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Visual Dysfunction in Patients with Traumatic Brain Injury: A Systematic Review

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PREFACE

Quality Enhancement Research Initiative's (QUERI) Evidence-based Synthesis Program (ESP) was established to provide timely and accurate syntheses of targeted healthcare topics of particular importance to Veterans Affairs (VA) clinicians, managers and policymakers as they work to improve the health and healthcare of Veterans. The ESP disseminates these reports throughout the VA, and some evidence syntheses inform the clinical guidelines of large professional organizations.

QUERI provides funding for four ESP Centers and each Center has an active university affiliation. The ESP Centers generate evidence syntheses on important clinical practice topics, and these reports help:

- develop clinical policies informed by evidence;
- guide the implementation of effective services to improve patient outcomes and to support VA clinical practice guidelines and performance measures; and
- set the direction for future research to address gaps in clinical knowledge.

In 2009, the ESP Coordinating Center was created to expand the capacity of HSR&D Central Office and the four ESP sites by developing and maintaining program processes. In addition, the Center established a Steering Committee comprised of QUERI field-based investigators, VA Patient Care Services, Office of Quality and Performance, and Veterans Integrated Service Networks (VISN) Clinical Management Officers. The Steering Committee provides program oversight, guides strategic planning, coordinates dissemination activities, and develops collaborations with VA leadership to identify new ESP topics of importance to Veterans and the VA healthcare system.

Comments on this evidence report are welcome and can be sent to Nicole Floyd, ESP Coordinating Center Program Manager, at Nicole.Floyd@va.gov.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 1
Introduction 1
Methods 1
Results 1
Conclusions 2
Table 1. Summary of Findings: Ranges of Visual Dysfunction Frequencies Across Studies 2

INTRODUCTION 3

METHODS 4
Topic Development 4
Search Strategy 4
Study Selection 5
Data Abstraction 5
Quality Assessment 6
Data Synthesis 6
Rating the Body of Evidence 6
Peer Review 6

RESULTS 7
Literature Flow 7
Key Question 1: What is the prevalence or incidence of visual dysfunction in a general population of individuals who have been diagnosed with a TBI? 8
Summary of Findings 15
Accommodation Dysfunction and Refractive Errors Findings 15
Convergence Insufficiency or Dysfunction Findings 16
Diplopia 17
Dry Eye 17
Nystagmus or Fixation Dysfunction 19
Photosensitivity, Photophobia, or Light Sensitivity 19
Pursuit or Saccadic Dysfunction 20
Strabismus and Cranial Nerve Palsy 21
Visual Field Defect 22
Visual Impairment or Dysfunction 23
Key Question 2: What are the types of visual dysfunction reported by individuals who have been diagnosed with a TBI and are presenting to Eye Care clinics? 26
Summary of Findings 26

SUMMARY AND DISCUSSION 30
Summary of Evidence by Key Question 30
Key Question 1 30
Key Question 2 31

Study Characteristics and Quality 31
Publication Bias 31
Heterogeneity 31
Applicability of Findings to the VA Population 31
Future Research Needs 32
Conclusions 32

REFERENCES 33

FIGURES

Figure 1: Literature Flow Chart 7

TABLES

Table 1. Summary of Findings: Ranges of Visual Dysfunction Frequencies Across Studies 9
Table 2. Sample and Study Characteristics 11
Table 3. Accommodation Dysfunction and Refractive Errors in Individuals with TBI History 15
Table 4. Convergence Insufficiency or Dysfunction in Individuals with TBI History 16
Table 5. Diplopia in Individuals with TBI History 17
Table 6. Dry Eye in Individuals with TBI History 18
Table 7. Nystagmus or Fixation Dysfunction in Individuals with TBI History 19
Table 8. Photosensitivity, Photophobia, or Light Sensitivity in Individuals with TBI History 20
Table 9. Pursuit or Saccadic Dysfunction in Individuals with TBI History 21
Table 10. Strabismus and Cranial Nerve Palsy in Individuals with TBI History 22
Table 11. Visual Field Defect in Individuals with TBI History 22
Table 12. Visual Impairment or Dysfunction in Individuals with TBI History 24
Table 13. Visual Dysfunction in Individuals with TBI Presenting to an Eye Care Clinic 27

APPENDIX A. TECHNICAL EXPERT PANEL 36

APPENDIX B. SEARCH STRATEGIES 37

APPENDIX C. PEER REVIEW COMMENTS AND RESPONSES 42

EVIDENCE REPORT

INTRODUCTION

There is a high prevalence of traumatic brain injury (TBI) in both military and non-military populations. The Centers for Disease Control and Prevention reported that, in 2009, approximately 3.5 million people (just over 1% of the population) received healthcare treatment related to a TBI in the United States (U.S.).[1,2] Researchers estimate that approximately 15% of Operation Enduring Freedom/Operation Iraqi Freedom/Operation New Dawn (OEF/OIF/OND) Service Members have incurred TBI during deployment, equating to 390,000 of the 2.6 million who have deployed through 2014.[3,4] The risk that patients with a history of TBI will experience symptoms over the long-term depends in part on the severity of injury. However, many patients with even mild TBI (mTBI) present with long-term symptoms, though it is unclear whether these symptoms are directly attributable to the brain injury.[5,6]

Vision-related symptoms are increasingly recognized as one possible long-term sequelae of TBI. Given that intact vision depends on portions of the brain interacting in complex ways, there are multiple potential mechanisms through which trauma can result in visual deficits. In brief, the visual pathways are organized in afferent and efferent arcs. The afferent arc receives and processes visual stimuli while the efferent arc moves the eyes in the direction of the object of visual regard. In the midst of this complex milieu, there exist anticipatory and interpretive systems which add neurocognitive input to the visual imagery.[7] TBI can cause a wide variety of injuries to the visual system including anterior and posterior visual pathway damage affecting visual acuity, color vision, and resultant visual fields defects. Cranial nerve injuries can manifest as diplopia and nystagmus due to oculomotor dysfunction.[8] Patients with TBI history may experience photosensitivity or difficulty reading, or may exhibit abnormal fixation and accommodative dysfunction.[9]

Although vision is an important sensory modality for critical activities of daily living (ADLs), the diagnosis and treatment of functional vision deficits has been inconsistent.[10] In 2008, the VA issued a policy statement requiring all TBI patients seen at Polytrauma Rehabilitation Centers (PRCs) be seen by an optometrist or ophthalmologist for a visual health examination, but the vision screening and treatment of other Veterans and U.S. Service members treated outside of PRCs varies.[11] Additionally, there are ongoing efforts in the VA and Department of Defense (DoD) to determine relationships among visual symptoms and TBI history, including efforts to examine oculomotor tracking as a way to detect mTBI.[12] To help inform VA policymakers and clinicians responsible for TBI program planning and service delivery, we conducted a systematic review of the literature examining the prevalence and type of visual dysfunction in military and non-military populations with a history of TBI.

METHODS

TOPIC DEVELOPMENT

This topic was submitted to the ESP Coordinating Center for development by Mary G. Lawrence, MD, MPH, Interim Director, VA/DoD Vision Center of Excellence (VCE), in collaboration with other key stakeholders Felix Barker, Associate Director, Research, Rehabilitation and Reintegration, Vision Center of Excellence, Salisbury VAMC; Christopher Moore, PhD, VA Scientific Program Manager for Sensory Systems and Communication Disorders Program; and Stuart W. Hoffman, PhD, Scientific Program Manager for Brain Injury, Rehabilitation Research and Development Service, TBI Point of Contact and Subject Matter Expert, Office of Research and Development. We also received input from a technical expert panel (see Appendix A).

The goal of this evidence report is to summarize current evidence examining the prevalence and types of visual dysfunction and impairment among patients diagnosed with TBI. Understanding the scope of visual disorders among these populations will aid the VHA in determining appropriate screening strategies for visual dysfunction and impairment among returning Veterans diagnosed with TBI. Better understanding of the specific visual dysfunctions that may be associated with TBI will also enable appropriate intervention within the vision care system. A secondary goal is to develop a strategy for the monitoring of outcomes from the assessment and management of TBI-related visual disorders, thus potentially producing improved outcomes in the overall rehabilitation and reintegration of affected Veterans.

The Key Questions, which were developed in concert with the stakeholders, are as follows:

Key Question 1: What is the prevalence or incidence of visual dysfunction in a general population of individuals who have been diagnosed with a TBI?

Key Question 2: What are the types of visual dysfunction reported by individuals who have been diagnosed with a TBI and are presenting to eye care clinics?

SEARCH STRATEGY

We identified an existing systematic review of visual dysfunction in patients with TBI published in 2009 by Adams and colleagues.[13] Because of overlapping Key Questions and inclusion criteria in that review and our current report, we based our search prior to 2009 on the studies included in the Adams 2009 review.[13] We also searched Medline (OVID), PsychINFO (OVID), and the Cochrane Register of Controlled Trials (OVID), SPORTDiscus, Rehabilitation & Sports Medicine Source (EBSCO), and Rehabdata (National Rehabilitation Information Center) for studies published between January 1st, 2009 and March 27th, 2014. The search strategy is reported in Appendix B. We obtained additional articles from systematic reviews, reference lists of pertinent studies, reviews, editorials, and by consulting clinical and research experts. All citations were imported into an electronic database (EndNote X4).

STUDY SELECTION

We included studies reporting outcomes in patients with a history of TBI diagnosis of any severity. We included studies using a definition of TBI consistent with that used in the Adams 2009 review, which is inclusive of cases meeting both American Congress of Rehabilitation Medicine (ACRM) and VA/DoD criteria: "This report will include clinical research of TBI caused by detonation or other mechanisms of diffuse closed head injury such as diffuse axonal injury from motor vehicle accidents, falls and sport/recreational activities that are likely to resemble the types of exposure experienced by our newest Veteran population; it will exclude causes of focal brain injury such as stroke, infection, and tumors."[13] Studies reporting only data on patients with ocular injuries were excluded, though studies that included a portion of patients with ocular injuries were included. Patients under 5 years of age were excluded. For Key Question 1, but not Key Question 2, we excluded studies reporting a population selected for the study based even in part on visual dysfunction.

We included visual dysfunction and outcomes that would likely be diagnosed or treated in an eye care clinic (*eg*, oculomotor disorders, visual acuity loss, strabismus, convergence insufficiency, diplopia, hemianopsia, other homonymous visual field defects, photosensitivity, nystagmus). We excluded physical injuries to the eye such as open globe injuries or retinal hemorrhage; shaken baby syndrome; visually administered cognitive assessments that do not assess a primarily visual outcome (*eg*, visual agnosia, spatial neglect, visuospatial abilities, visual scanning, visually administered tests primarily assessing memory, executive functioning including Stroop tests, academic achievement, reading, writing, math, language abilities, reaction time, attention, or concentration); vision-related outcomes that are primarily neurocognitive in nature and would not be diagnosed or treated in an eye care clinic; brain imaging results not reporting associated visual dysfunctions; and self-reported global vision difficulties reported on general screening tools (*eg*, single items on screening questionnaires assessing vision problems, blurred vision, double vision, trouble seeing, or light sensitivity). Research conducted at any length of time since injury was included.

For Key Question 1, included settings were primary care settings, school or athletic programs, or any settings serving a general population that is not being examined for suspected TBI-related vision symptoms. Studies of prevalence or incidence were included if they were cohort, case-control, controlled trials, or studies with a control or comparison group including self as control. Studies with fewer than 50 participants with a history of TBI were excluded.

For Key Question 2, included settings were eye care clinics. All study designs were considered. Consistent with the inclusion criteria for the Adams review, studies reporting type of visual dysfunction in eye care clinic populations were excluded if they reported fewer than 10 cases with visual dysfunction.

We published our key questions and abstract online so that they were available for public review.

DATA ABSTRACTION

We abstracted data from each included study on study design; sample size; TBI definition; participant selection and characteristics; key moderators and potential confounders including

mechanism of injury, time since injury, and ocular injuries; outcome measures; and results. These data are reported in Tables 3 to 12. Data was abstracted by one investigator and reviewed for accuracy by at least one additional investigator.

QUALITY ASSESSMENT

We assessed the quality of included studies pertaining to both Key Questions. Because the focus of this review is on estimating prevalence, we examined study quality using the Quality in Prognostic Studies (QUIPS) study appraisal tool[14] and highlight factors such as sample selection and outcome assessment which have the potential to impact prevalence estimates. Study data relevant to risk of bias was extracted by one investigator and reviewed for accuracy by at least one additional investigator. Specific study quality factors are summarized as relevant for each Key Question.

DATA SYNTHESIS

We constructed evidence tables showing the study characteristics and results for all included studies organized by outcome. We critically analyzed studies to compare their characteristics, methods, and findings. We compiled a summary of findings for each outcome category and key question, and drew conclusions based on qualitative synthesis of the findings. We did not combine the studies in a quantitative manner via meta-analysis because of the heterogeneity of study characteristics, particularly because studies did not report proportions of patients with different levels of TBI severity and those with ocular injuries, both of which likely influence the outcomes of interest. The synthesis was conducted by the principal investigator, though all results were reviewed with the team of investigators to review and obtain consensus on the reported findings.

RATING THE BODY OF EVIDENCE

Key questions focus on prevalence estimates and common types of visual dysfunctions treated in clinical settings; therefore, we did not formally rate the strength of the body of evidence as most rating schemes are applicable to strength of evidence for interventions or diagnostic tests (*eg*, Grading of Recommendations Assessment, Development, and Evaluation (GRADE) criteria).[15]

PEER REVIEW

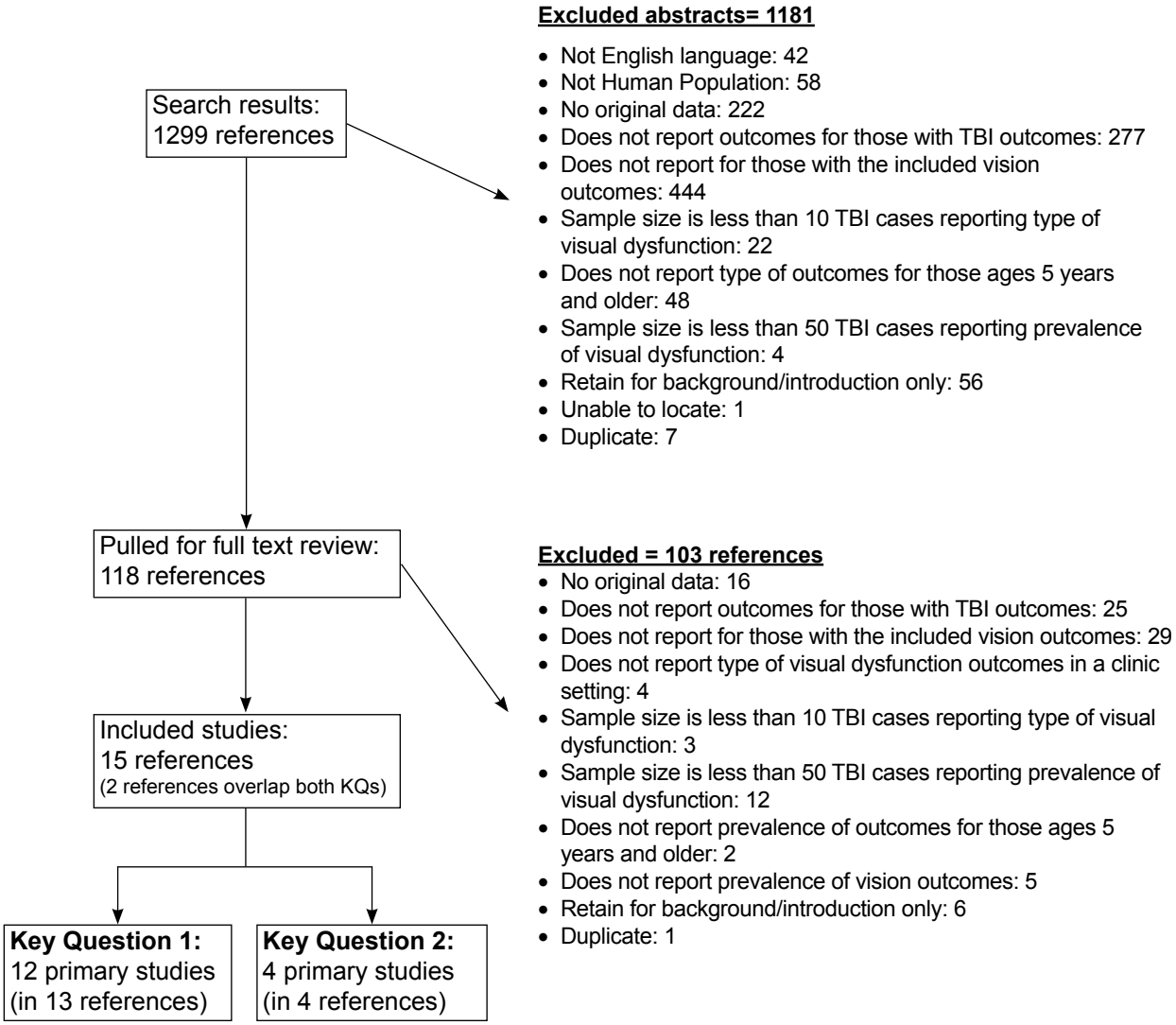
A draft version of this report was reviewed by 8 technical experts and clinical leaders. Their comments and the authors' responses are presented in Appendix C.

RESULTS

LITERATURE FLOW

We reviewed 1299 titles and abstracts from the electronic search. After applying inclusion/exclusion criteria at the abstract level, 118 full-text articles were reviewed, as shown in Figure 1. Of the full-text articles, we excluded 103 that did not meet inclusion criteria. We grouped the studies by outcome and Key Question. Figure 1 details the exclusion criteria and the number of references related to each of the Key Questions. We identified 12 primary studies (13 references) that addressed Key Question 1, and 4 primary studies that addressed Key Question 2; 2 studies provided information addressing both Key Questions for a total of 13 included primary studies published in 15 papers.[8,9,16-27] Two studies reported results for U.S. or Canadian civilians[16,22]; the rest reported results for U.S. Veterans or active-duty Service Members of the U.S. military. Table 2 shows the characteristics of the primary studies, and the following sections detail findings according to Key Questions, outcomes, and moderators.

Figure 1: Literature Flow Chart



KEY QUESTION 1: What is the prevalence or incidence of visual dysfunction in a general population of individuals who have been diagnosed with a TBI?

Twelve studies (published in 13 papers) of patients with TBI history met inclusion criteria for Key Question 1. The prevalence of visual dysfunction ranged widely according to the patient population examined, study setting, and whether or not patients underwent examination to screen for visual dysfunction. We excluded studies only providing data on patients who were referred or self-referred to the study based on visual complaints because these studies do not provide accurate data on the prevalence of visual dysfunction in unselected populations (*ie*, participants not selected for inclusion in the study based on visual dysfunction) with history of TBI. Sample selection criteria for each study are documented in Table 2. None of the studies meeting inclusion criteria stratified results based on TBI severity. There were 2 main types of study settings: settings that treat patients *regardless* of current, suspected TBI-related symptoms, and settings that treat *only* patients with current, suspected TBI-related symptoms.

Summary of findings from studies of patients in settings that treat patients regardless of current symptoms

Four studies included general populations of patients with TBI history *regardless* of current symptoms. In these studies, participants were all patients with TBI history (1) seen at a post-deployment clinic for a general medical appointment and screened for vision-related symptoms,[18] (2) with military record diagnostic data on visual dysfunctions,[19] (3) presenting to a Canadian emergency department related to a motor vehicle crash and screened for post-concussive symptoms including vision-related symptoms,[22] and (4) who had TBI evaluations performed at the VA and were screened for neurobehavioral symptoms including vision-related symptoms.[26]

One study by Dougherty and colleagues of an unscreened group of U.S. Service Members used a large administrative database to identify those with clinically diagnosed visual dysfunction.[19] This study reported data on clinical diagnosis in an unscreened group of U.S. Service Members, and excluded individuals with ocular injury and diagnosis of ocular or vision disorders prior to the TBI. This study found low rates of individual types of visual problems or dysfunction (0.1% to 7.3%, see Table 1), and reported that, overall, 11% of patients were diagnosed with one or more types of visual dysfunction. Unlike studies in which all participants are screened, this study provides an assessment of clinically significant impairment because patients experienced visual dysfunction to a degree that resulted in clinical presentation and diagnosis.

The other 3 studies used self-report measures to screen participants[18,22,26] and found higher rates of visual dysfunction (8.8% to 54%, see Table 1) than the data from Dougherty and colleagues that reported on unscreened patients with diagnosed visual dysfunction. One of these screening studies[18] also referred patients who self-reported visual problems for eye examinations, and the resulting visual diagnoses were less frequent upon examination compared to self-report (2% to 22%, see Table 1).

Summary of findings from studies of only patients with current symptoms

The second main type of study population examined in this review came from studies conducted

in Polytrauma Rehabilitation Centers (PRCs) and Polytrauma Network Sites (PNSs) within the VA.[8,9,17,20,21,23-25,27] Both types of treatment facilities provide interdisciplinary, rehabilitation care to Veterans who experienced TBI or polytrauma, but serve populations with different care needs. The 5 PRCs provide acute, inpatient care to those with more complex and severe TBI or polytrauma. The 23 PNSs provide care to those who are discharged from PRCs and need continued rehabilitation services, as well as to Veterans who require less intensive care for their TBI or polytrauma. In 2008, the VA began requiring all PRC patients with a history of TBI to "have a TBI-specific ocular health and visual functioning examination performed by an optometrist or ophthalmologist."[11] While Veterans treated at PRCs and PNSs differ in symptom severity and complexity, their results are grouped in this report because data from PRCs and PNSs were commonly aggregated in the included studies. However, results tables for each type of visual dysfunction stratify findings according to inpatient versus outpatient status, when these data were available in the original studies.

Because PRC and PNS patients receive care based on current symptoms, some of which may be vision-related, and because the patients undergo eye exams designed to screen for many types of visual problems, it is not surprising that the rates of visual dysfunction in these patient populations were generally much higher (0 to 93%, see Table 1) than in general VA populations.

A summary of the range of frequencies for each type of visual dysfunction included in this report is illustrated in Table 1, with results separated to reflect different study populations.

Table 1. Summary of Findings: Ranges of Visual Dysfunction Frequencies Across Studies

	Studies including patients with TBI history regardless of current symptoms		**Studies including patients with TBI history who all have current symptoms**
Outcome	Unscreened	Screened	Screened
Accommodation Dysfunction and Refractive Errors	7.3% (1 study[19])	3.0% (1 study[18])	19.0 - 66.7% (6 studies[9,17,20,21,24,27,28])
Convergence Insufficiency or Dysfunction	No studies	No studies	11.0 - 62.5% (6 studies[9,17,20,21,24,27,28])
Diplopia	No studies	No studies	3.0 - 40.0% (4 studies[9,20,21,27,28])
Dry Eye	0.1% (1 study[19])	2.0% (1 study[18])	93.0% with one or more positive tests (1 study[8])
Nystagmus or Fixation Dysfunction	No studies	No studies	0.0 - 23.4% (5 studies[9,17,20,21,24,27])
Photosensitivity, Photophobia, or Light Sensitivity	No studies	5.0 – 54.0% (1 study, diagnosed vs self-report[18])	51.0 - 59.0% (3 studies, all self-report[9,21,24,28])
Pursuit or Saccadic Dysfunction	No studies	No studies	2.0 - 70.8% (5 studies[9,17,21,24,27])
Strabismus and Cranial Nerve Palsy	0.6% (1 study[19])		0.0 - 37.5% (4 studies[9,17,21,24,27])
Visual Field Defect	0.1% (1 study[19])	2.0% (1 study[18])	0.0% - 38.8% (3 studies[17,20,27])
Visual Impairment or Dysfunction, Diagnosed	0.4% (1 study[19])	22.0% (1 study[18])	8.5% (1 study[17])
Visual Impairment or Dysfunction, Self-Reported	No studies	8.8 - 47.0% (3 studies[18,22,26])	32.2 - 77.4% (6 studies[9,17,21,23,25,27,28])

Methodological considerations

In addition to participant populations and selection factors, another factor that can influence prevalence estimates relates to outcome assessment.[14] The included studies used a variety of assessment methods to evaluate different types of visual dysfunction. These outcomes and assessment methods are reported in the results tables for each type of visual dysfunction. Studies based on administrative databases likely underestimate prevalence of outcomes as populations are not screened and diagnostic outcome data may be inconsistently entered.[19,22,26] In contrast, studies using clinic-based outcome assessments may be biased if providers or patients are aware of study hypotheses, particularly if outcomes require subjective assessment (*ie*, there is the potential for outcome ascertainment bias). None of the studies that employed clinic-based outcome assessment methods described outcome validation methods such as dual or blinded assessment, and therefore the potential for biased results from these studies is unclear.[8,9,17,18,20,21,23-25,27]

Key Questions in this systematic review do not focus on assessing causality or determining if visual dysfunction is more common in individuals with TBI history compared to those without. Though some included studies report data on control groups without TBI history, we did not assess study quality related to causal associations between TBI history and visual dysfunction.

Table 2. Sample and Study Characteristics

Citation and KQ	Study design; TBI Comparison group	TBI, control sample size	TBI severity; definition	Mechanism of injury; time since injury	Ocular injuries	Age in years, M (SD)	Gender; Race/ Ethnicity	Sample characteristics and selection
Alvarez, 2012[16] KQ2	Case series; None	557	NR	MVCs (70.9%), falls (14.7%), a strike or blow to the head (9.2%), sports injury (2.5%), other (2.7%; gunshot, assaults, or unspecified) Time NR	NR	40.3 (SD 17.4, range 5-89)	338/557 (61%) male	Inpatients with vision symptoms referred from Kesser Institute of Rehabilitation, John F. Kennedy Medical Center, and Robert Wood Johnson University Hospital in New Jersey. Outpatients: New Jersey private practice. January 1989 to February 2003; Sample is approximately one half of all neurologically impaired patients referred by neurologists.
Brahm, 2009[17] KQ1	Cross-sectional; None	192	Mild, moderate, and severe. Inpatients: No definition; Outpatients: Mild TBI screening using expanded version of 3-item DVBIC tool	57/68 (84%) blast, 11/68 (16%) non-blast in the PRC- group. Time NR	26/68 (38.2%) had "ocular injuries"	28.6 (median = 26.0) for PRC inpatients.	65/68 (96%) male	Palo Alto PRC inpatients: 68 consecutive patients; December 2004 to April 2008 Palo Alto PNS outpatients: 124 consecutive patients; August 2006 to December 2007
Bulson, 2012[18] KQ1 & KQ2	Case series and cross-sectional data; None	100 (KQ 1) 33 (KQ 2)	NR; TBI diagnosis given at initial post-deployment evaluation by a medical doctor.	Multiple blast injuries (69%), blasts associated with MVCs (13%), single blasts (10%), falls (7%), isolated MVCs (1%) Time NR	NR	29.9 (range 21-55)	99% male	Portland VA Medical Center Post-deployment Clinic: 185 OEF/OIF Veterans; January 2009 to 2012
Cockerham, 2013[8] KQ1	Case control; Recruited 18 men similar age range, ethnicity, but without TBI	53, 18	32% = mild, 49% = moderate, 19% = severe; definition NR	44/53 (83%) blast, 6/53 (11%) MVC, 3/53 (6%) fall Time ranged from 1-60 months (median = 6 months).	Eyes with open-globe injury and those using topical ocular medications were excluded	26 (range 19-46)	100% male 34/53 (65%) White, 19/53 (35%) non-White.	VA Palo Alto PRC inpatients; began testing tear production in 2006 in inpatients and former inpatients returning for eye examinations. No report of consecutive patient selection.

Citation and KQ	Study design; TBI Comparison group	TBI, control sample size	TBI severity; definition	Mechanism of injury; time since injury	Ocular injuries	Age in years, M (SD)	Gender; Race/ Ethnicity	Sample characteristics and selection
Dougherty, 2011[19] KQ1	Retrospect-ive cohort; same patient group with non-TBI blast injury	837, 1417	NR; rating system used was 0 = no TBI, 1 = minor, 2 = moderate, 3-5 = serious to critical according to ICD-9-CM (Thurman et al 1995) and AIS (Gennarelli et al 2005)	All TBI and control participants were injured by blast exposure Time NR, based on data collected during deployment in the combat zone	"Those who sustained eye injury were excluded from this analysis"	TBI: Median = 22 (range 18-59) Control: Median = 23 (range 18-59)	99.4% male Control = 98.7% male	Expeditionary Medical Encounter Database; March, 2004 to February, 2007: Medical records completed "in the combat zone, nearest to the point of injury" merged with DOD records. All had blast exposure. "US Service members who met the following criteria were included" suggesting all eligible participants included. Inclusion criteria stated "having only one recorded injury event and having not received a diagnosis of ocular or visual disorder prior to the injury event."
Goodrich, 2013[9] Goodrich, 2013[21] KQ1	Cross-sectional; None	100	27/98 Mild; 71/98 Moderate-Severe; Severity obtained from a DVBIC evaluation record, physician entry, and ACRM criteria applied to chart review	50/100 blast, all in Afghanistan or Iraq. 50/100 non-blast: MVC (58%); fall (16%); assault (12%); pedestrian struck by vehicle, gunshot, bicycle injury (4% each); snowboard injury (2%). Most occurred in the U.S. M = 8 months (range 2-56 wks) PTSD: M = 15.3 months No PTSD: M = 2.9 months Blast: M = 1.01 yrs (SD = 1.18) No Blast: M = .32 yrs (SD = .52)	29/98 "eye/ orbit trauma" Non-blast: 29% Blast: 31%	PTSD: M = 32.8 (range 19-59) No PTSD: M = 26.37 (range 19-63) No Blast: 29 (range, 19 to 63); Blast: 29 (range, 19 to 55)	95% Male Non-blast: 48/50 (96%) male. Blast: 47/50 (94%) male.	Palo Alto PRC inpatients with documented eye examinations with optometry. 16/50 blast TBI patients exposed to more than one blast; 4/50 non-blast TBI patients had past head injuries. No report of consecutive patient selection.

Citation and KQ	Study design; TBI Comparison group	TBI, control sample size	TBI severity; definition	Mechanism of injury; time since injury	Ocular injuries	Age in years, M (SD)	Gender; Race/ Ethnicity	Sample characteristics and selection
Goodrich, 2007[20] KQ1	Cross-sectional; None	50	NR	Blast = 50%; MVCs = 26%; Assault = 8%; Falls = 8%; Gunshot and/or shrapnel wounds = 4%; Anoxia = 4%. Combat = 59%. Time NR	17 (34.0%) "eye or orbit damage"	M = 28.1 (median 26, range 19-56)	45/50 (90%) male	Palo Alto PRC: Comprehensive vision examinations of OEF/OIF inpatients injured during combat or deployment from December 2004 to November 2006. "A specific eye complaint was unnecessary for referral, and the clinic attempted to see all Veterans and active-duty personnel admitted to the PRC."
Hartvigsen, 2014[22] KQ1	Cross-sectional; None	1716	100% Mild; endorsed one or more: amnesia or loss of memory; LOC, confusion or disorientation; excluded those with LOC > 30 mins.	All MVCs Included those who made an insurance claim within 42 days of injury, followed up at 6 weeks and 3, 6, 9, and 12 months following the insurance claim	NR	M = 37.7 (16.1)	812/1716 (47.3%) male	December, 1997 to November, 1999. All traffic injuries in persons 18 years or older who made an insurance claim in Saskatchewan, Canada.
Lemke, 2013[23] KQ1	Case control; Healthy controls (age M = 59, gender = 39% male); comparison data from a different study	60	Mild 37%, Moderate or Severe 38%, Penetrating 25%; Severity based on duration of LOC, PTA, GCS, history of penetrating head injury, imaging	Blast exposure 8.7 months (range 2-82 months) to initial testing	No open globe injury	Mean = 27	95% male	VHA hospital rehabilitation center; December, 2006 to January, 2012. TBI from combat blast exposure. Consecutive patients.
Lew, 2011[26] KQ1	Retrospect-ive cohort; Deployed non-TBI patients	12,521 9,196	Mild 85.4%; definition NR	Deployment-related TBI, including blast; blast exposure in 83.3% of cases, 70.4% of controls. Time NR	NR	31.3 (8.6)	93.9% male	Retrospective record review of 36,919 TBI evaluations performed in VHA between Oct 2007 and June 2009. 12,521 with deployment-related TBI and 9106 without TBI. Excluded patients with non-deployment TBI. Sample selection not specified, implies inclusion of all records.

Citation and KQ	Study design; TBI Comparison group	TBI, control sample size	TBI severity; definition	Mechanism of injury; time since injury	Ocular injuries	Age in years, M (SD)	Gender; Race/ Ethnicity	Sample characteristics and selection
Lew, 2009[25] KQ1	Cross-sectional; None	62	Mild, n=25 (40.3%) Moderate, n=12 (19.4%) Severe, n=25 (40.3%) Definition NR	Blast exposure M = 238.5 days	NR	27.3 (7.0)	93.5% male 74.2% Caucasian	Palo Alto PRC patients admitted Dec 2004 to March 2008 not previously admitted to the PRC for TBI treatment. Patients with blast-related TBI who completed both hearing and vision evaluations. "Retrospective chart review on all new admissions." 79 patients with blast-related TBI had hearing and vision evaluations ordered, but only 62 completed evaluations and were included.
Lew, 2007[24] KQ1	Cross-sectional; None	62	NR; 50% reported LOC; 31% reported only alteration of consciousness	79% blast, 8% MVC, 8% blunt trauma, 3% penetrating head injuries Time NR	NR	NR	NR	Palo Alto PNS; July 2006 to February 2007; 89% OEF/OIF Veterans, 5% Veterans from prior wars, 6% did not have combat related injuries (the latter 2 groups were retained to accurately represent the population flagged by the screening process). 71% PTSD, 55% Cognitive Disorder, 42% Both, 16% Neither. Consecutive participants.
Magone, 2014[28]	Case series	31	Mild; LOC for up to 30 min or an alteration in mental state and/ or memory loss for less than 24 hours	Blast-induced M = 50.5, SD = 19.8 months since injury, range 16-91 months	None	30.5(8.3)	94% male	All Washington DC VAMC eye clinic patients with blast induced mTBI; January 2009-December 2011.
Stelmack, 2009[27] KQ1 & KQ2	Case series and cross-sectional data; None	88	NR	NR	6% = orbit/ eye trauma	M = 31	92% male	Hines PNS; October 2005 to March 2008. "The majority (88%) were injured in OEF or OIF. Most (95%) presented with nonpenetrating injuries." No report of consecutive patient selection: "A list of patients was provided by a social work care manager and the Rehabilitation Service Line Coordinator."

Note. M = Mean; ED = Emergency Department; TBI = Traumatic Brain Injury; KQ = Key Question; NR = Not Reported; PRC = Polytrauma Rehabilitation Center; PNS = Polytrauma Network Site; MVC = Motor Vehicle Crash; DVBIC = Defense and Veterans Brain Injury Center; Abbreviated Injury Scale = AIS; DOD = Department of Defense; ACRM = American Congress of Rehabilitation Medicine; GCS = Glasgow Coma Scale; LOC = Loss of Consciousness, PTA = Posttraumatic Amnesia.

Summary of Findings

The following sections describe the findings from studies addressing Key Question 1 in this review. The sections are presented alphabetically according to visual dysfunction outcome, and include prevalence estimates from included studies as well as comparison data, when available.

Accommodation Dysfunction and Refractive Errors Findings

Seven studies described in 8 publications reported data on accommodation and refraction dysfunction in individuals with a history of TBI. These results are summarized in Table 3. Frequency of accommodation dysfunction and refractive errors varied greatly across the 6 studies reporting estimates not stratified by potentially confounding factors, ranging from under 10 percent in 2 studies,[18,19] around 20 percent in 3 studies,[20,24,27] to 66.7% in one study.[9,21] Only one study included a control group: Dougherty and colleagues report a 7.3% frequency of disorders of accommodation and refraction for those with TBI history compared to 5.8% for a similar population of control participants who were also deployed and blast-exposed, but who did not experience a TBI.[19]

Three studies reported frequency of accommodation dysfunction and refractive errors in those with TBI history stratified by subgroups. Brahm and colleagues reported a frequency of 39.6% for inpatients compared to 47.5% of outpatients.[17] The authors report higher frequencies for blast-exposed inpatients than non-blast exposed inpatients, but lower frequencies for blast-exposed outpatients compared to non-blast exposed outpatients. Goodrich and colleagues report similar rates of accommodation dysfunction and refractive errors for blast- and non-blast exposed inpatients (69.2% and 63.9%, respectively).[9] In a later paper on the same sample of inpatient Veterans treated in a PRC, Goodrich and colleagues report identical rates of accommodation dysfunction and refractive errors for both Veterans with TBI history with and without comorbid PTSD (66.7% in both groups).[21]

Table 3. Accommodation Dysfunction and Refractive Errors in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates (stratified if available)	P value
Brahm, 2009[17]	Pull-away method used for patients under age 40	Inpatient: 21/53 (39.6%) Outpatient: 47/99 (47.5%) Blast, inpatient: 19/45 (42.2%) No Blast, inpatient: 2/8 (25.0%) Blast, outpatient: 42/92 (45.7%) No Blast, outpatient: 5/7 (71.4%)	NR
Bulson, 2012[18]	Diagnosed accommodative dysfunction during eye clinic evaluation	3/100 (3%)	NR
Dougherty, 2011[19]	ICD-9-CM code 367 “Disorders of accommodation and refraction”	61/837 (7.3%) No TBI Control: 82/1417 (5.8%)	NR
Goodrich, 2013[9] Goodrich, 2013[21]	Accommodative amplitude tested monocularly on patients 40 years of age and younger with pull-away technique, rated as normal or deficient using age-established norms.	50/75 (66.7%) PTSD: 18/27 (66.7%) No PTSD: 32/48 (66.7%) Blast: 27/39 (69.2%) No Blast: 23/36 (63.9%)	PTSD vs no PTSD: p = “non-significant” Blast vs No Blast: p = “non-significant”
Goodrich, 2007[20]	Push-up/pull-away technique	10/46 (21.7%) Blast: 5/21 (23.8%) No Blast: 5/25 (20.0%)	NR

Citation	Outcome measure	Prevalence estimates (stratified if available)	P value
Lew, 2007[24]	NR; assessed at comprehensive eye exam.	13/62 (21%)	NR
Stelmack, 2009[27]	NR	17/88 (19%)	NR

Note. TBI = Traumatic Brain Injury; NR = Not Reported; PTSD = Post-traumatic Stress Disorder. No effect sizes were reported.

Convergence Insufficiency or Dysfunction Findings

Data on convergence insufficiency or dysfunction in individuals with a history of TBI were reported in 5 studies (described in 6 publications). These results are summarized in Table 4. Frequency of convergence insufficiency or dysfunction varied greatly across the 4 studies reporting estimates not stratified by potentially confounding factors, ranging from 11% in one study[27] to 62.5% in another.[9,21] The other 2 studies reported frequencies of 30.4% and 46%.[20,24] No studies with control groups reported data on convergence insufficiency or dysfunction.

Three studies report frequency of convergence insufficiency or dysfunction in those with TBI history stratified by subgroups. Brahm and colleagues report similar frequencies for inpatients and outpatients (42.6% and 48.4%, respectively).[17] The authors also report similar frequencies for blast- and non-blast exposed Veterans with the exception of a slightly higher rate for the outpatient, non-blast exposed subgroup (63.6%). Goodrich and colleagues report rates of convergence insufficiency or dysfunction for blast- and non-blast exposed Veterans of 78.3% and 48.0%, respectively, in a sample of PRC inpatients;[20] however, in a different sample of PRC inpatients, they report rates of 23.8% and 36.0% for blast- and non-blast exposed Veterans.[9,21] Goodrich and colleagues also report rates for those with and without comorbid PTSD (70.8% and 54.2%, respectively).[9,21]

Table 4. Convergence Insufficiency or Dysfunction in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates (stratified if available)	P value
Brahm, 2009[17]	Near Point of Convergence, > 7 cm	Inpatient: 26/61 (42.6%) Outpatient: 59/122 (48.4%) Blast, inpatient: 22/52 (42.3%) No Blast, inpatient: 4/9 (44.9%) Blast, outpatient: 52/111 (46.8%) No Blast, outpatient: 7/11 (63.6%)	NR
Goodrich, 2013[9] Goodrich, 2013[21]	Near Point of Convergence measured by the patient fixating on a single 20/50 letter, > 8 cm	30/48 (62.5%) PTSD: 17/24 (70.8%) No PTSD: 13/24 (54.2%) Blast: 18/23 (78.3%) No Blast: 12/25 (48.0%)	PTSD vs no PTSD: p = "non-significant" Blast vs No Blast: p = .062
Goodrich, 2007[20]	Near point of convergence was measured with a confrontation near target.	14/46 (30.4%) Blast: 5/21 (23.8%) No Blast: 9/25 (36.0%)	NR
Lew, 2007[24]	NR; assessed at comprehensive eye exam.	28/62 (46%)	NR
Stelmack, 2009[27]	NR	10/88 (11%)	NR

Note. TBI = Traumatic Brain Injury; NR = Not Reported; PTSD = Post-traumatic Stress Disorder. No effect sizes were reported.

Diplopia

Diplopia in individuals with a history of TBI was reported in 3 studies (described in 4 publications). These results are summarized in Table 5. Diplopia was infrequent in 2 studies (3% and 6.5%),[20,27] though significantly more common in another (40%).[9,21] No studies with control groups reported diplopia outcomes.

Two studies report frequency of diplopia in those with TBI history stratified by subgroups. One study reports rates of diplopia for blast- and non-blast exposed inpatients of 37.2% and 42.6% in a sample of PRC inpatients,[9] while another study reports rates of 0% and 12.0% for blast- and non-blast exposed Veterans.[20] One study reports rates for those with and without comorbid PTSD (44.7% and 36.5%, respectively).[21]

Table 5. Diplopia in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates (stratified if available)	P value
Goodrich, 2013[9] Goodrich, 2013[21]	NR	36/90 (40%) PTSD: 17/38 (44.7%) No PTSD: 19/52 (36.5%) Blast: 16/43 (37.2%) No Blast: 20/47 (42.6%)	Blast vs No Blast: p = .670
Goodrich, 2007[20]	Binocular vision function was assessed with cover tests in primary gaze at distance and near.	Total: 3/46 (6.5%) Blast: 0/21 (0.0%) No Blast: 3/25 (12.0%)	NR
Stelmack, 2009[27]	NR	3/88 (3%)	NR

Note. TBI = Traumatic Brain Injury; NR = Not Reported; PTSD = Post-traumatic Stress Disorder. No effect sizes were reported.

Dry Eye

Three studies reported data on dry eye in individuals with a history of TBI. These results are summarized in Table 6. Frequency of dry eye varied greatly across the 3 studies reporting estimates not stratified by potentially confounding factors, ranging from .1% to 2% in 2 studies[18,19] to 93% of Veterans obtaining at least one positive measure of dry eye in one study.[8] The study by Cockerham and colleagues reported significant differences between those with TBI history compared to a control group in terms of more than one positive test of dry eye or ocular strain, but non-significant differences for basal tear production, tear film break-up time, and tear osmolarity; however, the control group was potentially very different from cases in terms of factors other than TBI history.[8] Another study by Dougherty and colleagues reported a 0.1% frequency of dry eye for those with TBI history compared to 0.3% for a similar population of control participants who were deployed and blast-exposed, but did not experience a TBI.[19]

One study reported frequency of dry eye in those with TBI history stratified by blast and no blast mechanism of injury subgroups.[8] Different studies of dry eye yielded mixed findings among blast-exposed subgroups depending on the measures, and statistical significance of these differences was not reported in this study.

One study reported Ocular Surface Disease Index subscale scores for visual complaints, functional limitations, and sensitivity to conditions related to dry eye.[8] This study reported significantly higher scores indicating greater symptoms by those with TBI compared to controls; however, as noted above, control participants were likely different from cases in regards to more than just TBI status.

Table 6. Dry Eye in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates or Mean (SD) (stratified if available)	Prevalence estimates or Mean (SD) for control group (if available)	P value	Effect size (95% CI)
Bulson, 2012[18]	Diagnosed dry eye syndrome during eye clinic evaluation	2/100 (2%)	NR	NR	NR
Cockerham, 2013[8]	Basal tear production (BTP) < 4mm; tear film break-up time (TFBUT) < 10 sec.; tear osmolarity > 314 milliosmoles; ocular staining present (flourescein and lissamine green staining pattern scored on Oxford scale)	Total TBI, at least 1 positive test: 49/53 (93%) Total TBI, BTP: 19/53 (36%) Blast, BTP: 17/44 (39%) No Blast, BTP: 2/9 (22%) Total TBI, TFBUT: 14/53 (28%) Blast, TFBUT: 14/44 (33%) No Blast, TFBUT: 0/9 (0%) Total TBI, Tear Osmolarity: 19/53 (58%) Blast, Tear Osmolarity: 13/44 (54%) No Blast, Tear Osmolarity: 6/9 (67%) Total TBI, Ocular Stain: 42/53 (28%) Blast, Ocular Stain: 35/44 (80%) No Blast, Ocular Stain: 7/9 (78%)	At least 1 positive test: 8/18 (44%) BTP: 3/18 (17%) TFBUT: 1/18 (6%) Tear Osmolarity: 4/18 (33%) Ocular Stain: 5/18 (28%)	At least 1 positive test: p < .001 BTP: p = .13 TFBUT: p = .06 Tear Osmolarity: p = .15 Ocular Stain: p < .001	At least 1 positive test: chi-square = 19.56 BTP: chi-square = 2.3 TFBUT: chi-square = 3.57 Tear Osmolarity: chi-square = 2.07 Ocular Stain: chi-square = 15.91 No significant differences in results accounting for those on antidepressant medications considered risk factors for dry eye syndrome.
	3 Ocular Surface Disease Index (OSDI) categories: Visual complaints; Functional limitations; Sensitivity to conditions. Each of 12 questions scored 1 (mild) to 4 (severe) with total score tallied. Results reported as mean (SD) OSDI scores.	Total TBI, visual complaints: 23 (SD = 10) Blast, visual complaints: 24 (SD = 10) No Blast, visual complaints: 16 (SD = 10) Total TBI, functional limitations: 19 (SD = 28) Blast, functional limitations: 18 (SD = 28) No Blast, functional limitations: 24 (SD = 29) Total TBI, sensitivity: 17 (SD = 29) Blast, sensitivity: 19 (SD = 31) No Blast, sensitivity: 7 (SD = 17)	visual complaints: 2 (4) functional limitations: 0 (0) sensitivity: 1 (4)	visual complaints: p < .001 functional limitations: p < .001 sensitivity: p = .03	visual complaints: Z = 3.5 functional limitations: Z = 3.6 sensitivity: Z = 2.2
Dougherty, 2011[19]	ICD-9-CM code 375 “Disorders of lacrimal system”	1/837 (0.1%)	4/1417 (0.3%)	NR	NR

Note. TBI = Traumatic Brain Injury; NR = Not Reported; PTSD = Post-traumatic Stress Disorder.

Nystagmus or Fixation Dysfunction

Data on nystagmus or fixation dysfunction in individuals with a history of TBI were reported in 5 studies (described in 6 publications). These results are summarized in Table 7. Frequency of nystagmus or fixation dysfunction ranged from 0%[27] to 23.4%[9,21] in 4 studies reporting results not stratified by potentially confounding factors. The other 2 studies reported frequencies of 2.2% and 5%.[20,24] No studies with control groups reported outcome data on nystagmus or fixation dysfunction.

Three studies report frequency of nystagmus or fixation dysfunction in those with TBI history stratified by subgroups. Brahm and colleagues report similar frequencies for inpatients and outpatients (9.5% and 6.5%, respectively).[17] The authors report similar frequencies for blast- and non-blast exposed Veterans with the exception of similarly exposed outpatient Veterans (7.1% vs 0.0%, respectively). Goodrich and colleagues report rates of nystagmus or fixation dysfunction for blast- and non-blast exposed Veterans of 0% and 4.0%, respectively, in a sample of PRC inpatients.[20] In a different sample of PRC inpatients, they report rates of 17.4% and 29.2% for blast- and non-blast exposed Veterans and report rates for those with and without comorbid PTSD as 23.6% and 23.2%, respectively.[9,21]

Table 7. Nystagmus or Fixation Dysfunction in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates (stratified if available)	P value
Brahm, 2009[17]	Various targets depending on patient abilities and acuity limits including penlights, colored targets, and single letters down to 1.25 M letter size.	Inpatient: 6/63 (9.5%) Outpatient: 8/124 (6.5%) Blast, inpatient: 5/54 (9.3%) Non-blast, inpatient: 1/9 (11.1%) Blast, outpatient: 8/112 (7.1%) Non-blast, outpatient: 0/12 (0.0%)	NR
Goodrich, 2013[9] Goodrich, 2013[21]	Fixation was assessed by having the patient fixate on a 20/50 near target and noting any unsteadiness or nystagmus	22/94 (23.4%) PTSD: 9/38 (23.6%) No PTSD: 13/56 (23.2%) Blast: 8/46 (17.4%) No Blast: 14/48 (29.2%)	PTSD vs no PTSD: p = "non-significant" Blast vs No Blast: p = "non-significant"
Goodrich, 2007[20]	Fixation stability on a near target was assessed for steadiness, and any nystagmus noted	Total: 1/46 (2.2%) Blast: 0/21 (0.0%) Nonblast: 1/25 (4.0%)	NR
Lew, 2007[24]	NR; assessed at comprehensive eye exam.	3/62 (5%)	NR
Stelmack, 2009[27]	NR	0/88 (0%)	

Note. TBI = Traumatic Brain Injury; NR = Not Reported; PTSD = Post-traumatic Stress Disorder; M = M-unit, 1 M-unit is the ability to recognize a standard letter at a distance of 1 meter. No effect sizes were reported.

Photosensitivity, Photophobia, or Light Sensitivity

Three studies published in 4 papers reported data on photosensitivity, photophobia, or light sensitivity in individuals with a history of TBI. These results are summarized in Table 8. Frequency of photosensitivity, photophobia, or light sensitivity when assessed by patient self-report in 3 studies ranged from 51% to 59%.[9,18,21,24] The study by Bulson and colleagues also reported photosensitivity diagnosed during an eye clinic exam; in this study, only 5% of patients with TBI history received such a diagnosis.[18]

One study reported frequency of photosensitivity, photophobia, or light sensitivity as 67.4% and 77.5% in those with TBI history stratified by blast versus no blast mechanism of injury subgroups respectively, a difference that was statistically significant.[9,21] This same study reported rates of 86.1% for those with PTSD compared to only 27.1% for those without. This comparison was statistically significant ($p < .001$) and remained so after adjustment for age, medication, TBI severity, and mechanism of injury ($p = .002$).

Table 8. Photosensitivity, Photophobia, or Light Sensitivity in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates (stratified if available)	P value	Effect size (95% CI)
Bulson, 2012[18]	22-item Neurobehavioral Symptom Inventory (NSI-22), self-report measure item assessing "light sensitivity" with score of 2 or greater	54/100 (54%)	NR	NR
	Diagnosed photosensitivity during eye clinic evaluation	5/100 (5%)	NR	NR
Goodrich, 2013[9] Goodrich, 2013[21]	Self-reported photosensitivity	44/86 (51%) PTSD: 31/36 (86.1%) No PTSD: 13/48 (27.1%) Blast: 31/46 (67.4%) No Blast: 13/40 (77.5%)	PTSD vs no PTSD: p < .001 PTSD vs no PTSD adjusted for age, medication, TBI severity, and mechanism of injury: p = .002 Blast vs No Blast: p = .002	PTSD vs no PTSD: chi-square = 23.08 PTSD vs no PTSD adjusted for age, medication, TBI severity, and mechanism of injury: Adjusted OR = 8.22 (95% CI 2.20-30.70)
Lew, 2007[24]	Self-reported photosensitivity during evaluation	36/62 (59%)	NR	NR

Note. TBI = Traumatic Brain Injury; NR = Not Reported; PTSD = Post-traumatic Stress Disorder.

Pursuit or Saccadic Dysfunction

Data on pursuit or saccadic dysfunction in individuals with a history of TBI were reported in 5 studies (described in 6 publications). These results are summarized in Table 9. Frequency of pursuit or saccadic dysfunction ranged from 2%[27] to 70.8% (saccadic dysfunction) and 37.4% (pursuit dysfunction)[9,21] in 4 studies reporting results not stratified by potentially confounding factors. The other 2 studies reported saccadic and/or pursuit dysfunction frequencies of 19.6% and 25%.[20,24] No studies with control groups reported outcome data on pursuit or saccadic dysfunction.

Three studies report frequency of pursuit or saccadic dysfunction in those with TBI history stratified by subgroups. Brahm and colleagues report similar frequencies for inpatients and outpatients (30.2% and 23.4%, respectively).[17] When analyzed by blast versus non-blast exposure mechanism of injury, the authors report higher frequencies for those exposed to blast for both inpatients and outpatients. Goodrich and colleagues report rates of pursuit or saccadic dysfunction in the opposite direction for blast- and non-blast exposed Veterans (4.8% and 32.0%, respectively) in a sample of PRC inpatients.[20]

Table 9. Pursuit or Saccadic Dysfunction in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates (stratified if available)	P value
Brahm, 2009[17]	Various targets depending on patient abilities and acuity limits including penlights, colored targets, and single letters down to 1.25 M letter size.	Inpatient: 19/63 (30.2%) Outpatient: 29/124 (23.4%) Blast, inpatient: 18/54 (33.3%) Non-blast, inpatient: 1/9 (11.1%) Blast, outpatient: 27/112 (24.1%) Non-blast, outpatient: 2/12 (16.7%)	NR
Goodrich, 2013[9] Goodrich, 2013[21]	Saccades assessed by having a patient switch fixation between 2 targets located approximately 10 cm apart and 40 cm in front of midline; rated as normal or deficient following Northeastern State University College of Optometry oculomotor test criteria. Pursuits evaluated by having the patient follow a target that was moved into the cardinal positions of gaze.	Saccadic dysfunction: 68/96 (70.8%) Pursuit abnormalities: 37/99 (37.4%) PTSD, Saccadic dysfunction: 26/39 (66.7%) No PTSD, Saccadic dysfunction: 42/57 (73.6%) PTSD, Pursuit abnormalities: 14/41 (34.1%) No PTSD, Pursuit abnormalities: 23/58 (39.6%) Blast, Saccadic dysfunction: 29/50 (58.0%) No Blast, Saccadic dysfunction: 39/46 (84.8) Blast, Pursuit abnormalities: 15/50 (30.0%) No Blast, Pursuit abnormalities: 22/49 (44.9%)	PTSD vs no PTSD: p = "non-significant" Saccadic dysfunction, Blast vs No Blast: p = .006 Pursuit abnormalities: p = "non-significant"
Goodrich, 2007[20]	Saccadic eye movements were assessed for accuracy and speed of eye movements between the targets. Pursuit eye movements were assessed for accuracy and smoothness.	Total: 9/46 (19.6%) Blast: 1/21 (4.8%) No Blast: 8/25 (32.0%)	NR
Lew, 2007[24]	NR; assessed at comprehensive eye exam.	15/62 (25%)	NR
Stelmack, 2009[27]	NR	2/88 (2%)	NR

Note. TBI = Traumatic Brain Injury; NR = Not Reported; PTSD = Post-traumatic Stress Disorder. No effect sizes were reported.

Strabismus and Cranial Nerve Palsy

Strabismus and cranial nerve palsy in individuals with a history of TBI was reported in 5 studies (described in 6 publications). These results are summarized in Table 10. Frequency of strabismus and cranial nerve palsy was rare in most studies, ranging from 0% to 11% in 3 studies[19,24,27] though one study reported that 37.5% of Veterans with TBI history had strabismus diagnosed during an ocular exam. [9,21] One study reported similar rates of strabismus and other disorders of binocular eye movement in Veterans with TBI history compared to similar controls (0.6% vs 0.4%, respectively).[19]

Two studies report frequencies of strabismus and cranial nerve palsy in those with TBI history stratified by patient status. Brahm and colleagues report higher frequencies for inpatients (25.0%) than outpatients (7.3%), though they do not report statistical significance. Their results were similar after subanalysis by mechanism of injury.[17] Goodrich and colleagues report non-significantly different rates of strabismus and cranial nerve palsy stratified by mechanism of injury and PTSD diagnosis in a sample of PRC inpatients.[9,21]

Table 10. Strabismus and Cranial Nerve Palsy in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates (stratified if available)	P value	Effect size (95% CI)
Brahm, 2009[17]	NR	Inpatient: 17/68 (25.0%) Outpatient: 9/124 (7.3%) Blast, inpatient: 14/57 (24.6%) Non-blast, inpatient: 3/11 (27.3%) Blast, outpatient: 8/112 (7.1%) Non-blast, outpatient: 1/12 (8.3%)	NR	NR
Dougherty, 2011[19]	ICD-9-CM code 378 "Strabismus and other disorders of binocular eye movements"	5/837 (0.6%) No TBI Control: 5/1417 (0.4%)	NR	NR
Goodrich, 2013[9] Goodrich, 2013[21]	Ocular exam categorized by type of tropia (abnormal binocular eye position)	33/88 (37.5%) PTSD: 10/38 (26.3%) No PTSD: 23/50 (46.0%) Blast: 12/42 (28.6%) No Blast: 21/46 (45.7%)	PTSD vs no PTSD: p = .10 Blast vs No Blast: p = .125	PTSD vs no PTSD: chi-square = 2.78
Lew, 2007[24]	NR; strabismus assessed at comprehensive eye exam	7/62 (11%)	NR	NR
Stelmack, 2009[27]	NR; strabismus	3/103 (3%)	NR	NR
	Cranial Nerve Palsy or Disorder diagnosed by oculomotor function examination	0/88 (0%)	NR	NR

Note. TBI = Traumatic Brain Injury; NR = Not Reported; PTSD = Post-traumatic Stress Disorder.

Visual Field Defect

Visual field defects were assessed in a variety of ways in 5 included studies.[17-20,27] All reported low frequency of visual field defects in Veterans with TBI history (6% or less) with the exception of one study by Brahm and colleagues which reported rates of 3.2% and 38.8% for outpatient and inpatient groups, respectively.[17] Dougherty and colleagues reported similar rates for TBI and control groups.[19] Results are reported in Table 11.

Table 11. Visual Field Defect in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates (stratified if available)
Brahm, 2009[17]	Confrontation or Goldmann	38.8% inpatient, 3.2% outpatient
Bulson, 2012[18]	Diagnosed visual field defect during eye clinic evaluation	2/100 (2%)
Dougherty, 2011[19]	ICD-9-CM code 377 "Disorders of optic nerve and visual pathways"	1/837 (0.1%) No TBI Control: 4/1417 (0.3%)

Goodrich, 2007[20]	Paracentral Scotoma assessed by confrontation or Goldmann visual field testing	Right eye: 0/50 (0.0%) Left eye: 2/50 (4.0%)
	Visual field defect assessed by confrontation or Goldmann visual field testing	Right eye: 3/50 (6.0%) Left eye: 3/50 (6.0%)
	Hemianopsia, Left, with Macular Sparing assessed by confrontation or Goldmann visual field testing	Right eye: 3/50 (6.0%) Left eye: 4/50 (8.0%)
	Hemianopsia, Left, with Macular Splitting assessed by confrontation or Goldmann visual field testing	Right eye: 0/50 (0.0%) Left eye: 1/50 (2.0%)
	Hemianopsia, Right, with Macular Sparing assessed by confrontation or Goldmann visual field testing	Right eye: 0/50 (0.0%) Left eye: 1/50 (2.0%)
	Quadrantopsia, Left Inferior assessed by confrontation or Goldmann visual field testing	Right eye: 1/50 (2.0%) Left eye: 0/50 (0.0%)
	Quadrantopsia, Left Superior assessed by confrontation or Goldmann visual field testing	Right eye: 1/50 (2.0%) Left eye: 0/50 (0.0%)
Stelmack, 2009[27]	Visual field defect assessed by confrontation or Goldmann visual field testing	5/88 (6%)
	Optic Nerve and Visual Pathways Disorders assessed by confrontation or Goldmann visual field testing	2/88 (2%)

Note. TBI = Traumatic Brain Injury; NR = Not Reported. No p values or effect sizes were reported.

Visual Impairment or Dysfunction

Various aspects of visual impairment or dysfunction not previously categorized in this report were reported in the body of included literature. Three studies reported visual impairment diagnoses[17-19] while 8 studies (described in 9 papers) described self-reported visual impairment.[9,17,18,21-23,25-27] The variety of visual impairment/dysfunction and assessment tools precludes concise synthesis of data from this group of studies, though individual study results are reported in Table 12. One study described changes in self-reported visual impairment over time in a population of Canadian civilian adults who had sustained a TBI in a motor vehicle crash.[22] This study documents a decline in self-reported visual symptoms from 6 weeks to 12 months following injury.

One study reported that IDC-9-CM diagnosis of visual disturbances was significantly more common in those with TBI history compared to a control group without a TBI history that had similar characteristics (1.9% vs 0.6%, $p = .003$).[19] Another study compared visual impairment assessed using the 25-item National Eye Institute Visual Functioning Questionnaire (VFQ-25) self-report measure in Veterans with data from healthy controls obtained from another published paper. The authors note that Veterans with TBI history reported significantly worse functioning on this measure compared with controls ($p = .001$), though the control group was likely very different from cases in ways other than just TBI history.[23] Lew and colleagues compared self-reported visual symptoms in previously deployed Veterans with and without TBI history. After adjustment for demographic characteristics and hearing impairment, the authors reported that TBI and blast accounted for 0.69% and 0.14% of the variance in self-reported vision impairment.[26]

Table 12. Visual Impairment or Dysfunction in Individuals with TBI History

Citation	Outcome measure	Prevalence estimates or Mean (SD) (stratified if available)	Prevalence estimates or Mean (SD) for control group (if available)	P value	Effect size (95% CI)
Visual Impairment or Dysfunction, Diagnosed					
Brahm, 2009[17]	Visual acuity assessed by Feinbloom chart at 10 feet, Snellen worse than 20/60	Inpatient: 14/63 (23.2%) Outpatient: 2/124 (1.6%) Blast, inpatient: 11/54 (20.4%) Non-blast, inpatient: 3/9 (33.3%) Blast, outpatient: 2/112 (1.8%) Non-blast, outpatient: 0/12 (0.0%)	NR	NR	NR
Bulson, 2012[18]	Diagnosed uncorrected refractive error during eye clinic evaluation	22/100 (22%)	NR	NR	NR
Dougherty, 2011[19]	ICD-9-CM code 369 "Blindness and low vision"	3/837 (0.4%)	2/1417 (0.1%)	NR	NR
	ICD-9-CM code 378 "Other disorders of eye"	5/837 (0.6%)	5/1417 (0.4%)	NR	NR
	ICD-9-CM code 368 "Visual Disturbances"	16/837 (1.9%)	8/1417 (0.6%)	0.003	chi-square = 9.063
Visual Impairment or Dysfunction, Self-Reported					
Brahm, 2009[17]	Self-reported visual impairment	Inpatient: 46/61 (75.4%) Outpatient: 94/124 (75.8%) Blast, inpatient: 41/53 (77.4%) Non-blast, inpatient: 5/8 (62.5%) Blast, outpatient: 85/112 (75.9%) Non-blast, outpatient: 9/12 (75.0%)	NR	NR	NR
Bulson, 2012[18]	NSI-22, self-report measure item assessing "blur/trouble seeing" with score of 2 or greater	47/100 (47%)	NR	NR	NR
Goodrich, 2013[9] Goodrich, 2013[21]	Self-reported blurred vision, hazy vision, or other general visual symptoms	67/100 (67.0%) PTSD: 31/41 (75.6%) No PTSD: 36/59 (61.0%) No Blast: 34/49 (69.4%) Blast: 33/50 (66.0%)	NR	PTSD vs no PTSD: p = .19 Blast vs No Blast: p = "non-significant"	PTSD vs no PTSD: chi-square = 1.72

Citation	Outcome measure	Prevalence estimates or Mean (SD) (stratified if available)	Prevalence estimates or Mean (SD) for control group (if available)	P value	Effect size (95% CI)
Hartvigsen,2014[22]	Self-reported "vision problems"	6 weeks: 276/1716 (19.3) 3 months: 232/1716 (16.9) 6 months: 208/1716 (16.4) 9 months: 178/1716 (15.9) 12 months: 156/1716 (14.4)	NR	NR	NR
Lemke, 2013[23]	25-item National Eye Institute Visual Functioning Questionnaire (VFQ-25) self-report measure	General vision mean: 69 Ocular pain mean: 81 Near activities mean: 72 Distance activities mean: 77 Social functioning mean: 85 Mental health mean: 69 Role difficulties mean: 69 Dependency mean: 75 Driving mean: 73 Color vision mean: 89 Peripheral vision mean: 71 Composite score mean: 75	General vision mean: 83 Ocular pain mean: 90 Near activities mean: 92 Distance activities mean: 93 Social functioning mean: 99 Mental health mean: 92 Role difficulties mean: 93 Dependency mean: 92 Driving mean: 99 Color vision mean: 87 Peripheral vision mean: 98 Composite score mean: 97	Healthy control composite score: $p < .001$ Comparisons to patients with diabetes mellitus, glaucoma, and macular degeneration: $p < .001$ Comparisons to patients with dry eye: $p < .05$ Comparisons to patients with macular telangiectasia and cataract: p = "non-significant"	NR
Lew, 2011[26]	NSI-22, self-report measure item assessing "vision problems, blurring, trouble seeing."	44.5% Vision only: 9.9% Vision and hearing: 34.6% Blast: 44.2% Blast, vision only: 8.8% Blast, vision and hearing: 35.4% No blast: 46.0% No blast, vision only: 15.7% No blast, vision and hearing: 30.3%	Blast: 33.1% Blast, vision only: 8.5% Blast, vision and hearing: 24.6% No blast: 35.9% No blast, vision only: 13.2% No blast, vision and hearing: 22.7%	Regression predicting visual impairment from demographics, hearing, TBI, and blast: $p < .0001$	TBI accounted for .69% and blast for .14% of variance in vision impairment adjusting for demographics and hearing impairment.
Lew, 2009[25]	Combination of vision status self-report before/after injury; distance and near visual acuity measurements; visual field status; binocular vision status; and other vision measures, including reading speed and comprehension assessments.	41/62 (66%) Vision only: 21 (33.9%) Vision and hearing: 20 (32.3%)	NR	NR	NR
Stelmack, 2009[27]	NSI-22, self-report measure item assessing "vision problems, blurring, trouble seeing."	55/88 (63%)	NR	NR	NR

Note. TBI = Traumatic Brain Injury; NR = Not Reported; PTSD = Post-traumatic Stress Disorder.

KEY QUESTION 2: What are the types of visual dysfunction reported by individuals who have been diagnosed with a TBI and are presenting to Eye Care clinics?

Summary of Findings

Four studies met inclusion criteria for Key Question 2. All 4 provided case series data. Study and sample characteristics are reported in Table 2. Results are presented by outcome in Table 13, which includes presentation of results stratified by or adjusted for key modifiers such as mechanism of injury and inpatient versus outpatient status, when available. One study reports data from civilians[16] though 3 others report data from Veterans treated within the VA.[18,27,28] Two of the VA studies also provided data relevant to Key Question 1, describing frequency of visual dysfunction in populations of Veterans with TBI history, while also reporting data solely from those who were seen in eye care clinics.[15,24] As expected, the rates of visual dysfunction for Veterans seen in eye care clinics are higher than rates for unselected samples (*ie*, samples not selected studies based on visual dysfunction). Studies meeting inclusion criteria for Key Question 2 reported similar types of visual dysfunction as studies included for Key Question 1.

Given that Key Question 2 relates to types of visual dysfunction seen in eye care clinics, quality considerations are primarily related to generalizability of population and setting as summarized in Key Question 1. One included study reports on TBI in civilian populations[16]; the other 3 studies providing data relevant to Key Question 2 report data from Veterans presenting to eye clinics in conjunction with VA care including PNS and post-deployment clinics and referrals.[18,27,28]

Table 13. Visual Dysfunction in Individuals with TBI Presenting to an Eye Care Clinic

Citation	Outcome measure	Frequencies (stratified if available)	P value	Effect size (95% CI)
Accommodation Dysfunction and Refractive Errors				
Bulson, 2012[18]	Diagnosed accommodative dysfunction during eye clinic evaluation	3/23 (13%)	NR	NR
Magone, 2014[28]	Diagnosed when the lower limit of the expected value for the patient's age was abnormal according to Hofstetter's formula	7/31 (23%)	NR	NR
Stelmack, 2009[27]	NR	17/36 (47%)	NR	NR
Convergence Insufficiency or Dysfunction				
Alvarez, 2012[16]	Near point of convergence was measured with an approaching near target.	130/557 (23.3%) MVC: 90/395 (22.7%) Fall: 17/82 (20.7%) Strike/blow: 15/51 (29.4%) Sports: 2/14 (14.3%) Other: 6/15 (40.0%) Inpatient: 63/270 (23.3%) Outpatient: 67/287 (23.3%)	p = 0.36 (mechanism of injury)	chi-square = 4.4 (mechanism of injury)
Magone, 2014[28]	Diagnosed when there was exophoria greater at near compared with distance, an abnormal near point of convergence (NPC), and positive fusional vergence. NPC measures the ability to maintain binocularly with increased accommodative and vergence demand. NPC was measured with the red lens method. A red lens was placed in front of patient's right eye and the muscle light was moved close to the patient until the break (2 lights) was reported or a break in fusion was observed by the examiner. A remote NPC with a break of greater than 8 cm and recovery greater than 12 cm was considered abnormal.	8/31 (25%)	NR	NR
Stelmack, 2009[27]	NR	10/36 (28%)	NR	NR
Diplopia				
Magone, 2014[28]	NR	4/31 (13%)	NR	NR
Stelmack, 2009[27]	NR	3/36 (8%)	NR	NR

Citation	Outcome measure	Frequencies (stratified if available)	P value	Effect size (95% CI)
Dry Eye Syndrome				
Alvarez, 2012[16]	Slit-lamp evaluation of the corneal tear layer; portable blue filter with fluorescent staining was used for some inpatients.	58/557 (10.4%) Inpatient: 32 (11.9%) Outpatient: 26 (9.1%)	NR	NR
Bulson, 2012[18]	Diagnosed dry eye syndrome during eye clinic evaluation	2/23 (9%)	NR	NR
Nystagmus or Fixation Dysfunction				
Alvarez, 2012[16]	Findings outside the normal range on oculomotor examination	22/557 (3.9%) Inpatient: 10 (3.7%) Outpatient: 12 (4.2%)	NR	NR
Stelmack, 2009[27]	NR	0/36 (0%)	NR	NR
Photosensitivity, Photophobia, or Light Sensitivity				
Alvarez, 2012[16]	Patient sensitivity to direct light stimulation during pupil examination	56/557 (10.1%) Inpatient: 19 (7.0%) Outpatient: 35 (12.2%)	p = .04 (inpatient; non-significant after Bonferroni adjustment)	z = 2.06 (inpatient)
Bulson, 2012[18]	Diagnosed photosensitivity during eye clinic evaluation	5/23 (22%)	NR	NR
Magone, 2014[28]	Self-reported by patient	17/31 (55%)	NR	NR
Pursuit or Saccadic Dysfunction				
Alvarez, 2012[16]	Patients asked to track a transilluminator or other visual target. Pursuit and saccadic movements were noted to be smooth and accurate, or had fixation losses, or abnormal saccades, respectively (or were unable to perform the test)	42/557 (7.5%) Inpatient: 23 (8.5%) Outpatient: (19 (6.6%)	NR	NR
Stelmack, 2009[27]	NR	2/36 (6%)	NR	NR

Citation	Outcome measure	Frequencies (stratified if available)	P value	Effect size (95% CI)
Strabismus and Cranial Nerve Palsy				
Alvarez, 2012[16]	Cranial Nerve Palsy or Disorder diagnosed by oculomotor function examination	Third cranial nerve: 33 (5.9%) Inpatient, third: 19 (7.0%) Outpatient, third: 14 (4.9%) Fourth cranial nerve: 56 (10.1%) Inpatient, fourth: 28 (10.4%) Outpatient, fourth: 28 (9.8%) Sixth cranial nerve: 24 (4.3%) Inpatient, sixth: 19 (7.0%) Outpatient, sixth: 35 (12.2%)	p = .002 (inpatient, sixth cranial nerve palsy)	z = 3.08 (inpatient, sixth cranial nerve palsy)
Stelmack, 2009[27]	NR; strabismus	3/36 (8%)	NR	NR
	Cranial Nerve Palsy or Disorder diagnosed by oculomotor function examination	0/36 (0%)	NR	NR
Visual Field Defect				
Alvarez, 2012[16]	Homonymous Hemianopsia assessed by confrontation or Humphrey Field Test, depending on patient functionality	Right: 21/557 (3.8%) Left: 24/557 (4.3%)	NR	NR
	Quadrantopsia assessed by confrontation or Humphrey Field Test, depending on patient functionality	28 (15.7%)	NR	NR
Bulson, 2012[18]	Diagnosed visual field defect during eye clinic evaluation	2/23 (9%)	NR	NR
Stelmack, 2009[27]	Visual field defect assessed by confrontation or Goldmann visual field testing	5/36 (14%)	NR	NR
	Optic Nerve and Visual Pathways Disorders assessed by confrontation or Goldmann visual field testing	2/36 (6%)	NR	NR
Visual Impairment or Dysfunction				
Alvarez, 2012[16]	Visual acuity assessed by Snellen (eye chart) with targets appropriate to patient's cognitive functioning	>/= 20/60 = 473/557 (84.9%) 20/70-20/100 = 16/557 (2.9%) <20/100 = 27/557 (4.8%) No light perception = 4 (.07%) Patient unable to respond = 37 (6.6%)	NR	NR
Bulson, 2012[18]	Diagnosed uncorrected refractive error during eye clinic evaluation	22/23 (96%)	NR	NR
Magone, 2014[28]	Distance visual acuity was measured using the projected Snellen eye chart	21/31 (68%)	NR	NR

Note. TBI = Traumatic Brain Injury; NR = Not Reported; Hofstetter's formula: 18.5 - (0.30 * patient age in years)

SUMMARY AND DISCUSSION

SUMMARY OF EVIDENCE BY KEY QUESTION

Key Question 1

Twelve studies meeting inclusion criteria provided data relevant to Key Question 1.[8,9,17-27] These studies addressed a variety of objectively assessed and self-reported visual dysfunctions including accommodation dysfunction and refractive errors; convergence insufficiency or dysfunction; diplopia; dry eye; nystagmus or fixation dysfunction; photosensitivity, photophobia, or light sensitivity; pursuit or saccadic dysfunction; strabismus and cranial nerve palsy; visual field defect; and other types of visual impairment or dysfunction.

Evidence from a large study by Dougherty and colleagues[19] suggests that visual dysfunction is not commonly diagnosed in U.S. Service Members who experienced a TBI but who do not have an ocular injury or prior history of visual or ocular dysfunction. However, prevalence estimates of visual dysfunction varied greatly across the studies included in this review. The differences in frequencies reported across studies are likely due to differences in study populations and settings. Specifically, studies included different proportions of participants with mild versus moderate/severe TBI history, inpatient and outpatient settings, and settings treating only patients with current symptoms.

The study by Dougherty and colleagues[19] provides strong evidence about the prevalence of visual dysfunction diagnosed in Veterans who have TBI documented in their VA medical records. However, there are likely many other Veterans who may have experienced one or more TBIs or blast exposures but do not have this coded in their medical record for a variety of reasons (*eg*, not reporting TBIs or blast exposure while in combat, not being aware that blast exposure or hit to the head is severe enough to warrant a TBI diagnosis, *etc*). While large administrative datasets can provide valuable information about entire populations of Veterans served by the VA, these data need to be interpreted with caution because of the lack of granularity and manner in which the data is collected and compiled. For example, in the Dougherty study, it is unclear what type of provider diagnosed visual dysfunction, and what types of assessments were conducted. This study relied on ICD-9 data likely gathered from routine eye care appointments; data gathered in non-screening contexts are expected to provide lower prevalence estimates than data gathered during comprehensive screening assessments for a broad range of visual dysfunction.

Many of the included studies were conducted at PRCs or PNSs, in particular, at Palo Alto VA clinics. We contacted some of the authors in an attempt to ensure that data on the same patients were not reported in more than one study, though it is possible that there may be some overlap in study populations across some of the included studies. Because of the productivity of the researchers at these facilities, it is likely that this review provides a relatively thorough summary of data for these specific clinical populations, and additional research in other settings is likely needed to provide a more general, comprehensive picture of visual dysfunction in U.S. Service Members and Veterans across clinical settings.

Though this review was not designed to determine whether visual dysfunction is more common in individuals with TBI history compared to those without, similar inconsistency in results across

settings was found in studies comparing visual dysfunction frequency in individuals with TBI history versus control participants without TBI history. Overall, while visual dysfunction may be commonly reported by or diagnosed in some groups with TBI history (*eg*, PRC inpatients screened using comprehensive visual examination, many with comorbid ocular injuries[9,21]), visual dysfunction is infrequently diagnosed in other groups with TBI history (*eg*, unscreened samples of U.S. Service members without ocular injuries or prior history of visual dysfunction[19]).

Key Question 2

Only 4 studies meeting inclusion criteria provided evidence for Key Question 2.[16,18,27,28] These studies reported outcomes similar to those found for Key Question 1. In aggregate, all studies included in this review can provide policymakers and clinicians with a rough estimate of the types of visual dysfunctions that some individuals with TBI history may present with in eye care clinic settings, though the findings are limited by the small body of included literature.

Study Characteristics and Quality

Study quality was assessed pertaining to the Key Questions for all included studies. Though we excluded studies selecting patients based on visual dysfunction for Key Question 1, some methods such as outcome assessment were unclearly reported in some studies (see Tables 3-13), resulting in the potential for biased results. Additionally, none of the included studies stratified results by TBI severity. The best estimates of frequency of clinically significant, diagnosed visual dysfunction come from a study by Dougherty and colleagues which excluded patients with ocular injuries or visual disorders prior to the TBI.[19] This study did not screen patients to determine prevalence, instead reporting U.S. Service Member diagnostic results from a large-scale administrative military healthcare database. Eight studies reporting prevalence estimates included only those patients with TBI history who had current symptoms and were being treated at VA PRCs and PNSs; not surprisingly, frequencies of visual dysfunction were significantly higher in these studies.

Publication Bias

Given that the body of evidence relevant to this review was based on observational studies, and none of the studies reported registered protocols or *a priori* established primary aims or analyses, we were not able to formally assess publication bias.

Heterogeneity

Included studies addressed a variety of visual outcomes assessed by different methods in unique populations. Therefore, we were unable to combine studies quantitatively. Instead we provided a summary of findings for each key question and group of outcomes, with tabular presentations of study-level results. We provided a synthesis of the data for certain outcomes assessed across multiple studies, though results were often inconsistent across these studies, likely due to heterogeneity of study populations and assessment methods.

Applicability of Findings to the VA Population

The findings from this body of evidence are very applicable to the VA population, as the majority of the included studies were conducted in VA or U.S. military healthcare settings. Prevalence

estimates of a broad group of unscreened U.S. Service Members suggest that clinically significant, diagnosed visual dysfunction is uncommon in this general population,[19] though this study by Dougherty and colleagues relied on data from 2004 through 2007; it is likely that as the OEF/OIF/OND conflicts progressed, clinicians and Veterans became more aware of both TBI and potential associations with visual dysfunctions. Therefore, an examination of more recent data on these populations and outcomes is likely warranted to ensure comprehensiveness and generalizability of the results. Results from studies of patients screened for visual problems at VA PNSs or PRCs suggest that visual dysfunction is quite common for this group of Veterans who often have histories of severe injuries and multiple comorbid conditions.

FUTURE RESEARCH NEEDS

Well-designed, large-scale, prospective cohort studies on populations of interest provide the most accurate prevalence estimates and information about the relative frequency of symptoms. Ideally, longitudinal data on a large group of U.S. Service Members could be collected prior to TBI exposure. Screening the entire group for visual dysfunction after a portion had experienced a TBI could provide precise estimates of relative risk and prevalence when TBI history, ocular injuries, and time since injury are accounted for. Additionally, potential moderating variables such as comorbid PTSD or blast versus other mechanism of injury should be examined since studies included in this review provide preliminary evidence of associations among these variables and some types of visual dysfunction. Longitudinal studies could also better answer remaining questions related to prognosis over time than many of the cross-sectional studies included in this report. Research on effective treatments for visual problems experienced by individuals with TBI history was outside the scope of this review, though this information could help guide VA treatment options for affected Veterans, and additional research may be needed to establish referral guidelines for visual symptom complaints for Veterans with TBI history.

CONCLUSIONS

Studies included in this systematic review report a range of frequencies of visual dysfunction in people with TBI history. The wide ranges of frequencies for visual dysfunction outcomes reported in the included studies are likely due to population and setting heterogeneity across studies. While some studies reported results from individuals regardless of current symptoms, many of the included studies were conducted in VA PRCs and PNSs, clinics that only serve Veterans with current symptoms associated with TBI history as well as other, often serious, comorbidities. Overall, findings suggest that visual dysfunction in a general population of U.S. Service Members with TBI history who are treated in military healthcare systems is diagnosed with a frequency of 7.3% for disorders of accommodation and refractive errors and a frequency of less than 1% for other visual dysfunctions. Conversely, other studies of Veterans with TBI history and current symptoms being treated in inpatient and outpatient TBI rehabilitation clinics report higher frequencies, often over 50% for some types of visual dysfunction such as accommodation and refraction disorders, convergence insufficiency or dysfunction, dry eye syndrome, photosensitivity, pursuit or saccadic dysfunction, and self-reported visual impairments.

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