

The Comprehensive Systematic Review of Traumatic Brain Injury and Visual Disorders

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ABSTRACT

Background: Traumatic brain injury (TBI) is a leading cause of death and disability globally, affecting predominantly children, young people, and the elderly. Complications include concussions, focal injuries, and diffuse damage. Visual impairments caused by traumatic brain injury can have an influence on quality of life and functional independence. Understanding the relationship between TBI and visual abnormalities is critical for creating effective diagnostic tools and treatment plans. **Methods:** This systematic review followed PRISMA 2020 guidelines, concentrating solely on full-text articles published in English from 2014 to 2024. Editorials and review articles lacking a DOI were excluded to ensure the use of high-quality sources. A literature review was performed using reputable databases such as ScienceDirect, PubMed, and SagePub to identify pertinent studies. **Result:** The preliminary database search revealed more than 200 relevant papers on the subject. Following a comprehensive three-stage screening process, eight studies were selected that met the specified inclusion criteria for in-depth analysis. The research were subjected to rigorous critical assessment, enabling an in-depth analysis of traumatic brain injury and visual disorders. This focused approach ensured that the analysis employed strong evidence closely linked with the study's objectives. **Conclusion:** TBI patients often experience visual dysfunctions, affecting their outcomes. The severity and type of injury significantly influence these issues. Comprehensive eye examinations are crucial for detecting subtle impairments, and long-term monitoring and rehabilitation strategies are essential for improved patient care.

Keywords: disability, eye, TBI, visual dysfunction

INTRODUCTION

Traumatic brain injury (TBI), caused by external forces injuring the brain, is a leading cause of death and disability worldwide. Although individuals of all ages can be affected, children, young adults, and the elderly are particularly vulnerable.¹ Common causes of TBI include falls, motor vehicle accidents, violence, sports-related injuries, and military actions in conflict zones. Beyond its devastating physical and emotional toll, TBI imposes significant economic burdens, particularly given the often young age of affected individuals and the severity of resulting disabilities.² While research on the economic impact of TBI remains limited,³ estimates highlight its far-reaching consequences. For example, in the United States, the lack of bicycle helmet usage alone has been linked to \$81 million in direct costs and \$2.3 billion in indirect costs annually.⁴

A common consequence of TBI is concussion, resulting from rapid brain acceleration that causes

the brain to collide with the inner skull, leading to focal injuries such as cerebral lacerations and hemorrhages, as well as diffuse damage, including edema and axonal injury.⁵ Fatalities from TBI often occur within days or weeks following the traumatic event,⁶ with approximately 40% of hospitalized cases deteriorating post-admission.⁷ Beyond the immediate damage, secondary effects such as blood-brain barrier disruption and white matter fiber tract injuries can exacerbate outcomes.⁸ TBI can lead to a range of physical, cognitive, emotional, social, and behavioral complications, with prognoses varying from full recovery to permanent disability or death. Advances in treatment have recently contributed to declining mortality rates; however, this has coincided with a rise in the number of individuals living with TBI-related disabilities.⁹

Among the diverse complications of TBI are visual disorders, which can affect both the afferent and efferent visual systems.¹⁰ Notably, patients with milder forms

of TBI often exhibit prolonged visual symptoms, making them more likely to seek care from eye practitioners. These visual impairments, while sometimes subtle, can significantly impact quality of life and functional independence. Understanding the interplay between TBI and visual disorders is critical for developing targeted diagnostic tools and effective treatment strategies that address immediate and long-term visual complications.

METHODS

Protocol

This study was conducted in strict accordance with the PRISMA 2020 guidelines, ensuring a robust and methodologically sound research process. By adhering to these comprehensive protocols, the review prioritized transparency, reproducibility, and scientific rigor. Key procedures, such as exhaustive literature searches, precise data extraction, and thorough synthesis of findings, were meticulously executed to minimize potential biases. This rigorous approach strengthens the study's credibility and reliability,

offering a valuable contribution to advancing evidence-based research.

Criteria for Eligibility

This study seeks to evaluate the relationship between traumatic brain injury (TBI) and visual disorders through a systematic review and synthesis of data from a diverse array of studies. By identifying patterns and emerging trends in the literature, the research aims to provide valuable insights that inform the development of more effective diagnostic tools and patient care strategies. The overarching goal is to enhance the understanding of TBI-related visual disorders and improve outcomes for affected individuals.

To ensure analytical rigor, the study employed stringent inclusion and exclusion criteria. Peer-reviewed articles published in English between 2014 and 2024 were included, with each study's authenticity verified through DOI validation. Non-research materials, such as reviews, editorials, and duplicate entries, were excluded to maintain a focused and high-quality dataset. This meticulous selection process ensures that the analysis is grounded in reliable and

relevant sources, reinforcing the validity of the findings.

By adopting a systematic and comprehensive methodology, the study guarantees that its conclusions are based on robust and credible evidence. The anticipated findings are expected to deepen the understanding of the interplay between traumatic brain injury and visual disorders. Ultimately, this research aspires to drive advancements in diagnostic approaches, enhance patient care strategies, and contribute to better health outcomes for individuals living with TBI.

Search Strategy

A comprehensive search strategy was meticulously designed and executed to identify relevant studies for this systematic review, with a primary focus on the keywords "traumatic brain injury" and "visual disorders." Searches were conducted across three major academic databases—PubMed, SagePub, and ScienceDirect—ensuring a thorough and extensive exploration of the topic. This methodical approach facilitated the identification of diverse and high-quality sources, establishing a robust

evidence base for analysis. By prioritizing precision and inclusivity in the search process, the study enhances the reliability and validity of its findings, providing a strong foundation for meaningful conclusions.

Data retrieval

The authors conducted a thorough preliminary review of each article, systematically analyzing titles and abstracts to assess their relevance before proceeding to an in-depth evaluation. Only studies that aligned with the research objectives and met the predetermined inclusion criteria were selected for detailed examination. This structured and meticulous approach enabled the identification of consistent and meaningful patterns across the literature, ensuring the review remained focused on studies directly addressing the research question.

To ensure consistency and enhance the comparability of findings, only full-text articles published in English were included in the analysis. A rigorous screening process was applied to confirm that all selected studies adhered to the

established inclusion criteria and effectively addressed the study's objectives. Articles failing to meet these standards were excluded, resulting in a high-quality and precisely curated dataset that closely aligned with the research focus.

The evaluation process also involved a comprehensive assessment of multiple factors, including study titles, authorship, publication dates, research locations, and methodologies. This detailed consideration ensured the inclusion of the most relevant and reliable studies. By employing a systematic and robust selection process, the authors reinforced the credibility and rigor of the findings, providing a strong foundation for drawing reliable and actionable conclusions.

Quality Assessment and Data Synthesis

The authors employed a meticulous initial screening process, thoroughly evaluating the titles and abstracts of each article to identify studies relevant for further analysis. Only those that met predefined criteria for relevance and quality were advanced to a comprehensive and

detailed review. This rigorous and systematic approach ensured the inclusion of studies that were both methodologically robust and directly aligned with the research objectives. By refining the selection process, the authors curated a final dataset of contextually significant and scientifically sound studies. This meticulous approach not only enhanced the precision and focus of the analysis but also elevated the overall quality, relevance, and scientific rigor of the review.

Table 1. Search Strategy

Database	Search Strategy	Hits
Pubmed	("traumatic brain injury" AND "visual disorders")	14
Science Direct	("traumatic brain injury" AND "visual disorders")	179
Sagepub	("traumatic brain injury" AND "visual disorders")	28

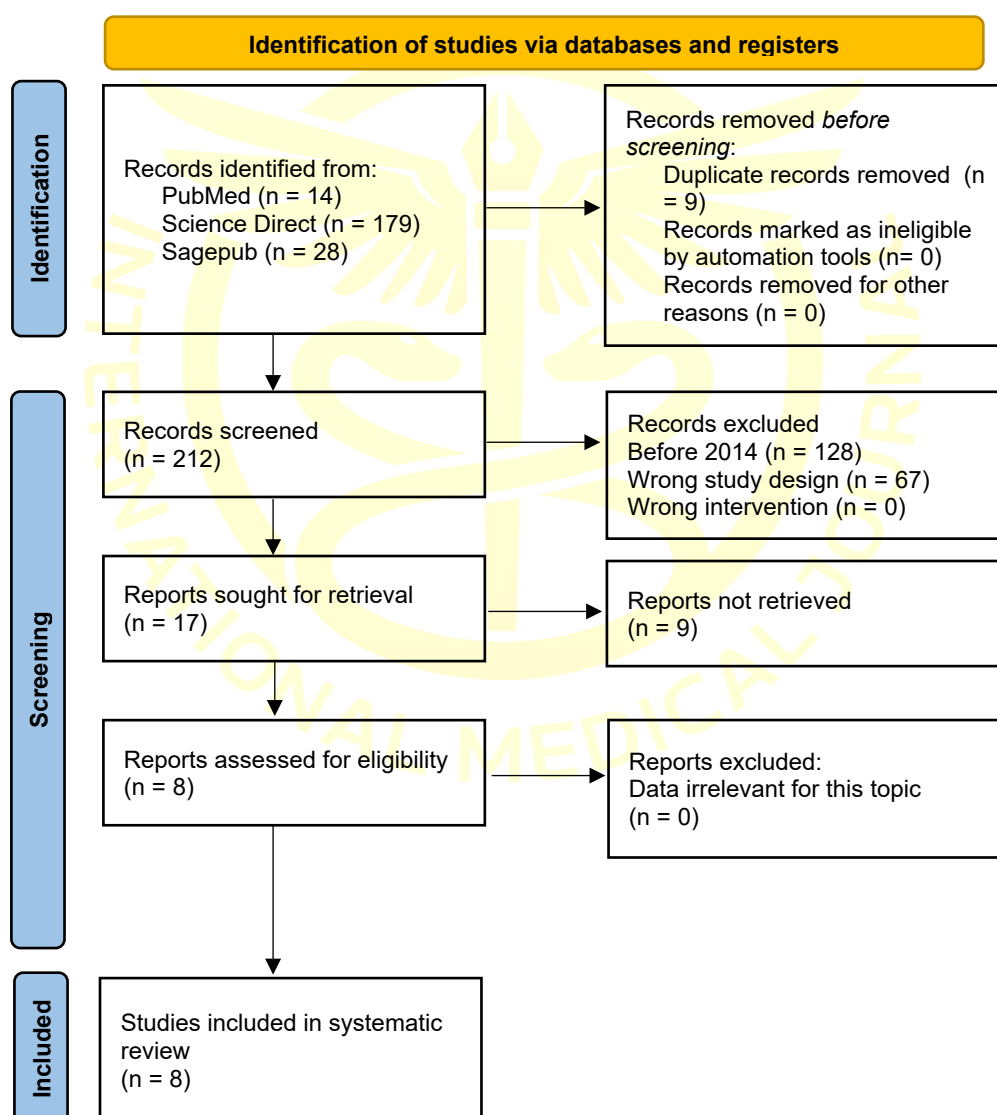


Figure 1. Article search flow chart

Table 2. Critical appraisal of Study

Parameters	(Richman et al., 2014)	(Arms tron, R., 2018)	(Fox et al., 2019)	(Merezhins kaya et al., 2019)	(Rauchman et al., 2022)	(Rauc hman et al., 2023)	Viswa natha n et al., 2023)	(Winkl er et al., 2023)
1. Bias related to temporal precedence								
Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Bias related to selection and allocation								
Was there a control group?	No	No	No	No	No	No	No	No
3. Bias related to confounding factors								
Were participants included in any comparisons similar?	No	No	No	Yes	No	No	No	Yes
4. Bias related to administration of intervention/exposure								
Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	No.	No.	No.	Yes.	No.	No.	No.	Yes.
5. Bias related to assessment, detection, and measurement of the outcome								
Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	No	No	No	No	No	No	No	No
Were the outcomes of participants included in any comparisons measured in the same way?	No	No	No	No	No	No	No	Yes
Were outcomes measured in a reliable way?	No	No	No	Yes	No	No	No	Yes
6. Bias related to participant retention								
Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	No	No	No	No	No	No	No	No
7. Statistical conclusion validity								
Was appropriate statistical analysis used?	No	No	No	Yes	No	No	No	Yes

RESULT

The investigation began with a systematic search of reputable academic databases, including ScienceDirect, PubMed, and SagePub, to identify studies relevant to the review. A rigorous three-stage screening process was employed to filter and select the most pertinent studies, ultimately narrowing the selection to eight papers that met the predefined inclusion criteria. These selected studies underwent an in-depth analysis, with critical topics meticulously extracted for detailed examination. To ensure clarity and enhance the presentation of findings, the results are concisely summarized in Table 3, offering a well-structured and accessible overview of the analyzed data.

Table 3. The literature included in this study

Author	Origin	Method	Sample	Result
Richman et al.¹¹ (2014)	USA	Review	-	TBI, or traumatic brain injury, can cause visual problems, with an estimated 287,861 service members experiencing mTBI between 2000 and 2013. Diagnosing mTBI-related visual impairment requires awareness and special assessment protocols, especially in military and VA settings.
Armstrong, R.¹² (2018)	United Kingdom	Review	-	TBI, a major cause of disability and death, affects all ages, particularly children, young adults, and the elderly. Visual rehabilitation is essential for patients with chronic dysfunction, addressing defects in primary vision, eye movement, and visuo-spatial function.
Fox et al.¹³ (2019)	USA	Review	-	TBI can lead to visual dysfunction, despite excellent visual acuity. Individuals experiencing visual dysfunction should be screened for symptoms and addressed through a

				TBI-specific eye examination. A comprehensive approach, including office-based and home-based vision therapy training, can maximize visual potential and functional results.
Merezhinskaya et al.¹⁴ (2019)	USA	Systematic Review	22 studies	TBI, a visual condition, is characterized by accommodative dysfunction, visual field loss, and visual acuity loss. These conditions can lead to visual impairments, with visual field loss being more prevalent in moderate to severe cases compared to mild cases. Understanding these visual conditions is crucial for effective treatment.
Rauchman et al.¹⁵ (2022)	USA	Review	-	TBI, a major public health issue, results in visual damage and secondary injury, affecting daily life. Primary injury causes headaches, dizziness, fatigue, and poor hand-eye coordination. Treatment and rehabilitation options are inadequate, requiring new approaches.
Rauchman et al.¹⁶ (2022)	USA	Review	-	TBI, a severe form of brain injury, can cause significant damage to the brain, leading to long-term effects such as visual difficulties, cognitive deficits, headaches, pain, sleep disturbances, and post-traumatic epilepsy. These effects include neuronal hyperexcitation, inflammation, and

				neuronal loss, affecting vision, cognition, balance, and sleep. Repair processes and neuronal preservation are crucial for recovery.
Viswanathan et al.¹⁷ (2023)	USA	Review	-	TBI can lead to visual abnormalities, which may be detected through the evaluation of the binocular oculomotor system, which may serve as a target for intervention in future clinical trials.
Winkler et al.¹⁸ (2023)	USA	Retrospective Study	350 participants	The visual acuity and visual field dysfunction in veterans receiving rehabilitation for TBI were frequently assessed, with intervention provided for eye-hand coordination, saccades, accommodation, vergence, and binocular dysfunction, with services influenced by patient comorbidities and specialty clinics.

DISCUSSION

Visual Field Loss in Traumatic Brain Injury

This study found that visual field loss occurs in approximately 18.2% of traumatic brain injury (TBI) patients. The assessment of visual field loss in TBI is challenging due to the varied nature of head injuries and the frequent coexistence of ocular trauma. Visual field deficits can result from direct ocular injuries or damage to the intracranial visual pathways, affecting areas from the retina to the occipital cortex.^{19,20} To isolate the impact of brain injuries, this analysis focused exclusively on post-chiasmal visual field loss, such as hemianopia and quadrantanopia, which manifest bilaterally and result from damage to the intracranial visual pathway. The findings highlight that visual acuity loss to the level of legal blindness is rarely caused solely by TBI, as such impairments are more commonly linked to pre-chiasmal damage stemming from severe head trauma involving loss of consciousness.²¹ This underscores the need for comprehensive visual assessments

beyond standard visual acuity tests, as the latter alone is insufficient to capture the nuanced visual dysfunctions associated with TBI.

Prevalence and Diagnostic Challenges

The prevalence of accommodative dysfunction and convergence insufficiency in TBI patients was notably higher than in the general population, with rates of 42.8% and 36.3%, respectively, compared to previously reported ranges of 5.8%–32.4% and 4.2%–31.4% in healthy individuals.^{22,23} Similarly, visual field loss prevalence in TBI patients (18.2%) far exceeded baseline rates reported for healthy populations, such as 0% in military personnel aged 20–43 years²² and 3% in civilians aged 55–64 years.²⁴ These findings suggest that visual impairments are a significant and underdiagnosed consequence of TBI. However, variability in prevalence estimates across studies may stem from differences in TBI severity, diagnostic methodologies, and study populations. Comparative analyses stratified by TBI severity revealed

that post-chiasmal visual field loss was significantly more prevalent in moderate-to-severe TBI (39.8%) compared to mild TBI (6.6%), aligning with prior research on the impact of distributed cerebral pathology in severe cases.²¹

Mechanisms of Visual Dysfunction

The mechanism of injury appears to influence the nature and prevalence of visual dysfunctions in TBI patients. While this study did not find significant differences in visual outcomes between blast-related and non-blast-related TBI, emerging research suggests that blast events may produce unique cellular and molecular effects. For instance, studies have identified distinct patterns of astroglial scarring in blast-exposed individuals, which are not observed in impact-related TBI cases.²⁵ Although computational models and animal studies indicate that blast overpressure waves generate lower-magnitude, distributed forces compared to direct impacts, their subtle effects on the visual system may be overshadowed by the more pronounced

consequences of blunt trauma during the same event.^{26,27} Further research is required to elucidate the specific contributions of blast mechanics to visual impairments.

Persistence of Visual Dysfunction

Visual impairments resulting from TBI often persist into the chronic phase, with significant long-term implications for patients. Longitudinal studies have reported that symptoms of accommodative dysfunction and convergence insufficiency can last for over a year post-injury, with 58% and 35% of patients, respectively, continuing to experience these issues.²² Despite the limited evidence, it is clear that a substantial proportion of TBI patients endure chronic visual dysfunctions, emphasizing the importance of long-term monitoring and management. Notably, one study found no significant differences in the prevalence of visual field loss, accommodative dysfunction, or convergence insufficiency across acute, subacute, and chronic recovery phases, suggesting that these

conditions may stabilize but remain unresolved over time.^{22,28}

Implications for Clinical Practice and Future Research

The findings of this study highlight the critical need for comprehensive eye examinations in TBI patients to detect subtle yet impactful visual dysfunctions. Such evaluations should extend beyond standard visual acuity tests to include detailed assessments of visual fields, accommodation, and convergence. Moreover, stratification by injury mechanism, severity, and recovery phase should be integrated into future research to better understand the

trajectory and underlying mechanisms of visual impairments in TBI. Advances in diagnostic tools and targeted interventions will be essential for improving the quality of life and functional outcomes for individuals affected by TBI-induced visual disorders.

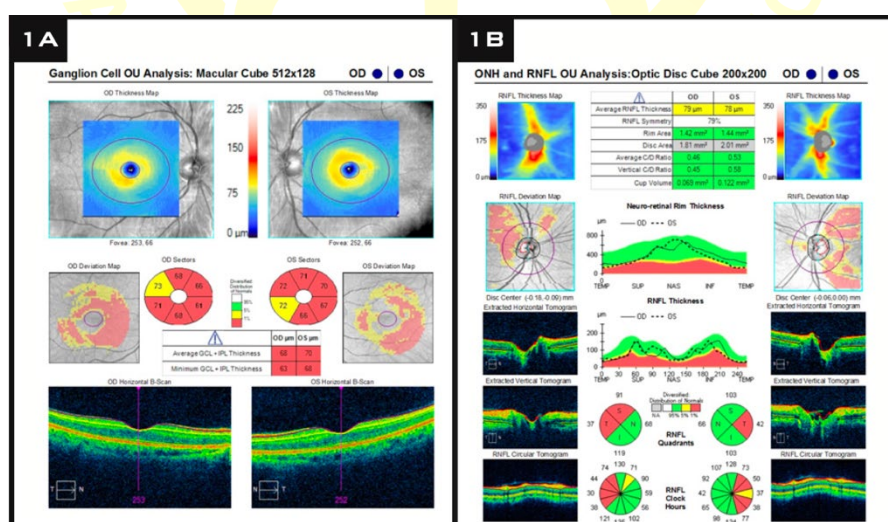


Figure 1. Thinning was more significant in the ganglion cell layer (1A) compared to the retinal nerve fibre layer (1B) in patient with TBI.¹¹

CONCLUSION

This study underscores the significant prevalence of visual dysfunctions, including visual field loss, accommodative dysfunction, and convergence insufficiency, in traumatic brain injury (TBI) patients, with severity and type of injury influencing outcomes. Comprehensive eye examinations are critical for detecting subtle visual impairments, as standard visual acuity tests are insufficient to assess the full spectrum of TBI-related visual complications. Persistent visual dysfunctions beyond the acute phase highlight the need for long-term monitoring and tailored rehabilitation strategies. Future research should prioritize the stratification of visual outcomes by injury mechanism, severity, and recovery phase to enhance diagnostic accuracy and improve patient care.

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