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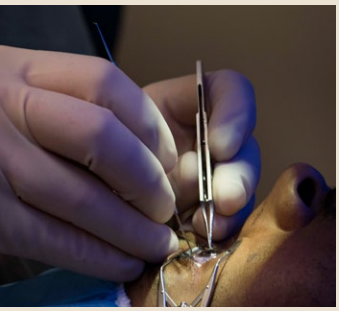

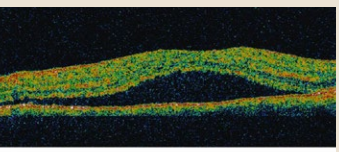

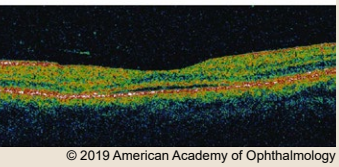

Editorial

The Department of Defense/Veterans Affairs Vision Center of Excellence

Mark E. Reynolds, MD, MPH (COL, USA)

Vision and visual function are essential for performance across multiple activities. When vision is compromised, it can negatively affect behavioral health, social functioning, and overall quality of life.[1] Studies have also linked decreased visual function to increased mortality.[2] In military populations, optimal visual function is required for demanding tasks ranging from effective weapons utilization[3] to aircraft-based flight operations.[4]

Ocular injuries present a particular problem for service members and the providers charged with their care. These injuries are associated with a substantial cost in terms of resources, rehabilitation, and training.[5] In response to the need for increased focus on ocular injuries and their treatment across the continuum of care, the Department of Defense (DoD)/Veterans Affairs (VA) Vision Center of Excellence (VCE) was established by congressional mandate in 2008 under the National Defense Authorization Act (Public Law 110-181, Section 1623) as a center of excellence in the prevention, diagnosis, mitigation, treatment, and rehabilitation of military eye injuries, including visual dysfunction related to traumatic brain injury (TBI).[6] Consistent with the requirement of all Defense Centers of Excellence to provide expertise across the entire clinical spectrum of care for a patient, the VCE addresses the full scope of vision care, from the prevention of diseases and treatment of clinical conditions through rehabilitation and transition to civilian life.[7]

The VCE continually executes initiatives in support of the 2008 mandate. In 2015, the VCE collaborated with the Joint Trauma System (JTS), the Committee on Tactical Combat Casualty Care (TC3), and the Defense Health Agency's Medical Logistics Division to increase the availability of rigid eye shields in the individual first aid kit. These eye shields are essential for preventing further damage to a traumatized eye until definitive treatment is available. This effort to increase the availability of rigid eye shields resulted in changes to the TC3 card (DD Form 1380) to allow for documentation of eye shield use (check boxes for eye shield use).[8] In further collaboration with the JTS, the VCE has initiated and/or contributed to multiple clinical practice guidelines (CPGs) designed to provide best care practices across the spectrum of ocular injuries. For example, the "Ocular Injuries and Vision-Threatening Conditions in Prolonged Field Care" CPG is currently available at https://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs, and the "Evaluation and Disposition of Temporary Visual Interference and Ocular Injury after Suspected Ocular Laser Exposure" CPG is pending publication on the JTS website.

A specific area of focus mandated to the VCE is visual dysfunction following TBI. To address this complex set of conditions, the VCE, in collaboration with a panel of experts in vision, rehabilitation, and TBI across the DoD, VA, and the civilian sector's diverse group of subject matter experts, including the Defense and Veterans Brain Injury Center, oversaw the production of clinical recommendations and associated clinical support tools for the care of visual dysfunction after TBI. These aids to clinical care include "Eye and Vision Care Following Blast Exposure and/or Possible Traumatic Brain Injury," "Care of Visual Field Loss Associated with Traumatic Brain Injury," and "Care of Oculomotor Dysfunctions Associated with TBI."[9–11] In coordination with the Uniformed Services University of the Health Sciences, the VCE is conducting a review of current visual dysfunction documentation, intervention options, and best practices. The article on visual dysfunction following TBI in this issue of the *MSMR* was developed to provide additional information on this diverse set of conditions, update current recommendations, and inform future clinical and research efforts.[12]

The VCE established the World Wide Ocular Trauma and Readiness Curriculum Teleconference to engage international, multiagency, and cross-specialty attendees spanning multiple sites in review of vision cases and identification of clinical process improvements. The monthly calls serve as a key platform for providing feedback and follow-up to deployed providers and for developing and disseminating best practices and clinical lessons learned.

In order to ensure continuity of care from injury through rehabilitation, the VCE developed a collection of reference guides that include vision resources across the DoD and VA as well as at the state and national level. The "Vision Care Coordination Reference Guide" expands network capabilities between stakeholders, increases partnerships, and enables care coordinators to assist in a rapid and thorough response to the patient population requiring trauma and vision care specialties. In addition, the VCE produces fact sheets to educate the care community to assist with engaging a visually impaired patient.

With continued emphasis on military readiness, the VCE is expanding focus beyond combat-related traumatic conditions to include disease and non-battle injuries. Ocular and vision-related conditions can have great impact on readiness and retention. The first article in this issue characterizes the burden of ocular and vision conditions and was developed to provide a broad overview of these conditions.[13] This information will provide key information to guide further initiatives and programs across the Military Health System.

The VCE was tasked with implementing and managing a registry of information to track diagnoses, interventions/treatments, and follow-up for each case of significant eye injury sustained by a member of the Armed Forces while serving on

active duty. The Defense Vision and Eye Injury and Vision Registry (DVEIVR) was developed to address this requirement. Registry data are available to ophthalmological and optometric personnel of the DoD and VA for purposes of encouraging and facilitating the conduct of research and the development of best practices and clinical education on eye injuries incurred by members of the Armed Forces in combat. Registry data have been used by DoD and academic institutions to better characterize the complex field of ocular trauma. DVEIVR data are also shared with the VA Blind Rehabilitation Service to maximize continuity of care. The VCE is currently incorporating DVEIVR data along with other data sources focused on providing evidence-based care recommendations.

The VCE continually strives to improve the recognition and management of ocular injuries and vision-threatening conditions across military and veteran populations. Such efforts supporting improved care and coordination of care are essential for maintaining the visual performance of U.S. service members and veterans. Additional information on the VCE and its products is available at https://vce.health.mil/. Further inquiries can be sent via email to dha.ncr.dod-va.mbx.vce@mail.mil.

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Absolute and Relative Morbidity Burdens Attributable to Ocular and Vision-Related Conditions, Active Component, U.S. Armed Forces, 2018

Mark E. Reynolds, MD, MPH (COL, USA); Valerie F. Williams, MA, MS; Stephen B. Taubman, PhD; Shauna Stahlman, PhD, MPH

The current report used an ocular and vision disease classification system and several healthcare burden measures to quantify the impacts of various ocular and vision-related illnesses and injuries among active component service members of the U.S. Armed Forces during 2018. More service members received care for refractive error and related disorders than any other ocular and vision-related major category; this category accounted for slightly more than one-half (51.1%) of all ocular and vision-related medical encounters. Conjunctival disorders accounted for the next highest percentage of total medical encounters (13.3%) followed by corneal disorders (7.5%). The 3 specific ocular and vision-related conditions that accounted for the most medical encounters (i.e., myopia, astigmatism, and acute conjunctivitis) accounted for almost one-half (47.7%) of all ocular and vision-related medical encounters overall. In general, the conditions that accounted for the most medical encounters were predominantly refractive error and related disorders and conjunctival disorders. More active component service members received medical care for myopia than for any other specific condition. Optic nerve conditions and visual discomfort/disturbances accounted for more than one-quarter (30.1%) of all ocular and vision-related hospital bed days.

WHAT ARE THE NEW FINDINGS?

This is the first *MSMR* report specifically focused on the burden of ocular and vision conditions among active component U.S. service members. Refractive errors accounted for the majority of eye-related encounters among service members. Neuro-ophthalmic diagnoses (conditions of the optic nerve, visual tract, and cranial nerves responsible for eye movements) accounted for the most hospital bed days.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Eye health and optimal visual function are key to performance of military duties across the services. Effective prioritization of the magnitude and burden of ocular and visual conditions is essential to inform the targets for prevention, allocation of resources, training objectives, and research goals.

Routinely collected healthcare utilization data are available for the U.S. Armed Forces and are regularly analyzed to inform prevention planning and resourcing.[1] The Armed Forces Health Surveillance Branch produces annual reports of overall healthcare burden measures for ongoing evaluation.[2] Accurate characterization of the frequency and impact of conditions affecting specific systems, such as the visual system, is essential. Degraded visual function can have a significant impact on both readiness and retention of service members. Financial costs of ocular injuries and visual dysfunction resulting from traumatic brain injury have been recently reported and are significant.[3]

Conditions of the eyes and visual system are responsible for considerable morbidity globally and have increased in incidence over time.[4,5,6] Many of these conditions increase in frequency with advancing age.[5] U.S. active component service members are a select subgroup of the population. As a result, the morbidity burden among service members may be significantly different from that in the general U.S. population. In addition, the U.S. military has rigorous standards for accession, including those for ocular conditions and visual acuity.[7] The challenges to military operational performance due to eye and vision problems often do not have direct correlates in the civilian population.

Because of the unique nature of ocular and vision problems, these conditions usually require monitoring and treatment by dedicated eye care professionals. Population-level evaluation of these conditions is necessary to characterize their effects across the active component and to identify needed enterprise-wide priorities within a specialized system of care. Effective characterization of the magnitude and impact of these conditions will inform the targets for prevention, allocation of resources, training objectives, and research goals.

The current report used an ocular and vision disease classification system and several healthcare burden measures to quantify the impacts of various ocular and vision-related illnesses and injuries among active component service members of the U.S. Armed Forces during 2018. This approach will allow for interpretation of data in the context of conditions across the active component and identification of specific conditions for further assessment of the impacts on operational performance.

METHODS

The surveillance period was 1 January through 31 December 2018. The surveillance population included all individuals who served in the active component of the U.S. Army, Navy, Air Force, or Marine Corps at any time during the surveillance period. All data used in this analysis were derived from records routinely maintained in the Defense Medical Surveillance System (DMSS). These records document both ambulatory encounters and hospitalizations of active component service members of the U.S. Armed Forces in fixed military and civilian (if reimbursed through the Military Health System [MHS]) treatment facilities worldwide.

For this analysis, DMSS data for all inpatient and outpatient medical encounters of all active component service members during 2018 were summarized according to the primary (first-listed) diagnosis (if reported with an International Classification of Diseases, 10th Revision [ICD-10] code) for ocular and vision-related conditions. For summary purposes, ocular and vision-specific diagnoses (as defined by the ICD-10) were grouped into 128 subcategories and 24 main categories by clinical and public health subject matter experts at the Department of Defense/Veterans Affairs Vision Center of Excellence. The groupings were designed for maximal capture of conditions, allowing for expected variability in diagnostic coding.

The "morbidity burdens" attributable to various ocular and vision-related "conditions" were estimated based on the total number of medical encounters attributable to each condition (i.e., total hospitalizations and ambulatory visits for the condition with a limit of 1 encounter per individual per condition per day), numbers of service members affected by each condition (i.e., individuals with at least 1 medical encounter for the condition during the year), and total bed days during hospitalizations for each condition.

The new electronic health record for the MHS, MHS GENESIS, was implemented at several military treatment facilities during 2017. Medical data from sites that are using MHS GENESIS are not available in the DMSS. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounters for individuals seeking care at any of these facilities during 2018 were not included in this analysis.

RESULTS

Morbidity burden, by category

In 2018, more active component service members (n=138,961) received care for refractive error and related disorders than any other ocular and vision-related major category **(Figure 1a)**; this category accounted for slightly more than one-half (51.1%) of all ocular and vision-related medical encounters **(Figure 1b)**. Conjunctival disorders accounted for the next highest percentage of total medical encounters (13.3%) followed by corneal disorders (7.5%).

Ocular and vision-related conditions were associated with a total of 535 hospital bed days in 2018. Neuro-ophthalmic disorders accounted for slightly more than one-quarter (25.2%) of the total hospital bed days **(Figure 1b)**. Together, neuro-ophthalmic disorders, ocular injuries, non-specific ocular diagnoses, corneal disorders, and vitreoretinal disorders accounted for more than two-thirds (67.3%) of all ocular and vision-related hospital bed days.

Medical encounters, by condition

In 2018, the 3 ocular and vision-related conditions that accounted for the most medical encounters (i.e., myopia, astigmatism, and acute conjunctivitis) accounted for almost one-half (47.7%) of all ocular and vision-related medical encounters overall **(Figure 2)**. Moreover, the top 8 conditions that accounted for the most medical encounters accounted for more than two-thirds (67.0%) of all medical encounters overall. In general, the conditions that accounted for the most medical encounters were predominantly refractive error and related disorders (e.g., myopia, astigmatism, hyperopia) and conjunctival disorders (e.g., acute conjunctivitis, unspecified conjunctivitis) (**Table**).

Individuals affected, by condition

In 2018, more active component service members received medical care for myopia than for any other specific condition **(Table)**. Of the top 10 ocular and vision-related conditions that affected the most service members, 4 were refractive error and related disorders (myopia, astigmatism, hyperopia, and other refractive disorders); 2 were conjunctival disorders (acute conjunctivitis and unspecified conjunctivitis); 1 was a lid and adnexal disorder (lid inflammation); 1 was an ocular injury (superficial ocular injuries); 1 was a glaucoma and related condition (preglaucoma and ocular hypertension); and 1 was a corneal disorder (dry eye syndrome).

Hospital bed days, by condition

In 2018, optic nerve conditions and visual discomfort/disturbances accounted for more than one-quarter (30.1%) of all ocular and vision-related hospital bed days **(Figure 3)**. Together, vision-threatening ocular injuries, orbital inflammatory conditions, and retinal detachments accounted for an additional 23.0% of the total hospital bed days.

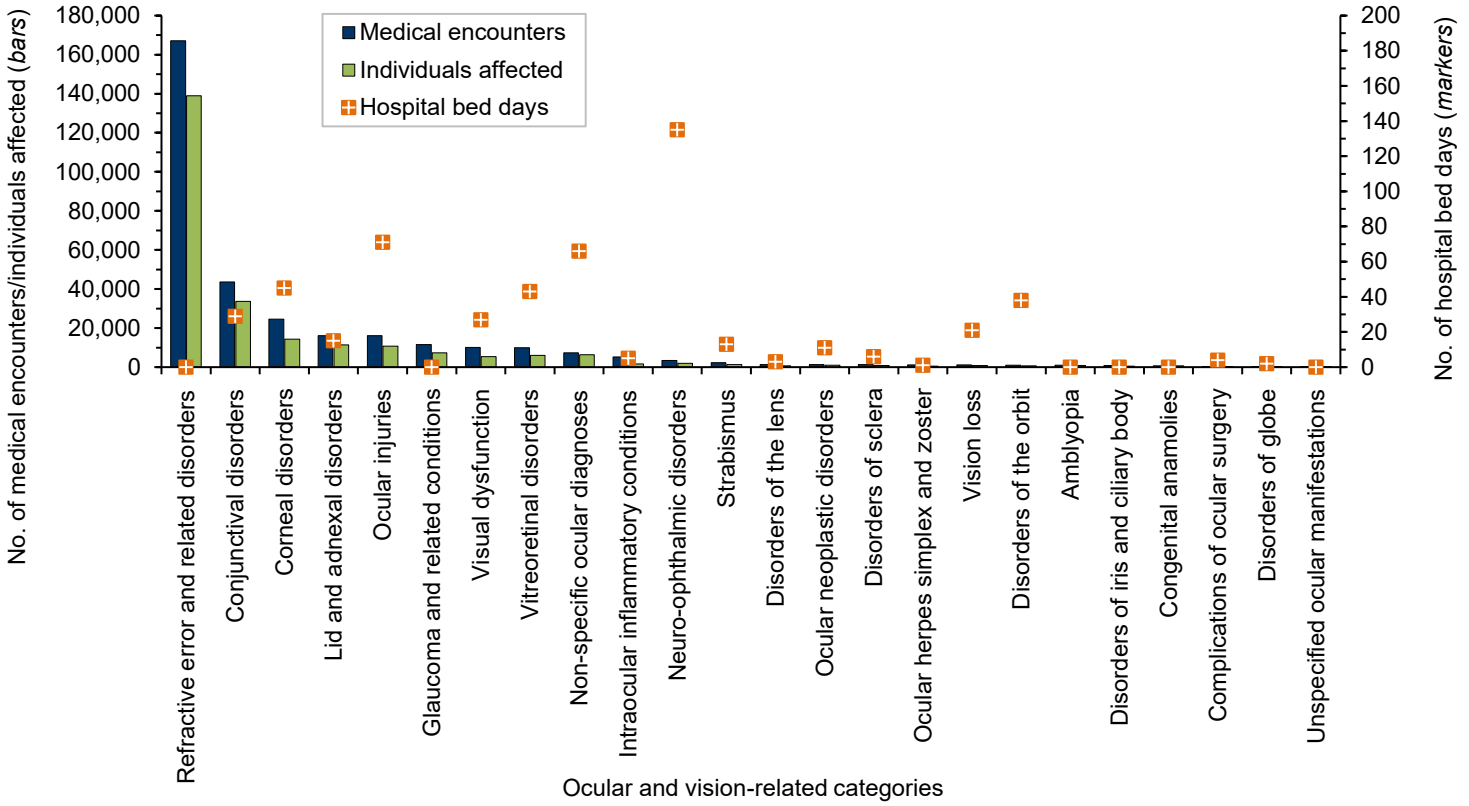
Relationships between healthcare burden indicators

There was a strong positive correlation between the number of ocular and vision-related medical encounters attributable to various conditions and the number of individuals affected by the conditions (r=0.99) **(data not shown)**. For example, the 6 leading causes of medical encounters were the 6 conditions that affected the most individuals **(Table)**. In contrast, there were very weak linear relationships between the hospital bed days attributable to ocular and vision-related conditions and either the numbers of individuals affected by (r=0.02) or medical encounters attributable to (r=0.05) the same conditions **(data not shown)**.

EDITORIAL COMMENT

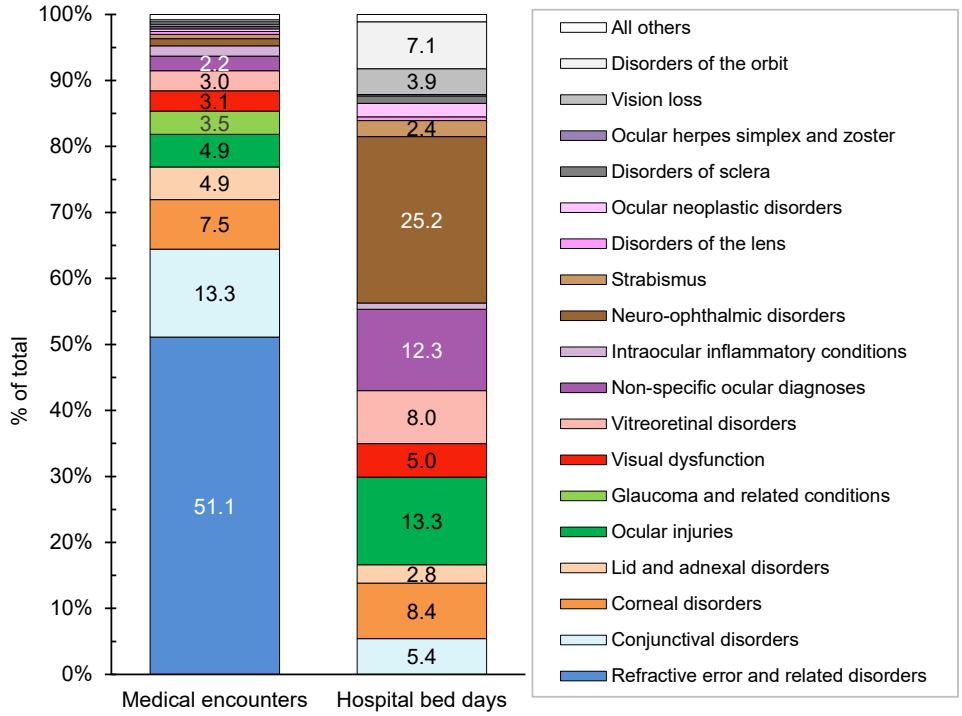
This is the first *MSMR* report on the burden of ocular and vision conditions among U.S. active component service members. Three of the 24 major categories (refractive error and related disorders, conjunctival disorders, and corneal disorders) accounted for

FIGURE 1a. Numbers of medical encounters,[a] individuals affected,[b] and hospital bed days, by ocular and vision-related major category, active component, U.S. Armed Forces, 2018



[a]Medical encounters include total hospitalizations and ambulatory visits for the condition with no more than 1 encounter per individual per day per subcategory.
[b]Individuals with at least 1 hospitalization or ambulatory visit for the condition.
No., number.

FIGURE 1b. Percentage of medical encounters[a] and hospital bed days[b] attributable to ocular and vision-related major categories, active component, U.S. Armed Forces, 2018



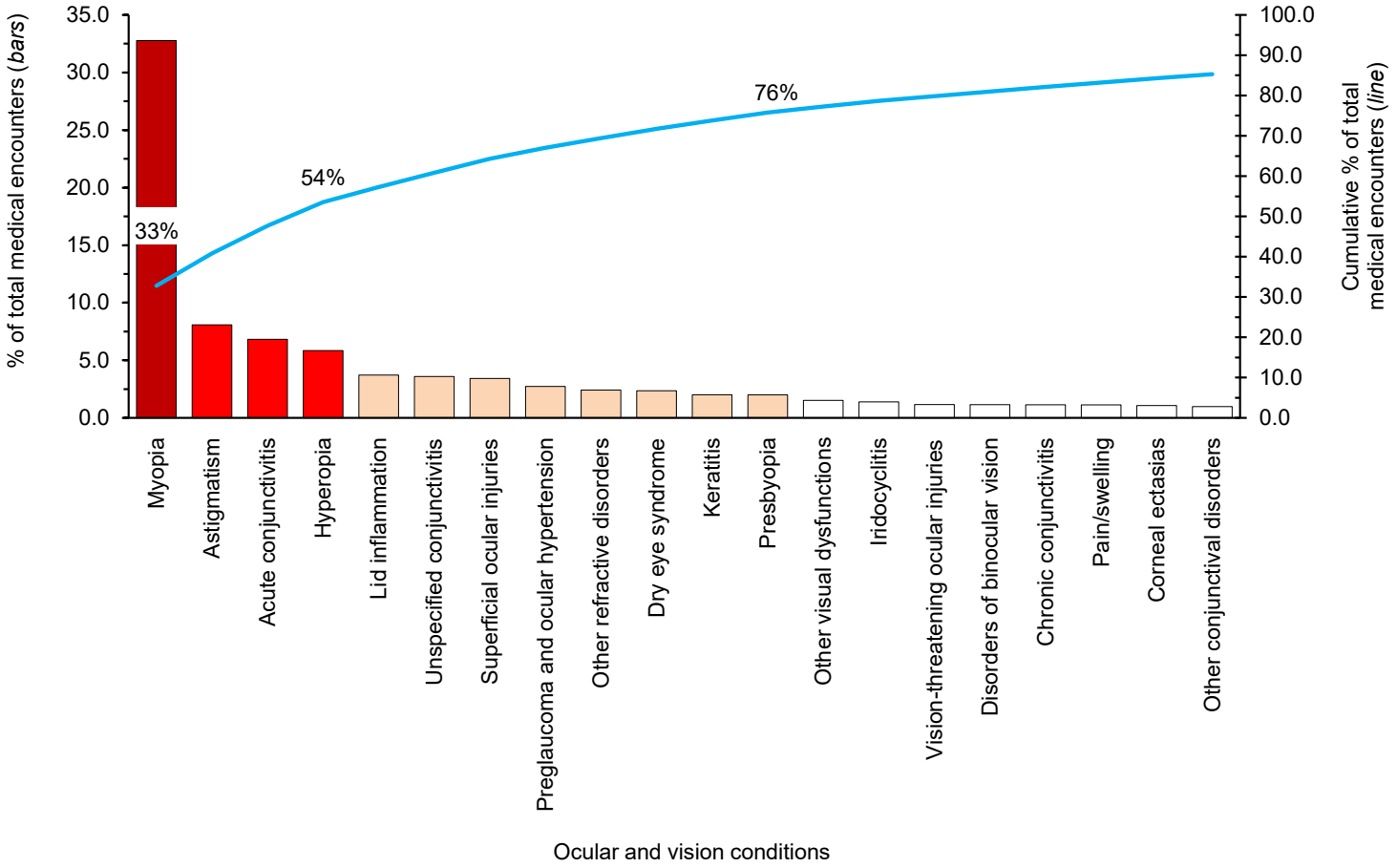
[a]Medical encounters include total hospitalizations and ambulatory visits for the condition with no more than 1 encounter per individual per day per subcategory (n=326,953).
[b]n=535.

72.0% of medical encounters during 2018. However, these same categories accounted for less than one-sixth (13.8%) of the total hospital bed days in 2018.

Refractive error and related disorders accounted for the most medical encounters and individuals affected; this category of conditions has specific readiness standards and, as such, the data reported here can provide insight into the burden of maintaining these requirements. Myopia, astigmatism, and hyperopia accounted for the vast majority (91.4%) of refractive error–related medical encounters. The significance of these conditions in relation to military readiness and performance is discussed in greater detail in a later report in this *MSMR* issue.[8]

Several of the categories examined in this analysis could have significant impacts on readiness and/or retention because of their potential for prolonged or permanent effects on visual performance. Ocular injuries accounted for 4.9% of total medical encounters and 13.3% of total hospital bed days. Out of the total ocular injury–related medical encounters reported in 2018, slightly

FIGURE 2. Percentage and cumulative percentage distribution, ocular and vision-related conditions that accounted for the most medical encounters, active component, U.S. Armed Forces, 2018



more than one-quarter (25.9%) were for non-superficial injuries (i.e., vision-threatening injuries, burns/corrosions, visual pathway injuries, and cranial nerve III/IV/VI injuries); non-superficial ocular injuries accounted for more than three-quarters (80.3%) of ocular injury–related hospital bed days.

Vitreoretinal conditions, which affect the posterior structures of the eye and often require subspecialist assistance in diagnosis and management, accounted for 2.6% of total medical encounters and 8.0% of total hospital bed days. Neuro-ophthalmic diagnoses (conditions of the optic nerve, visual tract, and cranial nerves responsible for eye movements) accounted for only 1.1% of all medical encounters but approximately one-quarter (25.1%) of total hospital bed days. Of note, complications of ocular surgeries accounted for less than 0.1% of encounters.

This report also allows for framing the burden of eye and vision conditions in the context of overall burden of disease across the active component. For example, in comparison to the other 141 specific conditions examined in the *MSMR's* annual analysis of the healthcare burden of diseases and injuries, disorders of refraction and accommodation ranked 18th in terms of the numbers of outpatient encounters and 7th in the numbers of service members affected. Refractive error and related disorders affected more individuals than either arm and shoulder injuries or leg injuries (although with considerably fewer attributable encounters).[2] Relationships between healthcare burden indicators were similar to those observed with overall disease burden among active component service members.[2] When comparing numbers of medical encounters to numbers of individuals affected, there was a strong positive correlation. When comparing hospital bed days attributable to conditions to numbers of individuals affected or to medical encounters attributable to the same conditions, there were very weak linear relationships. Many ocular and vision-related categories had zero bed days attributed to that category. In general, these correlations are consistent with the trend of eye care, especially ocular surgery, being provided in an ambulatory care setting.[9]

This report is subject to several limitations. As noted above, the change in electronic health record systems to MHS GENESIS removed data from multiple treatment facilities for this analysis, leading to underreporting of total numbers. In 2018, 6,396 active component service members received care for non-specific ocular diagnoses, and this category accounted for 12.3% of total hospital bed days in 2018. It is important to recall that this summary of the burden of ocular and vision conditions was limited to encounters in which such diagnoses were in the first diagnostic position of records. This method would exclude a relatively large number of ocular conditions related

TABLE. Healthcare burdens attributable to ocular and vision-related conditions, active component, U.S. Armed Forces, 2018

Ocular and vision condition	Medical encounters[a]		Individuals affected[b]		Bed days	
	No.	Rank[c]	No.	Rank[c]	No.	Rank[c]
Refractive error and related disorders						
Myopia	107,162	(1)	88,902	(1)	0	(43)
Astigmatism	26,421	(2)	24,858	(2)	0	(43)
Hyperopia	19,111	(4)	17,588	(4)	0	(43)
Other refractive disorders	7,904	(9)	5,800	(11)	0	(43)
Presbyopia	6,527	(12)	6,291	(10)	0	(43)
Conjunctival disorders						
Acute conjunctivitis	22,314	(3)	18,427	(3)	23	(7)
Unspecified conjunctivitis	11,750	(6)	10,638	(5)	2	(31)
Chronic conjunctivitis	3,717	(17)	2,926	(15)	0	(43)
Other conjunctival disorders	3,205	(20)	2,841	(16)	0	(43)
Pterygium and pinguecula	1,943	(27)	1,271	(26)	4	(24)
Blepharoconjunctivitis	691	(47)	556	(42)	0	(43)
Corneal disorders						
Dry eye syndrome	7,704	(10)	6,300	(9)	0	(43)
Keratitis	6,547	(11)	3,424	(12)	25	(6)
Corneal ectasias	3,502	(19)	1,512	(20)	2	(31)
Other corneal disorders	2,243	(23)	1,089	(30)	3	(27)
Contact lens disorders	2,195	(24)	1,373	(23)	0	(43)
Corneal neovascularization, edema, and opacities	1,745	(28)	1,213	(27)	9	(14)
Corneal dystrophies	323	(58)	244	(57)	6	(19)
Corneal degenerations	268	(69)	205	(62)	0	(43)
Lid and adnexal disorders						
Lid inflammation	12,154	(5)	8,788	(6)	3	(27)
Other lid disorders	2,036	(26)	1,685	(19)	2	(31)
Abnormal lid position or function	1,013	(37)	662	(37)	10	(13)
Other lacrimal system	409	(53)	298	(53)	0	(43)
Unspecified lid and adnexa	323	(58)	312	(52)	0	(43)
Lacrimal system inflammation	202	(74)	150	(68)	0	(43)
Ocular injuries						
Superficial ocular injuries	11,195	(7)	7,567	(7)	6	(19)
Vision-threatening ocular injuries	3,782	(15)	2,703	(17)	52	(3)
Unspecified ocular injuries	734	(42)	611	(39)	8	(16)
Ocular burns/corrosions	318	(60)	223	(59)	0	(43)
Optic nerve and visual pathway injuries	48	(90)	26	(92)	5	(22)
Cranial nerve III/IV/VI injuries	30	(98)	20	(98)	0	(43)
Glaucoma and related conditions						
Preglaucoma and ocular hypertension	8,931	(8)	6,515	(8)	0	(43)
Open angle glaucoma	1,720	(29)	765	(34)	0	(43)
Other glaucoma	290	(62)	157	(66)	0	(43)
Secondary glaucoma	273	(67)	112	(73)	0	(43)
Secondary open angle glaucoma	220	(73)	101	(76)	0	(43)
Angle closure glaucoma	51	(88)	36	(87)	0	(43)
Glaucomatous optic atrophy	22	(100)	19	(100)	0	(43)
Visual dysfunction						
Other visual dysfunctions	4,968	(13)	3,252	(14)	12	(12)
Disorders of binocular vision	3,752	(16)	1,348	(24)	13	(11)
Visual field defects	1,069	(34)	666	(36)	2	(31)
Color vision abnormalities	274	(66)	255	(56)	0	(43)
Night blindness	17	(103)	13	(103)	0	(43)

TABLE (cont.). Healthcare burdens attributable to ocular and vision-related conditions, active component, U.S. Armed Forces, 2018

Ocular and vision condition	Medical encounters[a]		Individuals affected[b]		Bed days	
	No.	Rank[c]	No.	Rank[c]	No.	Rank[c]
Vitreoretinal disorders						
Macular degeneration and maculopathies	2,179	(25)	1,202	(28)	0	(43)
Peripheral retinal degenerations	1,527	(30)	1,307	(25)	0	(43)
Retinal breaks/tears/holes	1,435	(31)	991	(31)	0	(43)
Vitreous deposits/opacities/degenerations	1,345	(32)	1,147	(29)	0	(43)
Retinal vascular disorders	832	(40)	392	(48)	8	(16)
Retinal detachments	739	(41)	291	(54)	35	(5)
Retinal and chorioretinal scars	552	(51)	454	(46)	0	(43)
Unspecified vitreoretinal or choroidal disorders	496	(52)	422	(47)	0	(43)
Non-specific retinal findings	328	(57)	211	(60)	0	(43)
Retinal/choroidal dystrophies	260	(70)	142	(70)	0	(43)
Retinoschisis and retinal cysts	108	(80)	79	(79)	0	(43)
RPE detachments	69	(84)	52	(82)	0	(43)
Choroidal rupture/detachment	53	(86)	22	(96)	0	(43)
Choroidal degeneration/atrophy	29	(99)	26	(92)	0	(43)
Choroidal hemorrhage	5	(117)	5	(113)	0	(43)
Non-specific ocular diagnoses						
Pain/swelling	3,692	(18)	3,305	(13)	5	(22)
Visual discomfort/disturbances	2,629	(21)	2,286	(18)	61	(2)
Unspecified ocular disorders	922	(38)	908	(32)	0	(43)
Intraocular inflammatory conditions						
Iridocyclitis	4,536	(14)	1,469	(21)	0	(43)
Posterior uveitis	372	(55)	154	(67)	1	(40)
Panuveitis	164	(77)	50	(83)	0	(43)
Ocular parasitic disease	51	(88)	20	(98)	0	(43)
Endophthalmitis	37	(95)	29	(90)	0	(43)
Ocular syphilis	4	(119)	3	(119)	4	(24)
Ocular tuberculosis	1	(123)	1	(123)	0	(43)
Neuro-ophthalmic disorders						
Optic nerve conditions	2,516	(22)	1,461	(22)	100	(1)
Nystagmus and eye movement disorders	351	(56)	184	(64)	0	(43)
Pupillary function abnormalities	283	(64)	210	(61)	2	(31)
Cranial nerve III/IV/VI conditions	270	(68)	139	(71)	16	(10)
Optic tract and visual pathways conditions	37	(95)	22	(96)	17	(9)
Strabismus						
Esotropia	694	(46)	368	(49)	1	(40)
Exotropia	645	(49)	363	(50)	3	(27)
Heterophoria	378	(54)	291	(54)	0	(43)
Vertical strabismus	239	(71)	145	(69)	0	(43)
Unspecified strabismus	124	(78)	105	(75)	2	(31)
Mechanical strabismus	44	(92)	26	(92)	0	(43)
Monofixation syndrome	44	(92)	42	(86)	0	(43)
Gaze palsy	20	(101)	5	(113)	7	(18)
Paralytic strabismus	15	(107)	10	(107)	0	(43)
Disorders of the lens						
Cataract	1,065	(35)	589	(40)	3	(27)
Secondary or after cataract	179	(75)	111	(74)	0	(43)
Aphakia, dislocation/subluxation of lens	70	(83)	27	(91)	0	(43)
Cataract due to ocular or systemic disorders	16	(105)	14	(102)	0	(43)
Other lens disorders	5	(117)	5	(113)	0	(43)
Ocular neoplastic disorders						
Benign ocular neoplasm of the eye/adnexa	1,043	(36)	843	(33)	2	(31)
Malignant ocular neoplasm of the eye/adnexa	227	(72)	68	(81)	9	(14)

TABLE (cont.). Healthcare burdens attributable to ocular and vision-related conditions, active component, U.S. Armed Forces, 2018

Ocular and vision condition	Medical encounters[a]		Individuals affected[b]		Bed days	
	No.	Rank[c]	No.	Rank[c]	No.	Rank[c]
Disorders of sclera						
Scleritis and episcleritis	1,174	(33)	700	(35)	6	(19)
Other sclera disorders	52	(87)	47	(85)	0	(43)
Ocular herpes simplex and zoster						
Ocular herpes simplex	912	(39)	335	(51)	0	(43)
Ocular herpes zoster	282	(65)	115	(72)	1	(40)
Ocular varicella	3	(120)	3	(119)	0	(43)
Vision loss						
Blindness and low vision	715	(44)	517	(43)	21	(8)
Transient visual loss	312	(61)	239	(58)	0	(43)
Sudden visual loss	115	(79)	94	(77)	0	(43)
Disorders of the orbit						
Orbital inflammatory conditions	695	(45)	481	(44)	36	(4)
Other orbital disorders	285	(63)	199	(63)	2	(31)
Amblyopia						
Refractive amblyopia	616	(50)	569	(41)	0	(43)
Strabismic amblyopia	176	(76)	165	(65)	0	(43)
Unspecified amblyopia	88	(82)	84	(78)	0	(43)
Deprivation amblyopia	13	(109)	12	(105)	0	(43)
Suspect amblyopia	6	(115)	6	(112)	0	(43)
Disorders of iris and ciliary body						
Degeneration/cysts of iris or ciliary body	649	(48)	460	(45)	0	(43)
Other pupil and iris abnormalities	39	(94)	35	(88)	0	(43)
Other disorders of iris and ciliary body	33	(97)	25	(95)	0	(43)
Pupillary membranes and adhesions	16	(105)	13	(103)	0	(43)
Vascular disorders of iris and ciliary body	2	(121)	2	(121)	0	(43)
Congenital anomalies						
Congenital anomalies of the eye/adnexa	723	(43)	642	(38)	0	(43)
Complications of ocular surgery						
Other complications	91	(81)	71	(80)	4	(24)
Chorioretinal scars after detachment	60	(85)	48	(84)	0	(43)
Intraocular lens complications	46	(91)	31	(89)	0	(43)
Bleb inflammation or infection	17	(103)	4	(118)	0	(43)
Orbit prosthetic complications	15	(107)	9	(108)	0	(43)
Cataract surgery complications	12	(110)	12	(105)	0	(43)
Postprocedural hemorrhage or hematoma	6	(115)	5	(113)	0	(43)
Accidental puncture or laceration	2	(121)	2	(121)	0	(43)
Disorders of globe						
Retained foreign body, old	18	(102)	16	(101)	0	(43)
Hypotony and related conditions	12	(110)	9	(108)	0	(43)
Other disorders of globe	12	(110)	8	(110)	2	(31)
Degenerative disorders of the globe	11	(113)	8	(110)	0	(43)
Metallosis of globe	1	(123)	1	(123)	0	(43)
Unspecified ocular manifestations of systemic disease						
Unspecified diabetic eye disease	10	(114)	5	(113)	0	(43)
Vitamin A deficiency	1	(123)	1	(123)	0	(43)

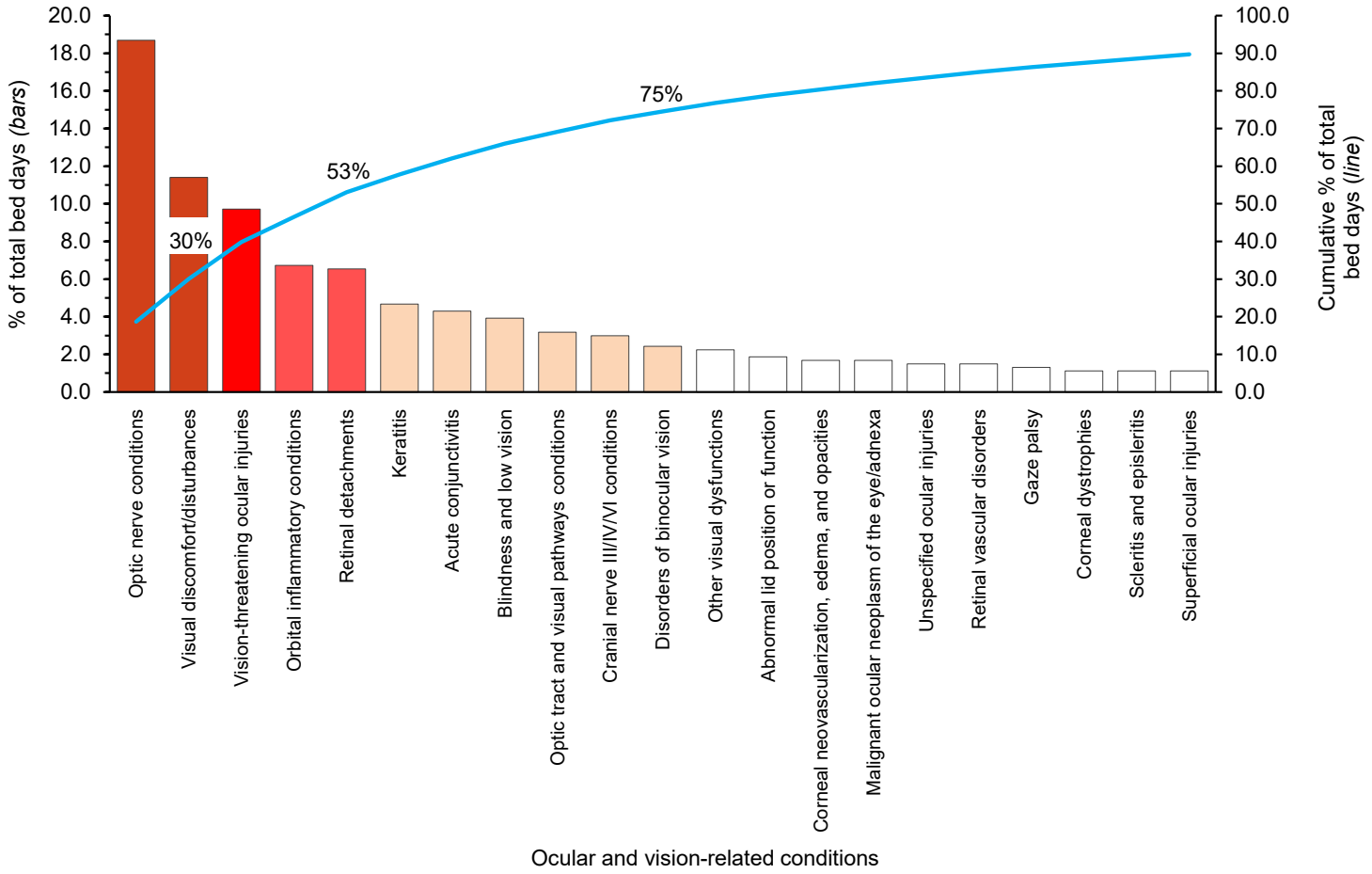
[a]Medical encounters include total hospitalizations and ambulatory visits for the condition with no more than 1 encounter per individual per day per subcategory.

[b]Individuals with at least 1 hospitalization or ambulatory visit for the condition.

[c]Rank based on 128 condition subcategories. Tied values were given the same ranking. For medical encounters and individuals affected, the highest rank was 123. For hospital bed days, the highest rank was 43.

No., number; RPE, retinal pigment epithelium.

FIGURE 3. Percentage and cumulative percentage distribution, ocular and vision-related conditions that accounted for the most hospital bed days, active component, U.S. Armed Forces, 2018



to encounters for other conditions listed in the first diagnostic position, such as trauma and respiratory tract infections. In addition, further exploration is needed to ascertain the final diagnoses determined for those affected by non-specific ocular diagnoses.

In summary, this initial report on the relative burden of ocular and vision conditions is critical to ongoing efforts to quantify the effects of ocular and vision conditions on the readiness of service members. The findings of the current analysis provide targets for further surveillance reports as well as conditions requiring further exploration using readiness and retention data. As with overall burden of illness and injury reports, ocular and vision conditions identified will inform key prevention, mitigation, and rehabilitation strategies.

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Incidence and Temporal Presentation of Visual Dysfunction Following Diagnosis of Traumatic Brain Injury, Active Component, U.S. Armed Forces, 2006–2017

Mark E. Reynolds, MD, MPH (COL, USA); Felix M. Barker II, OD, MS; Natalya Merezhinskaya, PhD; Gi-Taik Oh, MS; Shauna Stahlman, PhD, MPH

This analysis describes the incidence of visual dysfunctions following a diagnosis of traumatic brain injury (TBI) among active component service members. The visual dysfunctions were divided into 9 major categories. A comparison group of service members with no history of TBI was used to determine relative incidence rates. The most commonly diagnosed visual dysfunctions were subjective visual disturbances, convergence insufficiency (CI), visual field loss, and accommodative dysfunction (AD). Service members with mild or moderate/severe TBI had significantly higher incidences of AD and CI compared to service members with no TBI. Results of survival analysis showed that service members with mild or moderate/severe TBI had lower probabilities of remaining without the visual dysfunction outcome at almost every week of follow-up in the first year after TBI diagnosis compared to those with no TBI. The findings of this report suggest opportunities to improve both documentation and access to care for service members with these conditions.

WHAT ARE THE NEW FINDINGS?

This is the first *MSMR* report to describe visual dysfunctions following TBI among active component service members. These dysfunctions were found across all levels of TBI severity, with similar incidence among males and females. Many categories of dysfunction had a higher likelihood of diagnosis among the moderate/severe TBI group during the first year following TBI diagnosis.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Visual dysfunctions following TBI diagnosis can affect functioning in many areas and may be persistent. Service members should be evaluated for visual dysfunction following diagnosis of TBI. Incidence rates of certain dysfunctions, such as AD and CI, are significantly higher after TBI and should prompt providers to evaluate for a previously undiagnosed TBI.

Traumatic brain injury (TBI) is common in military service because of both deployment and non-deployment causes, including blast injuries, motor vehicle accidents, falls, and combative actions. Since 2000, there have been over 380,000 TBIs reported by the Defense and Veterans Brain Injury Center.[1] While the majority of these TBIs were classified as mild, it is well known that even mild TBI can lead to challenges in multiple areas of functioning and can cause physical (e.g., headaches, sleep disturbances, and balance problems), cognitive (e.g., concentration and attention problems), and emotional (e.g., irritability, anxiety, and depression) difficulties. These effects vary depending upon the severity of the injury. Recovery times may be different for each person and situation.[2]

The external force that causes TBI can also cause dysfunction in the visual system. The mechanisms of a brain injury can range from overpressure from a blast wave to brain displacement (e.g., coup–contrecoup injury); trauma secondary to direct, blunt, or penetrating injury to the brain; or a combination of the above. Military personnel are at a heightened risk for such trauma because of combat and military training activities as well as potential exposure to powerful blast explosions. TBI effects can negatively affect the ability to receive, process, and react to visual stimuli. Visual dysfunction is one of the most common concerns reported after TBI and includes a wide range of symptoms. These symptoms can include blurred and/or double vision, difficulties reading, light sensitivity (photophobia), and decreased peripheral vision.[3] Symptoms are often the result of oculomotor dysfunctions, such as accommodative dysfunction (AD), convergence insufficiency (CI), and also visual field loss (VFL), which have been reported at higher prevalence rates for patients with TBI.[4] AD is a group of disorders affecting the ability to adjust focus from distance to near tasks, such as reading. It can include difficulties with the initiation, magnitude, and sustainment of near focus effort.[5] CI is a condition where the eyes cannot be brought together in unison on a near target, often leading to visual suppression of 1 eye and/or double vision when performing near visual tasks. AD and CI can be present concurrently in the same patient, with variable contributions to overall symptoms of blurred vision, difficulty reading, irritability, intermittent diplopia, poor concentration, and headaches associated with near work.[6,7] Individuals can continue to experience these symptoms of visual dysfunction for years after recovery from other TBI symptoms.[8]

Because of the importance of vision to human activity, dysfunctions of the visual system associated with TBI can interfere with the overall rehabilitation and reintegration of the individual. Even with the increasing body of knowledge concerning these dysfunctions, screening for such conditions is not consistent, considering that as many as 79% of TBI patients report subjective visual complaints.[9] Moreover, a recent study estimated significant costs associated with TBI-related visual dysfunction.[10]

The objective of this report is to characterize the magnitudes and trends of multiple categories of visual dysfunctions among active component service members diagnosed with TBI as well as the development of these dysfunctions after the initial TBI diagnosis. This information will provide valuable input into screening recommendations for visual dysfunction after TBI. Additionally, these baseline data will inform ongoing evaluation of interventions for visual dysfunction after TBI.

METHODS

Data were obtained from the Defense Medical Surveillance System (DMSS), a longitudinal administrative data warehouse that contains electronic medical records of hospitalization and ambulatory medical encounters in military medical treatment facilities, civilian facilities (if care was reimbursed through the Military Health System), and in the deployed setting if documented in the Theater Medical Data Store. Data are limited to recorded diagnostic codes and demographic variables. No clinical data are available for further validation of the chosen case definitions.

Incident cases of TBI diagnosed between 2006 and 2017 among active component service members in the Army, Navy, Air Force, or Marine Corps were identified from DMSS records using the standard Armed Forces Health Surveillance Branch case definition.[11] The case definition required at least 1 inpatient, outpatient, or in-theater medical encounter with a diagnosis of TBI in any diagnostic position.[11] Severity of TBI was classified as mild or moderate/severe using International Classification of Diseases (ICD), 9th and 10th Revision, diagnostic codes.[11] An individual could be counted as a case of TBI only once per lifetime, and the earliest qualifying medical encounter was considered the incidence date. TBI cases were excluded if they had a diagnosis for any type of ocular trauma at any time during their military service that was recorded in any diagnostic position of an inpatient, outpatient, or in-theater medical encounter **(Table 1)**. In addition, TBI cases were excluded if they had a diagnosis for any visual dysfunction that was recorded in any diagnostic position of an inpatient, outpatient, or in-theater medical encounter before the TBI incidence date **(Table 2)**. The categories of visual dysfunction were based on the results of a meta-analysis of several visual dysfunctions.[4]

Each TBI case was matched to another active component service member (control) who was in service at the time of the case's TBI diagnosis and who had never been diagnosed with TBI or ocular trauma during their military service. Individuals were matched on age (within +/- 1 year) and sex. The TBI incidence date was considered the reference date for each matched pair. Controls were excluded if they had a diagnosis for any visual dysfunction in any diagnostic position of an inpatient, outpatient, or in-theater medical encounter before the reference date. Cases and controls were followed up to 1 year after the reference date to determine incidence of visual dysfunction. Follow-up time was censored at the time of incident visual dysfunction diagnosis, when a service member left active component military service, or at the end of 1 year, whichever came first. In addition, individuals were followed up separately for each type of visual dysfunction. For example, time at risk for AD was censored at the time of incident AD diagnosis; however, time at risk would continue to accrue for other outcomes such as CI. As such, individuals could be counted multiple times for different outcomes.

To qualify as a case of visual dysfunction, an individual was required to have at least 2 inpatient, outpatient, or in-theater medical encounters within 1 year. The diagnosis could be documented in any diagnostic position and had to be for the same visual dysfunction type in both encounters. The relative risk for each visual dysfunction was calculated by comparing the incidence

TABLE 1. ICD-9 and ICD-10 diagnostic codes for excluded conditions

ICD-9[a]	ICD-10[a]	Description
366.2, 366.20, 366.21, 366.22, 366.23	H26.10*, H26.11*, H26.12*, H26.13*	Traumatic cataract
376.32	H05.23*	Orbital hemorrhage
802.6, 802.7	S02.3*, S05.4*	Fracture of orbital floor
870.0, 870.1, 870.2, 870.3, 870.4, 870.8, 870.9	S01.10*, S01.11*, S01.12*, S01.13*, S01.14*, S01.15*	Open wound of ocular adnexa
871.0, 871.1, 871.2, 871.3, 871.4, 871.5, 871.6, 871.7, 871.9	S05.2*, S05.3*, S05.5*, S05.6*, S05.7*, S05.9*	Open wound of eyeball
371.2*, 918.0, 918.1, 918.2, 918.9, 930.0, 930.1	S00.20*, S00.21*, S00.25*, H18.2*, S05.00*, S05.01*, S05.02*, T15.0*, T15.1*	Superficial eye injury, corneal edema, foreign body on external eye
921, 921.0, 921.1, 921.2, 921.3, 921.9	S05.1*, S00.1*	Contusion of eye and adnexa
940.0, 940.1, 940.2, 940.3, 940.4, 940.5, 940.9	T26.0*, T26.1*. T26.2*, T26.3*, T26.4*, T26.5*, T26.6*, T26.7*, T26.8*, T26.9*	Burn confined to eye and adnexa

[a]An asterisk (*) indicates that any subsequent digit/character is included.
ICD, International Classification of Diseases.

TABLE 2. ICD-9 and ICD-10 diagnostic codes for visual dysfunction

ICD-9[a]	ICD-10[a]	Description
367.5, 367.51, 367.53	H52.52, H52.521, H52.522, H52.523, H52.529, H52.53, H52.531, H52.532, H52.533, H52.539	Accommodative dysfunction
378.83	H51.11	Convergence insufficiency
368.40–368.47	H53.4, H53.40, H53.41, H53.411, H53.412, H53.413, H53.419, H53.42, H53.421, H53.422, H53.423, H53.429, H53.43, H53.431, H53.432, H53.433, H53.439, H53.45, H53.451, H53.452, H53.453, H53.459, H53.46, H53.461, H53.462, H53.463, H53.469, H53.47, H53.48, H53.481, H53.482, H53.483, H53.489	Visual field loss
368.10–368.16	H53.1, H53.10, H53.12, H53.121, H53.122, H53.123, H53.129, H53.13, H53.131, H53.132, H53.133, H53.139, H53.14, H53.141, H53.142, H53.143, H53.149, H53.15, H53.19, H53.16	Subjective visual disturbances
369.00–369.08, 369.10–369.18, 369.20–369.25, 369.3, 369.4, 369.60–369.69, 369.70–369.76, 369.8, 369.9	H54.0, H54.0X, H54.0X3, H54.0X33, H54.0X34, H54.0X35, H54.0X4, H54.0X43, H54.0X44, H54.0X45, H54.0X5, H54.0X53, H54.0X54, H54.0X55, H54.1, H54.10, H54.11, H54.113, H54.1131, H54.1132, H54.114, H54.1141, H54.1142, H54.1151, H54.1152, H54.12, H54.121, H54.1213, H54.1214, H54.1215, H54.122, H54.1223, H54.1224, H54.1225, H54.2, H54.2X, H54.2X1, H54.2X11, H54.2X12, H54.2X2, H54.2X21, H54.2X22, H54.3, H54.4, H54.40, H54.41, H54.413A, H54.414, H54.414A, H54.415, H54.415A, H54.42, H54.42A, H54.42A3, H54.42A4, H54.42A5, H54.5, H54.50, H54.51, H54.511, H54.511A, H54.512A, H54.52, H54.52A, H54.52A1, H54.52A2, H54.6, H54.60, H54.61, H54.62, H54.7, H54.8	Blindness and low vision
379.50, 379.55–379.59	H55.00, H55.02, H55.03, H55.04, H55.09, H55.81, H55.89	Nystagmus and irregular eye movements
379.40–379.43, 379.49	H57.0, H57.00, H57.02, H57.03, H57.04, H57.09	Disorders of pupil function
378.85, 378.9	H51.8, H51.9	Disorders of binocular vision
378.50, 378.87	H49*, H50*	Strabismus disorders

[a]An asterisk (*) indicates that any subsequent digit/character is included.
ICD, International Classification of Diseases.

of visual dysfunction among those with no history of TBI to the incidence among those with incident mild or moderate/severe TBI. Multivariable Poisson regression models were used to calculate adjusted incidence rate ratios for the TBI cohorts, controlling for age, sex, race/ethnicity group, service branch, rank, military occupation, and history of deployment before the reference date. Because of the large sample size, p values less than .01 were considered statistically significant. As a secondary analysis, the time to first visual dysfunction encounter was plotted for each of the TBI cohorts.

RESULTS

A search of DMSS records between 2006 and 2017 identified 171,868 cases of mild TBI and 18,237 cases of moderate/severe TBI. These cases were matched to 190,105 controls **(Table 3)**. Of note, there was 1 female TBI case born in the 1940s who could not be matched to a control and was subsequently dropped from the analysis. Most incident TBI cases occurred among men, non-Hispanic whites, Army members, those less than 25 years of age, junior enlisted service members, and those who had ever deployed **(Table 3)**.

The most commonly diagnosed visual dysfunction was subjective visual disturbances (n=2,104; 87.0 per 10,000 person-years [p-yrs]), followed by CI, VFL, AD, binocular vision disorders, blindness and low vision, nystagmus, strabismus disorders, and disorders of pupil function (n=228; 9.4 per 10,000 p-yrs) **(Table 4)**. For AD and CI, overall incidence rates were highest among the moderate/severe TBI cohort and lowest in the no TBI cohort. For subjective visual disturbances, nystagmus, binocular vision disorders, and strabismus disorders, incidences were highest in the moderate/severe TBI cohort and similar among those in the mild TBI and no TBI cohorts. Overall rates of VFL were highest in the moderate/severe TBI cohort and lowest in the mild TBI cohort. However, for blindness and low vision and disorders of pupil function, incidences were highest in the no TBI cohort and lowest in the mild TBI cohort.

Among the 3 cohorts (mild TBI, moderate/severe TBI, and no TBI), overall incidence rates of visual dysfunction were higher in males compared to females for CI, nystagmus, and binocular vision disorders. Rates of other visual dysfunctions were similar among males and females except for strabismus disorders, for which the rate was higher in females compared to males. Overall incidence rates of AD, VFL, and pupil function disorders were higher among non-Hispanic white service members compared to those in other race/ethnicity groups; however, rates of CI and subjective visual disturbances were higher

TABLE 3. Demographic and military characteristics of service members by TBI cohort, active component, U.S. Armed Forces, 2006–2017

	No TBI		Mild TBI		Moderate/ severe TBI	
	No.	%	No.	%	No.	%
Total	190,105	100.0	171,868	100.0	18,237	100.0
Sex						
Male	166,788	87.7	150,255	87.4	16,533	90.7
Female	23,317	12.3	21,613	12.6	1,704	9.3
Age group (years)						
<25	97,369	51.2	90,644	52.7	9,576	52.5
25–34	66,260	34.9	58,013	33.8	6,186	33.9
35–44	21,346	11.2	19,255	11.2	1,998	11.0
45–54	4,851	2.6	3,756	2.2	448	2.5
55+	279	0.1	200	0.1	29	0.2
Race/ethnicity						
Non-Hispanic white	119,456	62.8	111,624	64.9	12,067	66.2
Non-Hispanic black	31,370	16.5	24,386	14.2	2,340	12.8
Other/unknown	39,279	20.7	35,858	20.9	3,830	21.0
Service						
Army	92,400	48.6	101,619	59.1	9,656	52.9
Navy	43,176	22.7	22,029	12.8	2,940	16.1
Air Force	30,911	16.3	20,699	12.0	2,319	12.7
Marine Corps	23,618	12.4	27,521	16.0	3,322	18.2
Rank						
Junior enlisted (E1–E4)	143,403	75.4	103,994	60.5	10,715	58.8
Senior enlisted (E5–E9)	28,128	14.8	54,697	31.8	5,876	32.2
Junior officer (O1–O3; W01–W03)	13,351	7.0	9,512	5.5	1,131	6.2
Senior officer (O4–O10; W04–W05)	5,223	2.7	3,665	2.1	515	2.8
Military occupation						
Combat-specific[a]	26,949	14.2	49,812	29.0	5,368	29.4
Motor transport	9,574	5.0	7,827	4.6	759	4.2
Pilot/air crew	2,411	1.3	1,795	1.0	279	1.5
Repair/engineering	36,993	19.5	39,888	23.2	4,286	23.5
Communications/intelligence	28,277	14.9	32,652	19.0	3,367	18.5
Healthcare	14,822	7.8	11,630	6.8	1,182	6.5
Other/unknown	71,079	37.4	28,264	16.4	2,996	16.4
Ever deployed						
Yes	44,892	23.6	105,206	61.2	10,934	60.0
No	145,213	76.4	66,662	38.8	7,303	40.0

[a]Infantry/artillery/combat engineering/armor.
TBI, traumatic brain injury; No., number.

in non-Hispanic black service members. The overall incidence rates of other visual dysfunctions were similarly distributed among the race/ethnic groups. Generally, for all types of visual dysfunctions, incidence increased with increasing age.

Overall incidence rates of AD, CI, subjective visual disturbances, nystagmus, and strabismus disorders were higher among service members in the Army compared to those in other service branches. Rates of binocular vision disorders and blindness and low vision were highest among Air Force members, rates of pupil function disorders were higher among those in the Navy, and rates of blindness and low vision were highest among those in the Marine Corps and Army. In general, incidence rates of visual dysfunctions were higher among the senior officer and enlisted ranks compared to the junior officer and enlisted ranks. Overall rates of AD, CI, and subjective visual disturbances were highest among service members in combat-specific occupations. In contrast, rates of all other visual dysfunctions were highest among those in pilot/air crew occupations. Except for strabismus disorders, overall incidence rates of visual dysfunctions were higher among those who had previously deployed compared to those who had not. Rates of strabismus disorders were similar among those with and without previous deployment.

After adjusting for age, sex, service branch, rank, military occupation, and history of deployment, service members with mild or moderate/severe TBI had significantly higher overall rates of AD (adjusted incidence rate [AIR]=3.58 and AIR=4.68, respectively) and CI (AIR=3.98 and AIR=5.64, respectively) compared to service members with no TBI **(Table 5)**. The AIRs of VFL, subjective visual disturbances, nystagmus, and binocular vision disorders were significantly lower among service members with mild TBI compared to those with no TBI; however, there were no significant differences in the AIRs of each of these visual dysfunctions among those with moderate/severe TBI compared to those with no TBI. The AIRs for blindness and low vision and disorders of pupil function were significantly lower in both the mild and moderate/severe TBI cohorts compared to the no TBI cohort. There were no statistically significant differences in the AIR of strabismus disorders among the TBI cohorts.

The survival curves (secondary analysis) show the proportion of individuals without incident diagnoses of visual dysfunction by week. These curves varied by TBI cohort and by visual dysfunction outcome **(Figures 1–9)**. For AD, CI, and subjective visual disturbances, service members with mild or moderate/severe TBI were more likely to receive the visual

TABLE 4. Incident cases and incidence rates of visual dysfunction diagnoses, by TBI cohort and demographic and military characteristics, active component, U.S. Armed Forces, 2006–2018

	Accommodative dysfunction		Convergence insufficiency		Visual field loss		Subjective visual disturbances		Blindness and low vision		Nystagmus and irregular eye movements		Pupil function disorders		Binocular vision disorders		Strabismus disorders	
	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]
Total	715	29.4	985	40.6	840	34.6	2,104	87.0	440	18.1	411	16.9	228	9.4	626	25.8	352	14.5
Sex																		
Male	626	29.3	894	41.8	737	34.5	1,869	87.7	390	18.2	371	17.3	203	9.5	567	26.5	291	13.6
Female	89	30.8	91	31.5	103	35.7	235	81.6	50	17.3	40	13.8	25	8.6	59	20.4	61	21.1
Age group (years)																		
<25	263	24.8	274	25.8	311	29.3	790	74.6	190	17.9	133	12.5	102	9.6	197	18.5	136	12.8
25–34	314	31.0	402	39.7	322	31.8	854	84.7	142	14.0	171	16.9	88	8.7	245	24.2	126	12.4
35–44	132	45.7	239	83.0	188	65.2	395	137.8	93	32.2	85	29.4	31	10.7	149	51.6	65	22.5
45–54	6	9.8	68	111.6	19	31.1	62	101.8	15	24.5	19	31.0	6	9.8	34	55.6	25	40.9
55+	0	0.0	2	47.6	0	0.0	3	71.5	0	0.0	3	71.4	1	23.8	1	23.8	0	0.0
Race/ethnicity																		
Non-Hispanic white	491	32.1	615	40.3	543	35.5	1,306	85.8	263	17.2	271	17.7	183	12.0	402	26.3	218	14.2
Non-Hispanic black	89	24.4	164	44.9	123	33.7	341	93.8	73	20.0	65	17.8	12	3.3	98	26.8	56	15.3
Other/unknown	135	25.2	206	38.5	174	32.5	457	85.8	104	19.4	75	14.0	33	6.2	126	23.6	78	14.6
TBI cohort																		
No TBI	66	8.8	75	10.0	347	46.2	625	83.5	254	33.8	140	18.6	125	16.6	206	27.4	133	17.7
Mild	575	38.0	798	52.7	378	24.9	1,316	87.2	150	9.9	227	15.0	87	5.7	355	23.4	184	12.1
Moderate/severe	74	45.9	112	69.7	115	71.5	163	101.6	36	22.3	44	27.3	16	9.9	65	40.4	35	21.7
Service																		
Army	567	41.3	762	55.6	454	33.1	1,481	108.4	263	19.1	266	19.4	114	8.3	386	28.1	244	17.7
Navy	42	10.9	49	12.7	130	33.7	170	44.1	60	15.5	55	14.2	52	13.5	72	18.6	41	10.6
Air Force	37	11.0	55	16.4	142	42.4	207	61.9	50	14.9	46	13.7	37	11.0	43	12.8	39	11.6
Marine Corps	69	20.7	119	35.7	114	34.2	246	74.0	67	20.1	44	13.2	25	7.5	125	37.5	28	8.4
Rank																		
Junior enlisted (E1–E4)	333	21.6	401	26.0	415	27.0	1,079	70.3	244	15.8	196	12.7	124	8.0	285	18.5	174	11.3
Senior enlisted (E5–E9)	305	47.7	455	71.3	319	50.0	808	127.2	139	21.7	150	23.4	62	9.7	261	40.8	110	17.2
Junior officer (O1–O3; W01–W03)	60	31.5	84	44.2	65	34.2	145	76.5	33	17.3	34	17.8	30	15.7	54	28.4	51	26.8
Senior officer (O4–O10; W04–W05)	17	28.7	45	76.2	41	69.4	72	122.4	24	40.5	31	52.4	12	20.2	26	43.9	17	28.7
Military occupation																		
Combat-specific[b]	256	44.8	348	61.0	204	35.7	651	114.6	106	18.5	95	16.6	51	8.9	175	30.6	85	14.9
Motor transport	23	19.0	43	35.5	45	37.2	111	92.0	33	27.2	21	17.3	12	9.9	39	32.2	15	12.4
Pilot/air crew	7	26.0	10	37.2	17	63.3	20	74.6	8	29.7	12	44.6	8	29.7	13	48.4	7	26.0
Repair/engineering	127	23.8	194	36.4	187	35.1	422	79.5	94	17.6	90	16.9	47	8.8	141	26.5	73	13.7
Communications/intelligence	156	36.1	198	45.9	164	38.0	417	97.0	83	19.2	79	18.3	30	6.9	113	26.2	44	10.2
Healthcare	56	27.9	64	31.9	69	34.4	139	69.5	29	14.4	37	18.4	32	15.9	49	24.4	41	20.4
Other/unknown	90	16.5	128	23.5	154	28.3	344	63.5	87	16.0	77	14.2	48	8.8	96	17.7	87	16.0
Ever deployed																		
Yes	491	42.2	765	65.8	534	45.9	1,366	117.9	257	22.0	268	23.0	118	10.1	451	38.7	156	13.4
No	224	17.7	220	17.4	306	24.2	738	58.6	183	14.5	143	11.3	110	8.7	175	13.8	196	15.5

[a]Rate per 10,000 person-years.
[b]Infantry/artillery/combat engineering/armor.
TBI, traumatic brain injury; No., number.

TABLE 5. Multivariable Poisson regression models for incidence of visual dysfunction outcome[a]

	AIR	95% CI	p-value
Accommodative dysfunction			
Mild TBI vs no TBI	3.58	2.70–4.76	<.0001
Moderate/severe TBI vs no TBI	4.68	3.29–6.66	<.0001
Convergence insufficiency			
Mild TBI vs no TBI	3.98	3.09–5.13	<.0001
Moderate/severe TBI vs no TBI	5.64	4.16–7.65	<.0001
Visual field loss			
Mild TBI vs no TBI	0.32	0.27–0.38	<.0001
Moderate/severe TBI vs no TBI	0.99	0.78–1.24	.912
Subjective visual disturbances			
Mild TBI vs no TBI	0.63	0.56–0.71	<.0001
Moderate/severe TBI vs no TBI	0.83	0.68–1.00	.046
Blindness and low vision			
Mild TBI vs no TBI	0.14	0.11–0.17	<.0001
Moderate/severe TBI vs no TBI	0.35	0.24–0.50	<.0001
Nystagmus and irregular eye movements			
Mild TBI vs no TBI	0.63	0.49–0.82	.0004
Moderate/severe TBI vs no TBI	1.19	0.83–1.72	.345
Disorders of pupil function			
Mild TBI vs no TBI	0.20	0.14–0.29	<.0001
Moderate/severe TBI vs no TBI	0.23	0.11–0.47	<.0001
Disorders of binocular vision			
Mild TBI vs no TBI	0.52	0.42–0.63	<.0001
Moderate/severe TBI vs no TBI	0.85	0.63–1.16	.310
Strabismus disorders			
Mild TBI vs no TBI	0.75	0.58–0.98	.033
Moderate/severe TBI vs no TBI	1.35	0.90–2.02	.144

[a]All models adjusted for service, sex, race/ethnicity, age, rank, military occupation, and deployment history.
AIR, adjusted incidence rate; CI, confidence interval; TBI, traumatic brain injury.

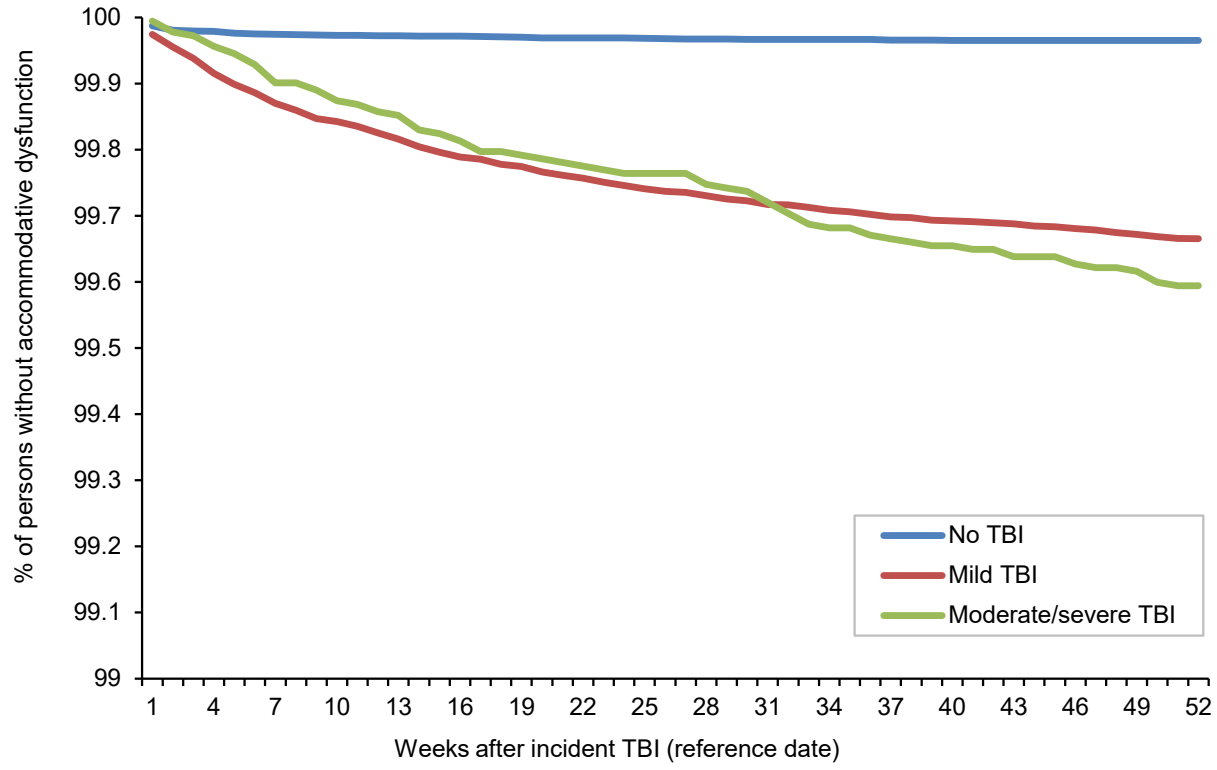
dysfunction diagnosis at almost every week of follow-up compared to those in the no TBI cohort **(Figures 1, 2, 4)**. For VFL, nystagmus, binocular vision dysfunction, and strabismus disorders, service members in the moderate/severe TBI cohort were more likely to receive the visual dysfunction diagnosis during almost every week of follow-up compared to those in the mild and no TBI cohorts; however, those with mild TBI were less likely to be diagnosed with the visual dysfunction during the earlier weeks of follow-up compared to those with no TBI **(Figures 3, 6, 8, 9)**. For blindness and low vision, the moderate/severe TBI cohort had consistently higher percentages of blindness and low vision diagnoses compared to the other 2 cohorts during weeks 15–52 **(Figure 5)**. For pupil dysfunction, the proportions of individuals without incident diagnoses were consistent during the entire 1-year follow-up period **(Figure 7)**. In the later weeks of follow-up, the mild TBI patients became more likely to be diagnosed with VFL, nystagmus, binocular vision problems, and strabismus disorders than the no TBI group. Finally, higher percentages of the mild TBI cohort remained without blindness and low vision or disorders of pupil function at each week of follow-up compared to the other 2 cohorts **(Figures 5, 7)**.

EDITORIAL COMMENT

This report demonstrated that service members with mild or moderate/severe TBI have significantly higher AIRs of AD and CI compared to service members with no TBI. AIRs of these conditions were highest among those with moderate/severe TBI.[4] This finding is consistent with a recently published meta-analysis on the prevalence of several visual dysfunctions after TBI. The meta-analysis reviewed 22 published studies through July 2018 on AD, CI, VFL, and visual acuity loss. This analysis found a high prevalence of AD and CI among mild TBI patients (43.2% and 37.2%, respectively).[4] These prevalence rates were also significantly higher than those reported in the literature for no TBI control populations. In this report, AIRs of AD and CI were highest among those with moderate/severe TBI.

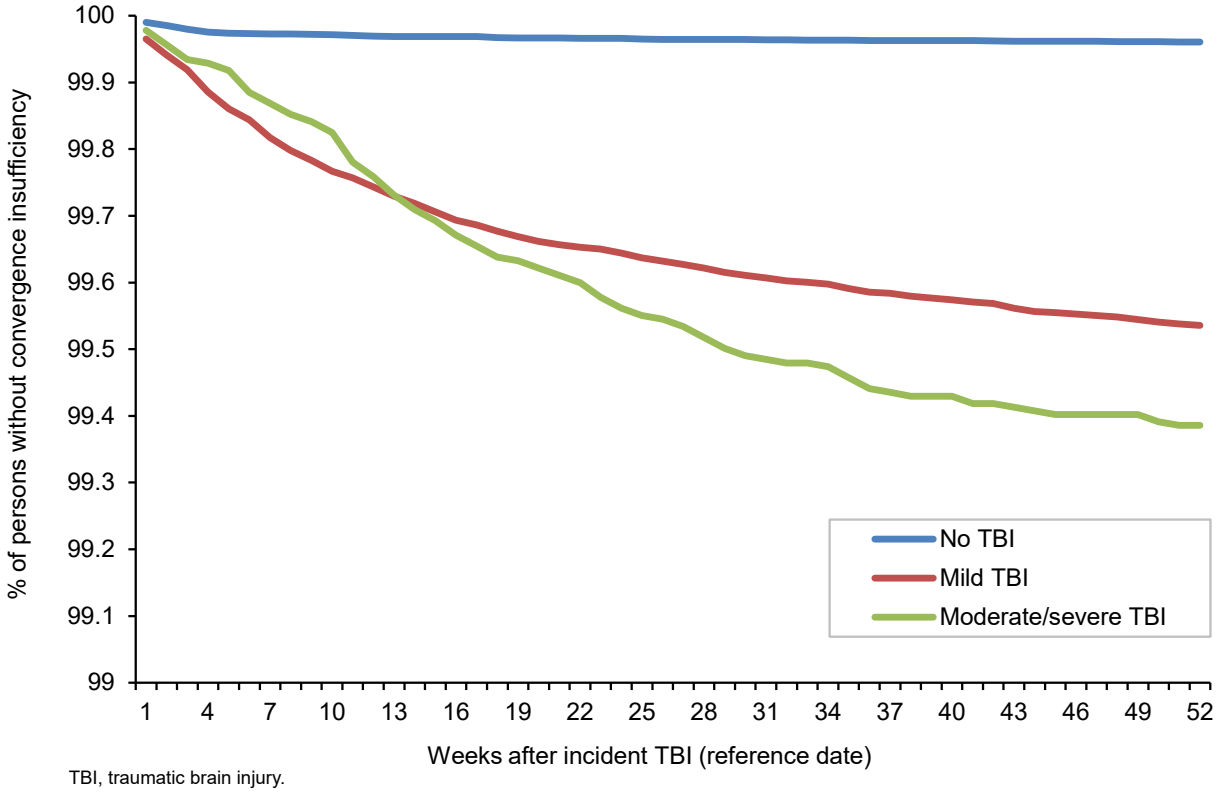
Results of the survival analysis showed that AD or CI may be diagnosed soon after the initial TBI diagnosis. Later diagnosis of these visual dysfunctions was observed among the moderate/severe TBI group. For AD, among mild TBI patients, approximately half of the cases were diagnosed by 12 weeks and three-quarters were diagnosed by 25 weeks after TBI diagnosis. Among moderate/severe TBI patients, half of the cases were not diagnosed until 18 weeks after TBI diagnosis and three-quarters were not diganosed until 33 weeks. For CI among mild TBI patients, approximately half were diagnosed by 10 weeks and three-quarters by 23 weeks. Among moderate/severe TBI patients, half of the cases of CI were not diagnosed until 15 weeks after TBI diagnosis and three-quarters were not diagnosed by approximately 27 weeks. It is unclear at present if a delay in recognition and subsequent treatment of these conditions affects recovery, but CI has been shown to assist in identifying athletes at risk for prolonged recovery after a sport-related concussion

FIGURE 1. Percentage of individuals without incident accommodative dysfunction diagnosis during the 1-year follow-up period, by TBI cohort, 2006–2018



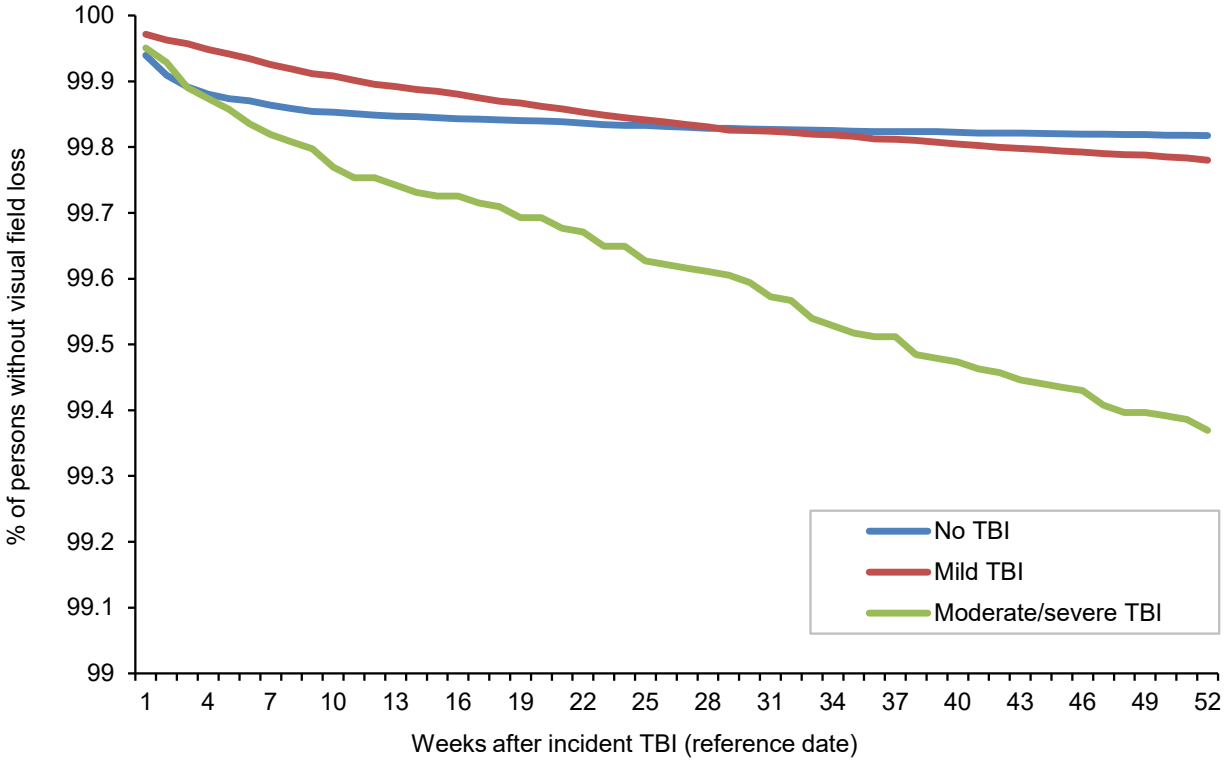
TBI, traumatic brain injury.

FIGURE 2. Percentage of individuals without incident convergence insufficiency diagnosis during the 1-year follow-up period, by TBI cohort, 2006–2018



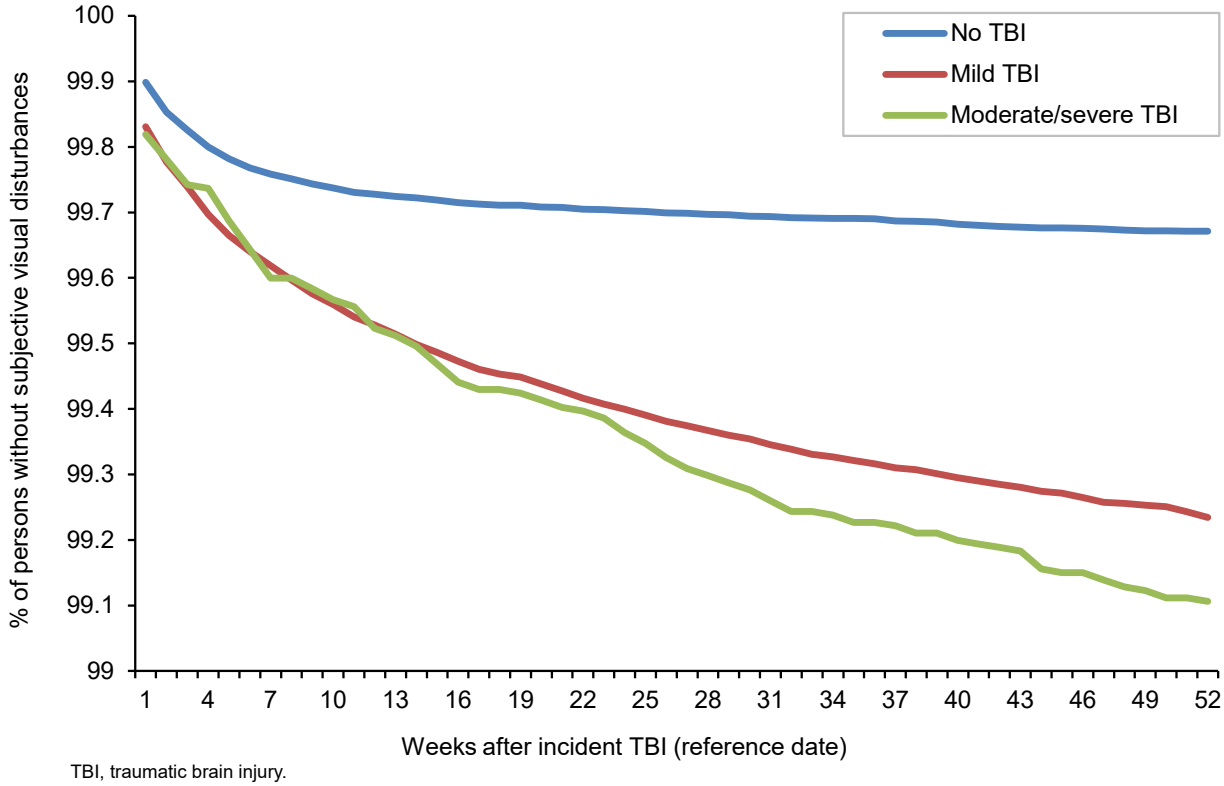
TBI, traumatic brain injury.

FIGURE 3. Percentage of individuals without incident visual field loss diagnosis during the 1-year follow-up period, by TBI cohort, 2006–2018



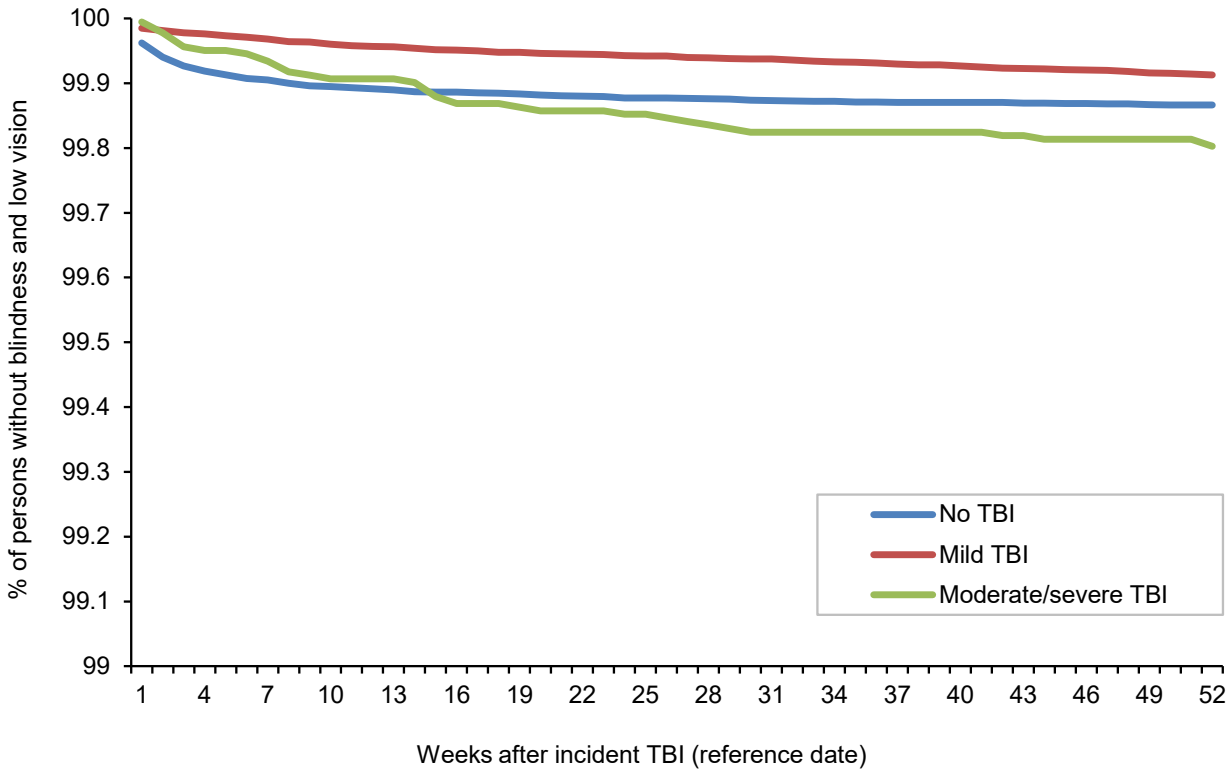
TBI, traumatic brain injury.

FIGURE 4. Percentage of individuals without subjective visual disturbances diagnosis during the 1-year follow-up period, by TBI cohort, 2006–2018



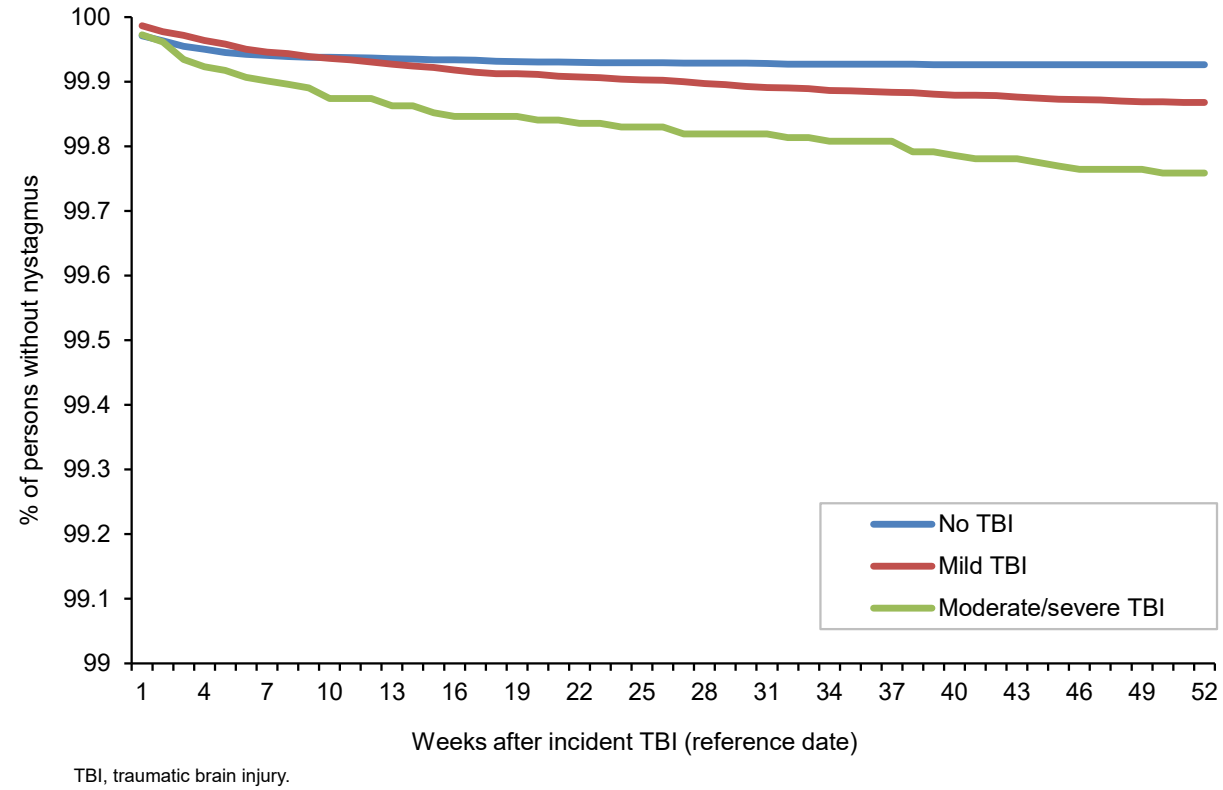
TBI, traumatic brain injury.

FIGURE 5. Percentage of individuals without blindness and low vision diagnosis during the 1-year follow-up period, by TBI cohort, 2006–2018



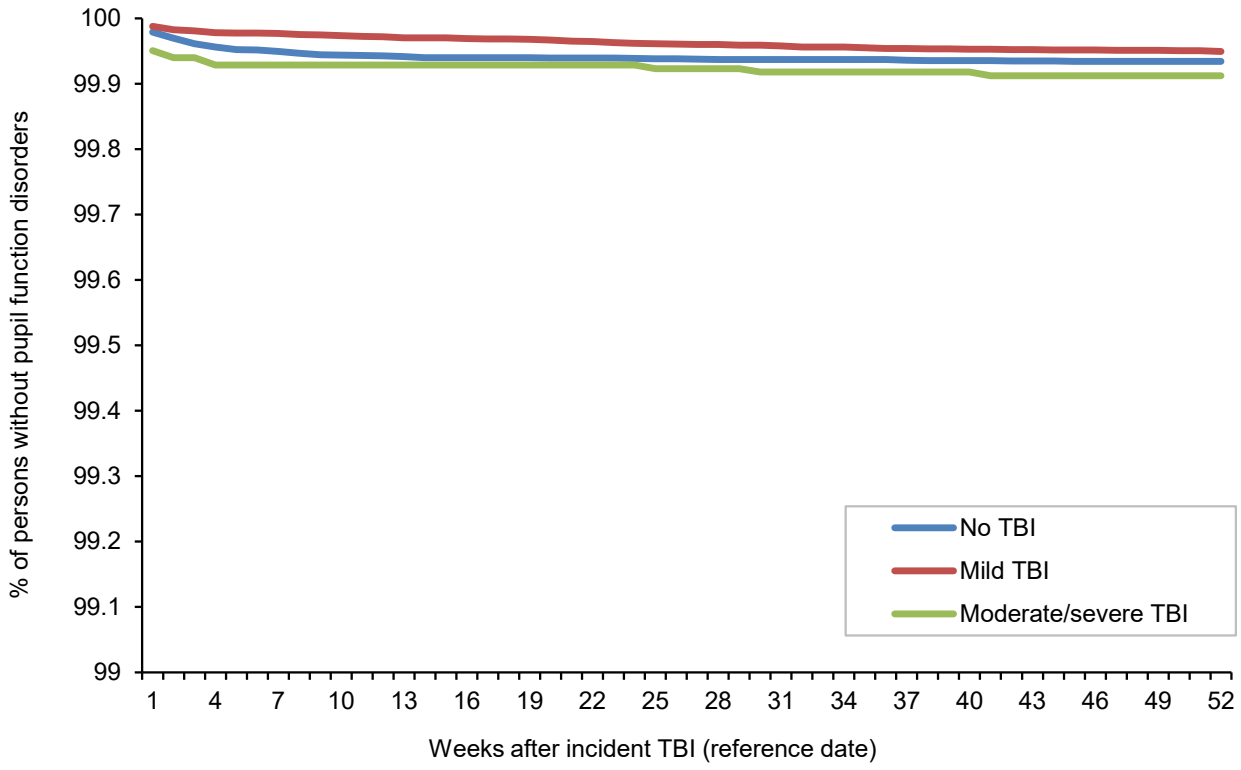
TBI, traumatic brain injury.

FIGURE 6. Percentage of individuals without nystagmus diagnosis during the 1-year follow-up period, by TBI cohort, 2006–2018



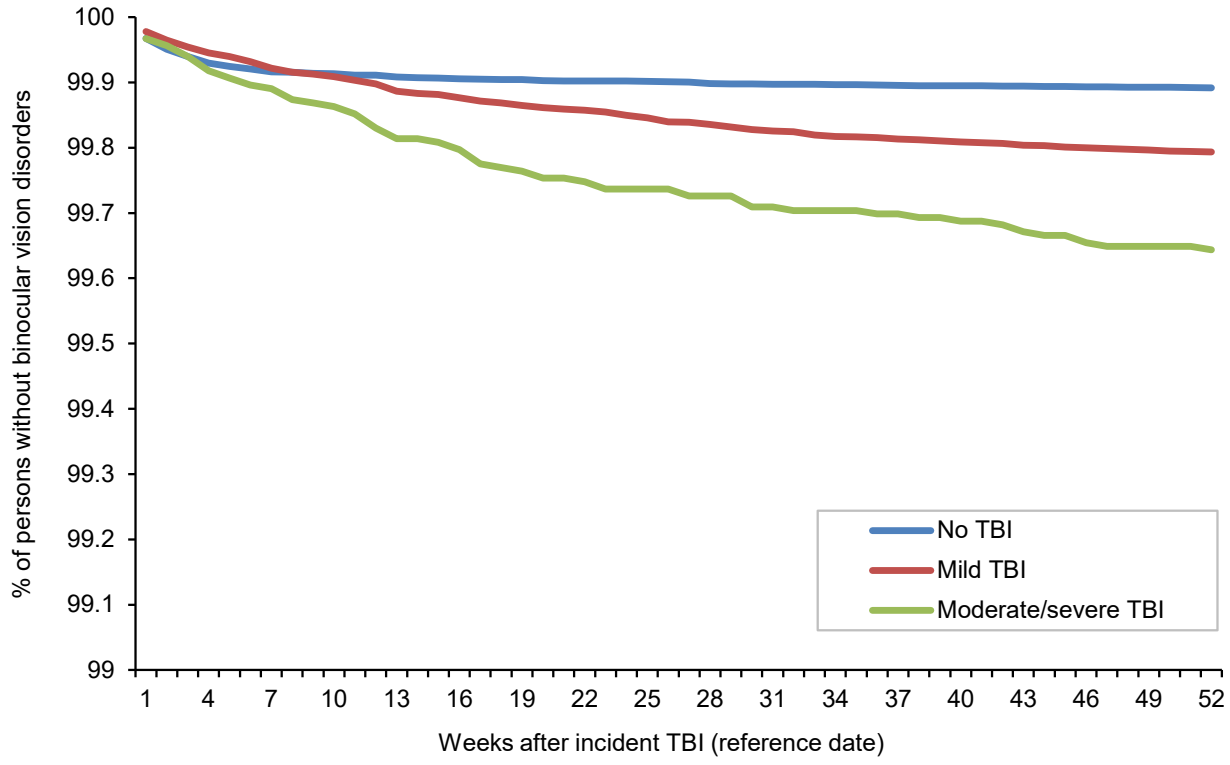
TBI, traumatic brain injury.

FIGURE 7. Percentage of individuals without pupil function disorders diagnosis during the 1-year follow-up period, by TBI cohort, 2006–2018



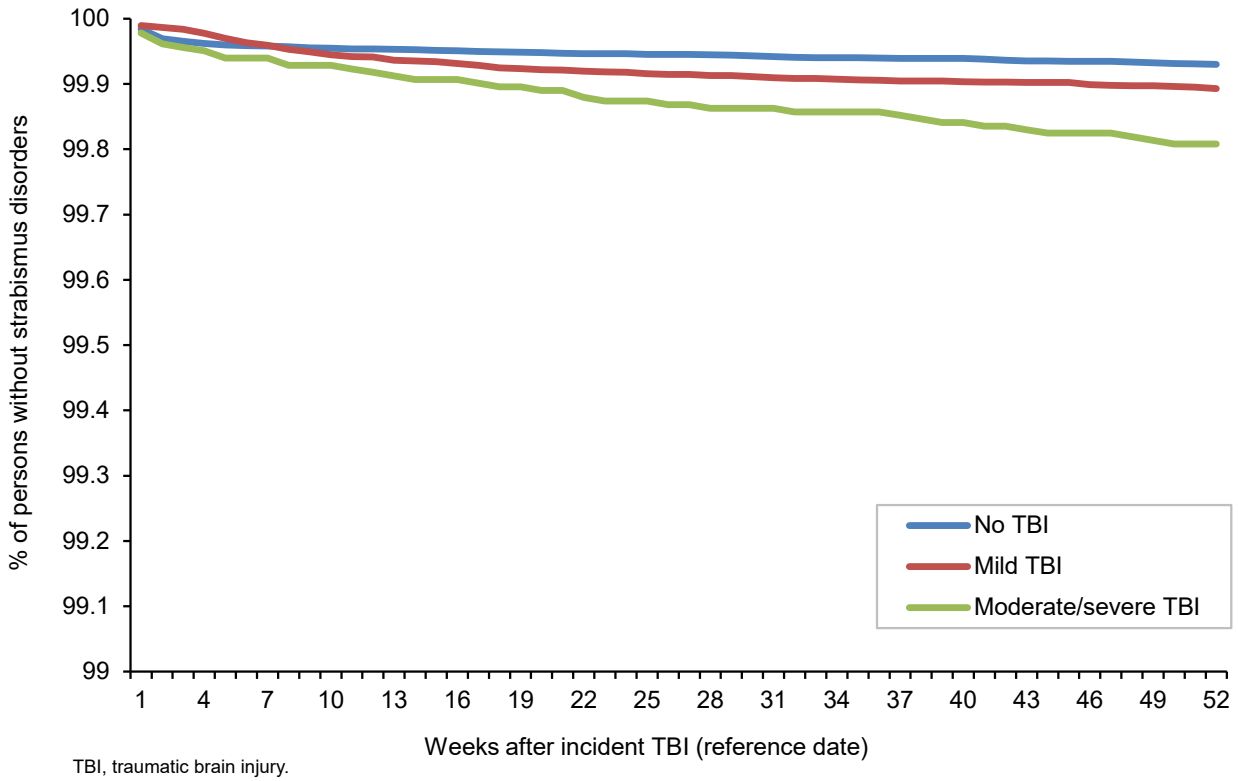
TBI, traumatic brain injury.

FIGURE 8. Percentage of individuals without binocular vision disorder diagnosis during the 1-year follow-up period, by TBI cohort, 2006–2018



TBI, traumatic brain injury.

FIGURE 9. Percentage of individuals without strabismus disorders diagnosis during the 1-year follow-up period, by TBI cohort, 2006–2018



TBI, traumatic brain injury.

and thus may be a prognostic screening method after TBI.[12]

This study is subject to certain important limitations. The categories of visual dysfunctions used were inclusive, allowing for broad capture in this initial surveillance report. All encounters were utilized in analysis rather than limiting to encounters by specific provider type. Additionally, no standard coding guidance is available for visual function following TBI, which would provide higher confidence in a surveillance definition. Because the analysis used administrative data, questions that would require detailed review of clinical records for optimal mapping of signs and symptoms were unable to be addressed. This is particularly important for conditions that would likely be asymptomatic and require specific diagnostic abilities (such as pupil function abnormalities, eye movement disorders, and nystagmus).

This study utilized a 1-year follow-up period after the documentation of the incident TBI diagnosis to ensure a greater likelihood that the diagnosed visual dysfunction was attributable to the TBI event. It is possible that there was a lag in diagnosis between the TBI event and documentation of a diagnosis of the TBI. Visual dysfunctions that occurred during this lag period would not be captured and attributed to the original TBI, potentially decreasing the counts of visual dysfunctions. Previous studies have reported no difference in multiple types of visual symptoms in terms of time after TBI event.[13] It is possible that visual dysfunction developed because of some other illness or injury; however, individuals with previously diagnosed ocular trauma were excluded from the current analysis. In addition, there could be a lag between the time of the TBI event and the time the diagnosis was actually recorded in the individual's medical record. The apparently later documentation of visual dysfunctions reflected by the survival curves for the moderate/severe TBI cohort for these conditions is unlikely to be a result of later onset of these conditions. Visual dysfunctions are known to manifest soon after injury, and the time difference observed in the current study may be related to detection bias in which the visual assessment of more severe TBI cases is delayed in favor of higher-priority medical care for the TBI itself and/or other associated injuries. Confounding due to factors that could not to be adjusted for in the analysis is another potential limitation. For example, if "sicker" service members are more likely to develop blindness and low vision and less likely to be diagnosed with TBI (perhaps because of being less physically active and therefore having less exposure opportunity), a negative bias in the association between TBI and blindness and low vision would exist. The more general categories of visual dysfunction (such as subjective visual disturbance) have multiple etiologies unrelated to TBI and would be expected to be recorded at high rates in the non-TBI population. Finally, the fact that criteria for the diagnosis of AD and CI are not standardized across providers could result in misclassification of these visual dysfunction outcomes. If service members diagnosed with TBI are more likely to be screened for visual dysfunction, a differential misclassification bias that would overestimate the rate ratios for the associations between TBI and visual dysfunction outcomes could result.

Consistent and timely diagnosis of these conditions will allow for early intervention. Current therapies include the use of specialized optical correction, including glasses with prisms (to address CI), oculomotor therapy to increase the efficiency of eye movements, and combination approaches using both correction and therapy.[14]

The findings of the current study suggest several initial recommendations for improving recognition and diagnosis of these visual dysfunctions. Providing primary care providers with standardized screening instruments and referral guidelines for visual dysfunctions after TBI would increase evaluations by eye care providers. Since visual acuity is not usually affected in mild TBI patients,[11] standard tests for visual acuity cannot be considered sufficient for the measure of visual health after TBI. In light of the increased risk of AD and CI among TBI patients of all severity, eye care providers diagnosing these conditions should seek a history of TBI that may not have been documented. This practice would identify additional service members who could benefit from comprehensive TBI evaluation and rehabilitation. Finally, the development and dissemination of standard documentation and coding guidelines for visual dysfunction following TBI would be expected to improve surveillance and monitoring efforts for these important conditions and possibly improve continuity of care for affected service members.

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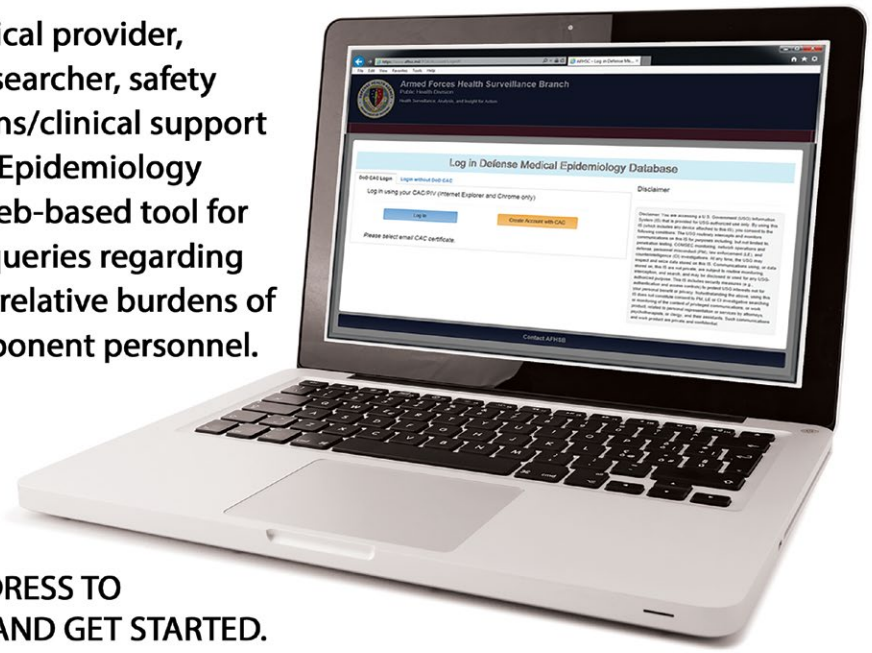

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Incidence and Prevalence of Selected Refractive Errors, Active Component, U.S. Armed Forces, 2001–2018

Mark E. Reynolds, MD, MPH (COL, USA); Stephen B. Taubman, PhD; Shauna Stahlman, PhD, MPH

During 2001–2018, there were approximately 1.38 million incident diagnoses of myopia, 1.21 million incident diagnoses of astigmatism, and 492,000 incident diagnoses of hyperopia among active component service members (crude overall incidence rates of 7.8, 6.6, and 2.2 diagnoses per 100 person-years, respectively). Incidence rates of all 3 conditions were higher among women compared to men. Service members in the Marine Corps, enlisted personnel, and those working in other/unknown military occupations had higher overall rates of incident myopia diagnoses compared to their respective counterparts. Incidence rates of astigmatism diagnoses were similar across all services and among both enlisted personnel and officers. Overall rates of hyperopia diagnoses were similar across all race/ethnicity groups and service branches and among both enlisted personnel and officers. However, across occupational groups, overall rates of hyperopia and astigmatism diagnoses were highest among service members working in healthcare occupations. Future analyses should focus on the specific effects of military refractive surgery programs on the readiness of service members.

WHAT ARE THE NEW FINDINGS?

This article updates previous reports and focuses on the types of refractive error amenable to refractive surgery interventions. During 2001–2018, myopia and astigmatism were the most common refractive errors at 1.4 million and 1.2 million incident diagnoses, respectively, among active component service members of all occupational groups. The crude annual lifetime prevalence was 38.5% for myopia and 32.9% for astigmatism.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Disorders of refraction directly affect the ability to function in a military environment. Myopia, astigmatism, and hyperopia remain a consistent concern for the operational force. The data presented here allow for ongoing monitoring of refractive error to direct interventions such as refractive surgery.

Refractive errors are a common cause of impaired vision. The World Health Organization estimates that 153 million people worldwide live with visual impairment due to uncorrected refractive errors.[1] Refractive errors occur when the focusing power of the eye does not allow for a sharp image on the retina, resulting in a blurred image and loss of detail. Myopia typically results from a longer axial length of the eye, causing images to be defocused in front of the retina and faraway objects to appear blurry. Hyperopia is usually due to a shorter axial length of the eye, causing an image to be defocused at a point behind the retina and resulting in distant objects being seen more clearly than objects that are near. Astigmatism typically results from variable curvature of the corneal surface, causing an image to be defocused along multiple points of the optical pathway.

Optimal visual performance in the setting of refractive error usually requires correction, either through eyeglasses, contact lenses, or refractive surgery. Uncorrected refractive errors can negatively affect functioning, quality of life, and work productivity.[2] Refractive errors have been linked to increased ocular morbidity; for example, myopia is a known risk factor in the development of retinal detachment, even at low levels of refractive error.[3]

Across military populations, refractive errors have multiple implications for readiness and operational effectiveness. Suboptimal visual acuity due to refractive error has been shown to affect target discrimination (positive identification) and marksmanship performance among military personnel.[4] Effects of refractive error on visual performance and associated ocular disease increase with higher degrees of refractive error. As a result, individuals with hyperopia, myopia, or astigmatism in excess of -8.00 or +8.00 diopters spherical equivalent, astigmatism in excess of 3.00 diopters, or a history of laser refractive surgery for that degree of refractive error do not meet the medical standards for appointment, enlistment, or induction into U.S. military service.[5]

In military populations, adequate characterization of the magnitude and trends of refractive errors may inform readiness and performance enhancement efforts such as refractive surgery programs. Adequate characterization may also inform planning for refraction and optical fabrication resources. In this report, myopia, astigmatism, and hyperopia codes were chosen to approximate the clinically important refractive error categories used in previous publications.[6] For military populations, these categories would also be the most relevant since these conditions are potentially

amenable to refractive surgery procedures. This report updates the incidence and prevalence rates of newly diagnosed disorders of refraction among members of the active component of the U.S. Armed Forces during 2001–2018.

METHODS

The surveillance period was 1 January 2001 to 31 December 2018. The surveillance population included all individuals who served in the active component of the U.S. Army, Navy, Air Force, or Marine Corps at any time during the surveillance period. Diagnoses of disorders of refraction were ascertained from records maintained in the Defense Medical Surveillance System (DMSS) that document outpatient encounters of active component service members. Such records reflect care in fixed military treatment facilities of the Military Health System (MHS) and in civilian sources of health care underwritten by the Department of Defense (DoD).

Case-defining diagnoses are shown in **Table 1**. Cases of myopia, hyperopia, and astigmatism were analyzed separately. An incident case of refraction disorder was defined by at least 1 outpatient medical encounter with a qualifying diagnosis in either the first or second diagnostic position. The incidence date was considered the date of the first qualifying outpatient encounter and an individual was counted as an incident case only once per lifetime. Service members with case-defining refractive disorder diagnoses before the start of the surveillance period (i.e., prevalent cases) were excluded from the analysis. For the incidence rate calculations, person-time at risk included all active component military service time before the date of incident diagnosis, termination of military service, or the end of the surveillance period, whichever came first. Incidence rates were calculated as incident refractive disorder diagnoses per 100 person-years (p-yrs).

Military lifetime prevalence was estimated for each refraction disorder for each year in the surveillance period. During each year of the 18-year period, the annual prevalence was calculated as the percentage of service members who had ever been diagnosed with the refraction disorder. An individual was identified as a prevalent case during a given year of the surveillance period if he or she was in active component service on 1 July of the given year and was diagnosed as an incident case on or before 1 July of that year (including those who were diagnosed as an incident case before the start of the surveillance period). The denominator for annual prevalence calculations consisted of the total number of service members in active component service on 1 July of each year. Annual prevalence estimates were calculated as the number of prevalent cases per 100 active component service members on 1 July.

TABLE 1. ICD-9 and ICD-10 diagnostic codes used to identify disorders of refraction

Disorder	ICD-9	ICD-10
Myopia	367.1	H52.10, H52.11, H52.12, H52.13
Hyperopia/ hypermetropia	367	H52.00, H52.01, H52.02, H52.03
Astigmatism	367.2, 367.20, 367.21, 367.22	H52.201, H52.202, H52.203, H52.209, H52.211, H52.212, H52.213, H52.219, H52.221, H52.222, H52.223, H52.229

ICD, International Classification of Diseases.

RESULTS

Between 2001 and 2018, there were approximately 1.38 million incident diagnoses of myopia, 1.21 million incident diagnoses of astigmatism, and 492,000 incident diagnoses of hyperopia among active component service members, which corresponded to crude (unadjusted) overall incidence rates of 7.8, 6.6, and 2.2 diagnoses per 100 p-yrs, respectively **(Table 2)**.

For myopia, overall incidence was higher among females (11.6 per 100 p-yrs) compared to males (7.2 per 100 p-yrs). When stratified by age group, the overall rate of incident myopia diagnoses was highest among service members aged 19 years or younger (21.2 per 100 p-yrs) **(Table 2)**. Compared to other race/ethnicity groups, Asian/Pacific Islanders had the highest overall incidence of myopia diagnoses (9.8 per 100 p-yrs) and American Indians/Alaska Natives had the lowest (5.2 per 100 p-yrs) **(Table 2)**. Service members in the Marine Corps (8.9 per 100 p-yrs), enlisted personnel (8.0 per 100 p-yrs), and those working in other/unknown military occupations (12.2 per 100 p-yrs) had higher overall rates of incident myopia diagnoses compared to their respective counterparts. The high rate for those in the non-specific category of "other/unknown" was largely due to the fact that 45% (n=187,536) of the cases were among recruit trainees.

Overall incidence of astigmatism diagnoses was highest among females (9.0 per 100 p-yrs) and those in the youngest (19 years and younger: 9.4 per 100 p-yrs) and oldest (55+ years: 8.5 per 100 p-yrs) age groups **(Table 2)**. Overall rates of incident astigmatism diagnoses were lowest among American Indian/Alaska Native service members (4.3 per 100 p-yrs) and similar among service members in the other race/ethnicity groups (range: 6.4–7.2 per 100 p-yrs). Incidence rates of astigmatism diagnoses were similar across all services and among both enlisted personnel and officers. However, across occupational groups, overall rates of incident astigmatism diagnoses were highest among service members working in health care (8.6 per 100 p-yrs).

For hyperopia, overall incidence was higher in females (2.9 per 100 p-yrs) compared to males (2.1 per 100 p-yrs) and highest among those in the oldest age group (aged 55 years and older: 5.0 per 100 p-yrs). Overall rates of hyperopia diagnoses were similar across all race/ethnicity groups, service branches, and among both enlisted personnel and officers. However, overall incidence of this condition was highest among service members in healthcare occupations **(Table 2)**.

Crude annual rates of incident diagnoses of myopia and astigmatism decreased 40.9% and 41.3%, respectively, between 2001 and 2010. Incidence rates then increased 15.9% and 50.0% for myopia and astigmatism, respectively, between 2010 and 2018 **(Figure 1)**. The crude annual

TABLE 2. Incident diagnoses and incidence rates[a] of eye disorders of refraction, active component, U.S. Armed Forces, 2001–2018

	Myopia		Astigmatism		Hyperopia	
	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]
Total	1,381,122	7.8	1,205,354	6.6	491,803	2.2
Sex						
Male	1,101,320	7.2	973,696	6.2	397,079	2.1
Female	279,802	11.6	231,658	9.0	94,724	2.9
Race/ethnicity						
Non-Hispanic white	816,666	7.5	721,274	6.4	303,756	2.3
Non-Hispanic black	219,995	7.3	200,180	6.5	82,679	2.2
Hispanic	188,798	8.8	156,119	7.0	60,378	2.3
Asian/Pacific Islander	61,333	9.8	47,787	7.0	15,311	1.8
American Indian/Alaska Native	10,681	5.2	9,168	4.3	3,953	1.6
Other/unknown	83,649	8.9	70,826	7.2	25,726	2.1
Age group (years)						
≤19	317,757	21.2	147,439	9.4	48,229	2.9
20–24	599,668	9.4	481,864	7.2	153,264	2.0
25–29	240,098	5.9	262,160	6.3	102,551	2.0
30–34	96,763	3.8	126,474	5.0	63,499	2.0
35–39	61,195	3.3	89,809	4.7	56,613	2.3
40–44	41,125	4.2	61,083	6.0	41,429	3.0
45–49	19,040	5.6	27,384	7.8	18,838	3.7
50–54	4,431	5.1	7,310	8.1	5,728	4.3
55+	1,045	4.9	1,831	8.5	1,652	5.0
Service						
Army	556,608	8.2	475,610	6.8	185,417	2.3
Navy	297,430	6.8	275,317	6.1	124,522	2.3
Air Force	302,313	7.4	291,534	6.9	117,250	2.2
Marine Corps	224,771	8.9	162,893	6.0	64,614	2.1
Rank						
Enlisted	1,216,831	8.0	1,028,953	6.6	411,067	2.2
Officer	164,291	6.3	176,401	6.5	80,736	2.3
Military occupation						
Combat-specific[b]	155,190	5.9	148,470	5.4	56,823	1.8
Motor transport	41,667	7.1	37,471	6.3	15,586	2.3
Pilot/air crew	20,135	3.0	29,323	4.4	15,815	2.0
Repair/engineer	345,546	6.5	335,511	6.2	138,367	2.1
Communications/intelligence	272,486	7.2	265,458	6.7	107,440	2.2
Healthcare	126,155	9.5	119,779	8.6	50,894	2.8
Other/unknown	419,943	12.2	269,342	7.5	106,878	2.5

[a]Incidence rate per 100 person-years.
[b]Infantry/artillery/combat engineering/armor.
No., number.

incidence of hyperopia diagnoses increased slightly over the course of the surveillance period, from 1.8 per 100 p-yrs in 2001 to 2.6 per 100 p-yrs in 2018.

During the 18-year surveillance period, the median crude annual prevalence was 38.5% for myopia, 32.9% for astigmatism, and 12.0% for hyperopia **(data not shown)**. In both sexes, the median crude annual lifetime prevalence of each type of eye disorder of refraction increased with increasing age **(Table 3)**. For myopia and astigmatism, crude annual prevalence rates increased markedly between 2001 and 2007 before leveling off and remaining relatively stable for the remainder of the surveillance period **(Figure 2)**. In contrast, crude annual prevalence rates of hyperopia increased gradually over the course of the surveillance period.

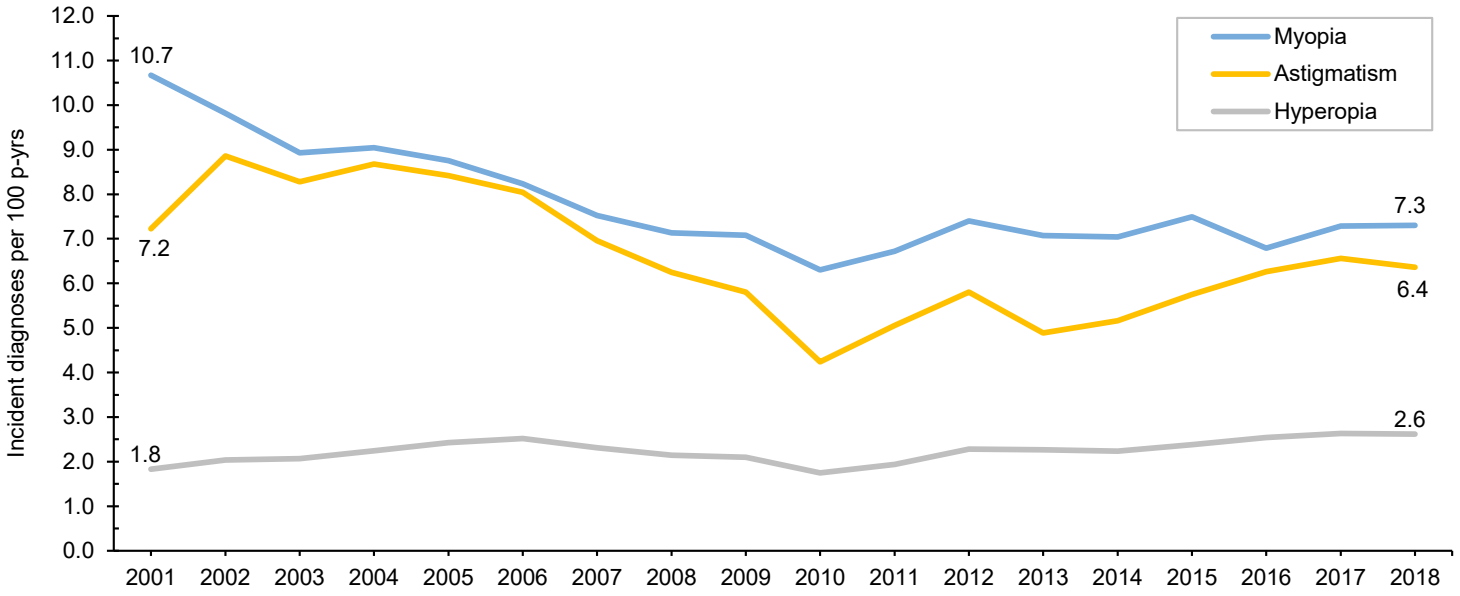
EDITORIAL COMMENT

This report demonstrates the high frequency of myopia, astigmatism, and hyperopia among active component service members across all subgroups examined. Results of the current analysis were consistent with findings of the previous *MSMR* report.[6] Analysis of vision examination data from the 1999–2004 U.S. National Health and Nutrition Examination Survey (NHANES) yielded age-adjusted point prevalence estimates of myopia, astigmatism, and hyperopia of 33.1%, 36.2%, and 3.6%, respectively.[7] The prevalence of hyperopia was considerably higher in the current analysis. However, the current analysis measured lifetime prevalence whereas the NHANES measured point prevalence (i.e., the percentage of the U.S. population with current hyperopia).[7]

The impact of refractive error on military members can be different than on other populations. Military personnel have defined and demanding physical performance criteria. Service members are frequently classified as "tactical athletes" because of high physical performance demands under stressful conditions often in austere environments.[8] Refractive error, even when corrected, has been shown to negatively affect both depth perception and peripheral vision in young athletes.[9] Many athletes will prefer either use of contact lenses or refractive surgery over eyeglasses.[10]

Certain limitations should be considered when interpreting the findings of this report. First, service members are, in many respects, not representative of the general U.S. civilian population. Because service members have been screened for disorders of refraction before joining the military, the visual disorders diagnosed among them do not include the most severe conditions. In addition, refractory surgery among the general civilian population has become more common, and candidates for

FIGURE 1. Annual rates of incident diagnoses of eye disorders of refraction, active component, U.S. Armed Forces, 2001–2018



P-yrs, person-years.

military service may elect to have refractive surgery before entering service. This could decrease the incidence and prevalence of refractive error over time. Further analysis is planned to specifically evaluate the incidence and temporal trends of refractive error among the recruit trainee population. Such an analysis may provide better insight into the incidence of refractive error among individuals entering the military during the surveillance period.

Refractive surgery procedures after entering the military may also influence the prevalence of refractive errors. For example, a recent report showed that the number of refractive procedures (both photorefractive keratectomy [PRK]/laser epithelial keratomileusis [LASEK] and laser-assisted in-situ keratomileusis [LASIK]) among active component service members averaged 12,157 per year from 2005 through 2014.[11] However, the direct impact of refractive procedures among service members on incidence and prevalence of refractive error was not evaluated in this report. Extrapolation of the findings of the current analysis to the general U.S. population should be undertaken with this limitation in mind.

The increasing prevalence of hyperopia found in this report may be due to increasing age among the surveillance population. Hyperopia incidence increases over time because of changes in the optical system of the eye associated with aging. However, the current report did not examine the potential change in age among cases of hyperopia during the study period.

TABLE 3. Median annual prevalence[a] of disorders of refraction and accommodation, by age group and sex, active component, U.S. Armed Forces, 2001–2018

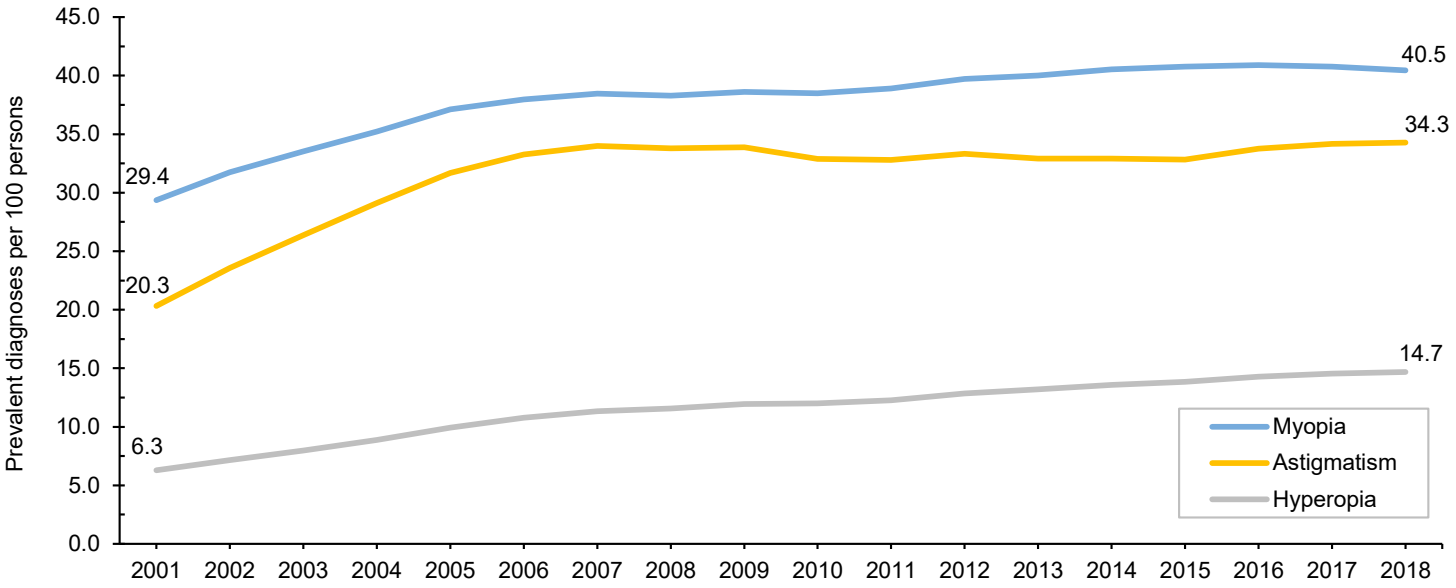
	Myopia		Astigmatism		Hyperopia	
Age group (years)	Males	Females	Males	Females	Males	Females
≤19	19.6	25.5	8.1	11.4	2.3	4.3
20–24	28.3	40.1	18.0	25.3	5.0	8.8
25–29	37.8	51.2	31.2	40.5	10.1	14.2
30–34	44.0	59.1	42.8	53.6	15.7	20.2
35–39	46.4	61.5	46.7	59.9	20.0	24.4
40–44	48.6	64.0	50.4	63.3	22.9	26.8
45–49	56.0	69.4	59.2	70.1	28.5	30.1
50–54	61.9	73.2	67.0	74.6	33.4	35.8
55+	66.6	72.8	70.8	76.0	38.9	44.8

[a]Prevalent cases per 100 service members on 1 July.

Another limitation is related to the new electronic health record for the MHS, MHS GENESIS, which was implemented at several military treatment facilities during 2017. Medical data from sites that are using MHS GENESIS are not available in the DMSS. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounters for individuals seeking care at any of these facilities during 2017–2018 were not included in this analysis.

This analysis did not attempt to ascertain the nature or frequency of any corrective measures of treatments, such as prescriptions for contact lenses or corrective surgery. For active component service members, contact lens use is limited to few operational situations.[11] Some aviation personnel require contact lens correction of refractive error for optimal use of instruments. Contact lens use in austere locations

FIGURE 2. Annual prevalence rates of eye disorders of refraction, active component, U.S. Armed Forces, 2001–2018



has been associated with high risk for microbial keratitis.[12] Refractive surgery has been associated with both improved military readiness and vision-related quality of life (including military-specific tasks such as use of night vision goggles and weapons-based tasks).[13] However, refractive surgery services are limited by location and necessary prioritization of resources. The correction of refractive errors in U.S. military personnel to optimize their readiness and performance does present some ongoing challenges. Future studies should focus on the specific effects of military refractive surgery programs on readiness of service members.

In addition, because refractive surgery has become very common in the general population, the proportion of incoming recruits with refractive errors may be decreasing over time. A history of refractive surgery is not disqualifying from military service and having had such surgery may not be disclosed at the time of entry into military service or documented in a recruit's medical records. If the proportion of recruit trainees with (uncorrected) refractive error has been decreasing, then the prevalence across the active component force would decrease over time. Such declining prevalence could affect the refractive surgery programs across the DoD. Future examination of recent trends in the prevalence of refractive disorders among recruits is warranted.

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Incident and Recurrent Cases of Central Serous Chorioretinopathy, Active Component, U.S. Armed Forces, 2001–2018

Mark E. Reynolds, MD, MPH (COL, USA); James W. Karesh, MD; Gi-Taik Oh, MS; Shauna Stahlman, PhD, MPH

Central serous chorioretinopathy (CSCR) is a condition that affects central visual function. It can produce blurred and/or distorted vision that can impact the performance of military duties. CSCR can recur in susceptible individuals. Incident cases of CSCR among active component service members were found to average 18.3 per 100,000 person-years (p-yrs) during 2001–2018. Incidence rates increased during the surveillance period by 60.7% and were more common with increasing age. Overall rates of incident CSCR diagnoses were highest among Air Force (20.7 per 100,000 p-yrs) and Navy members (19.9 per 100,000 p-yrs) and lowest among Marine Corps members (12.5 per 100,000 p-yrs). Pilot/air crew occupational groups had rates almost twice that of other groups. Annual recurrence rates increased 71.4% over the course of the 18-year period.

WHAT ARE THE NEW FINDINGS?

This is the first *MSMR* report of the incidence of CSCR among members of the U.S. Armed Forces. More than 4,400 individuals received incident diagnoses of CSCR during the 18-year surveillance period. Rates of incident CSCR diagnoses and rates of recurrent diagnoses increased from 2001 through 2018. Across the services, overall rates of CSCR were highest among those in pilot/air crew occupations, with comparable rates observed among Navy members in combat-related occupations.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

CSCR can affect critical visual performance by degrading central visual acuity. The acute disease typically lasts about 3 months, leading to operational limitations. Even after the resolution of acute symptoms, residual effects on vision may remain. Recurrences are commonly reported and may result in prolonged periods of non-deployability or non-retainability of service members.

Central serous chorioretinopathy (CSCR) is caused by fluid under the retina in the subretinal space. Fluid accumulation causes anatomic and functional changes affecting visual function. Typical symptoms include objects appearing smaller than normal (micropsia), straight lines appearing wavy (metamorphopsia), or partial loss or distortion of a portion of the central visual field. Symptoms may be more subtle as well and can include loss of contrast sensitivity (the ability to distinguish between bright and dim parts of an image) and color saturation.[1] CSCR is the fourth most common cause of retinopathy after age-related macular degeneration, diabetic retinopathy, and branch retinal vein occlusion. CSCR is a significant cause of both temporary and permanent loss of visual function among individuals aged 30–50 years.[1,2]

Although the etiology of CSCR remains poorly understood, a number of risk factors for the condition have been identified. Increased cortisol from either exogenous or endogenous sources has been associated with increased risk of developing CSCR.[3,4] Development of CSCR has often been associated with a "Type A" behavior pattern.[5] CSCR most commonly is a self-limiting condition, with resolution of retinal changes and return to baseline visual acuity within 3 months.[1] The condition can recur, and recurrences of CSCR have been reported in up to one-half of patients within 1 year.[6] Some patients may have a more prolonged course of the disease, with 15% of patients having signs and symptoms lasting longer than 6 months (chronic CSCR).[7]

The best available estimate of the incidence rates of CSCR in the U.S. comes from a population-based retrospective study in Olmstead County, MN, during 1980–2002.[8] This study reported an overall incidence rate of 5.8 per 10,000 persons. Age-adjusted incidence was 9.9 per 100,000 persons among men and 1.7 per 100,000 persons for women.[8] The reported male-to-female ratio ranged from 2.2:1 to 5.7:1.[8] These numbers are reported in both population-based retrospective cohort studies and case-control studies.[8] The current report summarizes the frequencies, rates, and temporal trends of CSCR among active component service members during 2001–2018.

METHODS

The surveillance period was 1 January 2001 to 31 December 2018. The surveillance population included all individuals who served in the active component of the U.S. Army, Navy, Air Force, or Marine Corps at any time during the surveillance period. Diagnoses of CSCR were ascertained from records maintained in the Defense Medical Surveillance System (DMSS) that document outpatient encounters of active component service members. Such records reflect care in fixed military treatment facilities of the Military Health System (MHS) and in civilian sources of health care underwritten by the Department of Defense.

International Classification of Diseases (ICD) codes for the case-defining diagnoses of CSCR are shown in **Table 1**. For surveillance purposes, an incident case was defined by at least 1 outpatient medical encounter with a qualifying diagnosis in any diagnostic position. The incidence date was the date of the first qualifying outpatient encounter and an individual was counted as an incident case only once per lifetime. Person-time at risk included all active component military service time before the date of incident diagnosis, termination of military service, or the end of the surveillance period, whichever came first. Incidence rates were calculated as incident CSCR diagnoses per 100,000 person-years (p-yrs). Prevalent cases (i.e., service members with case-defining diagnoses occurring before the start of the surveillance period) were excluded from the analysis.

Recurrent cases of CSCR were identified using a 120-day gap rule in that there had to be at least 120 days of no outpatient diagnoses for CSCR before the next case could be counted. Incident cases were not included in the analysis of recurrent cases. The person-time at risk for the analysis of recurrent cases included active component military service time from the incident case diagnosis to termination of military service or the end of the surveillance period, whichever came first.

TABLE 1. ICD-9 and ICD-10 diagnostic codes used to identify cases of central serous chorioretinopathy in electronic records of outpatient encounters

ICD-9	Description
362.41	Central serous retinopathy
ICD-10	
H35.71	Central serous chorioretinopathy
H35.711	Central serous chorioretinopathy, right eye
H35.712	Central serous chorioretinopathy, left eye
H35.719	Central serous chorioretinopathy, unspecified eye

ICD, International Classification of Diseases.

RESULTS

During 2001–2018, incident diagnoses of CSCR averaged 18.3 per 100,000 p-yrs **(Table 2)**. The crude overall incidence rate of CSCR diagnoses among males was more than 2.5 times that among females (20.2 per 100,000 p-yrs and 7.5 per 100,000 p-yrs, respectively). Overall rates increased markedly with increasing age, with the rates among service members 40 years or older almost 30 times the rate among those less than 20 years old. This age distribution is consistent with the finding of the highest rates among the most senior rank group (O4–O9 and W4–W5).

Across the services, overall rates of incident CSCR diagnoses were highest among Air Force (20.7 per 100,000 p-yrs) and Navy members (19.9 per 100,000 p-yrs) and lowest among Marine Corps members (12.5 per 100,000 p-yrs). Overall rates among military occupational groups showed considerable variation, with service members in the pilot/air crew occupations having a rate almost 2 times the rates of those in other occupational groups (with the exception of healthcare). Service members working as pilots/air crew had the highest overall incidence rates of CSCR diagnoses in all 4 of the services **(Table 3)**. Of note, within the combat-related occupations, Navy members had an overall incidence rate 1.8 and 3.3 times that of Army and Marine Corps members, respectively. Service members in healthcare occupations had the second highest overall rate of incident CSCR diagnoses during the surveillance period.

Crude annual rates of incident CSCR diagnoses increased during the surveillance period by 60.7% and fluctuated between a low of 13.0 per 100,000 p-yrs in 2001 and a high of 22.4 per 100,000 p-yrs in 2014 **(Figure)**. Annual recurrence rates increased 71.4% over the course of the 18-year period. The largest increase in recurrence rates over time was seen among members of the Marine Corps, and the smallest increase was observed among Navy members **(data not shown)**.

TABLE 2. Numbers and rates of incident diagnoses of central serous chorioretinopathy, by demographic characteristics, active component, U.S. Armed Forces, 2001–2018

	Count	Rate[a]
Total	4,492	18.3
Sex		
Males	4,217	20.2
Females	275	7.5
Age group (years)		
<20	61	1.8
20–24	231	3.6
25–29	532	9.6
30–34	956	25.8
35–39	1,319	44.7
40+	1,393	54.5
Service		
Army	1,620	17.8
Navy	1,209	19.9
Air Force	1,245	20.7
Marine Corps	418	12.5
Rank		
Junior enlisted (E1–E4)	540	5.0
Senior enlisted (E5–E9)	2,674	27.6
Junior officer (O1–O3; W1–W3)	548	21.7
Senior officer (O4–O9; W4–W5)	730	46.0
Military occupation		
Combat-related[b]	565	16.5
Motor transport	104	13.9
Pilot/air crew	329	35.4
Repair/engineering	1,322	18.3
Communications/ intelligence	960	17.5
Healthcare	520	24.8
Other	692	14.9

[a]Rate per 100,000 person-years.
[b]Infantry/artillery/combat engineering/armor.

EDITORIAL COMMENT

This is the first *MSMR* report focused on the incidence and distribution of CSCR among active component service members. Compared to previously reported rates of CSCR in U.S. civilian populations,[8]

rates among the active component were higher for both men and women, with male-to-female ratios within the previously reported ranges (male rate 2.7 times that of female). These elevated incidence rates are not directly comparable because of differences in methodology (e.g., the rates in this report are described in p-yrs, while the rates in other reports are per 100,000 people). Despite this comparability issue, the elevated rates may represent a unique risk factor profile for active component service members or increased recognition and diagnosis in the population.

The higher rates of incident CSCR diagnoses seen among service members working in pilot/air crew occupations are notable. These occupations have strictly defined visual function requirements across all services. In previous reports of CSCR among military aviators, service members with single episodes of CSCR usually recovered vision within aviation standards, but recurrences were more likely to result in permanent visual changes.[9] The increased rates found among Navy combat-related occupational groups warrants further investigation.

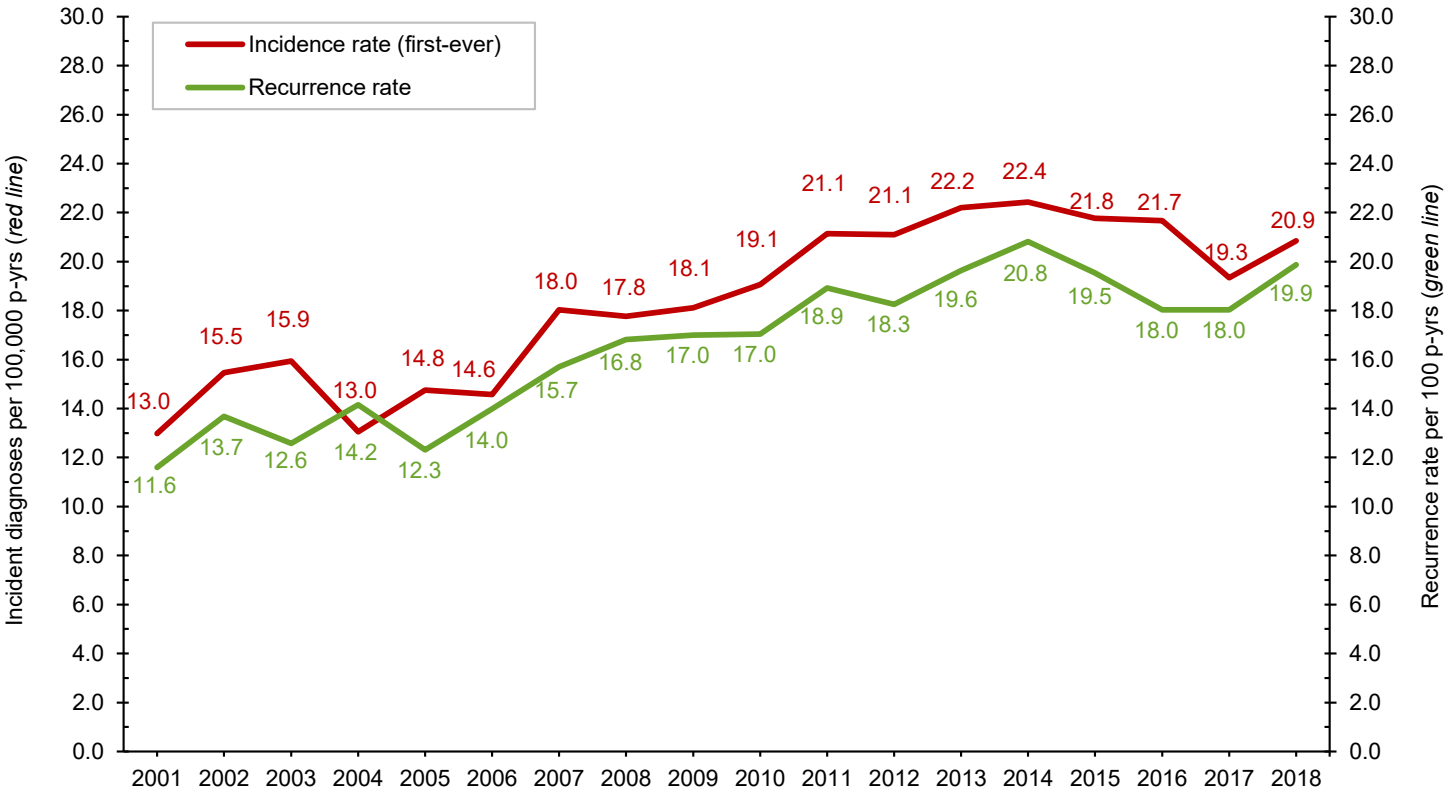
TABLE 3. Numbers and rates of incident diagnoses of central serous chorioretinopathy, by service and military occupation, active component, U.S. Armed Forces, 2001–2018

	Army		Navy		Air Force		Marines	
	Counts	Rates[a]	Counts	Rates[a]	Counts	Rates[a]	Counts	Rates[a]
Combat-related[b]	385	16.8	105	31.0	5	--	70	9.3
Motor transport	46	14.8	38	15.2	9	--	11	--
Pilot/air crew	61	38.7	96	32.9	137	36.5	35	33.5
Repair/engineering	313	16.6	471	18.3	421	21.6	117	14.5
Communications/intelligence	368	16.6	202	18.9	271	18.5	119	16.1
Healthcare	204	23.0	165	25.8	151	26.6	0	--
Other	243	18.0	132	14.6	251	15.8	66	8.2

[a]Rate per 100,000 person-years; rates are not reported when counts are less than 20.
[b]Infantry/artillery/combat engineering/armor.

An important consideration when interpreting increasing incidence rates of CSCR diagnoses is the advance in diagnostic capabilities. Optical coherence tomography (OCT), a diagnostic modality that provides a cross-sectional view of the retina, was developed in 1991.[10] OCT is frequently used to diagnosis and monitor CSCR and has increased in fidelity since it was first introduced.[11] The increased availability and utilization of OCT over the course of the surveillance period should be taken into account when interpreting the reported increased rates.

FIGURE. Incident cases and incidence and recurrence rates of central serous chorioretinopathy, active component, U.S. Armed Forces, 2001–2018



P-yrs, person-years.

An additional limitation of the current analysis is related to the implementation of MHS GENESIS, the new electronic health record for the MHS. Medical data from sites that were using MHS GENESIS were not available in the DMSS. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounters and person-time data for individuals seeking care at any of these facilities during 2017 and 2018 were excluded from the analysis. This is notable since Madigan Army Medical Center has a retina service that would be expected to be a referral center for patients with CSCR. Despite a possible attenuation of counts and rates, this report provides critical epidemiological information concerning this important ocular condition.

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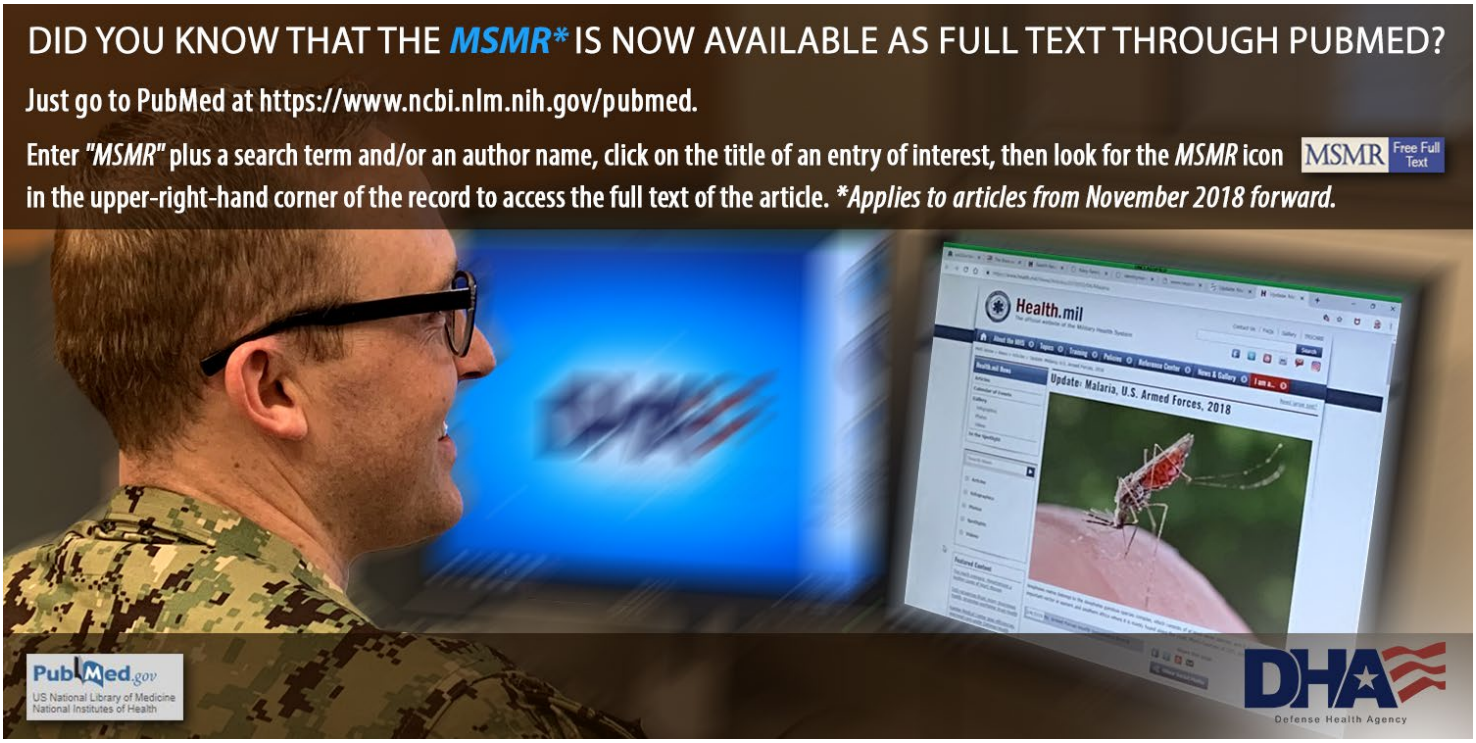

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