

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

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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.

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.

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

^aAn 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

^aAn 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

^aInfantry/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/intel- ligence	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

^aRate per 10,000 person-years.

^bInfantry/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

^aAll 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

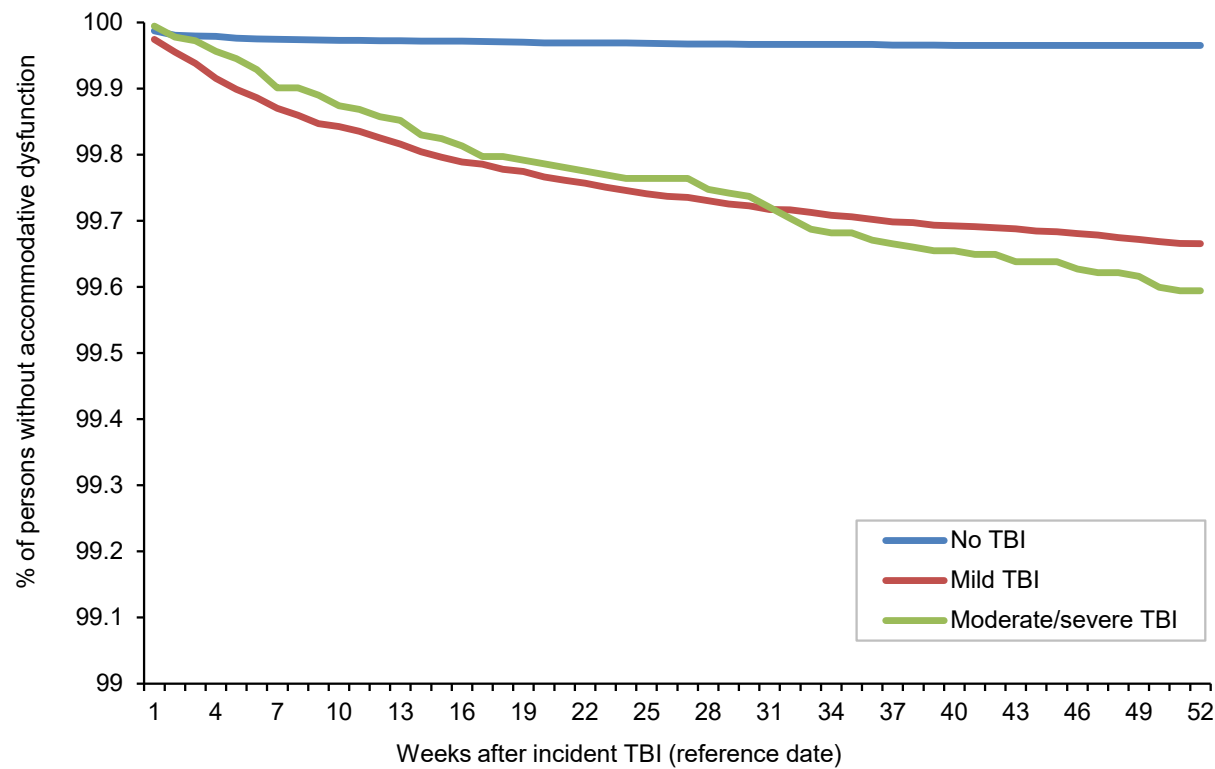
than the no TBI group. Finally, higher percentages of the mild TBI cohort remained without blindness and low vision or disorders of pupil function at each week of follow-up compared to the other 2 cohorts (**Figures 5, 7**).

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.

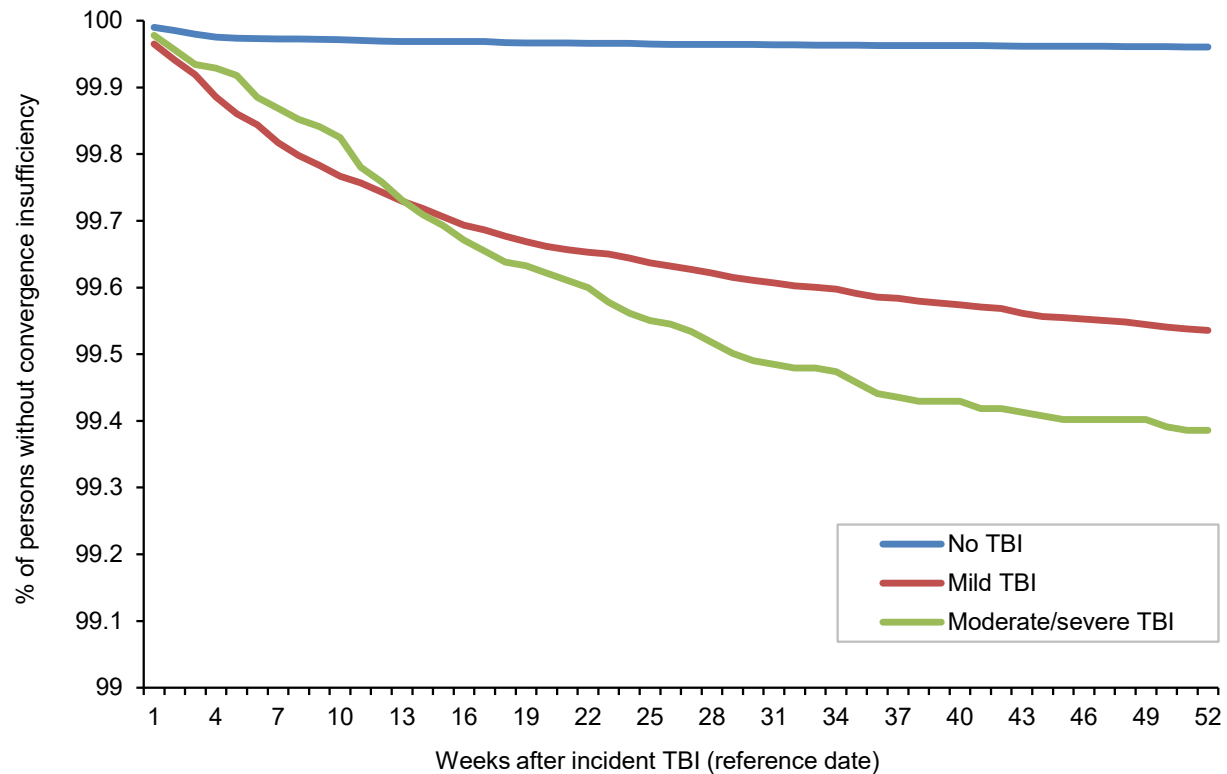
Results of the survival analysis showed that AD or CI may be diagnosed soon after the initial TBI diagnosis. Later diagnosis of these visual dysfunctions was observed among the moderate/severe TBI group. For AD, among mild TBI patients, approximately half of the cases were diagnosed by 12 weeks and three-quarters 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 diagnosed 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



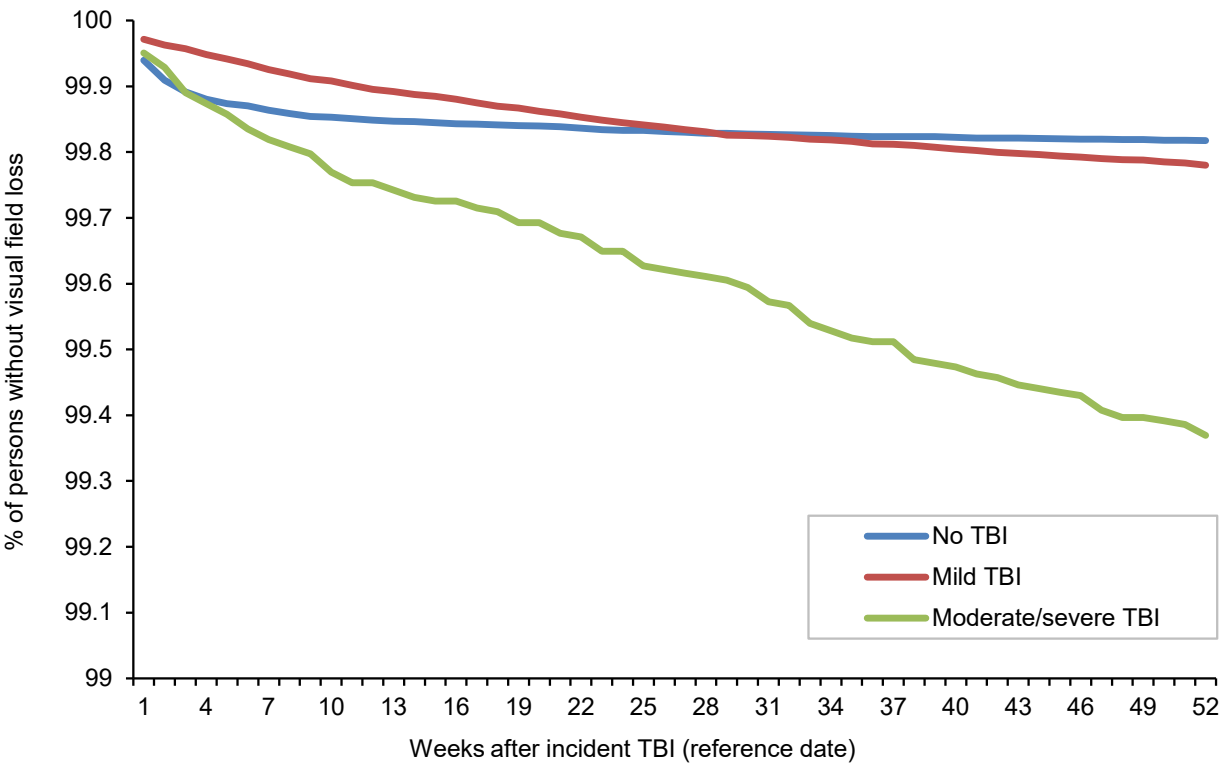
TBI, traumatic brain injury.

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



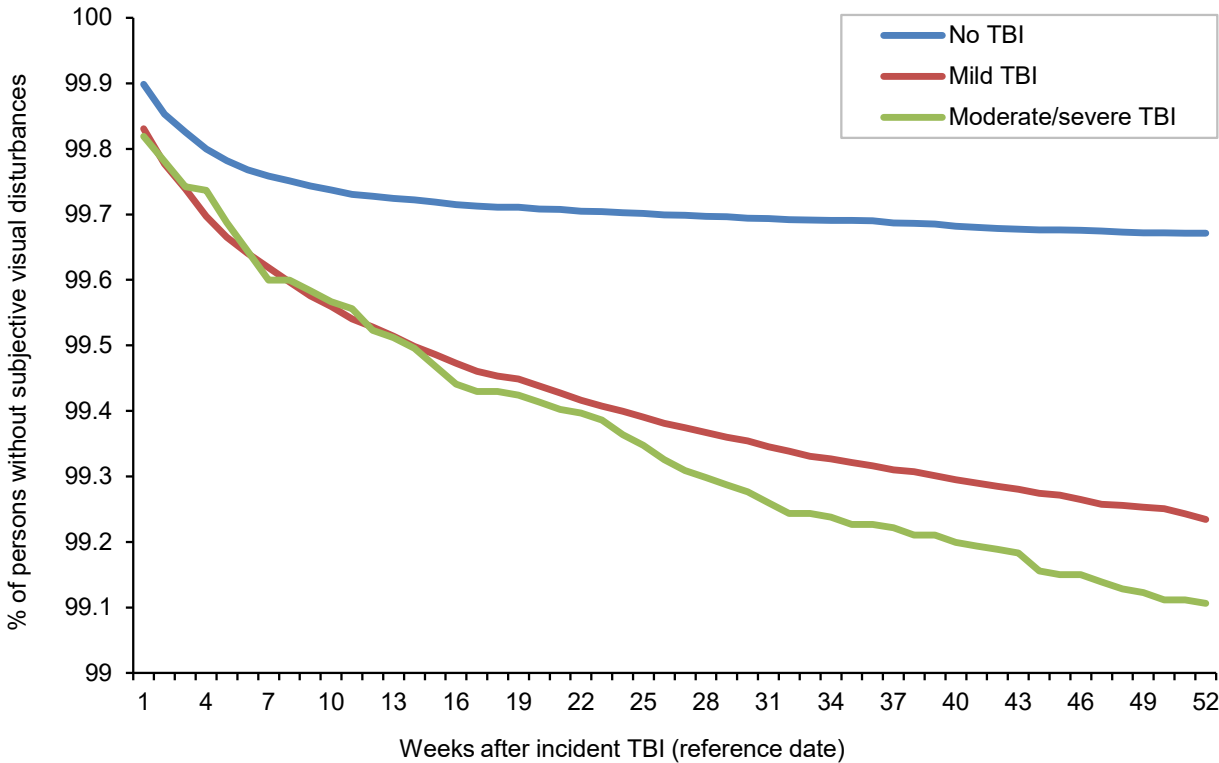
TBI, traumatic brain injury.

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



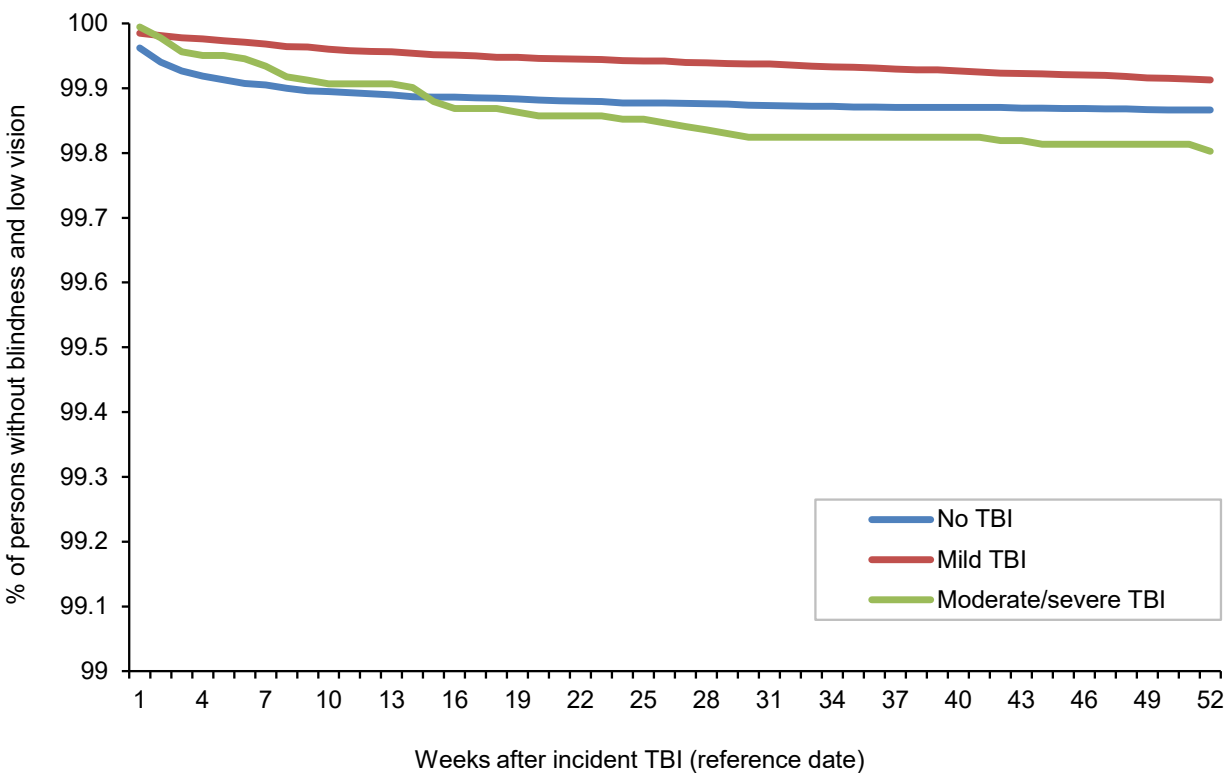
TBI, traumatic brain injury.

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



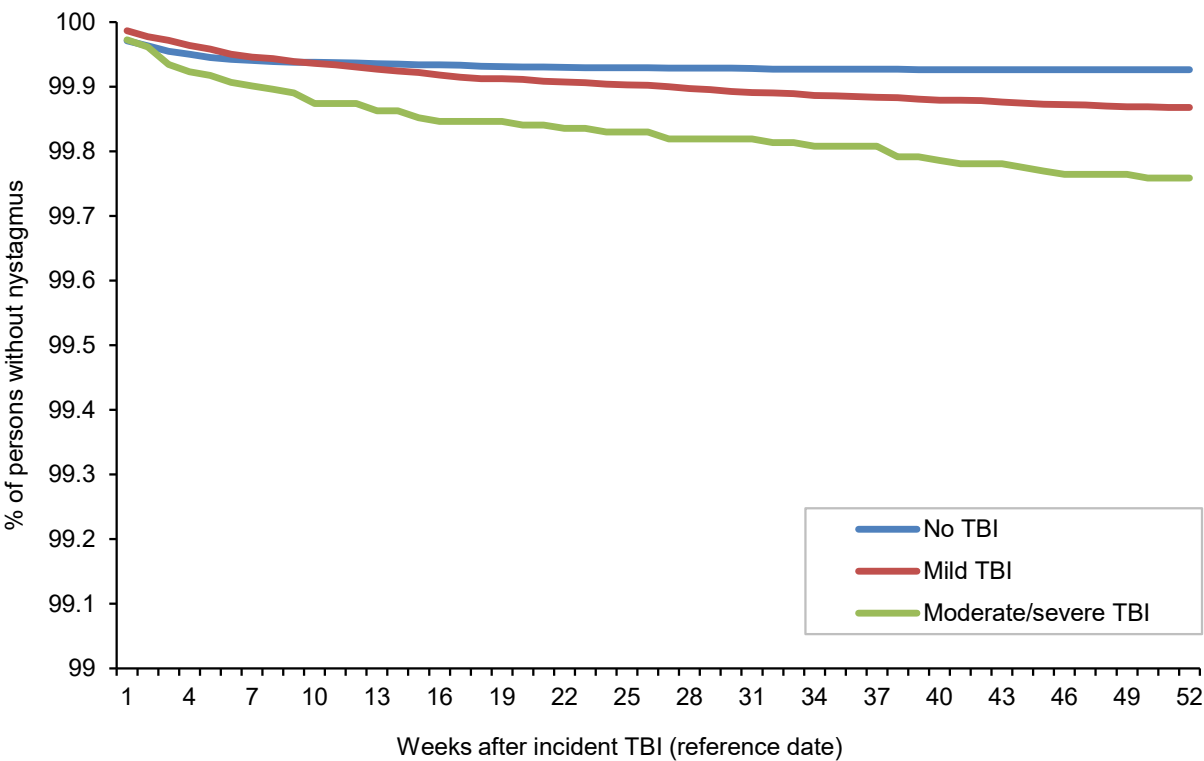
TBI, traumatic brain injury.

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



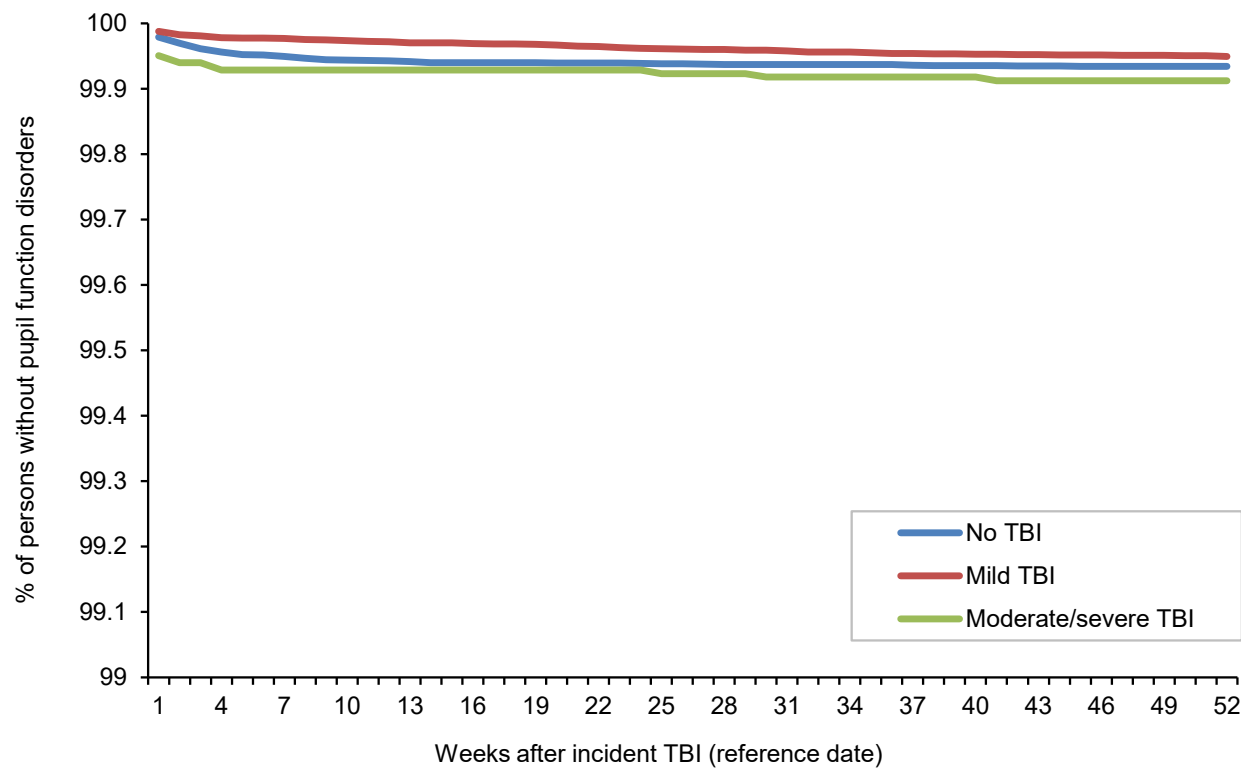
TBI, traumatic brain injury.

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



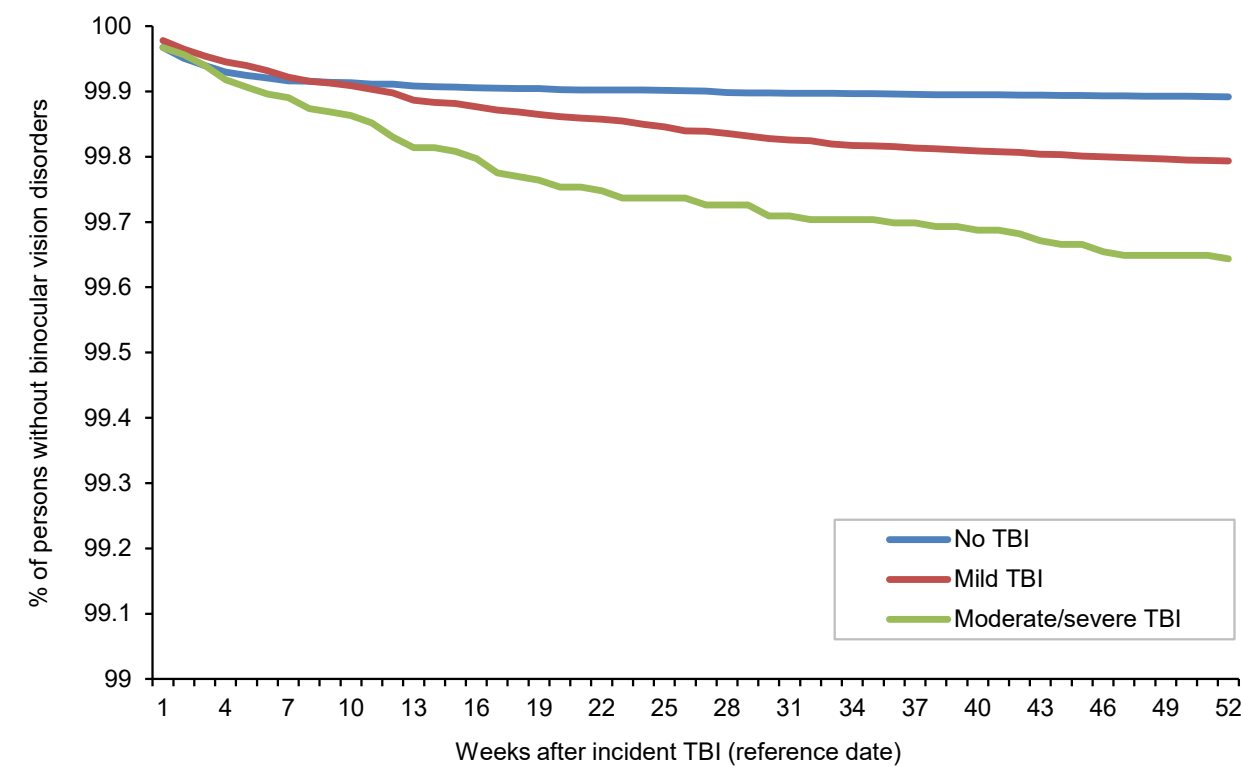
TBI, traumatic brain injury.

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



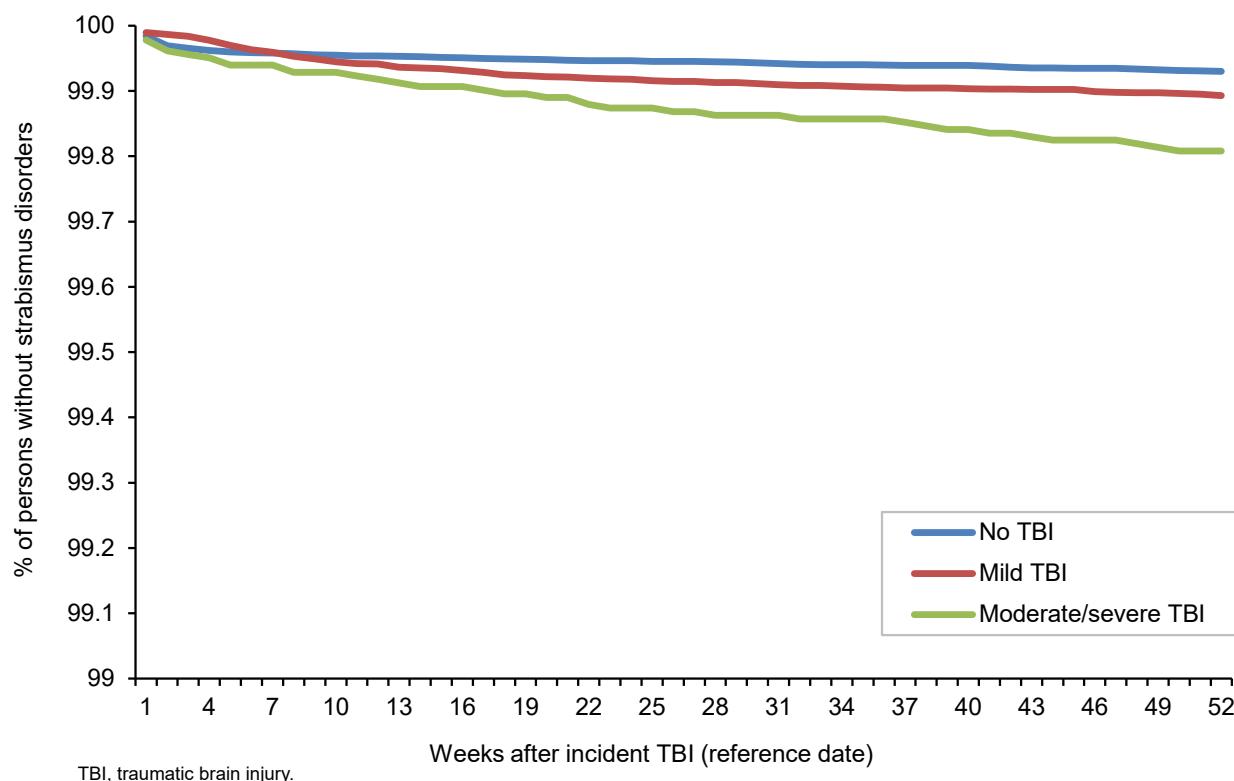
TBI, traumatic brain injury.

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



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 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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