Risk Factors for Lower Extremity Tendinopathies in Military Personnel

Brett D. Owens,*†‡ MD, Jennifer Moriatis Wolf,§ MD, Amber D. Seelig,‖ MPH, Isabel G. Jacobson,‖ MPH, Edward J. Boyko,¶ MD, MPH, Besa Smith,‖ MPH, PhD, Margaret A.K. Ryan,# MD, MPH, Gary D. Gackstetter,** DVM, MPH, PhD, and Tyler C. Smith,‖ MS, PhD, for the Millennium Cohort Study Team††

Investigation performed at the Naval Health Research Center, San Diego, California, USA

Background: Overuse injuries have a significant impact on United States military service members, but research to date has been limited in its ability to assess occupational and behavioral risk factors.

Hypothesis/Purpose: To prospectively identify risk factors for the development of lower extremity tendinopathy and plantar fasciitis in United States military personnel.

Study Design: Descriptive epidemiology study.

Methods: Baseline data from the Millennium Cohort Study, a long-term observational cohort of military personnel, were utilized. Service members were enrolled in the cohort in 2001, 2004, and 2007. A total of 80,106 active-duty personnel were followed over 1 year for the development of patellar tendinopathy, Achilles tendinopathy, and plantar fasciitis. Regression analyses were used to estimate significant associations between each tendinopathy, plantar fasciitis, and demographic, behavioral, and occupational characteristics.

Results: Using medical records, 450 cases of Achilles tendinitis, 584 cases of patellar tendinopathy, and 1228 cases of plantar fasciitis were identified. Recent deployment was associated with an increased risk for developing plantar fasciitis (adjusted odds ratio [AOR], 1.27; 95% confidence interval [CI], 1.04-1.56). Moderate weekly alcohol consumption was marginally associated with an increased risk for Achilles tendinopathy (AOR, 1.33; 95% CI, 1.00-1.76). Overweight or obese individuals were more likely to develop Achilles tendinopathy and plantar fasciitis.

Conclusion: Lower extremity tendinopathies and plantar fasciitis are common among military service members, and this study identified several modifiable risk factors for their occurrence. These potential risk factors could serve as the focus for future preventive and intervention studies.

Keywords: Achilles tendinopathy; plantar fasciitis; patellar tendinopathy; military deployment

Tendinopathies of the lower extremity can have a significant impact on activity levels. Reports have shown that Achilles, patellar, and quadriceps tendon tears as well as plantar fasciitis are common in the United States (US) military personnel.[15,21] Although studies to date have demonstrated a wide range of tendon injuries affecting a sizeable proportion of personnel in the US military, they were not able to evaluate and quantify occupational or behavioral risk factors. While uncertainty remains about the cellular mechanisms of tendinopathy, important behavioral risk factors such as tobacco consumption[8] and occupational exposures[28] are gaining more interest. Underlying the disproportionate incidence of tendinopathies in military populations may be the high priority placed on strenuous and continuous physical training as well as the demands of deployment.

The military is an ideal population to study tendinopathies, given its access to both primary care providers and specialty care. A greater understanding of modifiable risk factors may lead to the design and testing of intervention strategies. With prevention as the ultimate goal, the impact could significantly enhance military operational readiness as well as have implications for the prevention of tendon injuries across other occupational groups and the general public.

The Millennium Cohort Study prospectively collects information on deployment exposures as well as important demographic and behavioral risk factor information. The main objective of our study was to identify and evaluate any influence of both nonmodifiable and modifiable risk factors, including military deployment in support of the operations in Iraq and Afghanistan, on the occurrence of Achilles tendinopathy, patellar tendinopathy, and plantar fasciitis.

METHODS

Study Population

Data for these analyses included participants from 3 enrollment panels of the Millennium Cohort Study.[5,19] The goal

The Orthopaedic Journal of Sports Medicine, 1(1), 2325967113492707
DOI: 10.1177/2325967113492707

of this large prospective military cohort study is to assess any long-term health outcomes of military service as well as to evaluate potential impacts of deployment and other military-related experiences. Individuals were enrolled during 3 cycles (panels 1, 2, and 3) between 2001 and 2008. The first panel was drawn from a population-based stratified random sample of all US military personnel serving on rosters as of October 2000, with oversampling for those who had been previously deployed, Reserve and National Guard members, and women. Panels 2 and 3 employed the same general selection strategy but differed in criteria for oversampling: prior deployment was not a selection criterion, but the group was restricted by duration of service (panel 2 = 1-2 years; panel 3 = 1-3 years), and Marine Corps members and women were oversampled. A total of 77,047 participants were enrolled in panel 1 (2001-2003), 31,110 participants enrolled in panel 2 (2004-2006), and 43,440 participants enrolled in panel 3 (2007-2008). For our analyses, only active-duty participants who had not separated from military service by the end of the study time frame (N = 80,106) were evaluated, as obtaining study outcomes required Department of Defense electronic medical records. This study was approved by the Naval Health Research Center Institutional Review Board (protocol NHRC.2000.0007), and informed consent was obtained from all study participants.

Data Sources

Demographic, military, health, lifestyle, and behavioral information, including body mass index (BMI) and tobacco and alcohol consumption, were collected using the Millennium Cohort questionnaire. Electronic military personnel records including date of birth, sex, race/ethnicity, marital status, education, military occupation, pay grade, service branch, component, and deployment dates were provided by the Defense Manpower Data Center (DMDC).

Electronic medical record data were obtained from the Military Health Service Data Repository (MDR). The MDR provided all inpatient and outpatient hospitalization records from Department of Defense military treatment facilities as well as inpatient and outpatient encounters at civilian medical facilities if there was a fee for services. MDR data were available for service members who were eligible to receive benefits, including, but not limited to, activated reservist and active-duty personnel.

Outcomes of Interest

Our study examined Achilles tendinopathy, patellar tendinopathy, and plantar fasciitis, as determined by the presence of their *International Classification of Diseases, 9th Revision* (ICD-9) codes: 726.71/727.67, 726.64/727.66, and 728.71, respectively. These ICD-9 codes represent tendinopathies that may have been caused by acute injury or the result of chronic pathology; alternative codes for acute injuries, such as sprains and strains (840-848 series), were not considered for this study. Each tendinopathy and plantar fasciitis was analyzed as a separate outcome.

Exposure Variables

Demographic and military covariates for analyses included birth year, sex, race/ethnicity, service branch, component, pay grade, military occupation, and deployment up to 6 months prior to baseline to Iraq or Afghanistan in support of recent military operations (Table 1). Health and behavioral covariates obtained from the Millennium Cohort questionnaires included tobacco use, alcohol consumption, BMI, and depression symptoms. Tobacco use was measured based on participant responses to a set of survey questions asking whether they had ever smoked at least 100 cigarettes in their lifetime and whether they had ever successfully quit smoking. Weekly alcohol consumption was calculated separately for men and women. For men, weekly alcohol consumption was categorized as none (0 drinks), light (1-6 drinks), moderate (7-13 drinks), or heavy (>13 drinks), and for women as none (0 drinks), light (1-3 drinks), moderate (4-6 drinks), or heavy (>6 drinks).[2] The BMI was categorized based on Centers for Disease Control

*Address correspondence to Brett D. Owens, MD, Orthopaedic Surgery, Keller Army Hospital, 900 Washington Road, West Point, NY 10996, USA (e-mail: owensbrett@gmail.com).
† Orthopaedic Surgery, Keller Army Hospital, New York, New York, USA.
‡ Uniformed Services University of the Health Sciences, Bethesda, Maryland, USA.
§ New England Musculoskeletal Institute, University of Connecticut Health Center, Farmington, Connecticut, USA.
‖ Deployment Health Research Department, Naval Health Research Center, San Diego, California, USA.
¶ Seattle Epidemiologic Research and Information Center, Veterans Affairs Puget Sound Health Care System, Seattle, Washington, USA.
# Naval Hospital Camp Pendleton, Camp Pendleton, California, USA.
**Analytic Services Inc, Arlington, Virginia, USA.
†† All members are listed in the contributing authors section at the end of this article.
Current affiliations: Dr B. Smith is now with the Department of Family and Preventive Medicine, University of California–San Diego; Dr T.C. Smith is now with the Department of Community Health, School of Health and Human Services, National University Technology and Health Sciences Center, San Diego, California.

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of the Army, Department of the Air Force, Department of Defense, Department of Veterans Affairs, or the US Government. Approved for public release; distribution is unlimited. This research has been conducted in compliance with all applicable federal regulations governing protection of human subjects in research (Protocol NHRC.2000.0007). This represents report 12-22, supported by the Department of Defense, under work unit no. 60002.

One or more of the authors has declared the following potential conflict of interest or source of funding: Dr Owens is a paid consultant for the Musculoskeletal Transplant Foundation and Mitek (Johnson & Johnson); he also receives a salary from the *American Journal of Sports Medicine*. The Millennium Cohort Study is funded through the Military Operational Medicine Research Program of the US Army Medical Research and Materiel Command, Fort Detrick, Maryland. The funding organization had no role in the design and conduct of the study; collection, analysis, or presentation of data; or preparation, review, or approval of the manuscript. Dr Boyko's participation in this research was supported by VA Puget Sound, Washington.

TABLE 1
Baseline Characteristics (in Percentages) of 80,106 Active-Duty Personnel, 2001-2008

	No Tendon Injury (n = 77,902)	Achilles Tendinopathy (n = 450)	Patellar Tendinopathy (n = 584)	Plantar Fasciitis (n = 1228)
Deployment[a,b]				
No	89.66	91.33	89.73	90.88
Yes	10.34	8.67	10.27	9.12
Birth year				
Before 1960	5.34	8.22[a]	3.42[a]	9.77[a]
1960-1969	19.23	24.00[a]	16.78[a]	27.61[a]
1970-1979	30.14	29.56[a]	25.51[a]	30.05[a]
1980 and later	45.30	38.22[a]	54.28[a]	32.57[a]
Sex				
Male	70.30	69.33	63.53[a]	56.60[a]
Female	29.70	30.67	36.47[a]	43.40[a]
Race/ethnicity				
White, non-Hispanic	68.00	62.00[a]	67.29[a]	61.73[a]
Black, non-Hispanic	12.68	18.89[a]	16.61[a]	17.75[a]
Other	19.32	19.11[a]	16.10[a]	20.52[a]
Service branch				
Army	33.99	47.56[a]	42.64[a]	48.21[a]
Navy and Coast Guard	22.81	14.00[a]	16.44[a]	18.24[a]
Marine Corps	11.57	11.33[a]	9.25[a]	7.41[a]
Air Force	31.63	27.11[a]	31.68[a]	26.14[a]
Military rank				
E1-E4	58.63	52.67	67.12[a]	50.00[a]
E5-E9, W0-W5	26.03	31.56	23.80[a]	33.39[a]
O1-O4	13.30	13.56	7.53[a]	12.95[a]
O5-O9	2.04	2.22	1.54[a]	3.66[a]
Occupational codes				
Combat specialists	18.71	16.44[a]	13.53[a]	13.52[a]
Electronic equipment repair	10.33	12.00[a]	10.10[a]	11.32[a]
Communications/intelligence	9.48	11.78[a]	10.27[a]	7.90[a]
Health care	9.88	10.22[a]	11.30[a]	15.23[a]
Other technical and allied specialists	3.21	2.22[a]	4.79[a]	2.93[a]
Functional support and admin	16.71	18.67[a]	19.01[a]	20.36[a]
Electrical/mechanical equipment repair	16.92	10.89[a]	17.81[a]	14.01[a]
Craft workers	2.72	2.67[a]	2.23[a]	2.69[a]
Service and supply	8.36	11.11[a]	9.25[a]	10.26[a]
Students, trainees, and other	3.68	4.00[a]	1.71[a]	1.79[a]
Smoking status				
Never	55.80	58.22	53.08	58.39[a]
Past	22.53	21.78	23.12	24.51[a]
Current	21.67	20.00	23.80	17.10[a]
Body mass index				
Underweight or normal weight	44.76	35.11[a]	43.66	32.33[a]
Overweight	46.54	51.33[a]	44.86	53.42[a]
Obese	8.70	13.56[a]	11.47	14.25[a]
Weekly alcohol use[c]				
None	44.01	42.89	48.80	47.31[a]
Light	30.07	28.44	26.20	30.13[a]
Moderate	13.51	15.56	12.67	12.05[a]
Heavy	12.41	13.11	12.33	10.50[a]
Prior physical trauma[d]				
No	90.87	67.56[a]	73.29[a]	61.56[a]
Yes	9.13	32.44[a]	26.71[a]	38.44[a]
Depression[e]				
No	95.48	93.78	95.21	93.97[a]
Yes	4.52	6.22	4.79	6.03[a]
Physical component summary score[f]				
Lowest 15%	15.07	24.22[*]	28.25[a]	28.58[a]
Middle 70%	70.51	67.33[a]	64.38[a]	63.93[a]
Highest 15%	14.42	8.44[a]	7.36[a]	7.49[a]

[a] $P < .05$ (significantly associated with respective tendinopathy using χ^2 tests).
[b] Deployed to Iraq or Afghanistan in support of recent military operations up to 6 months prior to baseline survey assessment.
[c] For women, light = 1-3 drinks/wk, moderate = 4-6 drinks/wk, heavy = 7+ drinks/wk; for men, light = 1-6 drinks/wk, moderate = 7-13 drinks/wk, heavy = 14+ drinks/wk.
[d] Tendinopathy or fracture diagnosis prior to baseline survey assessment.
[e] Assessed using the Patient Health Questionnaire–9.
[f] Assessed using the Medical Outcomes Study Short Form 36-Item Survey for Veterans.

and Prevention guidelines (underweight [<18.5 kg/m^2], normal weight [18.5-24.9 kg/m^2], overweight [25.0-29.9 kg/m^2], and obese [≥30 kg/m^2]). Depression symptoms were assessed using the Patient Health Questionnaire–9.[3,11,24,25] Prior physical trauma or injury was assessed using electronic medical records to obtain ICD-9 codes for fractures and several lower extremity tendinopathies (Achilles tendinopathy and patellar tendinopathy) as well as plantar fasciitis that occurred prior to baseline. Finally, validated scoring algorithms were used to assess the physical component summary scores for the Medical Outcomes Study Short Form 36-Item Survey for Veterans (SF-36V).[9,13,14] All covariates were determined a priori to include known risk factors as well as the behavioral characteristics of interest. As separate models were used to assess each outcome, participants may have multiple outcomes.

Statistical Analysis

Descriptive and univariate analyses were used to investigate population characteristics. Unadjusted associations of tendinopathy outcomes with modifiable and nonmodifiable risk factors were determined using chi-square analysis. This study was prospective in design, as all covariate data were measured at baseline prior to reporting of any of the outcomes in the electronic medical records. True incidence of chronic pathology was understood to be difficult to assess using medical records, but recording of previously unrecognized diagnoses defined the study outcomes. Electronic medical records were queried for any tendinopathy or plantar fasciitis up to 1 year following baseline assessment. Multivariable logistic regression models were used to determine the adjusted odds of tendinopathy injury while controlling for relevant baseline covariates. Adjusted odds ratios (AORs) and 95% confidence intervals (CIs) are presented. Regression diagnostics were used to assess collinearity between all covariates using a variance inflation factor cutoff of 4 or greater to indicate potential collinearity. Over 30% of those who developed a tendinopathy or plantar fasciitis following baseline also had a tendinopathy prior to baseline in the medical records. This led us to conduct a sensitivity analysis to examine newly reported tendinopathies following baseline among participants without a prior tendinopathy. Additionally, since each tendinopathy could occur within 1 year of baseline, secondary analyses were also performed to include time from baseline to date of the tendinopathy medical visit using Cox proportional hazards time to event analyses. Data management and statistical analyses were performed using SAS statistical software version 9.2 (SAS Institute Inc, Cary, North Carolina).

RESULTS

Characteristics of active-duty Millennium Cohort participants by tendinopathy type are presented in Table 1. Of 80,106 participants, 450 service members were diagnosed with Achilles tendinopathy, 584 had patellar tendinopathy, and 1228 had plantar fasciitis within 1 year of baseline. Unadjusted associations are detailed in Table 1.

In adjusted analyses of lower extremity injuries (Table 2), overweight or obese individuals and moderate weekly alcohol drinkers had significantly increased risk for developing Achilles tendinopathy. A near-linear pattern showed younger age was associated with lower risk for Achilles tendinopathy. Army personnel had increased risk compared with all other services, although the odds ratio was not significant when comparing Army directly to Marine Corps. Other military-specific variables, including deployment, were not significantly associated with Achilles tendinopathy. Those personnel with a prior tendinopathy or fracture were over 3 times more likely to develop Achilles tendinopathy compared with those with no prior injury (AOR, 3.87; 95% CI, 3.16-4.75), and those who scored in the highest 15% according to the SF-36V physical component summary score had decreased odds compared with the middle 70%.

Risk factors for patellar tendinopathy varied somewhat from Achilles tendinopathy (Table 2). A near-inverse linear relationship existed with younger age associated with higher odds for patellar tendinopathy. Those in the Army and other technical and allied specialists had increased odds for developing patellar tendinopathy, while recent deployment was not significantly associated. Similar to Achilles tendinopathy, those with a prior injury were almost 3 times more likely to develop patellar tendinopathy.

Recent deployment was significantly associated with higher odds of having plantar fasciitis (AOR, 1.27; 95% CI, 1.04-1.56). Current smokers had reduced odds, while overweight and obese individuals had increased odds of being diagnosed with plantar fasciitis. Service in the Army and several occupation categories, including electronic equipment repair, health care workers, functional support and administration, and service and supply handlers, had increased odds for developing plantar fasciitis. Age and sex were both significant predictors: women had higher odds and younger military personnel had lower odds of plantar fasciitis diagnoses. Participants with a history of tendinopathy or fracture were over 4 times more likely to be diagnosed with plantar fasciitis compared with those with no injury history.

Results for the sensitivity analyses (data not shown), which those with a prior injury were removed from the models, were consistent with the main models. Deployment was not significantly associated with the development of Achilles or patellar tendinopathies but was significant in the plantar fasciitis model (AOR, 1.30; 95% CI, 1.02-1.67). Results from the secondary (time to event) analyses were also consistent with the main models (data not shown), in which deployment was significant only in the plantar fasciitis model (AOR, 1.25; 95% CI, 1.03-1.52). Similar trends were noted with regard to age, BMI, and alcohol use in both the sensitivity and secondary analyses.

DISCUSSION

Because of the high incidence of deployment-related injuries in theater,[23] this study investigated risk factors for 3 lower extremity tendinopathies and plantar fasciitis among US service members deployed to recent military

TABLE 2
Adjusted Odds Ratios of Developing Lower Extremity Injuries Among 80,106 Active-Duty Personnel, 2001-2008[a]

	Achilles Tendinopathy (n = 450)		Patellar Tendinopathy (n = 584)		Plantar Fasciitis (n = 1228)	
Baseline Characteristics	AOR	95% CI	AOR	95% CI	AOR	95% CI
Deployment[b]						
No	1.00		1.00		1.00	
Yes	0.96	0.68-1.34	0.98	0.74-1.28	1.27	1.04-1.56
Birth year						
Before 1960	1.00		1.00		1.00	
1960-1969	0.80	0.53-1.21	1.63	0.94-2.81	0.94	0.74-1.19
1970-1979	0.67	0.43-1.04	1.69	0.95-2.98	0.66	0.51-0.86
1980 and later	0.62	0.38-1.00	2.51	1.40-4.51	0.49	0.37-0.66
Sex						
Male	1.00		1.00		1.00	
Female	0.96	0.76-1.21	1.02	0.84-1.24	1.85	1.62-2.12
Race/ethnicity						
White, non-Hispanic	1.00		1.00		1.00	
Black, non-Hispanic	1.35	1.04-1.75	1.15	0.90-1.45	1.02	0.86-1.20
Other	0.94	0.73-1.22	0.86	0.68-1.09	0.93	0.80-1.09
Service branch						
Army	1.00		1.00		1.00	
Navy and Coast Guard	0.53	0.40-0.71	0.67	0.52-0.85	0.67	0.57-0.78
Marine Corps	0.85	0.62-1.18	0.64	0.47-0.88	0.71	0.56-0.89
Air Force	0.76	0.59-0.96	0.89	0.73-1.09	0.69	0.60-0.80
Military rank						
E1-E4	1.00		1.00		1.00	
E5-E9, W0-W5	1.02	0.75-1.38	1.00	0.76-1.33	0.99	0.82-1.20
O1-O4	1.05	0.74-1.48	0.79	0.55-1.13	1.00	0.80-1.24
O5-O9	0.74	0.35-1.59	1.45	0.64-3.30	1.26	0.84-1.88
Occupational codes						
Combat specialists	1.00		1.00		1.00	
Electronic equipment repair	1.40	0.98-2.00	1.31	0.93-1.84	1.56	1.24-1.97
Communications/intelligence	1.41	0.98-2.02	1.26	0.90-1.78	1.05	0.81-1.36
Health care	1.10	0.75-1.62	1.37	0.97-1.92	1.55	1.24-1.94
Other technical and allied specialists	0.77	0.39-1.50	1.76	1.13-2.74	1.17	0.81-1.70
Functional support/admin	1.15	0.83-1.60	1.35	1.00-1.84	1.30	1.06-1.61
Electrical/mech equipment repair	0.80	0.55-1.16	1.31	0.97-1.78	1.26	1.01-1.58
Craft workers	1.21	0.65-2.26	1.01	0.56-1.83	1.48	1.01-2.18
Service and supply	1.35	0.93-1.94	1.24	0.87-1.76	1.36	1.07-1.73
Students, trainees, and other	1.46	0.86-2.47	0.66	0.34-1.28	0.83	0.53-1.31
Smoking status						
Never	1.00		1.00		1.00	
Past	0.88	0.69-1.12	1.06	0.86-1.30	0.98	0.85-1.13
Current	0.88	0.68-1.14	1.07	0.86-1.32	0.81	0.68-0.95
Body mass index						
Under or normal weight	1.00		1.00		1.00	
Overweight	1.29	1.04-1.59	1.03	0.86-1.23	1.62	1.42-1.86
Obese	1.59	1.16-2.17	1.19	0.90-1.57	1.95	1.61-2.36
Weekly alcohol use[c]						
None	1.00		1.00		1.00	
Light	1.04	0.83-1.31	0.89	0.72-1.09	1.08	0.94-1.24
Moderate	1.33	1.00-1.76	0.93	0.71-1.21	1.00	0.83-1.20
Heavy	1.27	0.93-1.72	0.91	0.69-1.19	1.02	0.84-1.25
Prior physical trauma[d]						
No	1.00		1.00		1.00	
Yes	3.87	3.16-4.75	2.92	2.41-3.53	4.79	4.24-5.41
Depression[e]						
No	1.00		1.00		1.00	
Yes	1.22	0.82-1.82	0.80	0.55-1.19	1.13	0.88-1.45
Physical component summary score[f]						
Lowest 15%	1.25	0.99-1.57	1.72	1.42-2.09	1.43	1.25-1.64
Middle 70%	1.00		1.00		1.00	
Highest 15%	0.69	0.49-0.97	0.60	0.44-0.83	0.69	0.55-0.85

[a]AOR, adjusted odds ratio; CI, confidence interval.

[b]Deployed to Iraq or Afghanistan in support of recent military operations up to 6 months prior to baseline survey assessment.

[c]For women, light = 1-3 drinks/wk, moderate = 4-6 drinks/wk, heavy = 7+ drinks/wk; for men, light = 1-6 drinks/wk, moderate = 7-13 drinks/wk, heavy = 14+ drinks/wk.

[d]Tendinopathy or fracture diagnosis prior to baseline survey assessment.

[e]Assessed using the Patient Health Questionnaire–9.

[f]Assessed using the Medical Outcomes Study Short Form 36-Item Survey for Veterans.

operations in Iraq and Afghanistan, with the main objective to identify any modifiable factors not previously described in a military population. This study found that plantar fasciitis was significantly related to military deployment. Findings also identified elevated BMI as an important, potentially modifiable risk factor for the development of plantar fasciitis and Achilles tendinopathy. Moderate drinking was marginally associated with the development of Achilles tendinopathy. Other risk factors that may help focus future research or intervention and prevention strategies for these outcomes include previous tendinopathy or fracture diagnosis, certain military occupations, and lower self-perceived physical health.

The Achilles tendon is the largest and strongest tendon in the human body, and injury to this tendon, including rupture, is common in athletes.[7] Our finding of Achilles tendinopathy in older adults in the military is consistent with the epidemiology of these disorders in other physically active populations. However, our finding of nearly equal incidence in both men and women in the military differs from the findings in the general population, where research has shown Achilles tendinopathies may occur more frequently in men.[6,7] Although several small studies of active populations have demonstrated that women have increased odds for tendon injury, our findings likely reflect the relative equivalence between men and women in the military performing activities that stress the Achilles tendon.[10,27] We found a fairly strong and consistent relationship between high BMI and Achilles tendinopathy in this military cohort, as has been reported in other populations.[6,26] Finally, our finding of a relationship between heavier levels of alcohol consumption and Achilles tendinopathy was unique to this lower extremity disorder, and it has not been described previously. Alcohol may be associated with risk-taking behaviors and overuse activities that may lead to injury. Additionally, alcohol may affect metabolic or inflammatory factors that are associated with Achilles tendinopathy.[12] The magnitude of the odds ratio for these associations was modest (1.27-1.33) and not all statistically significant; however, the trend for heavier alcohol use associated with Achilles disorders deserves further study.

The etiology of plantar fasciitis is not well understood and is probably multifactorial.[1] Repetitive stress and trauma are suspected as underlying etiologies because of the higher occurrence of this condition in persons who are overweight, run in marathons, or spend a large amount of time on their feet each day.[4,18,20] One would expect the tempo and stress of deployments to result in a higher risk for this outcome, as was confirmed in our analyses. In addition to this novel finding, we also observed several occupational classifications associated with a higher risk of plantar fasciitis. Although we were not able to determine the specific daily occupational duties performed, the requirement of certain military personnel to be on their feet for long hours may have increased the risk of developing plantar fasciitis. We also found a curiously lower risk in current smokers that could not be explained by the tendency for smokers to be lighter, since our model was adjusted for overweight/obesity (Table 2). Our results showing a higher risk with overweight and obesity echo previous research, and the association with Army service probably reflects more time spent on their feet and repetitive-use injury in this branch of service.[26] Prior research in the military reported a higher risk of plantar fasciitis in women and members of the Army, consistent with our findings, but a higher risk in Marines as well, a finding not seen in our population.[21] Our results also raise a number of intriguing possibilities for further investigation to better understand and more clearly define the role of certain occupational classifications regarding the risk of plantar fasciitis.

Most prior studies have focused on nonmodifiable risk factors such as demographics for the development of lower extremity tendinopathies.[15,21] Previous research has shown that age older than 30 years, men, and black race were significant demographic risk factors for patella and Achilles tendon ruptures in a US military population.[15] Those results were not replicated in the current study, in which sex and race were not significant for patellar or Achilles tendinopathies and the youngest age group (born 1980 and later) had the greatest risk of developing patellar tendinopathy, while the same age group had the lowest risk of developing Achilles tendinopathy and plantar fasciitis. Although not seen in the patellar tendinopathy model, increasing age has consistently been cited as a risk factor for tendinopathy.[16,17,22] What is unclear is the role of sex and race, as these demographic determinations may also interact with activity levels as well as anatomic risk factors (eg, ligamentous laxity, foot anatomy) that act as confounding factors. Other factors in these demographic categories, such as estrogen levels,[10,27] may also suggest a different genetic blueprint for tendon microanatomy or differed response to loading and/or injury.[17]

The current study has several important limitations that should be noted. We hypothesized that deployment would be associated with each of the injuries we examined, but we found this to be true only for plantar fasciitis. The lack of observed association may be due to the fact that the Millennium Cohort Study provides a large population-level view of risk factors, and there was limited exposure assessment in theater that would have allowed a more granular or detailed investigation. Our findings would surely vary among distinct subgroups of the deploying population who had a greater burden of activities that would result in these injuries. Further, limited or nonexistent visibility of injuries treated in the field would have resulted in missing injuries where individuals did not seek medical care after returning from deployment. Analyses were restricted to active-duty personnel because complete availability of medical record data is limited among Reserve and National Guard members and individuals who separate from the military. The use of medical record data to measure morbidity also restricted our analyses to injuries severe enough to warrant medical treatment and may not measure all morbidities. This investigation focused on the first injury event to occur in each lower limb tendinopathy category in the first year following baseline assessment, though most tendinopathies are chronic conditions and may be episodic in nature. In addition, since we were only able to identify occupational categories and not actual tasks

performed on the job, we were unable to draw meaningful conclusions regarding occupational risk factors for plantar fasciitis. Other important data that may affect the development of lower extremity tendinopathies, including footwear and physical activity, were not available for inclusion in these models. Finally, results were not statistically adjusted for multiple comparisons, so some of the findings observed in this study may have been due to chance alone.

There were also several strengths of this study. First, this study examined modifiable risk factors associated with lower body tendinopathies which, to our knowledge, have not been studied previously among a military population. Sub-analyses performed using participants without a prior tendinopathy were consistent with the main regression models as was time to event modeling, demonstrating that our methods were robust and valid. The population-based, prospective cohort design allowed for adjustment of several potential confounders measured at baseline, including prior tendinopathy or fracture diagnoses. Additionally, the large sample size provided robust power to investigate the associations with lower body tendinopathies even among smaller subgroups of the population.

CONCLUSION

This study examined the potential risk factors, including military deployment, related to the occurrence of 2 lower extremity tendinopathies and plantar fasciitis and found plantar fasciitis significantly associated with deployment in support of the operations in Iraq and Afghanistan. Other potentially modifiable risk factors associated with lower extremity tendinopathy outcomes included overweight/obesity, alcohol consumption, and certain job types. To our knowledge, this is the first investigation of these outcomes that focuses on population-level data. Other research is still needed that converges on subgroups of the population with higher propensity for injury. This work may also help focus preventive efforts for tendinopathies in military and other working adult populations.

CONTRIBUTING AUTHORS

Melissa Bagnell, MPH; Gina Creaven, MBA; Nancy Crum-Cianflone, MD, MPH; James Davies; Nisara Granado, MPH, PhD; Dennis Hernando; Jaime Horton; Kelly Jones, MPH; Cynthia LeardMann, MPH; William Lee; Michelle Linfesty, Gordon Lynch; Hope McMaster, MA, PhD; Sheila Medina-Torne, MPH; Amanda Pietrucha, MPH; Teresa Powell, MS; Kari Sausedo, MA; Beverly Sheppard; Katherine Snell; Steven Speigle; Martin White, MPH; James Whitmer; and Charlene Wong, MPH, from the Department of Deployment Health Research, Naval Health Research Center, San Diego, California.

ACKNOWLEDGMENT

The authors thank Scott L. Seggerman from the Management Information Division, Defense Manpower Data Center, Monterey, CA; and Michelle LeWark from the Naval Health Research Center. They also thank the professionals from the US Army Medical Research and Materiel Command, especially those from the Military Operational Medicine Research Program, Fort Detrick, MD; and they appreciate the support of the Henry M. Jackson Foundation for the Advancement of Military Medicine, Rockville, MD. They are indebted to all the members of the Millennium Cohort for their participation in this important project.

REFERENCES

1. Buchbinder R. Clinical practice. Plantar fasciitis. *N Engl J Med*. 2004; 350:2159-2166.
2. *Dietary Guidlines for Americans 2010*. US Department of Agriculture and US Department of Health and Human Services. http://www.health.gov/dietaryguidelines/2010.asp. Accessed April 6, 2011.
3. Fann JR, Bombardier CH, Dikmen S, et al. Validity of the Patient Health Questionnaire–9 in assessing depression following traumatic brain injury. *J Head Trauma Rehabil*. 2005;20:501-511.
4. Fredericson M, Misra AK. Epidemiology and aetiology of marathon running injuries. *Sports Med*. 2007;37:437-439.
5. Gray GC, Chesbrough KB, Ryan MA, et al. The Millennium Cohort Study: a 21-year prospective cohort study of 140,000 military personnel. *Mil Med*. 2002;167:483-488.
6. Hess GW. Achilles tendon rupture: a review of etiology, population, anatomy, risk factors, and injury prevention. *Foot Ankle Spec*. 2010; 3:29-32.
7. Järvinen TA, Kannus P, Maffulli N, Khan KM. Achilles tendon disorders: etiology and epidemiology. *Foot Ankle Clin*. 2005;10:255-266.
8. Kane SM, Dave A, Haque A, Langston K. The incidence of rotator cuff disease in smoking and non-smoking patients: a cadaveric study. *Orthopedics*. 2006;29:363-366.
9. Kazis LE, Lee A, Spiro A 3rd, et al. Measurement comparisons of the Medical Outcomes Study and Veterans SF-36 health survey. *Health Care Financ Rev*. 2004;25(4):43-58.
10. Knobloch K, Schreibmueller L, Meller R, Busch KH, Spies M, Vogt PM. Superior Achilles tendon microcirculation in tendinopathy among symptomatic female versus male patients. *Am J Sports Med*. 2008; 36:509-514.
11. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med*. 2001;16:606-613.
12. Langberg H, Skovgaard D, Karamouzis M, Bulow J, Kjaer M. Metabolism and inflammatory mediators in the peritendinous space measured by microdialysis during intermittent isometric exercise in humans. *J Physiol*. 1999;515(pt 3):919-927.
13. McHorney CA, Ware JE Jr, Lu JF, Shelbourne CD. The MOS 36-item Short-Form Health Survey (SF-36): III. Tests of data quality, scaling assumptions, and reliability across diverse patient groups. *Med Care.* 1994;32:40-66.
14. McHorney CA, Ware JE Jr, Raczek AE. The MOS 36-Item Short-Form Health Survey (SF-36): II. Psychometric and clinical tests of validity in measuring physical and mental health constructs. *Med Care.* 1993; 31:247-263.
15. Owens B, Mountcastle S, White D. Racial differences in tendon rupture incidence. *Int J Sports Med*. 2007;28:617-620.
16. Paavola M, Kannus P, Järvinen TA, Khan K, Józsa L, Järvinen M. Achilles tendinopathy. *J Bone Joint Surg Am*. 2002;84-A:2062-2076.
17. Rees J, Maffulli N, Cook J. Management of tendinopathy. *Am J Sports Med*. 2009;37:1855-1867.
18. Riddle DL, Pulisic M, Pidcoe P, Johnson RE. Risk factors for plantar fasciitis: a matched case-control study. *J Bone Joint Surg Am*. 2003;85-A:872-877.
19. Ryan MA, Smith TC, Smith B, et al. Millennium Cohort: enrollment begins a 21-year contribution to understanding the impact of military service. *J Clin Epidemiol*. 2007;60:181-191.
20. Sadat-Ali M. Plantar fasciitis/calcaneal spur among security forces personnel. *Mil Med*. 1998;163:56-57.

21. Scher DL, Belmont PJ Jr, Bear R, Mountcastle SB, Orr JD, Owens BD. The incidence of plantar fasciitis in the United States military. *J Bone Joint Surg Am*. 2009;91:2867-2872.
22. Sharma P, Maffulli N. Tendon injury and tendinopathy: healing and repair. *J Bone Joint Surg Am*. 2005;87:187-202.
23. Smith TC, Corbeil TE, Ryan MA, Heller JM, Gray GC. In-theater hospitalizations of US and allied personnel during the 1991 Gulf War. *Am J Epidemiol*. 2004;159:1064-1076.
24. Spitzer RL, Kroenke K, Williams JB. Validation and utility of a self-report version of PRIME-MD: the PHQ primary care study. *JAMA.* 1999;282:1737-1744.
25. Spitzer RL, Williams JB, Kroenke K, Hornyak R, McMurray J. Validity and utility of the PRIME-MD patient health questionnaire in assessment of 3000 obstetric-gynecologic patients: the PRIME-MD patient health questionnaire obstetrics-gynecology study. *Am J Obstet Gynecol*. 2000;183:759-769.
26. Wearing SC, Hennig EM, Byrne NM, Steele JR, Hills AP. Musculoskeletal disorders associated with obesity: a biomechanical perspective. *Obes Rev*. 2006;7:239-250.
27. Wilber CA, Holland GJ, Madison RE, Loy SF. An epidemiological analysis of overuse injuries among recreational cyclists. *Int J Sports Med*. 1995;16:201-206.
28. Zakaria D. Rates of carpal tunnel syndrome, epicondylitis, and rotator cuff claims in Ontario workers during 1997. *Chronic Dis Can*. 2004; 25(2):32-39.