medical Department Journal* is published quarterly to expand knowledge of domestic and international military medical issues and technological advances; promote collaborative partnerships among the Services, components, Corps, and specialties; convey clinical and health service support information; and provide a professional, high quality, peer reviewed print medium to encourage dialogue concerning health care issues and initiatives.

Review Policy

All manuscripts will be reviewed by the *AMEDD Journal*'s Editorial Review Board and, if required, forwarded to the appropriate subject matter expert for further review and assessment.

Identification of Potential Conflicts of Interest

1. **Related to individual authors' commitments:** Each author is responsible for the full disclosure of all financial and personal relationships that might bias the work or information presented in the manuscript. To prevent ambiguity, authors must state explicitly whether potential conflicts do or do not exist. Authors should do so in the manuscript on a conflict-of-interest notification section on the title page, providing additional detail, if necessary, in a cover letter that accompanies the manuscript.
2. **Assistance:** Authors should identify Individuals who provide writing or other assistance and disclose the funding source for this assistance, if any.
3. **Investigators:** Potential conflicts must be disclosed to study participants. Authors must clearly state whether they have done so in the manuscript.
4. **Related to project support:** Authors should describe the role of the study sponsor, if any, in study design; collection, analysis, and interpretation of data; writing the report; and the decision to submit the report for publication. If the supporting source had no such involvement, the authors should so state.

Protection of Human Subjects and Animals in Research

When reporting experiments on human subjects, authors must indicate whether the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. If doubt exists whether the research was conducted in accordance with the Helsinki Declaration, the authors must explain the rationale for their approach and demonstrate that the institutional review body explicitly approved the doubtful aspects of the study. When reporting experiments on animals, authors should indicate whether the institutional and national guide for the care and use of laboratory animals was followed.

Informed Consent

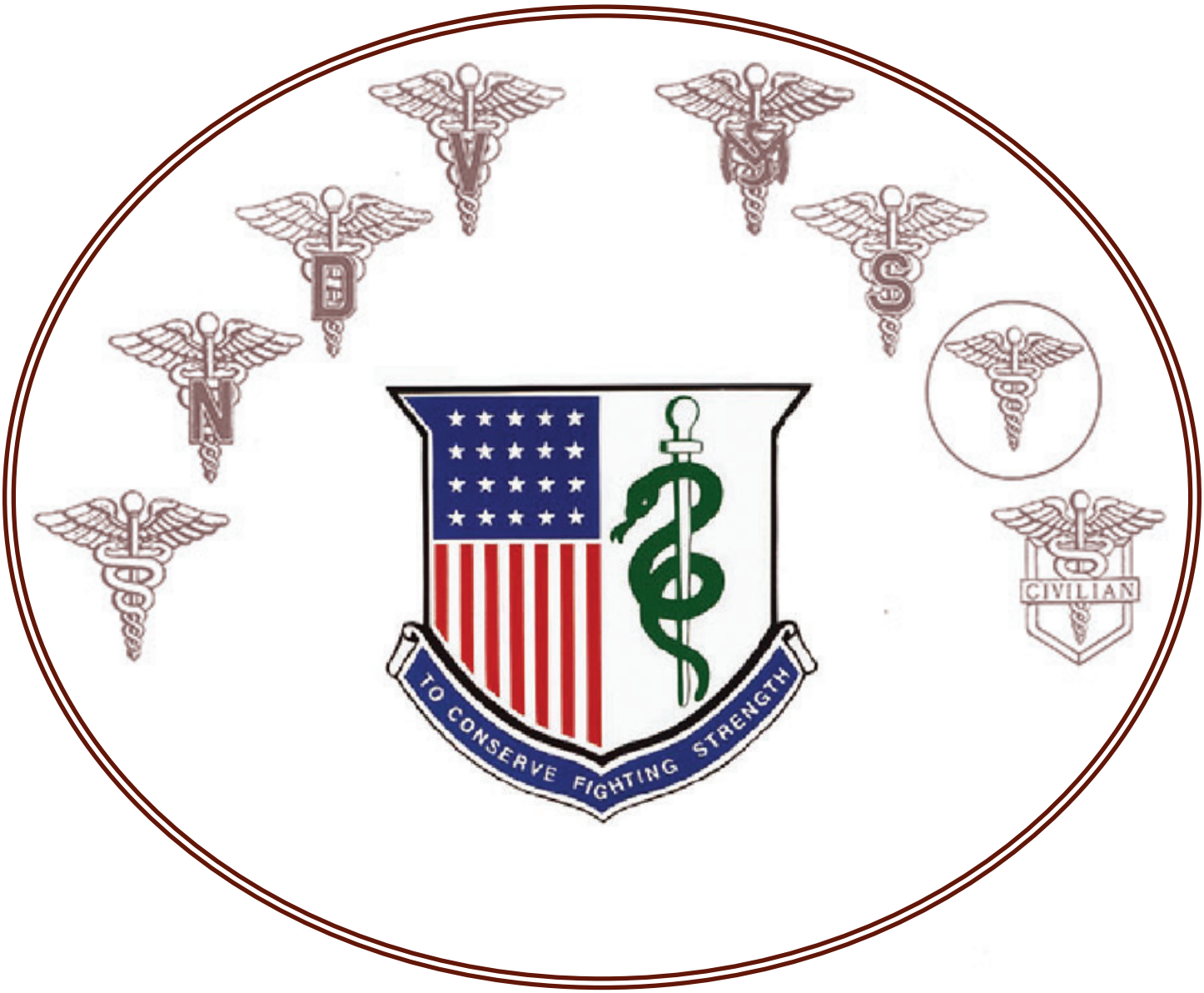
Identifying information, including names, initials, or hospital numbers, should not be published in written descriptions, photographs, or pedigrees unless the information is essential for scientific purposes and the patient (or parent or guardian) gives written informed consent for publication. Informed consent for this purpose requires that an identifiable patient be shown the manuscript to be published. Authors should disclose to these patients whether any potential identifiable material might be available via the Internet as well as in print after publication. Patient consent should be written and archived, either with the *Journal*, the authors, or both, as dictated by local regulations or laws.

Guidelines for Manuscript Submissions

1. Manuscripts may be submitted either via email (preferred) or by regular mail. Mail submissions should be in digital format (preferably an MS Word document on CD/DVD) with one printed copy of the manuscript. Ideally, a manuscript should be no longer than 24 double-spaced pages. However, exceptions will always be considered on a case-by-case basis.
2. The *American Medical Association Manual of Style* governs formatting in the preparation of text and references. All articles should conform to those guidelines as closely as possible. Abbreviations/acronyms should be limited as much as possible. Inclusion of a list of article acronyms and abbreviations can be very helpful in the review process and is strongly encouraged.
3. A complete list of references cited in the article must be provided with the manuscript, with the following required data:
   - Reference citations of published articles must include the authors' surnames and initials, article title, publication title, year of publication, volume, and page numbers.
   - Reference citations of books must include the authors' surnames and initials, book title, volume and/or edition if appropriate, place of publication, publisher, year of copyright, and specific page numbers if cited.
   - Reference citations for presentations, unpublished papers, conferences, symposia, etc, must include as much identifying information as possible (location, dates, presenters, sponsors, titles).
4. Either color or black and white imagery may be submitted with the manuscript. Color produces the best print reproduction quality, but please avoid excessive use of multiple colors and shading. Digital graphic formats (JPG, TIFF, GIF) are preferred. Editable versions with data sets of any Excel charts and graphs must be included. Charts/graphs embedded in MS Word cannot be used. Prints of photographs are acceptable. If at all possible, please do not send photos embedded in PowerPoint or MS Word. Images submitted on slides, negatives, or copies of X-ray film will not be published. For clarity, please mark the top of each photographic print on the back. Tape captions to the back of photos or submit them on a separate sheet. Ensure captions and photos are indexed to each other. Clearly indicate the desired position of each photo within the manuscript.
5. The authors' names, ranks or academic/certification credentials, titles or positions, current unit of assignment, and contact information must be included on the title page of the manuscript. Submit manuscripts to:

Editor, AMEDD Journal
DOTAA Borden Institute
3630 Stanley RD RM 1340
JBSA Fort Sam Houston, TX 78234-7697

DSN 471-6301
Comm 210-221-6301
Email: usarmy.jbsa.medcom-ameddcs.list.amedd-journal@mail.mil



PIN: 204218-000