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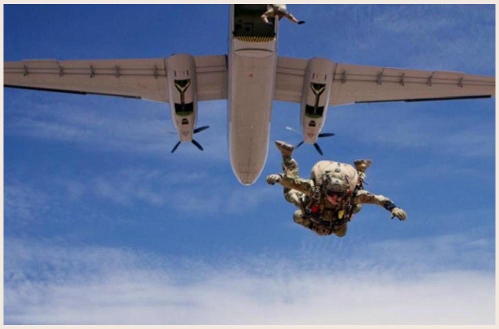

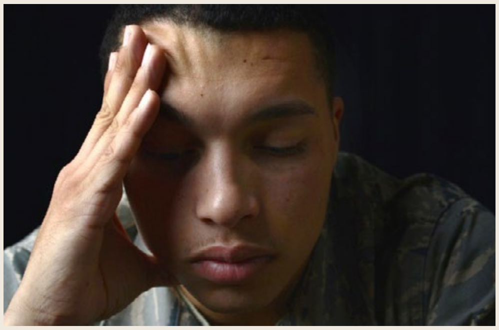

IN THIS ISSUE:

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Musculoskeletal Injuries During U.S. Air Force Special Warfare Training Assessment and Selection, Fiscal Years 2019–2021

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From the inception of the Special Warfare Training Wing in fiscal year 2019 through 2021, 753 male, enlisted candidates attempted at least 1 Assessment and Selection and did not self-eliminate (i.e., quit). Candidates were on average 23 years of age. During candidates' first attempt, 356 (47.3%) individuals experienced a musculoskeletal (MSK) injury. Among the injuries, the most frequent type was nonspecific (n=334/356; 93.8%), and the most common anatomic region of injury was the lower extremity (n=255/356; 71.6%). When included in a multivariable model, older age, slower run times on initial fitness tests, and prior nonspecific injury were associated with both any injury and specifically lower extremity MSK injury.

WHAT ARE THE NEW FINDINGS?

During Assessment and Selection, 356 (47.3%) of candidates suffered an MSK injury. The most frequent type was nonspecific (n=334/356; 93.8%) and the most common anatomic region of injury was the lower extremity (n=255/356; 71.6%). Older age, slower run times, and prior nonspecific injury were associated with injury during the course.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

MSK injuries are costly and continue to be the leading cause of medical visits and disability in the U.S. military, and are more prevalent in the special operations community than in conventional military forces. Identifying predictors of injury in this population can inform clinicians and staff regarding the provision of prevention and rehabilitative strategies to reduce this risk.

Musculoskeletal (MSK) injuries are costly and the leading cause of medical visits and disability in the U.S. military.[1,2] Within training environments, MSK injuries may lead to a loss of training, deferment to a future class, or voluntary disenrollment from a training pipeline, all of which are impediments to maintaining full levels of manpower and resources for the Department of Defense. Additionally, injuries sustained during training often lead to chronic conditions or impairments at a later time during a warfighter's career.[3]

Previous studies have found that special operations forces experience higher MSK injury rates than conventional forces,[4] and more so in training environments.[5] Although previous investigations have studied MSK injury rates in samples of Air Force (AF) special operators,[4,6] to date, there are no studies that have explicitly characterized the incidence of MSK injuries in the AF Special Warfare Training Wing (SWTW) pipeline.

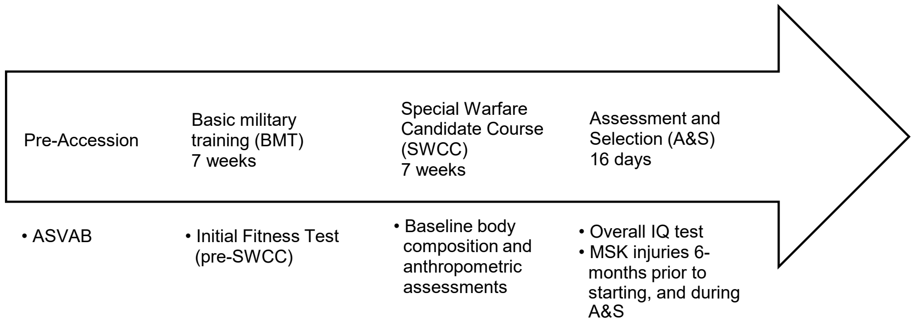
The AF SWTW was established in fiscal year 2019 to assess, select, and train individuals to become one of 4 AF Special Warfare (AFSPECWAR) specialties: Tactical Air Control Party (TACP), Pararescue, Combat Control, and Special Reconnaissance. With the exception of TACP, each of these specialties require a candidate to successfully complete an arduous 16-day Assessment & Selection (A&S) course. Due to the nature of this assessment process, MSK injuries are common. However, no studies have reported the incidence of MSK injuries during A&S. Thus, the purpose of this study was to report the incidence of MSK injury during the 16-day SWTW A&S; and identify factors that were associated with experiencing an MSK injury during this period.

METHODS

The cohort included enlisted AFSPECWAR candidates who first attempted A&S during fiscal years 2019–2021 and did not voluntarily disenroll (i.e., quit). Officer candidates were excluded from the analysis due to differences in their previous training prior to A&S. Female candidates were excluded due to the small number of candidates (n=5), which precluded comparisons by sex. Data for analysis were routinely collected throughout the pipeline leading up to the start of A&S **(Figure 1)**. The Armed Services Vocational Aptitude Battery (ASVAB)[7] was administered before the candidates entered Basic Military Training (BMT). Results from baseline fitness tests and body composition factors were collected at the start of the Special Warfare Candidate Course (SWCC). The Intelligence Quotient (IQ) test was administered at the start of A&S.

Data regarding MSK injuries were extracted from the Military Health System (MHS) Management Analysis and Reporting Tool. The direct care outpatient system was searched for encounters within the stated timeframes for the cohort. The 10th Revision of the International Classification of Disease (Clinical Modification) codes were categorized according to a matrix that

FIGURE 1. Schematic of training pipeline through Assessment and Selection, and time points of data collection for analysis



AVSAB, Armed Services Vocational Aptitude Battery; IQ, intelligence quotient; MSK, musculoskeletal.

assigned an injury type and region to each injury using a taxonomy adapted from a previously published work.[3,8] Briefly, the matrix broadened the inclusion of nonspecific, overuse, and other MSK conditions that can also impact completion of training. For the coding of prior MSK injury, the timeframe of 6-months prior to starting A&S was selected to align with the timeframe of a candidate entering BMT, at which point relevant healthcare records are collected within the MHS.

Covariates were selected for analysis based on 2 specific rationales; (1) explanatory covariates including baseline fitness, body composition, and prior injury status that are known from the literature to have an association with risk of injury, and (2) exploratory covariates including anthropometric measurements, cognitive factors, and age that are routinely collected by the SWTW and discussed internally as potentially related to injury risk.

The injury surveillance period included the 16-day course as well as an additional 7 days following course termination, when students were permitted to rest with little to no formal training conducted. The surveillance period was extended in this way because many candidates will not report their injuries until the training concludes. In addition, providers are often unable to document injuries in the electronic medical record system until the course finishes. Chi-square tests and independent samples t-tests were used for bivariate testing of categorical and continuous factors, respectively, for differences between candidates with and without MSK injury during A&S. Where appropriate, the Mann-Whitney U, and Fisher's exact tests were also employed. Binary logistic regression was used to build multivariable models to identify factors associated with MSK injury during A&S. In addition, binary logistic regression was also employed to identify factors associated with lower extremity MSK injury specifically, the most common anatomic site of injury. For multivariable modeling, complete-case analysis was employed. The TRIPOD checklist was followed for model development only (i.e., not validation).[9] The presented final binary logistic regression models were exploratory in nature and future validation will be necessary. SAS version 9.4 (SAS Institute, Cary, NC) was used for all statistical analyses. Odds ratios (ORs), adjusted ORs (AORs), and their associated confidence intervals (CI) are reported with a threshold of $p<.05$ for univariate significance and a threshold of $p<.10$ was used to determine retention of variables in the logistic regression models. The final logistic regression model was selected that obtained optimal goodness of fit and area under the receiver operating curve.

RESULTS

Overall, 753 male enlisted candidates attempted A&S at least once and did not self-eliminate during fiscal years 2019 (4 classes), 2020 (5 classes), or 2021 (6 classes) **(Figure 2)**. Candidates were, on average, 23 years of age at the start of their first A&S attempt. During candidates' first A&S attempt, 356 (47.3%) experienced an MSK injury; of those candidates, the most frequent injury type was nonspecific (n=334/356; 93.8%) **(Figure 3)**, and the most common anatomic region of injury was the lower extremity (n=255/356; 71.6%) **(Figure 4)**.

Any type of MSK injury

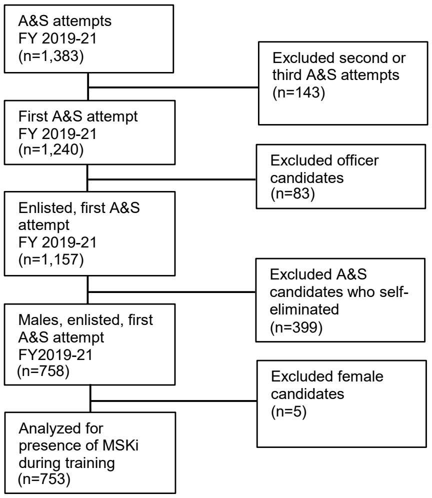
Bivariate analyses revealed that initial fitness, age, BMI, and prior MSK injury were statistically significantly associated with injury during candidates' first A&S attempt **(Table 1)**. The only baseline fitness measure significantly associated with injury during A&S was slower 1.5 mile run times. Body fat mass, lean body mass, dry lean mass, percent body fat, and skeletal muscle mass, were not significantly higher for candidates who were injured, compared with those who were not injured. Slightly more than one-half of the candidates (n=393; 52.2%) had suffered any prior MSK injury type, and a significant proportion of these candidates also suffered injury during A&S (64.0% vs 41.6%; $p<.001$). More specifically, prior nonspecific, nerve, sprain or joint damage, strain or tear, and systemic or genetic MSK conditions were all associated with a higher frequency of injury during A&S. Injuries that occurred at all anatomic sites other than the torso were associated with a higher frequency of any type of injury during A&S.

The average age of candidates injured during A&S was significantly higher (24.2 years, SD=4.1) compared with those who were not injured (23.0 years, SD=3.8). Other tested cognitive factors, including highest academic level, overall IQ, and ASVAB test scores were not significantly associated with injury during A&S in bivariate analyses.

Multivariable analysis

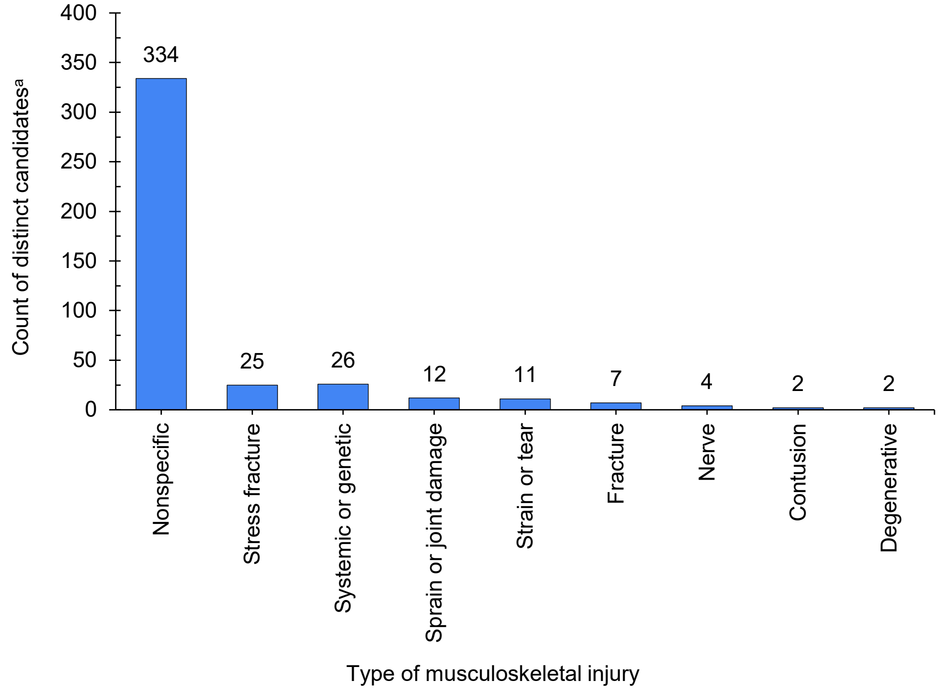
In an adjusted binary logistic regression model, factors that were retained as associated with injury during A&S included age at A&S start (AOR=1.09; 95% CI: 1.04–1.14; $p<.001$), 1.5 mile run time on initial fitness test (AOR=1.53; 95% CI: 1.15–2.05; $p=.004$), and prior nonspecific injury (AOR=2.25; 95% CI: 1.64–3.10; $p<.001$) **(Table 2)**.

FIGURE 2. Candidate inclusion and exclusion criteria for analysis



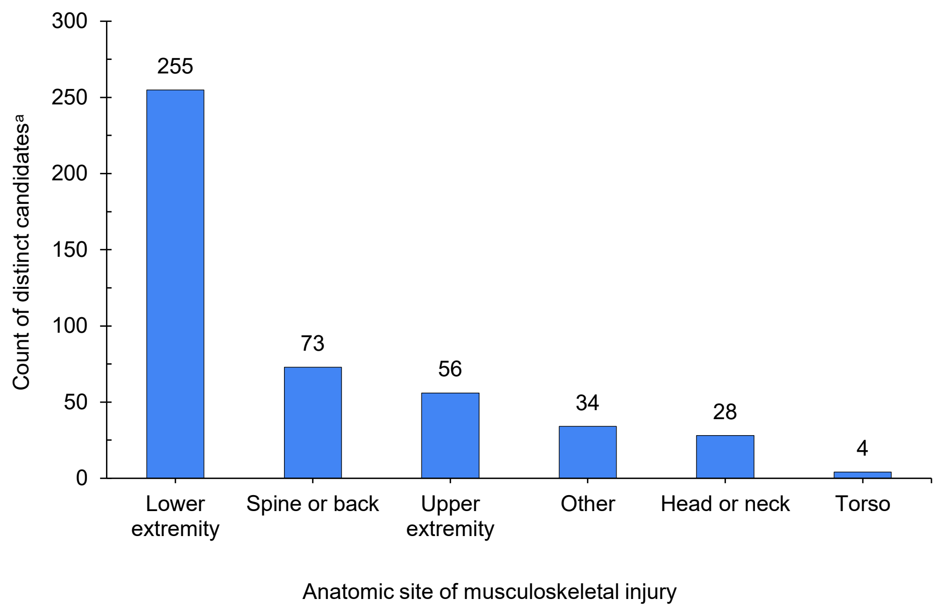
A&S, Assessment and Selection; FY, fiscal year; MSKi, musckuloskeletal injuries.

FIGURE 3. Frequency of musculoskeltal injuries by type, fiscal years 2019–2021



[a]Each category includes a distinct number of individuals although individuals can be represented in multiple categories.

FIGURE 4. Frequency of musculoskeletal injury by anatomic site, fiscal years 2019–2021



[a]Each category includes a distinct number of individuals although individuals can be represented in multiple categories.

In an adjusted model, factors that were retained as associated with lower extremity injury during A&S included age at A&S start (AOR=1.05; 95% CI: 1.01–1.10; p=.018), 1.5 mile run time on initial fitness test (AOR=1.41; 95% CI: 1.05–1.90; p=.023), and prior nonspecific injury (AOR=1.91; 95% CI: 1.37–2.67; p<.001) **(Table 3)**.

EDITORIAL COMMENT

The purpose of this study was to report the incidence of MSK injuries in a 16 day rigorous SWTW A&S, and to identify factors associated with suffering an MSK injury. This is the first characterization of MSK injury in a SWTW A&S population, finding 47.3% of candidates suffered an MSK injury, with the most frequent type as nonspecific (93.8%; of those injured). Knapik et al previously described medical encounters during a U.S. Army Special Forces A&S course, reporting 38% of the candidates experienced one or more injuries during the 19-20 day period.[10] The high percentage of injury among both cohorts is an indication of the rigorous requirements incurred by trainees in short periods of times under extremely challenging circumstances.

The lower extremity was identified as the most common anatomic region of injury during A&S (71.6%; of those injured). This finding is consistent with Lovalekar et al, who also reported lower extremity MSK injury as the most common region in Navy Sea, Air, and Land (SEAL) Qualification Training Students.[11] However, both findings should be interpreted with caution, as these values may be underestimates due to potential under-reporting.[12]

When put into a multivariable model, older age, slower run times on initial fitness tests and prior nonspecific injury increased the likelihood of any musculoskeletal injury and, more specifically, lower extremity MSK injury. Although BMI was significant on the univariate analysis, the variable did not meet

TABLE 1. Baseline demographic, fitness, and cognitive factors, by musculoskeletal status, fiscal years 2019–2021

Risk factor	Injury (n=356)		No injury (n=397)		p-value	Cohen's d[a]
	No. or Mean[a]	% or SD[a]	No. or Mean[a]	% or SD[a]		
A&S financial year						
2019	97	27.2	142	35.8	.042	-
2020	118	33.1	118	29.7		-
2021	141	39.6	137	34.5		-
Age at A&S start (years)	24.2	4.1	23.0	3.8	<.001	0.304
Anthropometric measurements						
Weight (pounds)	176.9	18.8	172.5	17.3	.071	-
Height (inches)	70.0	2.7	70.0	2.4	.875	-
BMI (kg/m2)	25.3	2.0	25.0	1.8	.038	0.158
Body composition measurements						
Body fat mass	21.0	6.6	20.2	6.0	.104	-
Lean body mass	155.9	17.6	154.2	15.5	.188	-
Dry lean mass	41.9	4.8	41.5	4.2	.225	-
Percent body fat	11.9	3.5	11.6	3.2	.241	-
Skeletal muscle mass	89.2	10.4	88.2	9.2	.217	-
Education level						
Associates degree	8	2.2	5	1.3	.279	-
Bachelors degree	8	2.2	15	3.8		-
High school/GED	168	47.2	170	42.8		-
Some college	172	48.3	207	52.1		-
Overall IQ score	111.9	9.4	112.1	9.6	.873	-
ASVAB score	79.5	14.3	78.9	14.3	.576	-
Initial fitness tests						
Pullups	14.0	3.2	14.4	3.3	.164	-
Pushups	57.3	8.9	58.1	9.9	.267	-
1.5mi run (minutes)	9.7	0.5	9.5	0.6	<.001	0.362
Situps	67.4	8.4	68.5	8.8	.114	-
500m swim (minutes)	10.0	1.2	10.1	1.3	.517	-
Type of prior injury (within 6 months of starting A&S)						
Any prior MSK injury type	228	64.0	165	41.6	<.001	-
Nonspecific	224	62.9	161	40.5	<.001	-
Nerve	4	1.1	0	0.0	.050	-
Degenerative	2	0.5	1	0.2	.605	-
Sprain/joint damage	27	7.6	9	2.3	<.001	-
Dislocation/subluxation	3	0.8	3	0.8	1.00	-
Systemic genetic	22	6.2	2	0.5	<.001	-
Strain/tear	22	6.2	7	1.8	.002	-
Stress fracture	13	3.7	11	2.8	.492	-
Fracture	14	3.9	8	2.0	.119	-
Contusion	4	1.1	2	0.5	.430	-
Amputation/crush/polytrauma	1	0.3	0	0.0	.473	-
Anatomic location of prior injury (within 6 months of starting A&S)						
Head or neck	33	9.3	17	4.3	.006	-
Spine or back	57	16.0	40	10.1	.015	-
Torso	5	1.4	3	0.8	.486	-
Upper extremity	88	24.7	43	10.8	<.001	-
Lower extremity	188	52.8	131	33.0	<.001	-
Other	32	9.0	9	2.3	<.001	-

SD and mean reported for continuous measures only.
[a]Cohen's d reported for continuous measures that were statistically significant.
SD, standard deviation.

the criteria for retention in the final adjusted model. These findings are similar to previous studies of similar populations that have found low levels of physical fitness, slower run time or history of a previous injury[13–15] were all associated with sustaining MSK injury. Age, poor muscular endurance, and slower run times have also been observed to be reliable indicators of future acute injuries in U.S. Army Infantry, Armor, and Cavalry basic trainees during initial entry training (IET),[16] but only performance deficits in running tests were correlated with 'overuse' MSK injuries in their cohort. Several additional observations of military IET samples have reported similarities in MSK injury risk associated with poor aerobic capacity test performances, which does indicate a distinct and historical association between aerobic fitness and MSK incidence early in military service.[17–19]

A novel aspect of this manuscript analyzed IQ and ASVAB scores for association with MSK injury. These potential covariates were selected a priori based on literature demonstrating relationships between neurocognition, biomechanics[20] and early screening[21] to detect MSK injury. Additionally, literature documents components of ASVAB scores as a reliable predictor for graduation in an Army course,[22] supporting the current study hypothesis to investigate an association between ASVAB scores and MSK injury during A&S. However, no significant relationship was found for either IQ or ASVAB scores.

There are inherent limitations to the collected data and analysis. First, this work is retrospective, and as such is subject to selection bias. Additionally, there was no delineation between injuries and training loss for the candidates, and therefore the results should be interpreted with caution. Also, the vast majority of candidates who voluntarily disenrolled during A&S did so within the first 2 days of A&S (internal data), and since this would potentially significantly impact the injury exposure, these candidates were excluded from analysis. However, as some of these candidates may have disenrolled due to an unspecified injury, this would impact the findings of this study.

Finally, all candidates were cleared medically to transition from BMT to SWCC, and again from SWCC to A&S. It is assumed at the start of SWCC and A&S that MSK injuries have been resolved, and candidates have

TABLE 2. Multivariable assessment of predictors of any musculoskeletal injury during Assessment and Selection (n=665)

Any MSK injury risk factor	AOR	95% CI	p-value
Age at A&S start (years)	1.09	1.04–1.14	<.001
Initial fitness test – 1.5 mile run time (minutes)	1.53	1.15–2.05	.004
Prior nonspecific Injury (yes vs no)	2.25	1.64–3.10	<.001

MSK, musculoskeletal; AOR, adjusted odds ratio; CI, confidence interval; A&S, Assessment and Selection.

TABLE 3. Multivariable assessment of predictors of lower extremity musculoskeletal injury during Assessment and Selection (n=665)

Lower extremity injury risk factor	AOR	95% CI	p-value
Age at A&S start (years)	1.05	1.01–1.10	.018
Initial fitness test – 1.5 mile run time (minutes)	1.41	1.05–1.90	.023
Prior nonspecific Injury (yes vs no)	1.91	1.37–2.67	<.001

AOR, adjusted odds ratio; CI, confidence interval; A&S, Assessment and Selection.

a 'clean bill of health'. However, due to the inherent nature of MSK injuries, challenges with diagnosis, and candidates' propensity to not report injuries that could delay the completion of their training, it is possible that some MSK injuries prior to A&S are indistinguishable from new injuries during A&S. Regardless, increased surveillance of candidates who had prior injuries is still warranted for injury prevention during A&S whether they are new or persistent. Future work is planned to examine the detailed timing and severity of MSK injuries, as well as elimination rates and types, throughout the training pipeline.

In conclusion, MSK injuries continue to be costly and the leading cause of medical visits and disability in the U.S. military, and are more prevalent in the special operations community than in conventional military forces. To increase the readiness and longevity of operators, continued efforts are required to reduce MSK injury risk. The findings from this project highlight the increased risk of MSK injury in this population and provide further evidence for the scientific community to continue to develop appropriate prevention, screening, and rehabilitative strategies to reduce that risk and increase the health and readiness of members in the Special Warfare community.

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Prevalence and Distribution of Refractive Errors Among Members of the U.S. Armed Forces and the U.S. Coast Guard, 2019

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During calendar year 2019, the estimated prevalence of myopia, hyperopia, and astigmatism were 17.5%, 2.1%, and 11.2% in the active component of the U.S. Armed Forces and 10.1%, 1.2%, and 6.1% of the U.S. Coast Guard, respectively. The prevalence of spectacle correction in the active component of the U.S. Armed Forces was 24.0%, which included single-vision distance (92.0%), multifocal (eg, bifocal, 6.0%), and single-vision reading (2.0%) spectacles. In comparison, the prevalence of spectacle correction was 14.6% in the U.S. Coast Guard. Additionally, among all U.S. Armed Forces service members who received spectacle correction for distance vision in 2019, service members of the reserve component, military academy cadets, and the National Guard were significantly more myopic (near-sightedness) than the active component or Coast Guard (p<.001). Within the active component, the Air Force was the most myopic and the Marine Corps followed it closely. These 2 military branches were not significantly different from each other (p=.46) but both were significantly more myopic than the Navy or the Army (p<.001). The Navy was more myopic than the Army (p=.01). The U.S. Coast Guard was significantly less myopic than any other military branch (p=.03).

WHAT ARE THE NEW FINDINGS?

Warfighters with a functional unaided vision have significant advantage on the battlefield or in other operational environments. During calendar year 2019, the prevalence of refractive errors in the active component of the U.S. Armed Forces and U.S. Coast Guard were relatively low. Approximately 20% of the active component service members had substantial refractive errors that require fulltime spectacle correction.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Refractive distribution of the U.S. Armed Forces is essential for better understanding of warfighter visual capabilities, establishing vision standards and policies, and supporting acquisition and development of the next generation military protective eyewear and devices.

Uncorrected refractive error is the leading cause of visual impairment worldwide.[1] Refractive error occurs when there is a mismatch between axial length of the eye and the refractive power produced by the cornea and the crystalline lens. The eye is myopic (near-sighted) when the eye's axial length is longer and images of distant objects focus in front of the retina.[2] Hyperopia (far-sightedness) occurs when the axial length is shorter and images of distant objects focus behind the retina.[2] With a low amount of hyperopia, a younger eye (i.e., approximately under age 40) can achieve clear images through accommodation in which the ciliary muscles contract and cause the crystalline lens to increase its refractive power. Astigmatism reduces quality of vision by differential magnification in each principal meridian of the cornea and/or the crystalline lens.[3] It is another form of ocular aberration that induces blurred vision.[3] Presbyopia is an age-related, blurred near vision due to progressive loss of accommodation (i.e., near focusing ability) that usually begins to manifest after the age of 40.[4]

The prevalence of myopia, the most common type of refractive error, increased worldwide from 10.4% to 34.2% between 1993 through 2016[5] and in the United States from 25.0% to 41.6% between 1970 through 2000.[6] Among military service members, one study describes a similar trend for Austrian military conscripts; Yang et al. reported that the prevalence of myopia increased from 13.8% to 24.4% between 1983 through 2017.[7]

In the active component of the U.S. Armed Forces, Reynolds et al. estimated a crude lifetime prevalence of myopia was 38.5%, based on medical diagnostic codes for refractive error in the U.S. Defense Medical Surveillance System from 2001 through 2018.[8] The study also reported a crude lifetime prevalence of 12.0% for hyperopia and 32.9% for astigmatism.[8] Moreover, an earlier study showed that 22% of the active component U.S. Army aviators and 27%–32% of the U.S. Army Reserve and National Guard members wore spectacle vision correction between 1986 through 1989.[9]

The distribution of refractive errors and the proportions of the U.S. Armed Forces and the U.S. Coast Guard that require spectacle vision correction are yet to be determined. The purpose of this study was to examine the prevalence and distribution of refractive errors and to evaluate spectacle corrections among active component U.S. Armed Forces and U.S. Coast Guard service members in 2019. Furthermore, the differences in mean refractive corrections are examined among all U.S. Armed Forces service members who received spectacle corrections for distance vision in 2019, to include the active component, reserve component, National Guard, and military academy cadets.

METHODS

This retrospective study evaluated spectacle prescriptions in the Spectacle Request Transmission System (SRTS) of the U.S. Department of Defense (DOD) during calendar year 2019. Study populations included the active component of the U.S. Armed Forces (Air Force, Army, Navy and Marine Corps) and the U.S. Coast Guard. The U.S. reserve component, National Guard, and military academy cadet populations were used for comparison. Denominator data to calculate prevalence estimates were obtained from the U.S. Defense Manpower Data Center (DMDC).

SRTS Database

The SRTS determines a member's military service status (e.g., Navy, active duty) automatically during spectacle ordering as result of its interface with the DMDC. There were 1,701,907 spectacle orders among 390,217 active duty service members in 2019. Specifically, active duty service members who ordered spectacle correction for distance and/or near vision (n=323,753) included the active component of the U.S. Armed Forces (97.9%), the U.S. Coast Guard (1.8%), and others (i.e., non-U.S. military, 0.3%).

Each member may have one or more spectacle orders using the same spectacle prescription (e.g., clear and sun-glasses, optical inserts for gas mask and military eye protection, etc.). Occasionally, different spectacle prescriptions may be used when distance and computer/reading spectacles were ordered separately (e.g., bifocal glasses for computer/reading or single vision glasses for near vision). Therefore, a spectacle prescription with the lowest spherical power of the right eye was selected to ensure only one spectacle prescription for distance vision per service member was chosen, and spectacle prescriptions exclusively for near vision were excluded from refractive distribution analysis.

As a result, the SRTS database for refractive distribution analysis identified 379,254 spectacle prescriptions for distance vision in 2019, which included prescriptions for service members of the active component (83.3%), National Guard (4.9%), reserve component (3.4%), retired military members (7.2%), military academy cadets (0.8%), and others (e.g., non-U.S. military) (0.3%). Analyses describing the proportions of refractive errors were restricted to active component service members, including 310,765 service members from the U.S. Armed Forces and 5,768 service members from the U.S. Coast Guard. Differences in the magnitudes of mean refractive corrections are examined for all U.S. Armed Forces, to include service members of the reserve component (n=12,984), military academy cadets (n=3,222), National Guard (n=18,773), Air Force (n=81,163), Marine Corps (n=37,253), Navy (n=56,985), Army (n=135,364) and Coast Guard (n=5,768).

Definition

Spectacle correction was defined as having a spectacle prescription in the SRTS. Spectacle refractive power is expressed in diopter (D) in spherical equivalent (SE), which was defined as spherical refraction plus one-half of the negative cylindrical value. A negative SE indicates refraction for myopia and a positive SE indicates refraction for hyperopia. Astigmatism is shown as a negative cylinder (CYL) power. Astigmatism type was defined as With-the-Rule (minus cylinder axis 180° ± 15°), Against-the-Rule (minus cylinder axis 90° ± 15°), and Oblique (all other orientations).

Refractive error classification

SE was utilized to classify the low/moderate/high classifications for myopia and hyperopia. Based on the current scientific consensus of refractive errors classification,[2,5,10-13] myopia was classified as SE≤-0.50 D and was further divided into Low (SE≤-0.50 D and >-3.00 D), Moderate (SE≤-3.00 D and >-6.00 D), and High (SE≤-6.00 D) myopia. Hyperopia was defined as SE>+0.50 D that was further divided into Low (SE>+0.50 D and <+3.00 D) and High (SE≥+3.00 D) hyperopia. Low Refractive Error was defined as SE>-0.50 D and ≤+0.50 D. Astigmatism was defined as CYL<-0.50 D that was further divided into Low (CYL<-0.50 D and >-1.50 D), Moderate (CYL≤-1.50 D and >-2.50 D), and High (CYL≤-2.50 D) astigmatism.

Statistical analysis

IBM SPSS Statistics for Windows, Version 21.0 (Armonk, NY: IBM Corp) was used for statistical analyses. To estimate the prevalence of spectacle correction, counts of active duty service members who had spectacle correction for distance and/or near vision served as numerators and DMDC population counts served as denominators. Likewise, counts of active duty members, which were grouped by refractive error classification from their spectacle prescriptions for distance vision, served as numerators and DMDC population counts served as a denominators for prevalence of refractive error calculations.

For refractive distribution analysis, a two-tailed paired t-test was used to compare refractive errors between the right and left eyes and z-tests were used to compare the active component of the U.S. Armed Forces and the U.S. Coast Guard populations. Analysis of variance was used to analyze overall effects on refractive correction among military branches and groups. A Bonferroni post hoc test was used to adjust for multiple comparisons. Results were expressed as mean ± standard error. The statistical significance level was set at p<.05.

RESULTS

Prevalence of spectacle correction

Assuming all members who required vision correction had ordered spectacles in 2019, the prevalence of spectacle correction was 24.0% in the active component of U.S. Armed Forces and 14.6% in the U.S. Coast Guard. The difference between the two populations was statistically significant (p<.001). Single-vision distance glasses were the most common type (92.0%) and followed by multifocal (e.g., bifocal, 6.0%) and single-vison reading (2.0%) glasses in the active component of the U.S. Armed Forces.

Prevalence of refractive errors

The prevalence of myopia (SE≤-0.50 D) was 17.5%, hyperopia (SE>+0.50 D) was 2.1%, and astigmatism (CYL<-0.50 D) was 11.2% in the active component of the U.S.

Armed Forces (n=310,765). In comparison, the prevalence of myopia was 10.1%, hyperopia was 1.2%, and astigmatism was 6.1% in the U.S. Coast Guard (n=5,768). There was a statistically significant difference between the two populations (p<.001). The prevalence of high myopia (SE≤-6.00 D) and high hyperopia (SE≥+3.00 D) were 1.1% and 0.7% in the active component of the U.S. Armed Forces, and 0.5% and 0.4% in the U.S. Coast Guard, respectively.

Refractive distribution

The overall refractive distribution of the two active duty populations is shown in **Figure 1**. The right and left eyes had a small but statistically significant difference in sphere (mean difference: -0.020±0.001 D), cylinder (mean difference: 0.013±0.001 D), and spherical equivalent (mean difference: -0.013±0.001 D) refraction (p<.001). Both eyes were significantly correlated (r=0.954, 0.780, and 0.959, respectively, [p<.001]).

The proportion of refractive errors in spherical equivalent **(Figure 2)** was not significantly different between the active component of the U.S. Armed Forces and the U.S. Coast Guard (p=.79). In the active component of the U.S. Armed Forces, the largest proportion of myopia was classified as Low (50.8%), followed by Moderate (19.2%), and just 4.7% were classified as High. Similarly, a larger proportion of hyperopia was classified as Low (7.1%) versus High (1.6%). The proportion of Low Refractive Error was 16.7%. Astigmatic spectacle correction **(Figure 3)** was 30.2% (Low), 11.3% (Moderate), and 5.8% (High). With-the-Rule astigmatism (minus cylinder axis 180°±15°) was 55.5%. Against-the-Rule astigmatism (minus cylinder axis 90°±15°) was 18.2%. Oblique astigmatism (all other orientations) was 26.3%.

Analysis of differences in the magnitude of mean refractive corrections among the active component of the U.S. Armed Forces and the U.S. Coast Guard, National Guard, Reserve, and military academy cadets revealed a statistically significant difference in refractive correction among these groups (p<.001) **(Figure 4)**. Pairwise comparison with Bonferroni adjustment showed that refractive correction for the active component of the U.S. Armed Forces or the U.S. Coast Guard was significantly less myopic (near-sightedness) than that of the National Guard, the military academy cadets, and the Reserve (p<.001). In the active component of the U.S. Armed Forces, mean refractive corrections of the Air Force and of the Marine Corps were significantly more myopic than those of the Navy (p<.001) and the Army (p<.001). The Navy was more myopic than the Army (p=.01). Each military branch was more myopic than the Coast Guard (p=.03).

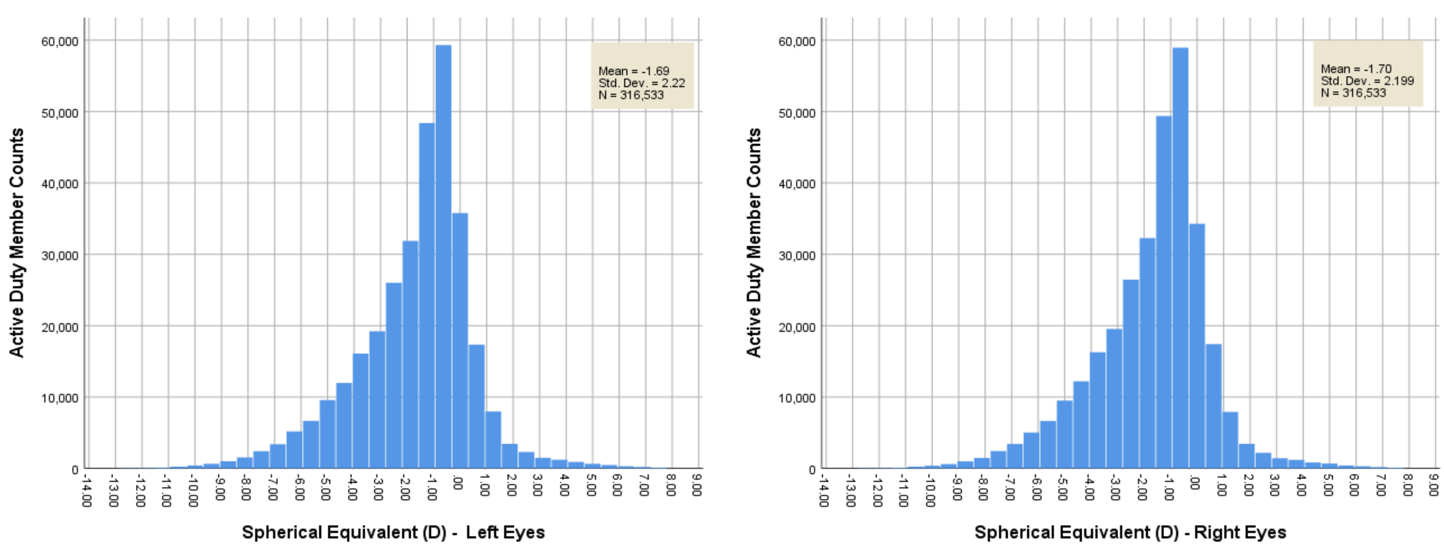
EDITORIAL COMMENT

Prevalence of spectacle correction

Functional unaided vision is crucial in emergency, volatile, and high stress military operational environments. In agreement with an earlier study in which 22% of U.S. Army aviators wore spectacle correction,[9] the estimated prevalence of spectacle correction from the current analysis was 24.0% in the active component of the U.S. Armed Forces and 14.6% in the U.S. Coast Guard.

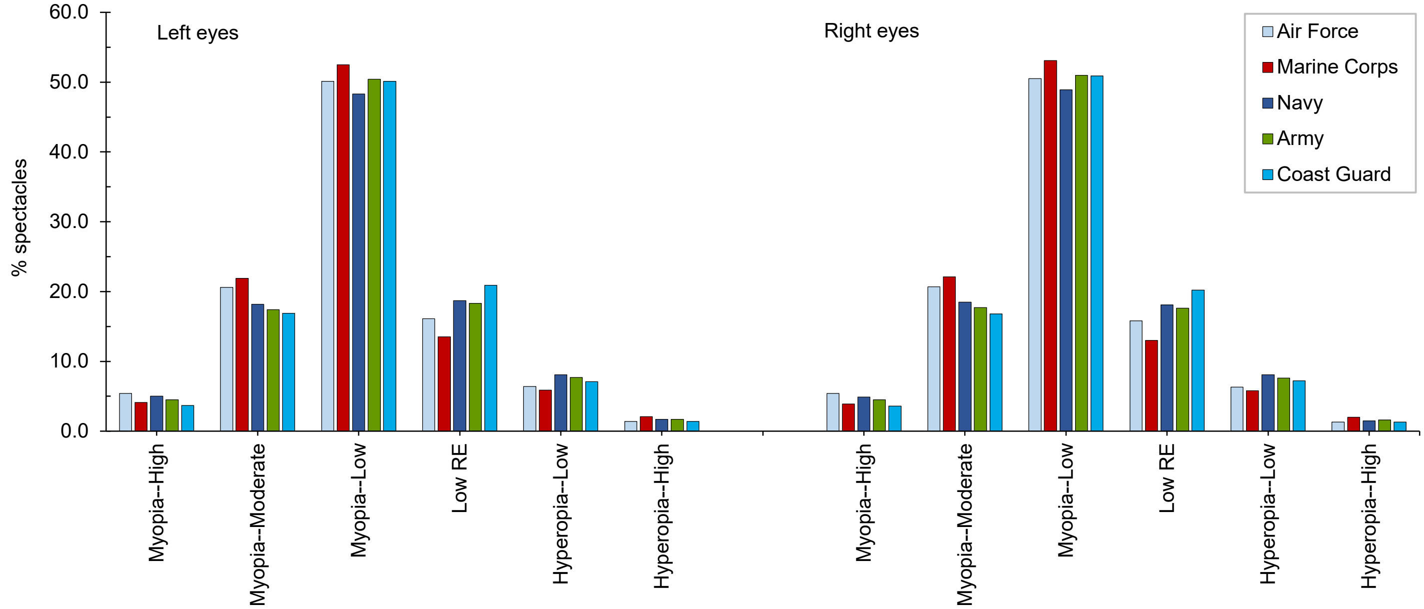
The U.S. military medical requirements, the Periodic Health Assessment for individual medical readiness, and the Pre-Deployment Health Assessment require an annual vision screening and spectacle orders (e.g., prescription glasses and lens inserts for military combat eye protection/safety glasses).[14-20] This study indicates that spectacles for vision correction were not ordered for over 3/4 of the active component of the U.S. Armed Forces. Furthermore, about 1/5 of those who ordered spectacles may not need fulltime vision correction because members with low refractive error or younger people with low hyperopia generally have "functional" unaided distance vision.

FIGURE 1. Refractive distribution of spectacles for distance vision correction in the active component of the U.S. Armed Forces (n=310,765) and Coast Guard (n=5,768), 2019



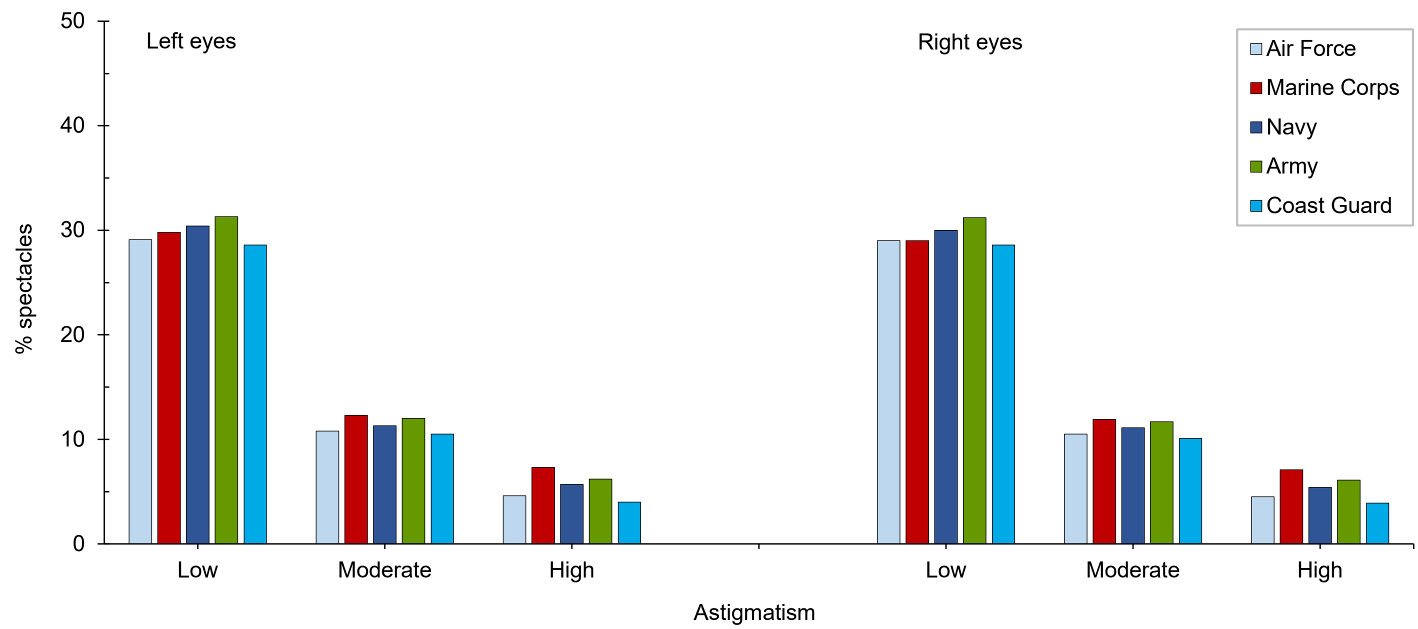
Mean refractive error in spherical equivalent (± standard error) was -1.69±0.004 D of the left and -1.70±0.004 D of the right eyes. Skewness was -0.59 for the distribution of each eye and kurtosis was 2.14 of the left and 1.95 of the right eyes. Spherical equivalent was defined as spherical refraction plus one-half of the negative cylindrical value in diopter (D).

FIGURE 2. Proportion of refractive errors among spectacles for distance vision correction in the active component of the U.S. Armed Forces and Coast Guard, 2019



Myopia was defined as spherical equivalent (SE) ≤ -0.50 diopter (D): Low myopia (SE ≤-0.50 D and >-3.00 D), Moderate myopia (SE ≤-3.00 D and >-6.00 D), and High myopia (SE ≤-6.00 D). Hyperopia was defined as SE > +0.50 D: Low hyperopia (SE >+0.50 D and <+3.00 D) and High hyperopia (SE ≥+3.00 D). Low Refractive Error (RE) was defined as SE >-0.50 D and ≤+0.50 D.

FIGURE 3. Proportion of astigmatism among spectacles for distance vision correction in the active component of the U.S. Armed Forces and Coast Guard, 2019

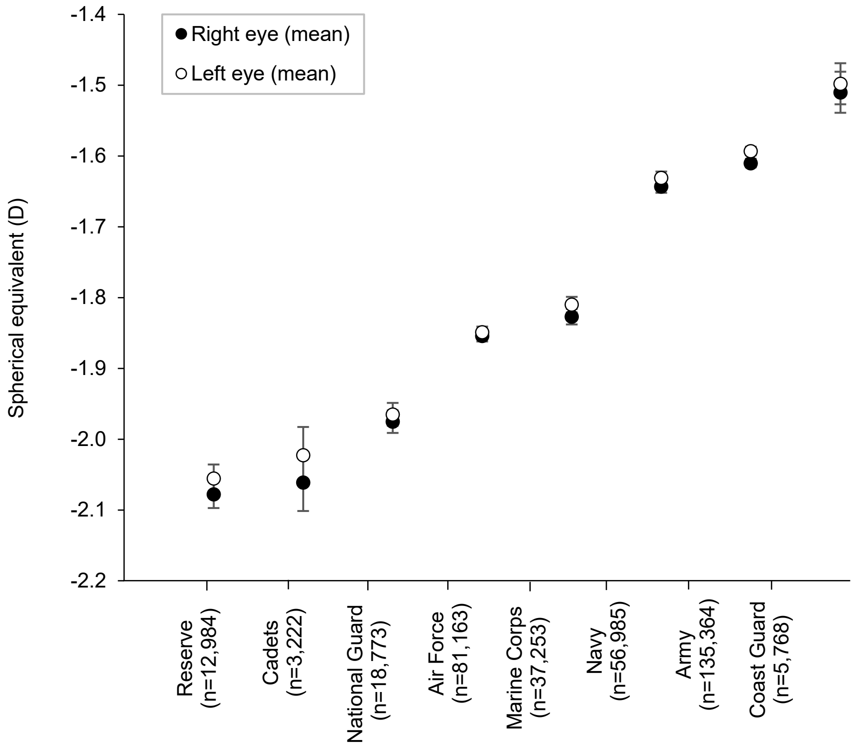


Astigmatism was defined as cylinder (CYL) < -0.50 D: Low (CYL < -0.50 D and > -1.50 D), Moderate (CYL ≤ -1.50 D and > -2.50 D), and High (CYL ≤ -2.50 D).

Prevalence of refractive errors

The prevalence of refractive errors in the U.S. Armed Forces and the U.S. Coast Guard was low relative to the general U.S. population. This study shows that the prevalence of myopia (SE≤-0.50 D), hyperopia (SE>+0.50 D), and astigmatism (CYL<-0.50 D) was 17.5%, 2.1%, and 11.2%, respectively in the active component of the U.S. Armed Forces. In comparison, a recent systematic review and meta-analysis study showed that an estimated pooled prevalence of myopia (SE≤-0.50 D), hyperopia (SE>+0.50 D), and astigmatism (CYL<-0.50 D) was 11.7%, 4.6%, and 14.9% among those under age 20, and 26.5%, 30.9%, and 40.4% in those over age 30.[5] The 2004 Eye Diseases Prevalence Research Group estimated myopia prevalence at 26.6%, 25.4%,

FIGURE 4. Refractive status of the right and left eye spectacles for distance vision correction, by service and duty status, 2019



Note: The spherical equivalent of the right and left eyes is expressed as mean ± standard error in diopter (D). The U.S. military Reserve was -2.078±.019 D and -2.056±.019 D. The military academy cadets was -2.061±.039 D and -2.023±.039 D. The National Guard was -1.975±.016 D and -1.965±.016 D. The Air Force Active Duty was -1.854±.008 D and -1.849±.008 D. The Marine Corps Active Duty was -1.827±.011 D and -1.810±.011 D. The Navy Active Duty was -1.643±.009 D and -1.631±.009 D. The Army Active Duty was -1.610±.006 D and -1.593±.006 D. The Coast Guard Active Duty was -1.510±.029 and -1.498±.029. Spherical equivalent was defined as spherical refraction plus a half of the negative cylindrical value. A negative sign indicates myopia.

and 16.4 % for European, North American, and Australian populations.[21]

Moreover, visual impairment increases with increased magnitude of refractive errors. For instance, high myopia is much more likely to result in sight threatening visual impairments (e.g., myopic macular degeneration, retinal detachment, cataract, or open angle glaucoma) and hyperopic eyes had a 13% higher risk of early age-related macular degeneration.[22-26] Results of this study show that the prevalence of pathologic high refractive errors, i.e., high myopia (SE≤-6.00 D) or high hyperopia (SE≥+3.00 D), was low in the active component of the U.S. Armed Forces and U.S. Coast Guard. In comparison, the prevalence of high myopia was 2.4–4.2% in the general population, and the prevalence of high hyperopia was 1–3% of younger and 10–13% of the older European population.[12,27]

The prevalence of refractive errors in this study was low in comparison to a crude annual prevalence of 38.5% for myopia, 12.0% for hyperopia, and 32.9% for astigmatism reported by Reynolds and colleagues.[8] Different methodologies likely contribute to the major differences between the results of the two studies. The earlier study used outpatient medical encounter data and the refractive error definitions were based on International Classification of Disease (ICD) codes.[8] In comparison, the current study used spectacle prescription data and relied on a more rigorous scientific consensus of refractive error classification. Another key factor is that individuals with a refractive error ICD code associated with an outpatient medical encounter may not necessarily require spectacle correction.

The U.S. Armed Forces had a lower prevalence of hyperopia because this study used spectacle prescriptions (i.e., not cycloplegic refraction), and a majority of the military population (90.5%) in the current study were under 40 years of age. A rising prevalence of hyperopia occurs in elderly populations due to age-related lens changes.[5]

Military medical policy on refractive error distribution

Vision screening prior to entering the military services contributes to the low prevalence and magnitude of refractive errors in the U.S. Armed Forces. Specifically, refractive errors in excess of -8.00 D or +8.00 D spherical equivalent or astigmatism in excess of 3.00 D are "disqualifying conditions" for entering the U.S. military.[19]

Additionally, the U.S. military refractive surgery program may further reduce the prevalence and magnitude of refractive errors by providing approximately 36,000 refractive surgeries (i.e., 18,000 service members) annually.[28,29] The U.S. military refractive surgery program aims to enhance military members' visual capability by reducing or eliminating dependency on spectacles and contact lenses.[29,30] The program impacts on refractive distribution in the U.S. Armed Forces require further investigation; however, the low prevalence of refractive errors in the active component U.S. Armed Forces and Coast Guard was likely a result of better access to the medical procedure. Certainly, refractive surgery does not remove risks associated with pathologic high refractive errors or eliminate vision correction for life. Some individuals after refractive surgery may still need mild spectacle correction due to refractive progression over time.

Military implications and path forward

Warfighters with functional unaided vision have significant advantage on the battlefield or in other operational environments. In the U.S. Armed Forces and the U.S. Coast Guard, the study showed that around 20% of the active duty members required fulltime spectacle correction for distance vision. The study results are useful in understanding of warfighter unaided visual capabilities, determining the cost to the Military Health System, and budgeting for DOD and Defense Health Agency programs, such as the military refractive surgery, military combat eye protection (MCEP), the optical fabrication enterprise, and more.

Furthermore, the refractive distribution of the U.S. Armed Forces are valuable for planning and procuring the next generation MCEP or future military devices. For instance, the U.S. Army Program Executive Office Soldier may use the information for its consideration of MCEP with embedded prescription, which can negate the need for an additional layer of an optical insert and thus improve warfighters' compliance, safety, and performance.[31] Moreover, the study shows that the difference of refractive error between the right and left eyes was nearly 1/100th of a diopter, which is too small to be "clinically significant". Therefore, engineers may consider using the same optical parameters for each eye when designing or developing future visual augmentation or enhancement devices (e.g., the integrated visual augmentation system).

Astigmatic (cylindrical) correction is another important parameter for MCEP or other military devices. The prevalence of astigmatism (CYL<-0.50 D) was 11.2% of the active component of the U.S. Armed Forces and With-the-Rule astigmatism (minus cylinder axis 180°±15°) was the most common type. Cylindrical correction, especially for moderate and high astigmatism (CYL≤-1.50 D) that was approximately 4.1% of the active component of U.S. Armed Forces, can greatly improve warfighter visual capability.

Lastly, presbyopia is less of a concern as over 90% of the active component service members were under 40 years of age. The prevalence of multifocal and reading glasses was less than 2% of the U.S. active component service members.

In general, refractive distribution of the U.S. Armed Forces is essential for better understanding of warfighter visual capabilities, establishing vision standards and policies, and supporting acquisition and development of the next generation military protective eyewear and devices.

Strengths and limitations

The major strengths of this study are large sample size and the scientific refractive error classification, which provide a precise description of refractive distribution in the active component of the U.S. Armed Forces and the U.S. Coast Guard members. One limitation of the study is that prevalence of refractive errors calculation was under an assumption that all active duty members who needed spectacle correction had ordered one in 2019. Because some service members may have ordered their spectacle outside the observation period, the estimates of prevalence for all of the refractive errors may be underestimates.

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Brief Report: Pain and Post-Traumatic Stress Disorder Screening Outcomes Among Military Personnel Injured During Combat Deployment

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The post-9/11 U.S. military conflicts in Iraq and Afghanistan lasted over a decade and yielded the most combat casualties since the Vietnam War.[1] While patient survivability increased to the highest level in history, a changing epidemiology of combat injuries emerged whereby focus shifted to addressing an array of long-term sequelae, including physical, psychological, and neurological issues.[2,3] The long-term effects of combat injury can adversely impact well-being and exact a significant burden on the health care system.[4–6]

Physical pain is common among military personnel returning from deployment, particularly those injured in combat,[7–9] and is associated with detrimental effects such as medical discharge[10] and substance use disorders.[11] Pain has also been linked to post-traumatic stress disorder (PTSD), which is common in veterans of the Iraq and Afghanistan conflicts.[12] The mutual maintenance model posits that PTSD symptoms may exacerbate chronic pain and, in turn, pain may contribute to or enhance existing PTSD symptoms.[13] PTSD is associated with negative outcomes among veterans with chronic pain, including disability, decreased functioning, and sleep disturbances,[14] making the study of pain and PTSD essential for improved patient care and rehabilitation.

Previous research on the co-occurrence of pain and PTSD in wounded service members has been limited by small sample sizes, specific injuries, or short follow-up periods.[15–17] The present study adds to the existing literature by examining the association between pain and PTSD screening outcomes nearly a decade after combat injury among a large, national sample of service members and veterans who were injured during deployment and experienced a wide range of injuries.

METHODS

Data were collected from the Wounded Warrior Recovery Project (WWRP).[4] Participants are identified from the Expeditionary Medical Encounter Database (EMED), a deployment health repository maintained by the Naval Health Research Center that includes clinical records of service members injured in overseas contingency operations since 2001.[18] Individuals whose data are in the EMED are approached via postal mail and email to provide informed consent for participation in the WWRP and to complete biannual assessments of patient-reported outcomes for 15 years. Enrollment is conducted on a rolling basis, and data collection is ongoing.

The present study utilized cross-sectional data from the seventh wave of the WWRP (i.e., 36 months post-baseline survey), when participants were asked to report on their pain during the past 6 months using the Chronic Pain Grading Scale.[19] The measure was introduced into the WWRP in 2015, and was asked of all participants only at the seventh wave. Standardized scoring procedures were used to calculate (1) pain intensity (a composite variable derived from current pain, worst pain in the past 6 months, and average pain in the past 6 months), (2) frequency of pain interference (number of days in the past 6 months that the respondent has been kept from their usual activities such as work, school, or housework because of pain), and (3) level of pain interference (a composite variable of how much pain has interfered with daily activities; recreational, social, and family activities; and ability to work, including housework).

PTSD screening status was measured using the PTSD Checklist–Civilian version (PCL-C) and PTSD Checklist for the DSM-5 (PCL-5). Both versions of the PCL are comparable in military personnel and veterans.[20] WWRP measures and procedures were updated in late 2018 to remain consistent with current standards of measurement of PTSD symptoms. Scores were summed for each PCL-related measure. Standard cutoffs of 44 and 33 indicated positive screens for PTSD using the PCL-C and PCL-5, respectively.[21,22]

Data from 2,649 combat-injured service members and veterans who participated in the WWRP between 1 December 2015 and 30 September 2021 were included in the analysis. Injury date, Injury Severity Scores (ISS), and demographics were obtained from the EMED. The ISS is a scoring system that accounts for multiple injuries in a patient and provides an overall measure of injury severity that ranges from 0 (no injury) to 75 (fatal injury). ISS was categorized as mild (1–3), moderate (4–8), and serious/severe (ISS 9+). Independent sample t-tests were used to examine mean differences in pain variables by PTSD screening status. An alpha level of .05 was considered statistically significant. Analyses were performed using SPSS Statistics, version 25 (IBM Corp., Armonk, NY).

RESULTS

Participants were mostly enlisted, non-Hispanic White males in the Army **(Table)**. At the time of the WWRP assessment, mean age was 37.2 years (standard deviation [SD]=7.6) and average time since injury was 9.4 years (SD=3.7). A majority of participants (86.9%) were injured in a blast and over one-half (54.1%) sustained mild injuries overall. Injury severity was not associated with PTSD screening status (p=.212). Participants who screened positive for PTSD had higher average pain intensity (60.6 vs. 37.5, p<.001, d=1.10), days of pain interference (42.7 vs. 9.8, p<.001, d=0.80), and level of pain interference (50.7 vs. 20.3, p<.001, d=1.29) than those who screened negative.

TABLE. Characteristics of the study population and pain items by post-traumatic stress disorder (PTSD) screening status

Characteristic	Total (n=2,649)	PTSD positive (n=1,094)	PTSD negative (n=1,555)	p-value
Mean time since injury, years (SD)	9.4 (3.7)	9.5 (3.7)	9.4 (3.6)	.690
Mean age, years (SD)	37.2 (7.6)	37.3 (7.5)	37.2 (7.6)	.675
Male, n (%)	2,533 (95.6)	1,052 (96.2)	1,481 (95.2)	.255
Race/ethnicity, n (%)				<.001
Non-Hispanic White	2,043 (77.1)	783 (71.6)	1,260 (81.0)	
Hispanic/Latino	284 (10.7)	153 (14.0)	131 (8.4)	
Non-Hispanic Black	156 (5.9)	80 (7.3)	76 (4.9)	
Asian/Pacific Islander	78 (2.9)	33 (3.0)	45 (2.9)	
American Indian/Alaska Native	33 (1.2)	19 (1.7)	14 (0.9)	
Other/unknown	55 (2.1)	26 (2.4)	29 (1.9)	
Military status (n = 2,058), n (%)				<.001
Active duty	363 (17.6)	74 (8.7)	289 (24.0)	
Active Reserve/National Guard	142 (6.9)	41 (4.8)	101 (8.4)	
Inactive Reserve/National Guard	34 (1.7)	11 (1.3)	23 (1.9)	
Medically retired	518 (25.2)	279 (32.7)	239 (19.9)	
Retired	292 (14.2)	127 (14.9)	165 (13.7)	
Separated/discharged	709 (34.5)	322 (37.7)	387 (32.1)	
Service branch, n (%)				.350
Army	1,838 (69.4)	742 (67.8)	1,096 (70.5)	
Air Force	49 (1.8)	19 (1.7)	30 (1.9)	
Marine Corps	688 (26.0)	304 (27.8)	384 (24.7)	
Navy	74 (2.8)	29 (2.7)	45 (2.9)	
Enlisted, n (%)	2,312 (87.3)	1,024 (93.6)	1,288 (82.8)	<.001
Blast, n (%)	2,303 (86.9)	973 (88.9)	1,330 (85.5)	.010
Injury Severity Score, n (%)				.212
Mild (1–3)	1,433 (54.1)	598 (54.7)	835 (53.7)	
Moderate (4–8)	619 (23.4)	267 (24.4)	352 (22.6)	
Serious/severe (9+)	597 (22.5)	229 (20.9)	368 (23.7)	
Characteristic pain intensity[a], mean (SD)[b]	47.0 (24.2)	60.6 (19.3)	37.5 (22.7)	<.001
Pain interference[a], days (n = 2,375), mean (SD)[c]	22.8 (41.6)	42.7 (52.7)	9.8 (24.8)	<.001
Pain interference[a], level (n = 2,625), mean (SD)[d]	32.8 (27.8)	50.7 (25.5)	20.3 (21.9)	<.001

[a]Characteristic pain intensity and pain interference level are measured on a 0–100 scale. Pain interference days were in the last 6 months.
[b]Effect size (Cohen's d)=1.10. [c]Effect size (Cohen's d)=0.80. [d]Effect size (Cohen's d)=1.29. Note: d≥0.8 is considered large.
SD, standard deviation.

EDITORIAL COMMENT

This study describes a significant association between PTSD screening outcomes and pain following combat injury. These results are consistent with previous literature and reaffirm that psychological and physical health issues can overlap and potentially complicate patient management.[3] In a report by Shipherd et al.,[23] 66% of veterans who sought treatment for PTSD had comorbid chronic pain. Another study found that diagnosis of PTSD yielded 5 times greater odds of persistent pain complaints,[24] and other research suggests a link between greater pain severity after combat injury and PTSD risk.[25] Further, the polytrauma clinical triad (co-occurrence of concussion, pain, and PTSD) was found in 42% of military polytrauma patients.[8] Sharp and Harvey[13] highlighted several possible pathways whereby pain and PTSD could be mutually maintaining, including pain acting as a reminder of the trauma, reduced activity levels, and increased pain perception due to elevated anxiety. Notably, injury severity in the present study was not associated with PTSD screening status. This finding is consistent with previous research[17] and can be explained by ISS being a measure of mortality risk, which may not be directly related to other outcomes, such as mental health. Future studies are needed to elucidate the etiological pathways of comorbid pain and PTSD after combat injury.

Because pain and PTSD can co-occur many years after injury, the early recognition and identification of these conditions in primary care settings and through periodical health assessments may be important to refine clinical practice and, ultimately, improve the overall public health of the military. Furthermore, the use of multidisciplinary health care teams should be examined and considered for use in future military conflicts to address co-occurring physical and psychological issues, which negatively impact long-term quality of life.[3] A similar model was successfully employed to increase return-to-duty rates following concussion and could be adapted to address other injuries.[26] Such interventions should be considered for veterans in long-term care and also during the early phase following combat injury, as recent research demonstrated that symptom complaints in the initial year post-injury predicted mental and physical health years later.[27]

This analysis has several limitations that should be considered when interpreting the results. A key limitation is due to the cross-sectional design of this study; because PTSD and pain were measured at a single point in time, their temporality could not be assessed. Elucidating this relationship could be useful in developing targeted intervention and treatment strategies. Further, measures were obtained on average 9 years after injury, and other factors unaccounted for in the present study (e.g., depression, sleep problems, concussion) may influence the relationship between pain and PTSD. Additional research is needed to examine this relationship over time and include an assessment of confounders. Nevertheless, the findings suggest that pain is associated with PTSD years after injury and could inform medical providers involved in the treatment and rehabilitation of military personnel after combat injury.

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