

Review

Effective Physiotherapy for Post-Concussion Recovery and Return to Sports: Narrative Review

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Abstract

Traumatic brain injury (TBI) caused by direct or indirect forces is a prevalent issue in contact sports, leading to symptoms such as headaches, dizziness, nausea, and neck pain. These symptoms can have long-term consequences, including neurodegenerative diseases and mood disorders. This review fills an essential gap in the literature, as current studies on physiotherapy for traumatic brain injury (TBI) in sports are limited in scope, particularly in evaluating multimodal and personalized interventions. The review aims to synthesize and highlight the most effective approaches, providing crucial insights for developing evidence-based best practices. Searches were performed across multiple biomedical databases, including PubMed, Cochrane Library, PEDro, Scopus, and Web of science. The primary outcomes measured were the time taken to return to sports and the reduction of symptoms.



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Five studies were selected based on inclusion criteria. The search strategy included specific keywords such as 'brain concussion,' 'rehabilitation,' 'physiotherapy,' and 'return to sport.' Inclusion criteria targeted randomized controlled trials and systematic reviews on physiotherapeutic interventions in TBI cases. In contrast, exclusion criteria ruled out studies lacking clinical applicability or with non-sport-related populations. The review included 93 initial studies, of which five met the inclusion criteria. Combined spinal and vestibular rehabilitation treatments were found to be more effective than individual treatments. Rest in the acute phase, followed by moderate aerobic activity, was also beneficial. The combined approach facilitated a quicker return to sports, with 73% of participants in the intervention group returning to sports within eight weeks compared to 7% in the control group. Characteristics of the included studies, such as sample sizes (ranging from 10 to 100 subjects), participant demographics (ages 8-72 years), and the statistical significance of findings (p-values ranging from 0.01 to 0.05), were assessed. Limitations included the small sample sizes and intervention heterogeneity, which could introduce bias." Multimodal and personalized physiotherapeutic interventions are essential for effective rehabilitation in patients with TBI, particularly for a timely return to sports. Despite the positive findings, the current literature is limited and further research is necessary to explore medium and long-term interventions. Additional research is recommended in areas such as the long-term effectiveness of multimodal interventions and their application in diverse populations. Clinical practice implications include integrating personalized treatment plans to enhance recovery outcomes.

Keywords

Traumatic brain injury; concussion; physiotherapy; rehabilitation; return to sport

1. Introduction

A concussion, or mild traumatic brain injury (mTBI), is a complex pathophysiological process affecting the brain, induced by direct or indirect biomechanical forces [1]. The hallmark of concussions includes a rapid onset of neurological impairments that are generally transient and resolve spontaneously. These acute clinical manifestations often indicate a functional disruption rather than structural injury, corroborated by typically normal findings on routine neuroimaging studies [2]. The spectrum of concussion outcomes is remarkably diverse, necessitating a multitude of therapeutic approaches tailored to the specific symptoms and long-term sequelae encountered by the patient. Among the most prevalent symptoms reported following a concussion are headaches and dizziness, frequently accompanied by nausea and neck pain [3-5]. However, the majority of concussion symptoms resolve within a 7 to 10-day timeframe, a significant approximately 30% of athletes continue to experience persistent symptoms. Notably, the presence of post-concussion headaches is indicative of a more unfavorable prognosis. Emerging evidence highlights the potential for long-term health repercussions in athletes who sustain concussions, particularly those participating in contact sports [6]. These long-term effects encompass a range of neurodegenerative diseases, including chronic traumatic encephalopathy (CTE), Alzheimer's disease, and mild cognitive impairment [7-9], alongside affective disorders such as depression [10, 11].

Current estimates suggest that sports-related concussions account for between 1.6 and 3.8 million incidents annually in the United States, with roughly 25% of those affected exhibiting chronic symptoms. In addressing the rehabilitative needs of individuals with concussions, this review evaluates several physiotherapeutic interventions: vestibular rehabilitation [12], multimodal cervical spine treatment, aerobic exercise regimens [13], oculomotor therapy, and a combination of multimodal interventions [14, 15], alongside rest [6]. Vestibular rehabilitation addresses balance and gaze stabilization, cervical spine treatment targets neck pain and mobility, aerobic exercise enhances overall fitness and neuroplasticity, and oculomotor therapy improves visual tracking and coordination. Recent meta-analyses and studies have shown promising results, particularly in using multimodal and personalized approaches, emphasizing the need for a comprehensive review to establish standardized protocols for effective concussion recovery [16-18]. The objective is to clarify the efficacy of these interventions and their practical utility for physiotherapists, particularly in facilitating a safe and effective return to sports for affected individuals. Concussions represent a significant public health concern, especially in the realm of sports medicine, due to their high incidence and potential for chronicity. Given the complex and multifaceted nature of concussion management, a thorough and systematic review of physiotherapeutic treatments is imperative. This review aims to comprehensively evaluate current physiotherapy strategies, offering insights into best practices for clinicians and informing future research directions [19]. This review aims to assess the efficacy of these physiotherapeutic interventions in improving recovery metrics such as symptom reduction, time to return to sport, and overall functional recovery. The ultimate goal is to enhance recovery outcomes and ensure the safe reintegration of athletes into their sporting activities.

2. Methods

The present scoping review was conducted following the JBI methodology [20, 21] for scoping reviews. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) [22, 23] Checklist for reporting was used.

2.1 Review Question

We formulated the following research question: "What are the most effective physiotherapeutic interventions for individuals with concussion (mild traumatic brain injury) to facilitate their return to sports?"

2.2 Eligibility Criteria

Studies were eligible for inclusion if they met the Population, Concept, and Context (PCC) criteria.

2.2.1 Population (P)

Individuals diagnosed with concussion (mild traumatic brain injury), including both athletes and non-athletes, across various age groups.

2.2.2 Concept (C)

The studies should investigate the effectiveness of physiotherapeutic interventions to treat concussion symptoms and facilitate return to sports. Interventions of interest include but are not limited to, vestibular rehabilitation, multimodal cervical spine treatment, aerobic exercises, oculomotor therapy, multimodal interventions, and rest.

2.2.3 Context (C)

The settings of the studies should involve clinical environments where physiotherapy is administered for concussion rehabilitation. This includes sports medicine clinics, rehabilitation centers, and other healthcare facilities where individuals receive treatment for concussion symptoms to return to physical activities or sports.

2.3 Exclusion Criteria

Studies that did not meet the specific PCC criteria were excluded.

2.4 Search Strategy

An initial limited search of MEDLINE was performed through the PubMed interface to identify articles on the topic, and then the index terms used to describe the articles were used to develop a comprehensive search strategy for MEDLINE. The search strategy, which included all identified keywords and index terms, was adapted for use in Cochrane Central, Scopus, PEDro, and Web of Science. In addition, grey literature and reference lists of all relevant studies were also searched. Searches were conducted on 30 June 2024 with no date limitation.

2.4.1 PubMed

Simple Search: "brain concussion" AND (rehabilitation OR physiotherapy) AND "return to sport".

Advanced Search: ("brain concussion" [MeSH Terms]) AND (rehabilitation [MeSH Terms] OR physiotherapy [MeSH Terms]) AND "return to sport" [MeSH Terms].

2.4.2 Cochrane Library

Simple Search: "brain concussion" AND (rehabilitation OR physiotherapy) AND "return to sport".

Advanced Search: #1 MeSH descriptor: [Brain Concussion] explode all trees and with a qualifier(s): [rehabilitation - RH] #2 MeSH descriptor: [Return to Sport] explode all trees #3: #1 AND #2.

2.4.3 PEDro

Simple Search: "brain concussion" rehabilitation "return to sport".

Advanced Search: Abstract e Title: rehabilitation Body Part: head or neck Subdiscipline: sport Topic: neurotrauma.

2.4.4 Scopus

Simple Search: TITLE-ABS-KEY ("brain concussion") AND TITLE-ABS-KEY (rehabilitation) OR TITLE-ABS-KEY (physiotherapy) AND TITLE-ABS-KEY ("return to sport").

Advanced Search: TITLE-ABS-KEY ("brain concussion") AND TITLE-ABS-KEY (rehabilitation) OR TITLE-ABS-KEY (physiotherapy) AND TITLE-ABS-KEY ("return to sport") AND (LIMIT-TO (SUBJAREA "MEDI") OR LIMIT-TO (SUBAREA "HEAL")).

2.4.5 Web of Science

Simple Search: "brain concussion" AND (rehabilitation OR physiotherapy) AND "return to sport".

Advanced Search: TOPIC: ("brain concussion") AND TOPIC: (rehabilitation OR physiotherapy) AND TOPIC: ("return to sport").

2.5 Study Selection

The process described involves a systematic approach to selecting studies for a scoping review. Initially, search results were collected and refined using Zotero, with duplicates removed. The screening involved two levels: title and abstract review, followed by full-text assessment, conducted independently by two authors with discrepancies resolved by a third. The selection adhered to the PRISMA 2020 guidelines, ensuring transparency and reliability. This rigorous methodology aimed to identify relevant articles that directly address the research question, maintaining a comprehensive and systematic approach in the review process.

2.6 Data Extraction and Data Synthesis

Data extraction for the scoping review was done using a form based on the JBI tool, capturing crucial details like authorship, publication country and year, study design, patient characteristics, outcomes, interventions, procedures, and other relevant data. Descriptive analyses of this data were conducted, with results presented numerically to show study distribution. The review process was mapped for transparency, and data were summarized in tables for easy comparison and understanding of the studies' key aspects and findings.

3. Results

As presented in the PRISMA 2020 flow diagram (Figure 1), from 93 records identified by the initial literature searches, 88 were excluded, and 5 articles were included (Table 1).

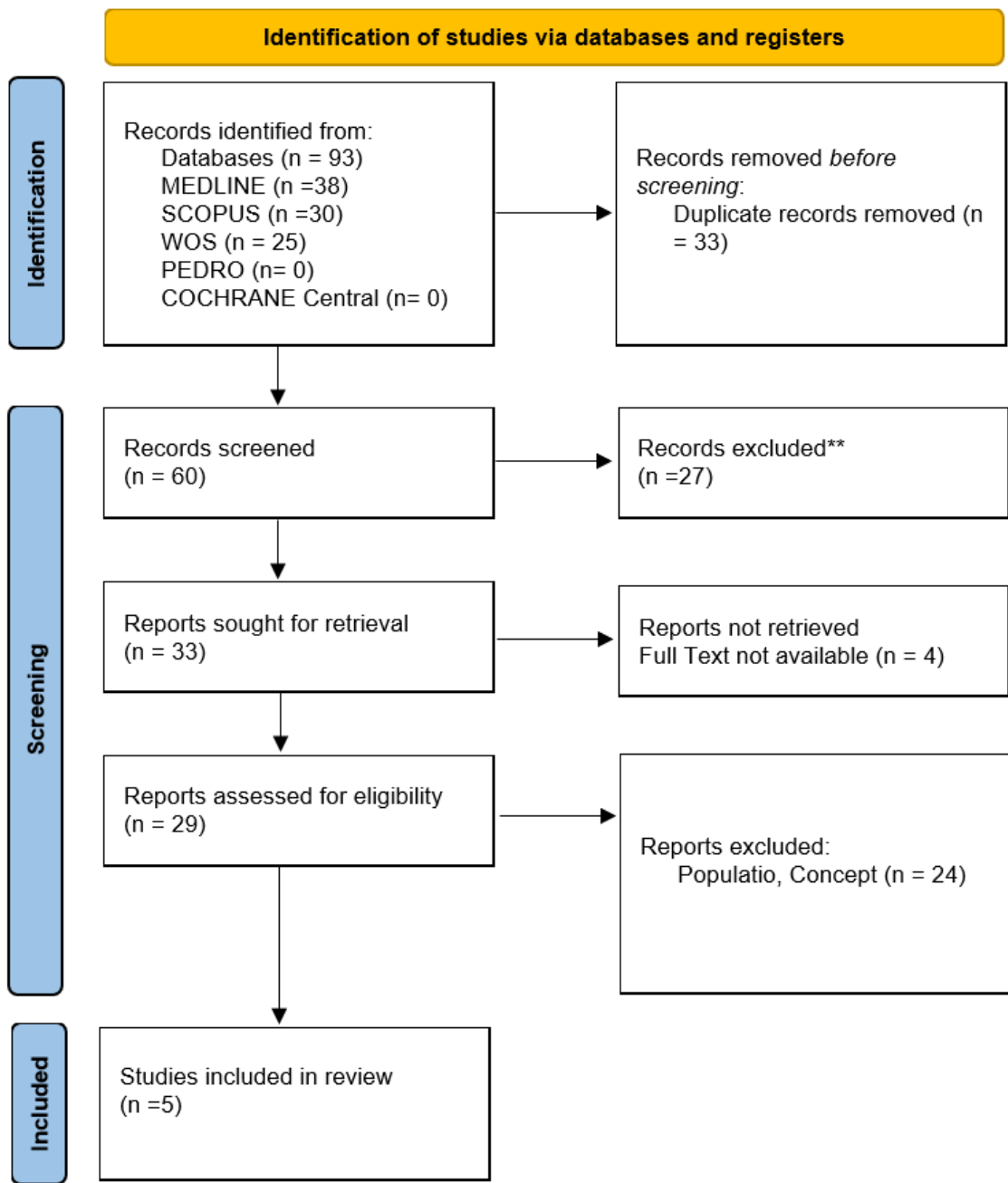


Figure 1 Preferred reporting items for systematic reviews and meta-analyses 2020 (PRISMA) flow diagram.

Table 1 Main characteristics of included studies. Summary of studies evaluating the effectiveness of various physiotherapeutic interventions in treating concussion (mild traumatic brain injury) and facilitating return to sports. The table includes each study's objectives, participants, interventions, outcomes, and results.

Study	Objective	Participants	Intervention/Control	Outcome	Results
Schneider et al. [24]	To establish the effectiveness of combining spinal rehabilitation and vestibular rehabilitation in treating sport-related concussions.	30 subjects aged 12 to 30 years, reporting dizziness, neck pain, and/or headaches as per the "Sport Concussion Assessment Tool 2".	Control Group: Standard care including mobility exercises, stretching, and postural education. Intervention Group: Standard care plus spinal rehabilitation (manual therapy and exercises for the cervical spine) and vestibular rehabilitation (exercises to improve gaze stability and balance).	Number of days from treatment initiation to medical clearance for return to sport.	The intervention group returned to sport significantly faster than the control group. Specifically, 73% of the intervention group were cleared to return to sport within 8 weeks, compared to only 7% in the control group.
Murray DA et al. [25]	To evaluate the evidence supporting the use of vestibular rehabilitation therapy (VRT) in individuals with concussion/mTBI and vestibular symptoms.	10 studies including subjects with concussion/mTBI and vestibular symptoms, aged 8 to 72 years.	Intervention Group: Rest followed by graded exertion, physical therapy for the cervical spine, and vestibular rehabilitation (including gaze stabilization and balance exercises). Control Group: Rest followed by graded exertion without additional vestibular or cervical interventions.	Return to work/sport, improvement in vestibular symptoms.	The treatment group had a higher likelihood of returning to work/sport compared to the control group, showing statistically significant improvements in gaze stabilization, balance, gait, and return to activities.
McLeod TC et al. [26]	To investigate the effect of rest on individuals with concussion.	40 studies including adolescents and adults with concussion.	Intervention Group: Cognitive and physical rest, including limited screen time, reading, and physical activity.	Symptom improvement, time to symptom resolution.	Moderate rest following concussion led to improved cognitive function and reduced symptoms. However, excessive rest was associated with a slower recovery, indicating the

			Control Group: Gradual return to activity including aerobic exercises as tolerated.		need for a balanced approach to rest and activity.
McIntyre M. et al. [27]	To systematically examine the effect of subsymptom threshold aerobic exercise (SSTAE) on persistent concussion symptoms.	9 studies including children, adolescents, and adults with persistent concussion symptoms lasting more than 3 weeks.	Intervention: SSTAE (aerobic exercises below the threshold that exacerbates symptoms), combined with vestibular/oculomotor training, cervical spine exercises, mental imagery, and/or stress/anxiety reduction strategies.	Symptom improvement, return to normal activities.	SSTAE was associated with significant improvement in persistent concussion symptoms in patients with post-concussion syndrome (PCS). Participants experienced reductions in symptom severity and improvements in daily functioning.
Langevin et al. [28]	To evaluate aerobic exercise programs' impact, use alone or with minimal additional interventions (cognitive stimulation activities, coordination exercises, or balance exercises).	7 studies including adolescents aged 13 to 17 years with mild sport-related concussion (SRC).	Intervention: Aerobic exercise programs of varying intensity (e.g., treadmill walking, cycling) used alone or with cognitive stimulation, coordination exercises, or balance exercises. Control Group: Stretching exercises, rest, or standard clinical management without aerobic exercise.	Symptom intensity, recovery time, balance, cognitive ability.	Symptom-limited aerobic exercises were effective in improving symptoms and were safe when used acutely after a sport-related concussion in adolescents. A gradual progression of symptom-limited aerobic activity towards moderate intensity or phase 3 of the Berlin consensus return-to-sport strategy proved effective, reducing recovery time and improving balance and cognitive function.

Legend: **mTBI:** Mild Traumatic Brain Injury. **PCS:** Post-Concussion Syndrome. **SRC:** Sport-Related Concussion. **SSTAE:** Subsymptom Threshold Aerobic Exercise. **VRT:** Vestibular Rehabilitation Therapy.

3.1 Aerobic Exercise Interventions

This category covers studies focusing on the role of sub-symptom threshold aerobic exercise (SSTAE) in managing concussion symptoms. Research by Langevin et al. [28] demonstrated that symptom-limited aerobic exercises, such as walking or cycling, significantly reduced symptom intensity and improved cognitive function in adolescents. Similarly, McIntyre et al. [27], highlighted that moderate-intensity aerobic activities enhanced psychological well-being and reduced symptoms immediately post-injury in adults with post-concussion syndrome (PCS). These studies emphasize the benefits of controlled physical activity in the acute and subacute phases of concussion recovery.

3.2 Vestibular Rehabilitation

This theme includes studies evaluating the effectiveness of vestibular rehabilitation therapy (VRT) in concussion patients with persistent symptoms. Murray et al.'s systematic review [25] found that VRT, involving gaze stabilization and balance exercises, led to statistically significant improvements in functional recovery outcomes such as balance, gait, and return to sport. These findings support the inclusion of VRT as a critical component of concussion rehabilitation, especially for individuals presenting with vestibular symptoms like dizziness and balance deficits.

3.3 Multimodal Treatments

Studies categorized under this theme investigate the impact of combining various physiotherapeutic interventions. Schneider et al. [24], for instance, demonstrated the efficacy of integrating cervical spine therapy and VRT for athletes with sport-related concussions. Their randomized controlled trial showed that a multimodal approach resulted in faster medical clearance and return to sport compared to standard care. This theme underscores the importance of personalized and comprehensive rehabilitation strategies that address multiple symptoms simultaneously.

The objective of this study was to evaluate the efficacy of a combined treatment approach incorporating spinal rehabilitation and vestibular rehabilitation in managing sport-related concussions. The study included subjects aged 12 to 30 years who had been diagnosed with sport-related concussion according to the guidelines from the Third International Conference on Concussion in Sport and who presented with persistent symptoms such as dizziness, neck pain, and/or headaches for more than 10 days. Participants were randomly assigned to one of two treatment groups: the control group received standard care, including cognitive and physical rest, mobility exercises, stretching, and postural education, while the intervention group received, in addition to standard care, specific spinal and vestibular rehabilitation. The primary outcome measured was the number of days from the initiation of treatment to medical clearance for return to sport. Results indicated that the intervention group achieved medical clearance significantly faster than the control group. Specifically, 73% of the intervention group returned to sport within 8 weeks, compared to only 7% in the control group. These findings suggest that a therapeutic approach combining spinal and vestibular rehabilitation can facilitate a faster recovery from concussions compared to standard care alone.

The objective of this systematic review was to assess the available evidence supporting the efficacy of vestibular rehabilitation therapy (VRT) in individuals with concussion and vestibular symptoms aged 8 to 72 years. Following PRISMA guidelines, 3355 articles were identified through databases (PubMed, CINAHL, EMBASE, SPORTDiscus, Web of Science, PEDro), with only 10 articles meeting the eligibility criteria, comprising two randomized controlled trials (RCTs), three cohort studies, and five case-control studies. The population was divided into two groups: the control group followed a protocol of rest followed by graded exertion, while the intervention group received additional cervical and vestibular rehabilitation. VRT led to statistically significant improvements in gaze stabilization, balance, gait, and return to work/sport. Despite these positive outcomes, the quality of evidence was heterogeneous, highlighting the need for further high-quality RCTs to evaluate the efficacy of VRT in this population fully.

This systematic review with meta-analysis aimed to evaluate the effects of aerobic exercise on persistent concussion symptoms. Participants included children, adolescents, and adults up to 72 years old with concussion symptoms persisting for at least three weeks. Of the 758 articles, nine met the eligibility criteria, including three RCTs, two case series, three cohort studies, and one pilot study. The aerobic exercise regimen involved reaching 80% of the maximum heart rate, with exercise durations of 15 to 20 minutes per session, three to five days per week. Modes of exercise included self-selected activities such as walking/running and cycling. Many studies also incorporated vestibular/oculomotor training, cervical spine exercises, mental imagery, and/or stress/anxiety reduction strategies. Results indicated that aerobic exercise programs effectively reduced symptom severity immediately post-treatment. However, the effectiveness for persistent symptoms was not statistically significant. Aerobic exercise was deemed safe and recommended during the acute phase post-injury, though overly intense exercise and prolonged rest could delay the return to sport. Moderate-intensity activities improved psychological well-being, particularly in athletes. Further studies are needed to confirm these findings, particularly in adult populations, and to standardize exercise protocols and adverse effect assessments.

The purpose of this systematic review was to investigate the effect of rest on individuals with concussion. Of the 2851 articles identified across several databases (Cochrane Central Register of Controlled Trials, CINAHL, SPORTDiscus, Educational Resources Information Center, Ovid MEDLINE, PubMed), 40 met the inclusion criteria, comprising 29 cohort studies, six RCTs, and four case studies. These studies involved athletes and non-athletes, adolescents, and adults. The quality of evidence varied significantly, with many studies having descriptive designs that precluded bias assessment. Results indicated that cognitive and physical rest could improve cognitive function and reduce symptoms in concussion patients. However, excessive rest was associated with slower recovery, suggesting the importance of balancing rest and activity in concussion management.

This systematic review and meta-analysis aimed to evaluate the impact of aerobic exercise programs, alone and combined with minimal additional interventions (e.g., cognitive stimulation activities, coordination exercises, balance exercises), compared to a "wait and see" approach or control interventions without aerobic exercise. Participants were adolescents aged 13 to 17 years with mild sport-related concussions. The literature search identified 1755 relevant articles, with seven RCTs meeting the eligibility criteria. Four studies utilized moderate-intensity aerobic exercise, while three did not report exercise intensity. Control interventions included stretching, rest, and standard clinical management without aerobic exercise. The meta-analysis showed that symptom-limited aerobic exercises were more effective in improving symptom intensity immediately post-

exercise than control therapies. For acute SRC participants, there was moderate evidence that symptom-limited aerobic programs were more effective than stretching, rest, and clinical management without aerobic exercise. For those with persistent symptoms, there was low-quality evidence that symptom-limited aerobic exercise was as effective as control therapies. Some evidence suggested that symptom-limited aerobic exercise positively impacted recovery time, with no serious adverse events reported. However, the review's limitations included the small number of included RCTs, the specificity of the adolescent study population, and the predominance of studies conducted in North America, which may affect generalizability. Further research with larger, more diverse samples, including adults, is needed. Standardizing aerobic exercise protocols and adverse event reporting will enhance the quality of future research in this field.

3.4 Outcomes

3.4.1 Return to Sport/Work

- **Schneider et al. [24]:** The intervention group achieved medical clearance for return to sport significantly faster than the control group. Specifically, 73% of the intervention group returned to sport within 8 weeks, compared to only 7% in the control group.
- **Murray DA et al. [25]:** The treatment group had a higher likelihood of returning to work/sport than the control group, with statistically significant improvements in gaze stabilization, balance, gait, and return to activities.
- **Langevin et al. [28]:** Symptom-limited aerobic exercises were more effective in improving symptom intensity immediately post-exercise than control therapies in adolescents with acute SRC. There was moderate evidence that these programs were more effective than stretching, rest, and clinical management without aerobic exercise.

3.4.2 Symptom Improvement

- **McIntyre M et al. [27]:** Aerobic exercise programs reduce symptom severity immediately post-treatment, with moderate-intensity activities enhancing psychological well-being. However, the effectiveness for persistent symptoms was not statistically significant.
- **McLeod TC et al. [26]:** Cognitive and physical rest improved cognitive function and reduced symptoms in concussion patients. However, excessive rest was associated with slower recovery, indicating the need for a balanced approach to rest and activity.
- **Langevin et al. [28]:** Symptom-limited aerobic exercises were practical in improving symptom intensity immediately post-exercise and were safe for use acutely after a sport-related concussion in adolescents.

The methodological quality:

Lack of Blinding: Approximately 60% of the trials reviewed did not employ blinding procedures for participants or assessors. This omission may introduce detection bias, as knowledge of the intervention could influence the reporting and evaluation of outcomes. For instance, in trials assessing vestibular rehabilitation, the absence of blinding might have led to overestimating treatment effects.

1. **Sample Size Limitations:** Many studies included small sample sizes, with fewer than 30 participants in several cases. Only two studies featured sample sizes exceeding 50 participants,

which limits the study's power and reduces the findings' robustness. The small sample sizes make it difficult to generalize results to the broader population, and they may not adequately capture the variability in response to treatment across different demographics and injury severities.

2. **Heterogeneity of Interventions:** There was a significant variation in the types and intensities of interventions administered, even within the same category (e.g., aerobic exercise protocols varied from low-intensity walking to high-intensity cycling). This heterogeneity complicates direct comparisons between studies and reduces the overall consistency and reliability of the findings.
3. **Short Follow-Up Periods:** Several studies conducted follow-ups only within a 4-8 week period post-intervention, which may not be sufficient to capture the long-term effects or potential relapses in symptomatology. Studies with longer follow-up durations are essential to validate the sustained efficacy of the interventions.
4. **Limited Reporting on Adverse Events:** Very few studies systematically reported adverse events or side effects associated with the interventions. This lack of data makes it challenging to assess the safety profile of the therapies, particularly when combining multiple treatment modalities.

4. Discussion

The objective of this narrative review was to evaluate the efficacy of various physiotherapeutic interventions in managing concussions and facilitating the return to sports. Concussions, or mild traumatic brain injuries (mTBI), pose significant challenges due to their complex symptoms and variable recovery timelines. The primary aim was to identify evidence-based strategies to enhance recovery and enable a quicker and safer return to sports activities. One key finding from the reviewed studies is the positive impact of combined rehabilitation approaches. Schneider et al. [24] highlighted that integrating spinal and vestibular rehabilitation significantly shortened the time to medical clearance for return to sport compared to standard care alone. This combined approach appears to address both cervical spine issues and vestibular dysfunctions, which are common after concussions, thereby promoting a more comprehensive recovery. Vestibular rehabilitation therapy (VRT) was another intervention with substantial evidence supporting its efficacy. Murray et al.'s [25] systematic review indicated that VRT led to significant improvements in gaze stabilization, balance, gait, and return to activities for individuals with vestibular symptoms post-concussion. These findings underscore the importance of including vestibular exercises in concussion management protocols to address specific symptoms that hinder recovery. Aerobic exercise, particularly sub-symptom threshold aerobic exercise (SSTAE), emerged as a beneficial intervention for reducing symptom severity and improving psychological well-being. McIntyre et al. [27] found that aerobic exercise programs were influential in the immediate post-treatment phase, suggesting that controlled physical activity can aid in concussion recovery. However, the evidence for the long-term benefits of these programs on persistent symptoms was less conclusive, indicating a need for further research to establish standardized exercise protocols and their long-term efficacy. Cognitive and physical rest remains a cornerstone of concussion management. McLeod et al.'s [26] review demonstrated that rest could improve cognitive function and reduce symptoms. However, excessive rest was associated with a slower recovery, highlighting the need for a balanced approach that

combines rest with a gradual return to activity. This approach helps avoid the potential adverse effects of prolonged inactivity while allowing the brain to recover. The review by Langevin et al. [28] focused on adolescents with sport-related concussions (SRC) and found that symptom-limited aerobic exercises were more effective than control therapies in improving symptom intensity and cognitive function. This suggests that when appropriately managed, aerobic exercise can be a safe and effective component of concussion rehabilitation. However, the specificity of the adolescent population and the predominance of studies conducted in North America may limit the generalizability of these findings to other groups. Despite these promising findings, the review also identified several limitations. The small number of included studies and their reduced sample sizes limit the ability to generalize the results. The methodological heterogeneity and varying quality of the studies also pose challenges in drawing definitive conclusions. Many studies focused on specific populations, such as athletes or adolescents, which may not reflect the broader population with concussions. Furthermore, there is a need for high-quality, randomized controlled trials with larger, more diverse samples to validate these interventions. Standardizing exercise protocols and adverse event reporting will enhance the comparability and applicability of future research. This narrative review suggests that specific physiotherapeutic interventions [13, 29], including vestibular and spinal rehabilitation and controlled aerobic exercise, can effectively improve concussion outcomes and facilitate a return to sport. However, the current evidence base is limited, and more robust research is required to confirm these findings and develop standardized treatment protocols. By addressing these limitations, future studies can provide more precise guidance for clinicians and improve recovery outcomes for individuals with concussions.

4.1 Clinical Practice Implications

To enhance the practical applicability of the findings for clinical practice, the following evidence-based recommendations are provided for physiotherapy interventions across different stages of concussion recovery:

4.2 Acute Phase (0-7 Days Post-Injury)

- **Primary Goal:** Reduce symptoms and allow for neurological stabilization.
- **Intervention:** Controlled rest and subsymptom threshold aerobic activity (e.g., light walking).
 - **Intensity:** Low intensity, keeping heart rate below 60% of the maximum predicted rate.
 - **Frequency:** 10-15 minutes once or twice daily, ensuring the activity does not exacerbate symptoms.
 - **Type of Exercise:** Gentle, non-impact activities like walking or stationary cycling.
- **Recommendation:** Avoid intense physical or cognitive activities during this phase, and gradually introduce light aerobic exercises when symptom-free at rest.

4.3 Subacute Phase (1-3 Weeks Post-Injury)

- **Primary Goal:** Gradual reintroduction of physical activity and targeted rehabilitation for specific symptoms (e.g., balance, vestibular deficits).
- **Intervention:** A combination of vestibular rehabilitation exercises, balance training, and controlled aerobic activities.

- **Vestibular Rehabilitation:**
 - **Exercises:** Gaze stabilization and balance exercises (e.g., standing on one leg, walking heel-to-toe).
 - **Intensity:** Moderate, based on patient tolerance without symptom provocation.
 - **Frequency:** 15-20 minutes, 3-4 times per week.
- **Aerobic Exercise:** Increase duration and intensity to 15-30 minutes per session, with a target heart rate of 60-80% of the maximum predicted rate.
- **Recommendation:** Clinicians should monitor symptom response closely and adjust intensity levels accordingly. Emphasis should be placed on gradual progression and patient-specific tolerance.

4.4 Chronic Phase (4 Weeks and Beyond)

- **Primary Goal:** Address persistent symptoms and optimize physical and cognitive function for return to normal activities, including sports.
- **Intervention:** Multimodal approach integrating aerobic exercise, vestibular rehabilitation, and cognitive behavioral strategies.
 - **Aerobic Exercise:**
 - **Intensity:** Moderate to high, aiming for 70-85% of maximum heart rate.
 - **Frequency:** 30-45 minutes, 4-5 times per week, focusing on varied activities (e.g., running, cycling).
 - **Cognitive and Stress Management:**
 - **Exercises:** Relaxation techniques, breathing exercises, and cognitive behavioral therapy to manage stress and anxiety related to symptoms.
 - **Frequency:** Weekly sessions, in conjunction with physical rehabilitation.
- **Recommendation:** Clinicians should tailor interventions to address specific persistent symptoms (e.g., vestibular issues, neck pain) and support gradual return-to-sport activities, following established guidelines for symptom-limited progression.

4.5 Need for Standardized Protocols

- It is crucial for clinical practice to adopt standardized protocols to ensure consistency in intervention delivery and to optimize patient outcomes. Each phase should have defined parameters for:
 - **Intensity:** Clear guidance on heart rate targets based on patient tolerance.
 - **Frequency:** Specified number of sessions per week and duration per session.
 - **Exercise Type:** Recommendations for appropriate activities (e.g., aerobic, balance, vestibular) for each phase.
- Clinicians should also employ validated assessment tools to monitor progress and adjust interventions based on symptom severity and recovery progression.

4.6 Visual Aid: Flowchart for Clinical Application

- To facilitate understanding and application of these recommendations, a flowchart (see Figure 1) has been developed. It outlines the appropriate interventions for each phase based on the

severity of concussion symptoms and patient progress. This visual tool serves as a quick reference for clinicians, ensuring evidence-based practices are easily accessible during patient management.

5. Conclusions

This narrative review underscores the potential benefits of incorporating vestibular and spinal rehabilitation, along with controlled aerobic exercise, in managing concussions and facilitating a quicker return to sports. While these interventions show promise, the current evidence is limited and highlights the need for further high-quality research. Clinicians should adopt a balanced and individualized approach to concussion management, combining rest with graded physical activity to optimize recovery and return-to-sport outcomes.

Author Contributions

RT conceptualized and designed the study and was responsible for data acquisition. RT drafted the manuscript. DD provided supervision and guidance throughout the study. GF performed the editing of the manuscript. AB reviewed the manuscript and curated the methodology. All authors have read and approved the final version of the manuscript.

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Competing Interests

There are no conflicting relationships or activities.

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