Individualized Interventions for Mild Traumatic Brain Injury: A Comparative Review of Exercise-Based and Non-Exercise-Based Approaches.

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Background and Purpose

Mild traumatic brain injury (mTBI) and concussion are a prevalent neurological condition, often leading to prolonged post-injury symptoms that pose significant management challenges.

- **Traditional guidelines** prioritize rest after injury.
- **Emerging evidence** supports early, active interventions to promote recovery.
- **Gap in research:** Effective mode of intervention across adolescent and adult populations.

This study aims to evaluate the effectiveness of mTBI/Concussion interventions in improving post-concussive symptoms and functional recovery among adolescent and adults recovering from mild traumatic brain injury (mTBI) or concussion.

Methodology

This study was conducted as a systematic review following PRISMA 2020 framework. Randomized control trials published in the last 15 years were identified from Embase, CINAHL, and PubMed. All records underwent a rigorous screening and critical appraisal process to ensure methodological quality and relevance.

Figure 1. *Data Processing Flowchart*

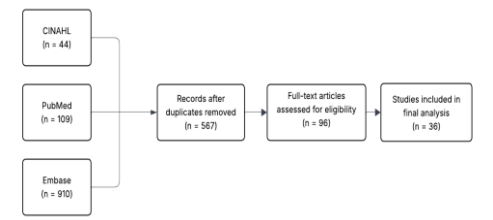
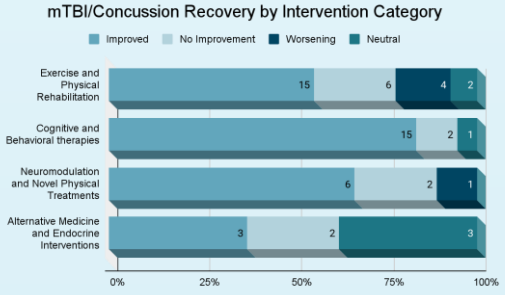


Figure 4. *Recovery Status by Intervention Category*

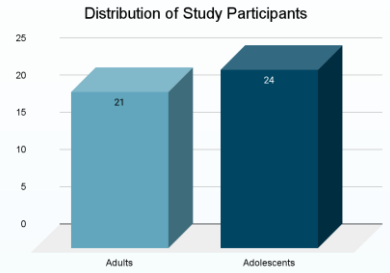


Summary of Evidence

Table 1. *mTBI/Concussion Interventions*

Intervention Category	Code	Improved	No Improvement / Equivalent	Worsened / Delayed Recovery	Neutral
Exercise and Physical Rehabilitation	A-1	- VESTIB [18] - Standard mTBI Instructions [3, 17, 38, 42] - Personalized sub-symptom exacerbation home aerobic exercise training [20] - Full-body stretching program [20] - Single session of Upper cervical spine mobilization [10] - Vestibular Rehabilitation + Treatment as Usual [38] - Sub-symptom threshold aerobic exercise daily [3, 17, 22] - Stretching exercises [21, 22, 28, 37] - Personalized exercise intensity based on target heart rate [16] - Graded, sub-symptom threshold aerobic exercise protocol [3, 28] - Aerobic exercise intervention [37] - Structured Aerobic Exercise Prescription (SAEP) [17] - Vestibular rehabilitation [3] - Heart Rate Variability Biofeedback [7, 21, 23] - Sub-symptom exacerbation home aerobic exercise training [13] - Active Rehabilitation Program [9]	- 30 Min Daily light exercise [43] - Standard mTBI Instructions [16, 43] - Stretching exercises [28] - Enhanced graded Exertion [33]	- Strict Rest [42] - Multidimensional Rehabilitation + Enhanced Graded Exertion [33]	- Single session of Lower cervical spine mobilization [10]
Cognitive and Behavioral therapies	A-2	- Behavior Management Strategies [43] - Brain Plasticity-Based Computerized Cognitive Training [25] - Computer games [25] - Psychoeducation Control Group [6, 23] - Therapist-Directed Traditional Cognitive Rehabilitation [6] - Integrated Cognitive Rehabilitation + CBT [6] - Treatment as Usual [2, 40] - Individually Tailored and Goal-Oriented Rehabilitation Program [2] - Cognitive-Behavioral Therapy tailored to Functional Cognitive Disorder [34] - Cognitive Rehabilitation [34] - Intervention based on CBT principles and gradual return to activities/exposure + Enhanced Usual Care [40] - Strategic Memory Advanced Reasoning Training (SMART) [8] - Traditional Cognitive Rehabilitation Program (SCORE) [8] - Embedded Cognitive Rehabilitation Intervention [30]	- Computerized Cognitive Rehabilitation [6] - Compensatory Cognitive training (CCT) and Supported Employment (SE) [11] - Treatment as Usual [11] - Psychoeducation Control Group [23] - Supportive Client-Centered Therapy [30]		
Neuromodulation and Novel Physical Treatments	A-3	- LED Transcranial Light therapy (tPBM) [39] - Placebo light Therapy [39] - Daily Blue light therapy [18] - Blue Light therapy [32] - Hyperbaric Oxygen therapy (HBOT) [14, 15] - Head and Neck Cooling Therapy (Pro2cool) [5, 36]	- LED Transcranial Light therapy (tPBM) [39] - Placebo light Therapy [39] - Sham Intervention [14]	- No-Treatment [15]	- Amber placebo light therapy [18]
Alternative Medicine and Endocrine Interventions	A-4	- Verum Acupuncture [44] - Recombinant Human Growth Hormone (rhGH) Therapy [27] - Endocrinologist treatment [27]	- Sham Acupuncture [44] - Waiting-list control [44]	- No endocrinology treatment [27]	- Healthy controls [44] - Endocrinology not indicated [27]

Figure 2. *Distribution of Participants*



Near even split between adult and adolescent participants. Geographically, over half of the participants are from the USA, with the rest from Canada, Norway, and other countries.

Figure 3. *Geographic Distribution*

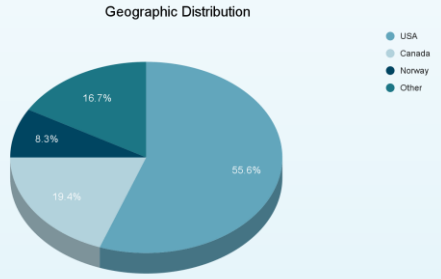


Table 2. *Key Findings*

Major Theme/Pattern	Intervention Category	Combined Key Findings	Intervention Type
Paradigm Shift: Rejecting Strict Rest & Embracing Early Activity	Ineffectiveness of Strict Rest	Strict rest is ineffective or harmful. Strict rest offered no benefit over usual care in adults and was associated with increased symptom reporting in pediatrics. Pediatric patients showed no advantage from strict rest post-concussion.	A-1, A-2, A-3
	Early Active Exercise	• Early active exercise is safe and effective. Sub-symptom threshold aerobic exercise in adolescents accelerates recovery and lowers the risk of delayed recovery (>30 days). • Aerobic exercise (HR-based protocol) is effective when initiated within the first week of sport-related concussion (SRC). • Active rehabilitation is safe for highly symptomatic pediatric patients. • Adults with acute mTBI: early light exercise not sufficient to prevent persistent PCS, but safe and may be encouraged as tolerated.	A-1, A-2
	Timing & Customization	Early aerobic rehab is feasible when initiated 2 weeks post-injury. Individualized Care: A "one-size-fits-all" approach is ineffective; personalization, timing, and dosing are emphasized for future research.	A-1, A-2, A-3, A-4
Multimodal Interventions for Heterogeneous Pathology	Active Physical/Physiological Therapies	• Aerobic Exercise improved recovery speed in adolescents faster than stretching. • Vestibular Rehabilitation (VR) improved vestibular-ocular reflex scores and improved HRQOL (Health-Related Quality of Life) in patients with dizziness/balance issues post-mTBI. • Cervical Mobilization decreased cortisol and modulated HRV; cervical spinal manual therapy modulates the stress response (PSNS activity, cortisol), serving as a potential ANS treatment. • Acupuncture improved symptoms and white matter integrity. • Head/Neck Cooling reduced SCATS scores at immediate, 72h, and 10-day follow-up compared to standard care.	A-1, A-4
	Novel Modalities Targeting Brain Structure/Function	• Blue Light Therapy (BLT) increased Grey Matter Volume (GMV) in the pulvinar thalamus and improved visual/memory performance and executive function. • Hyperbaric Oxygen Therapy (HBOT) (e.g., 40 sessions, 1.5 ATA) is effective in chronic mTBI, improving symptoms, cognition, sleep, and QoL, suggesting it may be a possible disease-modifying therapy. Pediatric HBOT improved cognition and brain structural changes. • Head/Neck Cooling: Decreased SCAT 5 symptom scores immediately, at 72h, and 10-day follow-up	A-3
	Cognitive and Behavioral Therapies	• CBT-based interventions are effective. GAIN (graduated activity + CBT) resulted in greater symptom reduction (RPQ scores) than usual care. • Cognitive Rehabilitation (CR) / SMART training improved functional outcomes (KBCI) in service members. • CBT for Insomnia (CBT-I) improved sleep quality and insomnia symptoms. • Home-based, goal-oriented rehab reduced anxiety/TBI symptoms. • Vocational Rehabilitation (CCT-SE) supported earlier return to work (3 months) versus Treatment As Usual (TAU).	A-2, A-3
Critical Influence of Psychological & Affective Factors	Anxiety and Symptom Burden	• Adolescents with higher PROMIS Anxiety scores, exhibit higher PCSI/PCS symptoms, often regardless of the intervention type. • HBOT, CBT, and GAIN improved mood/anxiety alongside core mTBI symptoms.	A-1, A-2, A-3
	Pre-existing Comorbidity	• Chronic mTBI patients often present with baseline depression/PTSD (PCL-C), which influences prognosis. • CBT-based programs (HBOT, GAIN) are effective in addressing these pre-existing conditions.	A-1, A-2, A-3
	Stress Physiology & Endocrine Complications	• Dysregulated stress response (ANS/HPA-axis) is linked to the persistence of PPCS. Chronic symptoms linked to stress-response dysfunction (SCOR, HRV). • Growth Hormone Deficiency is a common but often unrecognized endocrine complication post-mTBI, representing a non-psychiatric cause of chronic symptoms requiring screening.	A-1, A-2, A-4

Limitations

- **Small sample sizes** reduced statistical power and generalizability across most studies.
- Heavy **reliance on self-reported measures** and lack of objective biomarkers or neurophysiological data.
- **Variability in control group** interventions affecting interpretability. Therapeutic control groups potentially confounded interpretation.

Conclusion

- **Active interventions** regardless of intervention type are more effective than prolonged rest for mTBI recovery.
- **Rehabilitation:** Aerobic exercise, vestibular/cervical therapy, and multidisciplinary programs are effective, low-risk interventions for improving function and quality of life.
- **Psychosocial Interventions:** Psychoeducation, CBT, and cognitive/vocational rehabilitation reduce persistent symptoms, enhance psychological resilience, and support reintegration into work and academic settings.
- **Emerging Therapies:** Hyperbaric oxygen therapy, blue-light therapy, acupuncture, and head-neck cooling demonstrate encouraging preliminary results, but require further evaluation.
- Contemporary management of mTBI should be multimodal, individualized, and time-sensitive, integrating physical, cognitive, and psychosocial domains to mitigate the risk of persistent post-concussion symptoms and optimize long-term recovery.

References

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