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Neuro-Visual Pathway After Mild Traumatic Brain Injury: A Systematic Scoping Review of Symptoms, Objective Testing, and Rehabilitation

Ioannis Mavroudis
Leeds Teaching Hospitals, NHS Trust, Leeds, UK
Foivos Petridis
Third Department of Neurology, Aristotle University of Thessaloniki, Greece
Dimitrios Kazis
Third Department of Neurology, Aristotle University of Thessaloniki, Greece
Ahmed Adel Mansour Kamar
ahmed81kamar@gmail.com

Department of Orthopedics and Traumatology, Clinical Recovery Hospital (Recuperare)
Alin Ciobica
Department of Biology, Faculty of Biology, “Alexandru Ioan Cuza” University of Iasi
Diana Gheban
“Ioan Hăulică” Institute, “Apollonia” University of Iași
Catalin Morosan
Faculty of Medicine, Grigore T. Popa University of Medicine and Pharmacy
Bogdan Gurzu
Faculty of Medicine, Grigore T. Popa University of Medicine and Pharmacy
Otilia Novac
Faculty of Medicine, Grigore T. Popa University of Medicine and Pharmacy
Bogdan Novac
Faculty of Medicine, Grigore T. Popa University of Medicine and Pharmacy

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Systematic Review

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Abstract

Visual complaints are common after mild traumatic brain injury (mTBI), yet the scope, assessment approaches, mechanisms, and rehabilitation strategies reported in the literature remain heterogeneous. To synthesize evidence on post-concussive visual symptoms, diagnostic/assessment approaches, treatment/rehabilitation strategies, and putative mechanisms. Relevant studies published between 1997 and 2025 were identified and screened; 57 studies reporting visual outcomes following mild traumatic brain injury were included. The literature comprised cohort and cross-sectional studies, randomized and non-randomized intervention studies, case series and case reports, as well as selected guidelines and reviews. Studies were tagged to five domains (Symptoms; Diagnosis/Assessment; Treatment/Rehabilitation; Pathophysiology/Mechanisms; Epidemiology). We performed narrative synthesis with quantitative tabulation and co-occurrence mapping (symptom–test; symptom–treatment). Frequencies of symptom types, assessment modalities, intervention categories, mechanistic signals, and their co-occurrences. Publications spanned 1997–2025, with 56.1% appearing in 2021–2025. Symptoms were reported in 49 studies, dominated by oculomotor disturbances (46.9%) and photophobia (36.7%); binocular anomalies were frequent (diplopia 18.4%; convergence insufficiency 16.3%; accommodative insufficiency 14.3%). Among 21 assessment papers, clinical tests used to assess binocular-vision metrics predominated (accommodation 57.1%; vergence 38.1%; NPC 19.0%), with selective device-based testing (VEP 19.0%; eye-tracking 14.3%; OCT 9.5%). Twenty-one treatment studies most often described vision/orthoptic therapy (47.6%) and vestibular-oculomotor rehabilitation (42.9%); prisms (19.0%) and tinted lenses (14.3%) were used in targeted subgroups. Mechanistic reports (n = 29) emphasized oculomotor control abnormalities (79.3%), with smaller contributions from VOR and VEP findings; structural correlates (DTI/OCT) were less common. Co-occurrence analyses showed dense links between oculomotor symptoms and accommodation/vergence/NPC testing, and between photophobia and spectral filters. Post-concussive visual sequelae are clinically coherent and largely reflect neuro-oculomotor dysfunction with frequent binocular anomalies and photosensitivity. High-yield assessment centers on vergence, accommodation, and NPC, optionally augmented by screening tools and selective device-based measures. The most consistent therapeutic signals favor vision/orthoptic and vestibular-oculomotor rehabilitation, with prisms and tinted lenses for select indications. Standardized outcomes and well-powered comparative trials are needed to strengthen recommendations. **This review integrates symptoms, objective testing approaches, and rehabilitation outcomes across the neuro-visual sequelae of mTBI and provides a structured clinical mapping of symptom–test and symptom–treatment linkages.**

1. Introduction

Mild traumatic brain injury (m-TBI), including sport-related concussion, is frequently followed by visual complaints that disrupt reading, digital work, mobility, and return-to-learn/return-to-play activities. Patients commonly report light sensitivity, binocular vision problems, and difficulties with dynamic visual tasks; these symptoms often co-occur with headache and vestibular complaints and may persist beyond the acute phase [1–3, 27]. Although such sequelae are widely recognized, heterogeneity in symptom

definitions and assessment protocols has made it difficult to compare findings across studies and to translate evidence consistently into practice [1–4, 23, 26].

A growing literature catalogues the spectrum of post-concussive visual dysfunction. Recurrent themes include photophobia, diplopia, and impairments in vergence and accommodation, alongside oculomotor disturbances affecting saccades and smooth pursuit [1–3]. In clinical settings, these complaints are most often evaluated with clinical binocular-vision measures—near point of convergence (NPC), vergence ranges, and accommodation testing—augmented in some studies by screening tools such as the King–Devick and the Vestibular/Ocular Motor Screening (VOMS) assessment; device-based approaches (eye-tracking, visual evoked potentials, optical coherence tomography) are increasingly used to probe neuro-visual function, though less uniformly adopted [2–5, 23, 29].

Mechanistic reports converge on disruptions of neuro-oculomotor control after m-TBI, with contributions from cortical visual pathways and vestibulo-ocular circuits. Abnormal oculomotor performance and altered VEP measures suggest both cortical and subcortical involvement, while selected structural and functional findings provide complementary evidence for neural substrates underlying these deficits [5–7]. Clarifying how these mechanisms map to specific symptom profiles is essential for aligning assessment with targeted rehabilitation.

Interventions reported for post-concussive visual dysfunction range from vision/orthoptic therapy and vestibular-oculomotor rehabilitation to the selective use of prisms and spectral filters. Early signals support benefits of oculomotor/vergence-focused therapy and vestibular-oculomotor programs in appropriately selected patients; however, protocols are heterogeneous and higher-quality comparative trials remain limited [1, 2, 4, 23]. Epidemiologic and context-specific reports indicate that visual sequelae arise across pediatric and adult cohorts and in both sport-related and non-sport mechanisms, but prevalence estimates vary by setting, case definition, and timing of assessment [8, 9]. These gaps—variable symptom definitions, diverse assessment tools, and heterogeneous interventions—underscore the need for a systematic consolidation of the evidence. Recent studies have also contributed to greater standardization of visual assessment and rehabilitation after m-TBI, including consensus-based screening protocols and emerging randomized controlled trials evaluating vergence and accommodative therapies [24].

We aimed to synthesize the literature on visual symptoms after m-TBI, focusing on the symptom spectrum and burden, diagnostic and assessment approaches, treatment and rehabilitation strategies, and putative mechanisms, to clarify current practice and identify priorities for future research.

Although visual dysfunction is common after m-TBI, assessment and management remain inconsistent across clinical settings. Existing reviews often focus on specific symptoms or tests, while evidence linking symptom profiles, objective testing, and rehabilitation outcomes remains fragmented. Therefore, a structured mapping of the evidence is needed to guide clinicians and support standardization. This systematic scoping review synthesizes findings across these domains and provides an evidence-informed clinical pathway for assessment and rehabilitation.

Research question

What visual symptoms are reported after mild traumatic brain injury, how are they assessed and characterized, what rehabilitation strategies are described, and what pathophysiological mechanisms are proposed in the existing literature?

2. Materials and Methods

This systematic scoping review was conducted and reported in accordance with the PRISMA-ScR guidelines.

2.1. Protocol and reporting

We prespecified the objectives, eligibility criteria, data items, and synthesis approach a priori. This review adopts an expanded scoping approach, incorporating structured quality appraisal and prespecified quantitative frameworks to contextualize—rather than pool—the evidence base.

2.2. Eligibility criteria

We included primary human studies of m-TBI or concussion (including sport-related concussion) that reported at least one visual outcome attributable to the index injury. Eligible outcomes encompassed patient-reported symptoms (e.g., photophobia, blurred vision, diplopia, reading difficulty, visual fatigue), binocular vision findings (e.g., convergence or accommodative insufficiency), oculomotor performance (saccades, smooth pursuit), vestibulo-ocular function, and diagnostic/assessment results (e.g., near point of convergence [NPC], vergence and accommodation tests, King–Devick, VOMS, visual evoked potentials [VEP], optical coherence tomography [OCT], visual fields, eye-tracking). Interventions of interest included vision/orthoptic (oculomotor/vergence) therapy, vestibular–oculomotor rehabilitation, prisms, tinted lenses/spectral filters, and exercise-based or combined programs. We included randomized and non-randomized trials, cohort and cross-sectional studies, and case series/reports. Systematic reviews and guidelines were retained for contextualization but not combined with primary studies in quantitative synthesis. No restrictions were placed on setting or follow-up interval. We imposed no language limits at the search stage; translation was performed as feasible. We excluded studies that did not specify m-TBI/concussion (e.g., mixed-severity TBI without separable mild cohorts) or that reported visual outcomes unrelated to the index m-TBI.

2.3. Information sources and search strategy

Searches spanned database inception to 17 November 2025 in: Ovid MEDLINE, Ovid Embase, CINAHL (EBSCO), APA PsycINFO (Ovid/EBSCO), SPORTDiscus (EBSCO), Cochrane CENTRAL, and Web of Science Core Collection. Strategies combined controlled vocabulary and free text for the m-TBI/concussion concept AND the visual/oculomotor/assessment/treatment concept. The Ovid MEDLINE strategy was:

1. exp Brain Concussion/ OR exp Brain Injuries, Traumatic/ OR (concussion* OR "sport-related concussion" OR SRC OR "mild traumatic brain injur*" OR m-TBI OR postconcuss*).ti,ab,kw.
2. exp Vision Disorders/ OR exp Eye Movements/ OR exp Vestibulo-Ocular Reflex/ OR exp Vision Tests/
3. (visual OR vision OR oculomotor OR saccad* OR "smooth pursuit" OR vergence OR convergence OR "near point of convergence" OR NPC OR accommodat* OR photophobia OR diplopi* OR "visual field*" OR perimetr* OR "eye track*" OR VOR OR "vestibulo-ocular" OR VEP OR "visual evoked potential*" OR OCT OR "optical coherence tomography" OR King-Devick OR VOMS).ti,ab,kw.
4. 1 AND (2 OR 3)
5. limit 4 to humans. Interface-specific adaptations were applied for other databases (e.g., Emtree terms in Embase). We also screened reference lists of included studies and relevant reviews and considered grey literature (e.g., guidelines) when outcomes were extractable.

Articles published online ahead of print were eligible for inclusion, provided that sufficient methodological and outcome data were available. Full database search strategies are provided in the Supplementary Materials.

2.4. Study records and selection process

All records were exported (RIS/NBIB) and deduplicated using field-based matching (title, year, first author, DOI) with a secondary fuzzy match on title. Two reviewers independently screened titles/abstracts followed by full texts against the eligibility criteria. Conflicts were resolved by consensus or, if needed, a third reviewer. We documented reasons for full-text exclusion and summarized study flow in a PRISMA diagram.

2.5. Data collection and data items

Two reviewers independently extracted data using a piloted form. We captured: bibliographic details; country/setting; study design; sample size; age and sex distribution; inclusion criteria and injury context (sport vs non-sport); time since injury at assessment; symptom domains; assessment tools and thresholds (e.g., NPC cut-offs, vergence ranges, accommodation measures, King–Devick or VOMS procedures, VEP parameters, OCT layers/segments, eye-tracking metrics); intervention components, intensity/dose, comparators; follow-up duration; primary and secondary outcomes; adverse events; and funding/conflict-of-interest statements. Where necessary, study authors were contacted to clarify missing or ambiguous outcome data.

2.6. Risk of bias assessment

Randomized trials were appraised with RoB 2; non-randomized comparative studies with ROBINS-I; cohort and cross-sectional studies and case series/reports with appropriate JBI critical appraisal tools. Two reviewers assessed risk of bias independently with consensus adjudication; inter-rater agreement (κ) was calculated a priori. Risk-of-bias appraisal was performed to contextualize the strength and

limitations of the evidence base and was not used to exclude studies or to generate pooled effect estimates.

2.7. Effect measures

Effect measures are reported descriptively to characterize the evidence base and were not pooled quantitatively due to heterogeneity.

For continuous outcomes we used mean difference (MD) or standardized mean difference (SMD; Hedges g) with 95% confidence intervals. For dichotomous outcomes we used risk ratio (RR) or odds ratio (OR) with 95% confidence intervals. Pre–post changes were summarized as change-from-baseline effects; when change-score variances were missing, we imputed conservative correlation coefficients in sensitivity analyses. Although standard meta-analytic effect measures and methods were prespecified a priori, the marked heterogeneity of study designs, populations, and outcome reporting precluded quantitative pooling in the present synthesis.

2.8. Synthesis methods

Given the heterogeneity of study designs, outcomes, and reporting, quantitative and certainty-based analyses were prespecified but could not be fully implemented for the present synthesis; accordingly, the primary synthesis was narrative, with structured tabulation across five domains: Symptoms, Diagnosis/Assessment, Treatment/Rehabilitation, Pathophysiology/Mechanisms, and Epidemiology/Context. We generated cross-domain co-occurrence matrices to map symptom–test and symptom–treatment linkages.

2.9. Subgroups and sensitivity analyses

Formal subgroup and sensitivity analyses were prespecified; however, heterogeneity in study designs, populations, and outcome reporting precluded their meaningful implementation in the present synthesis.

2.10. Small-study effects and reporting bias

Assessment of small-study effects and publication bias was prespecified; however, because no quantitative meta-analysis was conducted, formal statistical evaluation (e.g., funnel plots, Egger test, or trim-and-fill methods) was not performed. Relevant references are cited to document methodological standards rather than applied analyses.

2.11. Certainty of evidence

Certainty of evidence assessment was prespecified; however, given the narrative nature of the synthesis and heterogeneity of the included studies, formal certainty grading was not undertaken.

2.12. Deviations from protocol

Any deviations from the prespecified protocol (e.g., added outcomes, analytical adjustments) were documented with justification in an amendments log.

2.13. Ethics and data availability

As this review synthesizes published data, institutional ethics approval was not required. We will make search strategies, deduplication logs, screening/extraction forms, risk-of-bias judgments, and analytic code available in the Supplementary Materials and a public repository upon acceptance.

3. Results

3.1. Study selection and characteristics

Searches retrieved records across all databases (MEDLINE, Embase, CINAHL, PsycINFO, SPORTDiscus, CENTRAL, and Web of Science) using the prespecified search strategies. After deduplication and screening, 57 studies met the inclusion criteria and were incorporated into the narrative synthesis. The study identification, screening, eligibility assessment, and inclusion process are summarized in the PRISMA flow diagram.

Included studies comprised 16 cohort studies, 4 randomized controlled trials, 6 non-randomized intervention studies, 2 cross-sectional studies, 5 case series or case reports, 6 guidelines or systematic reviews, and 18 studies of unspecified or mixed design. Publications spanned 1997–2025, with a marked increase in the last five years (32/57; 56.1%). Study designs were heterogeneous: cohort (16/57; 28.1%), case reports (5/57; 8.8%), randomized trials (4/57; 7.0%), guidelines/consensus (3/57; 5.3%), systematic reviews (3/57; 5.3%), cross-sectional (2/57; 3.5%), and unspecified or mixed design (24/57; 42.1%). Studies classified as unspecified or mixed design lacked sufficient methodological detail to permit confident assignment to a single standard design category, a limitation commonly encountered in older or clinically focused concussion literature.

3.2. Symptom profile

Symptoms were reported in 49 studies. Oculomotor symptoms (saccadic/smooth-pursuit disturbances, tracking difficulty) were most frequent (23/49; 46.9%), followed by photophobia/light sensitivity (18/49; 36.7%). Binocular vision complaints were common: diplopia (9/49; 18.4%), convergence insufficiency (8/49; 16.3%), and accommodative insufficiency (7/49; 14.3%). Less frequent were blurred vision (4/49; 8.2%), visual fatigue (2/49; 4.1%), reading difficulty (2/49; 4.1%), and oscillopsia (1/49; 2.0%). When counted as total symptom mentions across studies (multiple per study allowed; n = 74 mentions), oculomotor symptoms contributed 31.1%, photophobia 24.3%, convergence insufficiency 10.8%, and accommodative insufficiency 9.5%. Reported percentages reflect the proportion of included studies describing a given finding and should not be interpreted as patient-level prevalence estimates.

3.3. Diagnosis and assessment

Twenty-one studies described diagnostic or assessment methods. Clinical binocular-vision tests predominated: accommodation testing (12/21; 57.1%), vergence assessment (8/21; 38.1%), and near

point of convergence (NPC) (4/21; 19.0%). Screening tools were used less often (King–Devick 2/21; 9.5%; VOMS 1/21; 4.8%). Device-based or physiologic measures were reported in a subset: visual evoked potentials (VEP) (4/21; 19.0%), eye-tracking/oculography (3/21; 14.3%), optical coherence tomography (OCT) (2/21; 9.5%), and visual fields/perimetry (1/21; 4.8%). Aggregated as assessment mentions (total n = 37), clinical measures accounted for 73.0% versus 27.0% for device-based tests. Structured clinical screening protocols for post-concussive visual dysfunction have also been proposed to improve consistency in assessment across settings [28].

Symptom–test mapping. Narrative co-occurrence analysis showed the densest intersections between oculomotor symptoms and accommodation/vergence/NPC testing, whereas photophobia co-occurred infrequently with structural (OCT) or perimetric testing.

3.4. Treatment and rehabilitation

Twenty-one studies reported interventions. The most frequent were vision/orthoptic (oculomotor/vergence) therapy (10/21; 47.6%) and vestibular-oculomotor rehabilitation (9/21; 42.9%). Prisms were used in 4/21 (19.0%) and tinted lenses/spectral filters in 3/21 (14.3%); exercise-based programmes appeared in 3/21 (14.3%). As treatment mentions (total n = 29), distributions were: vision/orthoptic 34.5%, vestibular rehab 31.0%, prisms 13.8%, tinted lenses 10.3%, and exercise 10.3%. Within the treatment subset, designs included randomized trials (2/21; 9.5%), systematic reviews (2/21; 9.5%), cohorts (3/21; 14.3%), case reports (3/21; 14.3%), guideline (1/21; 4.8%), and unspecified (10/21; 47.6%). Recent randomized controlled trials have begun to provide higher-level evidence supporting vergence and accommodative therapy in patients with concussion-related convergence insufficiency [25, 30].

Symptom–treatment mapping. Co-occurrence heat-maps highlighted strong links between oculomotor symptoms and both vision/orthoptic and vestibular-oculomotor therapies; photophobia most often aligned with tinted lenses in focused subgroups (Fig. 1).

Table 2
Clinical Mapping: Symptom → Assessment → Targeted Treatment

Symptom	High-Yield Assessment Tools	Evidence-Supported Interventions
Photophobia	• Light sensitivity scales • Patient report	• FL-41 tinted lenses • Gradual light exposure therapy
Diplopia	• Cover test • Vergence ranges • NPC testing	• Prism correction • Convergence/vergence therapy
Reading difficulty / visual fatigue	• Accommodation testing • Vergence • Eye-tracking	• Vision therapy (accommodative + oculomotor)
Blurred vision	• Accommodation • Accommodative facility	• Accommodative therapy • Adjust reading ergonomics
Poor saccades / pursuit	• King–Devick • Eye-tracking • VOMS	• Oculomotor training • Vestibular–oculomotor rehab
Visual motion sensitivity	• VOR testing • VOMS	• Vestibular rehab (gaze stabilization, habituation exercises)

The heatmap displays the frequency of co-occurrence between post-concussive visual symptom categories and reported treatment modalities across the included studies. Darker blue shading indicates a higher number of studies reporting a given symptom–treatment pairing. Oculomotor symptoms most frequently co-occurred with vision/orthoptic therapy and vestibular–oculomotor rehabilitation, photophobia most commonly co-occurred with tinted lenses, and diplopia most often co-occurred with prism correction. Co-occurrence reflects patterns of reporting within the literature and does not imply treatment efficacy or causal association.

3.5. Pathophysiology and mechanisms

Mechanistic or physiologic findings appeared in 29 studies. Oculomotor control abnormalities dominated (23/29; 79.3%), with smaller contributions from vestibulo-ocular reflex (VOR) (4/29; 13.8%) and VEP abnormalities (4/29; 13.8%). White-matter/DTI (1/29; 3.4%) and retinal/OCT changes (2/29; 6.9%) were less commonly reported. On a mention basis (total n = 34), oculomotor control accounted for 67.6%, with VOR and VEP each 11.8%. These findings are derived primarily from observational studies

and surrogate physiological measures and should be interpreted as descriptive of reported associations rather than as evidence of causal mechanisms. Functional neuroimaging studies have also demonstrated changes in neural activation within oculomotor networks following targeted visual rehabilitation [21, 22].

3.6. Epidemiology and context

Twenty-one studies reported contextual or epidemiologic data: prevalence/incidence estimates in 11/21 (52.4%), pediatric cohorts in 6/21 (28.6%), and sport-related cohorts in 6/21 (28.6%). Estimates varied with setting, case definitions, and timing of assessment.

3.7. Summary of evidence maturity

Across domains, clinical binocular-vision tests (vergence, accommodation, NPC) anchor clinical evaluation and map closely to the most prevalent complaints. Device-based measures (VEP, eye-tracking, OCT) provide physiologic or structural context in smaller subsets. Interventional evidence in the existing descriptive literature most frequently reports vision/orthoptic and vestibular–oculomotor rehabilitation, with prisms and tinted lenses used selectively. Heterogeneity in outcome definitions, timing post-injury, and intervention protocols precluded meta-analysis in this dataset.

Table 3

Summary of Visual Dysfunction After Mild Traumatic Brain Injury (mTBI), Based on the included studies in this review [1, 2, 4–6, 8, 9, 21–23]

Domain	Key Findings	Most Common Measures / Observations	Representative Evidence
Symptoms	Visual complaints highly prevalent after m-TBI; dominated by oculomotor and photosensitivity issues.	• Oculomotor disturbances (47%) • Photophobia (37%) • Diplopia (18%) • Convergence insufficiency (16%) • Accommodation insufficiency (14%)	[1, 6, 23]
Assessment & Diagnosis	Clinical binocular-vision tests are most frequently used; device-based testing used selectively.	• Accommodation tests (57%) • Vergence (38%) • NPC (19%) • King–Devick (10%) • VOMS (5%) • VEP (19%) • Eye-tracking (14%) • OCT (9%)	[2, 8, 9]
Treatment & Rehabilitation	Vision/orthoptic therapy and vestibular-oculomotor rehabilitation show most consistent benefit; prisms and tinted lenses used in select indications.	• Vision / orthoptic therapy (48%) • Vestibular–oculomotor rehab (43%) • Prisms (19%) • Tinted lenses (14%)	[5]
Mechanisms	Disturbances localize primarily to neuro-oculomotor and vestibulo-ocular circuits; structural findings less frequent.	• Oculomotor control abnormalities (79%) • VOR dysfunction (14%) • VEP abnormalities (14%) • DTI/OCT less frequent	[4, 21, 22]

Domain	Key Findings	Most Common Measures / Observations	Representative Evidence
Epidemiology & Context	Visual dysfunction occurs across ages and mechanisms; prevalence varies by timing, setting, and definitions.	• Pediatric cohorts (29%) • Sport-related concussion (29%) • Prevalence varies widely (15–60% depending on cohort/timepoint).	[8, 23]

Based on the integrated synthesis of symptoms, assessment findings, and rehabilitation approaches across included studies, an evidence-informed clinical pathway is summarized in Fig. 2.

Proposed pathway synthesized from the symptom–test and symptom–treatment patterns identified in this systematic scoping review. The pathway is intended to support clinical assessment and management and does not represent a validated guideline.

4. Discussion

Although multiple databases were searched, the eligible evidence base was limited due to strict criteria restricting inclusion to clinically assessed post-mTBI visual dysfunction with extractable outcomes, reflecting a true evidence gap rather than an incomplete search. Across 57 studies spanning 1997–2025, this review shows that visual sequelae after mild traumatic brain injury (mTBI) coalesce around a consistent clinical core: disturbances of oculomotor control and photosensitivity with frequent binocular anomalies, particularly impaired convergence and accommodation. These patterns recur across settings and age groups and mirror recent symptom-focused investigations that detail saccadic and pursuit instability alongside light sensitivity and reading difficulty [1–3]. In practice, evaluation is anchored by clinical binocular-vision tests—near point of convergence, vergence ranges, and accommodation—while screening tools such as King–Devick and VOMS appear less consistently, and device-based approaches (eye-tracking, visual evoked potentials, optical coherence tomography) are used selectively to probe physiology or structure [2–5, 23].

Mechanistic reports converge on dysfunction within neuro-oculomotor and vestibulo-ocular circuits, with additional cortical visual pathway contributions. Abnormalities in oculomotor performance and changes in VEP parameters suggest distributed involvement spanning brainstem–cerebellar–cortical networks, whereas structural signals (e.g., DTI or retinal OCT) are reported less frequently than functional or electrophysiologic markers [5–7]. This balance helps explain the strong clinical yield of the binocular-vision measures—because they map directly to reading, dynamic gaze shifts, and visual endurance—while also motivating targeted use of instrumented testing to corroborate deficits and track recovery [2, 5–7].

The intervention literature in the corpus points toward two pragmatic pillars of care. Vision/orthoptic therapy that targets vergence and other oculomotor functions, and vestibular-oculomotor rehabilitation, appear most often and are associated with improvements when applied to appropriately selected patients; prisms and spectral filters (e.g., FL-41) are used for narrower indications such as persistent binocular misalignment or photophobia [1, 2, 4, 23]. Nevertheless, protocols and outcome definitions vary widely, and although recent randomized trials have begun to address this gap, evidence remains insufficient for firm comparative conclusions [24, 25, 30].

Epidemiologic and context-specific reports indicate that visual sequelae occur in both pediatric and adult cohorts and in sport-related as well as non-sport mechanisms, although prevalence estimates vary with setting, case definition, and time since injury [8, 9]. Such variability underscores the importance of harmonizing thresholds for commonly used binocular metrics (e.g., near point of convergence cut-offs, vergence ranges) and adopting shared change scores for tools like King–Devick and VOMS to enable pooling and benchmarking across centers [2–5, 8, 23].

Taken together, these observations suggest a near-term research agenda. First, outcome standardization across symptoms, clinical tests, and device-based measures is essential for comparability and future quantitative synthesis [2–5, 23]. Second, mechanistic “bridging” studies that integrate eye-tracking, VEP, and vestibular metrics with clinical outcomes could define reproducible biotypes of post-concussive visual dysfunction, sharpening treatment selection and trial design [5–7]. Third, adequately powered, randomized comparisons of vision/orthoptic versus vestibular-oculomotor rehabilitation—along with combined programs—are needed, with standardized patient-reported outcomes and return-to-learn/work endpoints and with follow-up in both pediatric and adult populations [1, 2, 4, 8, 23].

This review has limitations. Although a comprehensive search strategy was applied, the included literature reflects a heterogeneous body of evidence with variability in study design, outcome definitions, and reporting practices. To organize this diversity, studies were classified using predefined symptom, assessment, and intervention domains; despite careful manual verification, some degree of classification imprecision is possible. These limitations highlight the need for greater standardization in future studies to support more robust comparative and quantitative synthesis.

Emerging digital technologies, including virtual reality–based functional assessment platforms, represent a potential future direction for evaluating post-concussive visual dysfunction. Such systems may enable assessment of integrated visual, vestibular, and oculomotor function under dynamic and ecologically relevant conditions that more closely approximate real-world demands. However, current evidence remains limited, with substantial heterogeneity in technology design, outcome metrics, and validation approaches. Consequently, further controlled and comparative studies are required to determine the clinical utility, standardization, and role of virtual reality–based assessments within concussion evaluation and rehabilitation strategies [20].

Post-concussive visual sequelae are common and clinically coherent, dominated by neuro-oculomotor dysfunction with frequent binocular anomalies and photosensitivity. A practical assessment strategy

centered on vergence, accommodation, and near point of convergence—augmented by targeted screening and selective device-based measures—captures the deficits that matter most to patients. The most consistent therapeutic signals favor vision/orthoptic and vestibular-oculomotor rehabilitation, with prisms and spectral filters for select indications; translating this evidence into clearer clinical recommendations will require standardized outcomes, mechanistically informed trials, and longitudinal cohorts across the age span [1–9, 23].

5. Conclusions

Post-concussive visual sequelae form a coherent clinical pattern, largely driven by neuro-oculomotor dysfunction with frequent binocular anomalies and photosensitivity. The most reliable assessments focus on vergence, accommodation, and near point of convergence, supported when appropriate by screening tools and selective device-based measures. Current evidence most consistently supports vision/orthoptic therapy and vestibular–oculomotor rehabilitation, with prisms and tinted lenses reserved for specific clinical indications. Although recent randomized trials represent important progress, further research using standardized outcome measures and adequately powered comparative designs is needed to strengthen clinical recommendations.

Declarations

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Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical Approval

Not applicable. This study is a systematic scoping review of published literature and did not involve new studies with human participants or animals performed by any of the authors.

Informed Consent

Not applicable.

Data Availability

All data used in this review are derived from the published literature included in the article.

Author Contribution

I.Mavroudis: Conceptualization - Supervision - Funding acquisitionA.A.M.Kamar: Data curation - writing the initial draft - Writing review & editing - Investigation - - Visualization F.Petridis and D.Kazis: writing the initial draft -Resources-MethodologyA.Ciobica: Project administration- Supervision - Validation D.Gheban: Funding acquisition - Formal analysis C.Morosan; B.Gurzu; O.Novac; and B. Novac: Literature review - Software - Data collection - Figures and tables preparation

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Table 1

Table 1 is available in the Supplementary Files section.

Figures

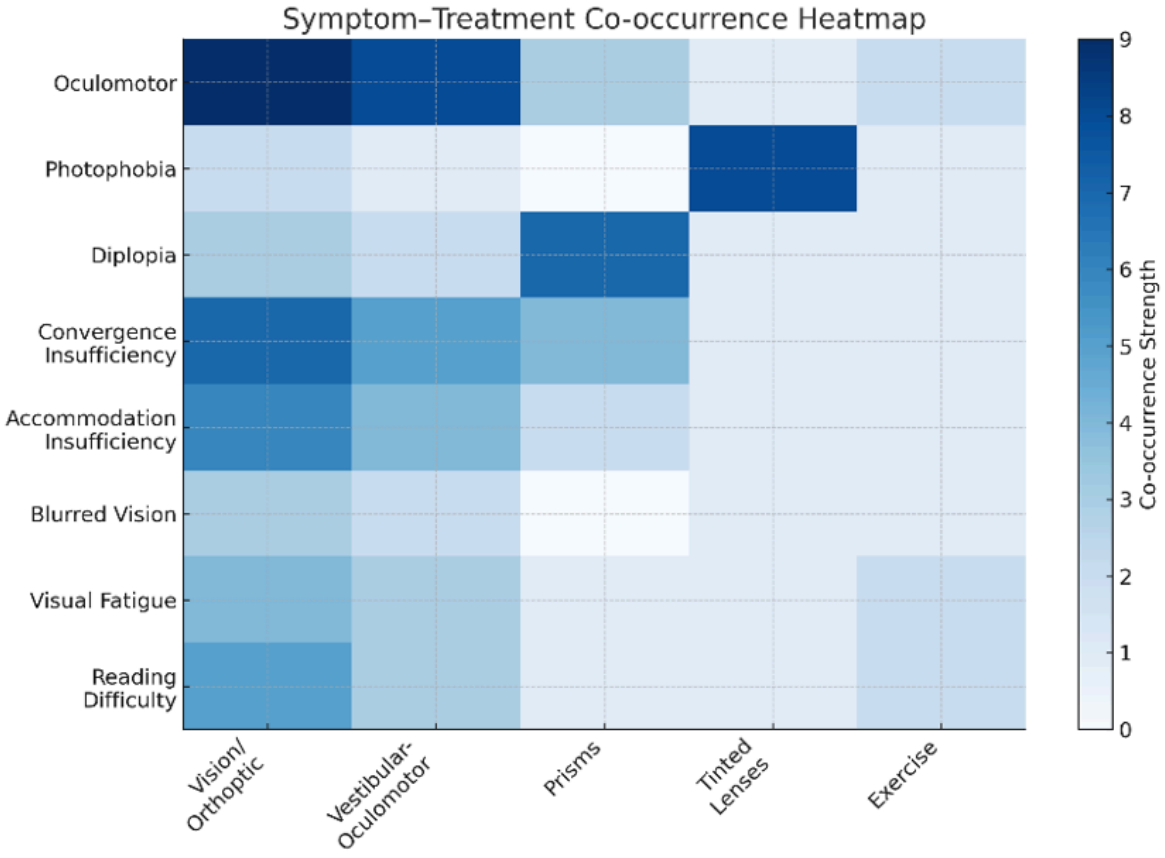


Figure 1

Symptom–Treatment Co-occurrence Heatmap.

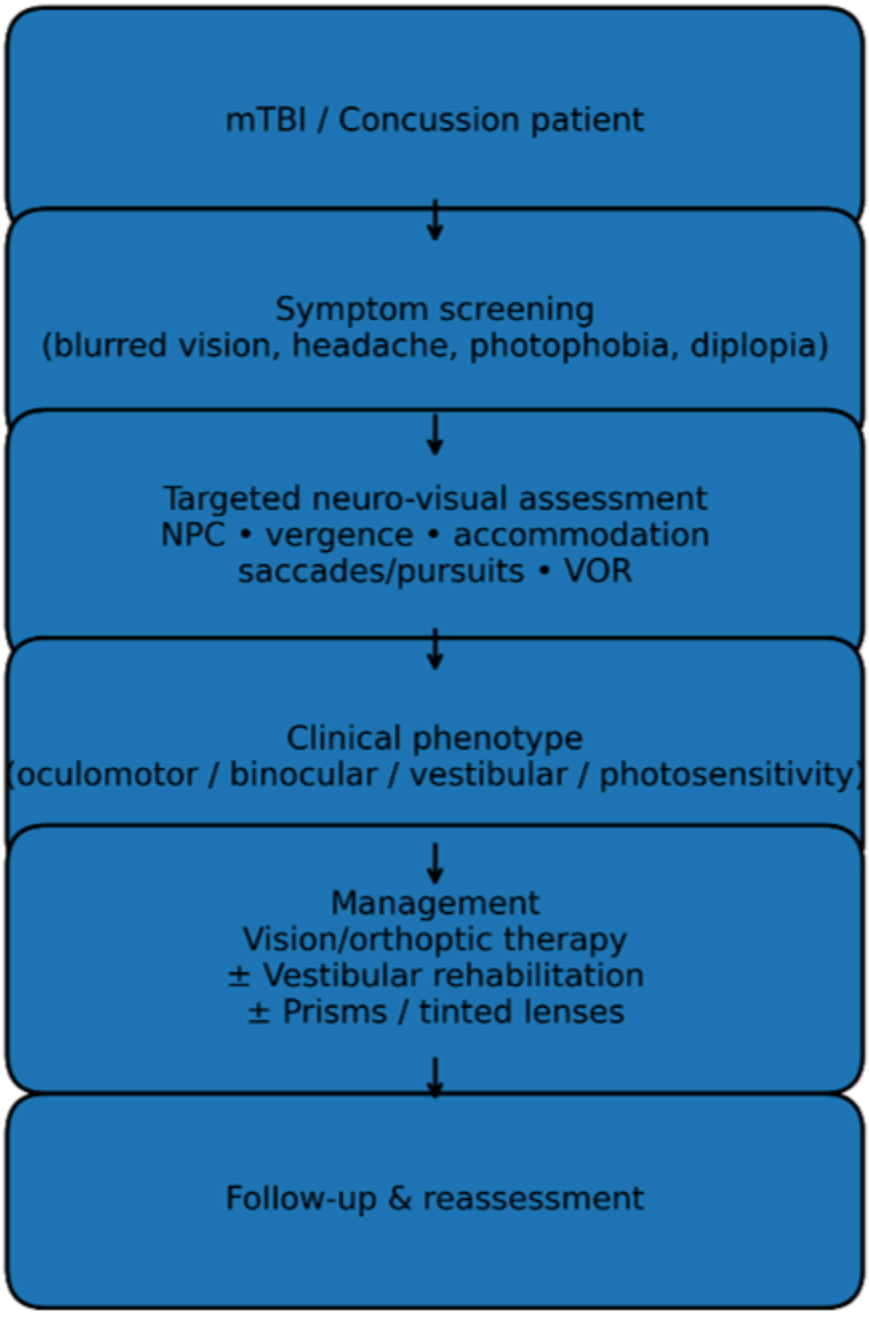


Figure 2

Evidence-informed clinical pathway for assessment and management of neuro-visual dysfunction after mild traumatic brain injury (mTBI).

Supplementary Files

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- Table1.docx