QUALITY IN SPORT
eISSN 2450-3118 · Open Access · Peer-reviewed
apcz.umk.pl/QS Nicolaus Copernicus University in Toruń

JONAKOWSKI, Jakub, GRANDOS, Jakub, NOWAK, Julia, ŁASZCZYCH, Mateusz and POLAK, Mateusz. Targeted Cervicovestibular Rehabilitation for Persistent Symptoms After Sport-Related Concussion: A Narrative Review. Quality in Sport. 2026;70:747643. https://doi.org/10.12775/QS.2026.70.74643

ARTICLE TIMELINE
Received: 24.07.2026. Accepted: 17.08.2026. Published: 23.08.2026.

The journal has been awarded 20 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32553). Unique Journal Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 – aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

Targeted Cervicovestibular Rehabilitation for Persistent Symptoms After Sport-Related Concussion: A Narrative Review

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Abstract

Background: Sport-related concussion (SRC) usually resolves within the expected window, but a subgroup of athletes develops persistent symptoms that delay return-to-play (RTP), possibly reflecting overlapping cervical, vestibular, and vestibulo-ocular contributors rather than one post-concussion syndrome.

Aim: To synthesize evidence on cervical, vestibular, and vestibulo-ocular dysfunction after SRC, with emphasis on persistent symptoms, targeted rehabilitation, and RTP.

Material and methods: A structured PubMed search identified literature on SRC, persistent symptoms, cervical and vestibulo-ocular dysfunction, and rehabilitation. Full texts were narratively stratified; no pooling or risk-of-bias assessment was performed.

Results: Cervical, vestibular, and vestibulo-ocular findings are clinically relevant in athletes with delayed recovery and are associated with persistent symptoms in observational studies. One small randomized trial supports combined cervical-vestibular physiotherapy in youth with persistent dizziness, neck pain, or headache; retrospective data suggest earlier vestibular therapy may shorten recovery, though causality remains unproven.

Conclusions: Persistent symptoms after SRC warrant structured reassessment of cervical, vestibular, vestibulo-ocular, balance, and exertional domains. Targeted cervicovestibular rehabilitation appears promising; prospective trials are needed to define referral criteria, timing, sequencing, and RTP criteria.

Keywords

sport-related concussion; persistent post-concussion symptoms; cervical spine dysfunction; vestibulo-ocular dysfunction; vestibular rehabilitation; cervicovestibular rehabilitation; return-to-play; oculomotor dysfunction; dizziness; neck pain

1. Introduction

Sport-related concussion (SRC) is a common clinical problem in athletes and is typically characterized by a transient disturbance of neurological function after biomechanical force transmission to the head, neck, or body. Although most athletes recover within the expected clinical window, a clinically important subgroup experiences persistent symptoms that delay return to school, training, competition, or full return-to-play (RTP). These persistent symptoms commonly include headache, dizziness, visual complaints, imbalance, neck pain, fatigue, sleep disturbance, and cognitive or emotional symptoms. Importantly, these symptoms are not specific to concussion-related brain dysfunction and may reflect several overlapping clinical mechanisms rather than a single homogeneous post-concussion syndrome. Makdissi et al. emphasized that difficult concussion cases require assessment for coexisting pathologies and multidisciplinary management rather than passive waiting alone [1].

A central challenge in delayed recovery is that symptom-based classification may obscure clinically relevant contributors. Leddy et al. proposed a physiological and clinical approach in which prolonged recovery after SRC may involve several overlapping symptom generators, including cervical injury, vestibular dysfunction, visual dysfunction, migraine, mood or anxiety disorders, chronic pain, and exercise intolerance [2]. This framework shifts clinical reasoning from simply documenting persistent symptoms toward identifying which systems may be contributing to symptom persistence.

The cervical spine is one important and sometimes under-recognized contributor to persistent post-concussion symptoms. Biomechanical forces sufficient to cause SRC may also affect the cervical spine, and cervical dysfunction can present with neck pain, cervicogenic headache, dizziness, restricted range of motion, and altered sensorimotor control. These symptoms overlap substantially with those commonly attributed to concussion. A systematic review by Cheever et al. reported that cervicogenic symptoms are present in both acute and chronic phases after concussion and that neck pain at initial evaluation was associated with an increased risk of persistent post-concussive symptoms; however, this association should not be interpreted as proof of causality [3]. Rebbeck et al. similarly emphasized that whiplash-associated disorder and concussion may share symptoms such as neck pain, headache, dizziness, fatigue, and cognitive complaints, creating a risk that coexisting cervical injury may be missed in primary care [4].

Vestibular and vestibulo-ocular dysfunction are also clinically important after SRC. For the purposes of this review, vestibular dysfunction refers primarily to dizziness, balance, gaze-stability, and vestibular rehabilitation domains, whereas vestibulo-ocular dysfunction refers to visual-vestibular and oculomotor findings such as VOR provocation, smooth pursuit, saccades, near point of convergence, accommodation, and visual motion sensitivity; these domains are discussed together when they overlap clinically. Dizziness, imbalance, blurred vision, difficulty focusing, reading intolerance, visual motion sensitivity, and symptoms provoked by head or eye movement may indicate vestibular or oculomotor involvement. Vestibulo-ocular dysfunction has been associated with prolonged recovery in pediatric SRC cohorts. Ellis et al. reported that vestibulo-ocular dysfunction at initial consultation was associated with longer recovery and was an independent predictor of post-concussion syndrome in pediatric SRC [5]. Master et al. found that vision and vestibular deficits, including provocable symptoms with vestibulo-ocular reflex and smooth pursuit testing, abnormal balance, and accommodative amplitude, predicted prolonged recovery time in children with concussion [6]. These findings support structured vestibular and oculomotor assessment in athletes with persistent dizziness, visual symptoms, balance impairment, or delayed recovery.

Screening and outcome measures can support this domain-informed approach. VOMS may help identify vestibular or oculomotor involvement and guide further evaluation, while clinical outcome tools such as PCSS, DHI, NDI, and HDI may help monitor recovery [7-8,13-14]. Targeted rehabilitation evidence is most relevant when persistent symptoms are linked to identifiable cervical, vestibular, or oculomotor impairments. One small randomized trial supports combined cervical spine physiotherapy and vestibular rehabilitation in a selected subgroup with persistent dizziness, neck pain, and/or headache after SRC, and retrospective studies suggest that earlier vestibular therapy or referral may be associated with shorter symptom resolution or RTP timing [9-12].

Therefore, this narrative review aims to synthesize current evidence on cervical spine, vestibular, and vestibulo-ocular dysfunction after sport-related concussion, with emphasis on their contribution to persistent symptoms, their role in clinical assessment, and the implications of targeted rehabilitation for symptom resolution and return-to-play decision-making.

2. Literature Search Strategy and Evidence Stratification

This article was designed as a structured narrative review focused on the clinical relevance of cervical spine, vestibular, and vestibulo-ocular dysfunction after sport-related concussion (SRC), with particular emphasis on persistent symptoms and return-to-play (RTP) implications. It was not designed as a systematic review or meta-analysis; therefore, no quantitative pooling of effect estimates, formal risk-of-bias assessment, or PRISMA-based study selection process was performed.

A structured PubMed search was performed using the final search strategy provided in Appendix 1. The PubMed export used for this draft contained 88 records. The search combined terms related to SRC and mild traumatic brain injury with terms describing persistent or prolonged symptoms, cervical spine dysfunction, vestibular and oculomotor impairment, rehabilitation, clinical recovery, symptom resolution, medical clearance, and RTP.

Records were screened narratively at the title and abstract level, and full texts were prioritized when they addressed delayed recovery after SRC, cervical spine dysfunction or cervicogenic symptoms, vestibular/balance/vestibulo-ocular or oculomotor dysfunction, targeted rehabilitation, or clinically relevant outcomes such as symptom resolution, medical clearance, return-to-learn, or RTP.

Full-text articles were categorized according to relevance and evidentiary function. Core evidence included studies directly addressing cervical, vestibular, or vestibulo-ocular dysfunction after SRC or persistent post-concussion symptoms with clinically relevant outcomes. Supportive evidence addressed assessment tools, outcome measures, pediatric or adult subgroups, rehabilitation, or multidisciplinary care. Background and optional evidence included broader mTBI literature, protocols, case reports, and highly indirect approaches.

Throughout the synthesis, causal language was reserved for interventional evidence when appropriate. Observational studies were interpreted as evidence of association rather than causation, and evidence from selected pediatric, specialty-clinic, military, non-sport, or chronic mild traumatic brain injury populations was identified as indirect when applied to SRC-specific clinical decisions.

The key evidence domains and cautious interpretive limits are summarized in Table 1.

Table 1. Evidence map: what the current literature supports. This table distinguishes cautious conclusions from claims that should not be overextended.

Clinical question	Main evidence	What can be concluded	What should not be overclaimed
Are persistent symptoms after SRC homogeneous?	Makdissi et al.; Leddy et al.; Shah et al.	Persistent symptoms may reflect overlapping cervical, vestibular, ocular, exertional, headache, sleep, and psychological contributors.	Symptoms alone do not identify the underlying mechanism.

Is cervical dysfunction relevant after SRC?	Cheever et al.; Kennedy et al.; Rebbeck et al.; van der Walt et al.	Cervical symptoms are common in selected PPCS populations and may overlap with concussion symptoms.	Neck pain should not be assumed to cause delayed recovery in all athletes.
Do cervical and vestibulo-ocular problems overlap?	van der Walt et al.; Schneider et al.; Wong et al.	Cervical and vestibulo-ocular treatment needs often coexist in selected clinical samples.	These domains cannot be cleanly separated in all patients.
Are vestibular/oculomotor findings linked to delayed recovery?	Ellis et al.; Master et al.; Kontos et al.; Kaae et al.	VOD and selected vision/vestibular findings are associated with prolonged recovery in pediatric cohorts.	Association does not prove that VOD independently causes delayed recovery.
Is VOMS useful?	Kontos et al.; Kaae et al.	VOMS may help identify patients needing further vestibular/ocular evaluation.	VOMS is not a stand-alone diagnostic or RTP clearance tool.
Does cervicovestibular rehabilitation help?	Schneider et al.	One small RCT supports combined cervical and vestibular physiotherapy in selected youth and young adults.	It does not isolate cervical versus vestibular treatment effects.
Does earlier VRT improve recovery?	Ahluwalia et al.; Ferry et al.; Zargari et al.	Earlier VRT/referral is associated with shorter recovery or RTP in retrospective cohorts.	Observational data cannot prove causality or define optimal timing.
How should recovery be monitored?	Langevin et al.; D'Silva et al.; Smulligan et al.	Global symptom scales should be complemented by domain-specific and functional measures.	A lower symptom score alone does not prove full functional recovery.

3. Persistent Symptoms After SRC: A Symptom-Generator Framework

Persistent symptoms after SRC are best interpreted as a heterogeneous clinical presentation rather than a single uniform entity. Headache, dizziness, fatigue, cognitive fogginess, visual discomfort, imbalance, sleep disturbance, and emotional symptoms are clinically important, but they are not specific to one mechanism. In delayed recovery, these symptoms may reflect overlapping contributions from concussion-related physiological changes, cervical spine dysfunction, vestibular or vestibulo-ocular impairment, headache or migraine phenotype, mood and anxiety symptoms, sleep disturbance, pain, or exercise intolerance [1-2]. Because similar symptoms can arise from different systems, symptom checklists are useful for monitoring burden over time but are insufficient as the sole basis for diagnosis, referral, or RTP decisions. Multidisciplinary clinic data further support the concept that persistent post-concussion presentations may include multiple treatable diagnoses. In a pediatric multidisciplinary concussion clinic, Shah et al. reported a range of specialty-specific findings among children and adolescents with postconcussion syndrome, including binocular vision dysfunction, anxiety, depression, refractive error, myofascial pain syndrome, and benign paroxysmal positional vertigo [15]. Because this was a retrospective clinical sample from a specialty setting, these proportions should not be generalized to all athletes after SRC. However, the findings are clinically relevant because they illustrate how persistent symptoms can involve several modifiable contributors that may be missed by a purely symptom-based approach.

A smaller prospective rehabilitation study in adults with post-concussion syndrome illustrates a related clinical logic: Moser et al. used standardized examination to classify participants into autonomic, cervical, and vestibulo-ocular subgroupings and then prescribed customized rehabilitation. Because this study was small and non-randomized, it should be interpreted as supportive evidence for feasibility of subgroup-informed care rather than proof of efficacy for a specific rehabilitation component [16].

4. Cervical Spine Dysfunction After Sport-Related Concussion

Cervical spine dysfunction should be considered a clinically relevant contributor in athletes with persistent symptoms after SRC, particularly when headache, dizziness, neck pain, or restricted cervical motion are present. The biomechanical forces involved in SRC may be transmitted through the head and neck, and cervical structures can plausibly contribute to symptoms that overlap with post-concussion complaints. However, the current evidence does not justify assuming that cervical dysfunction is the primary cause of persistent symptoms in all athletes. A more defensible interpretation is that cervical dysfunction represents one potentially modifiable symptom generator that should be actively assessed when the clinical presentation suggests cervical involvement. [3,4,17,18]

In their systematic review, Cheever et al. reported that cervicogenic symptoms occur in both acute and persistent post-concussion presentations. The reported prevalence varied widely across studies, ranging from 7% to 69% in acute stages and increasing to as high as 90% in selected patients with persistent post-concussive symptoms. Across the studies included in that review, neck pain at initial evaluation was associated with a higher risk of developing persistent post-concussive symptoms; reported estimates included an odds ratio of 2.58 in one study and a regression coefficient (beta) of 6.38 in another, reflecting different statistical approaches across primary studies rather than a single consistent effect size [3]. Because these findings derive from heterogeneous observational studies and selected clinical populations, they should be interpreted as evidence of association rather than proof that neck pain causes delayed recovery.

The cervical clinical profile after concussion may include neck pain, cervicogenic dizziness, and cervicogenic headache. These features can resemble symptoms attributed to concussion itself, supporting structured cervical examination in delayed or atypical recovery [3].

The overlap between cervical injury and concussion is also supported by literature on whiplash-associated disorder. Rebbeck et al. emphasized that whiplash and concussion may share similar presenting symptoms, biomechanical mechanisms, and neurophysiological sequelae, while neither condition has a single diagnostic gold standard. In their clinical commentary, shared symptoms included neck pain, headache, dizziness, fatigue, and cognitive impairment [4]. Although this work is not specific to SRC and includes motor vehicle collision contexts, it is relevant to clinical reasoning because it highlights the risk of attributing all persistent symptoms to brain injury when cervical injury may coexist.

Clinical examination appears particularly important because symptoms alone may not reliably distinguish cervical contributors from other post-concussion mechanisms. In a retrospective chart review of 46 patients with persistent post-concussion symptoms referred for cervical spine assessment, Kennedy et al. reported that those judged to have a cervicogenic component were distinguished from those without such a component mainly by physical examination findings, especially pain on manual segmental examination. In the subgroup receiving physiotherapy for a cervicogenic component, function improved and pain decreased [17]. Because this study was retrospective, clinic-based, and involved selected patients referred for cervical assessment, the findings should be viewed as preliminary support for cervical assessment and treatment rather than definitive evidence of efficacy.

Another clinically relevant observation is that cervical, vestibular, and vestibulo-ocular problems often appear together. In a retrospective analysis of 147 patients with persistent post-concussion symptoms from a concussion service where both neck and vestibulo-ocular assessments were routinely performed, van der Walt et al. reported that neck treatment was received or recommended in 54% of cases, vestibulo-ocular treatment in 72%, and both in 40% [18]. These results come from a specific service model and should not be generalized directly to all SRC populations. Still, they support the practical point that clinicians should avoid treating cervical, vestibular, and vestibulo-ocular domains as entirely separate when evaluating persistent symptoms.

Emerging mechanistic work provides a possible, but still preliminary, rationale for cervical interventions beyond local musculoskeletal effects. In a proof-of-concept trial limited to males with persistent post-concussion symptoms, cervical mobilization was associated with short-term changes in salivary cortisol or heart-rate variability; these findings remain hypothesis-generating and should not be treated as clinical proof of improved recovery [19].

These cervical findings have practical implications for RTP. Athletes returning to contact, collision, or visually dynamic sports need to tolerate rapid head and neck movements, visual tracking, changes in direction, and sport-specific loading. When cervical movement, palpation, exertion, visual-vestibular tasks, or sport-specific activities reproduce headache, dizziness, or visual symptoms, cervical reassessment and targeted management should be considered before unrestricted progression. [3,4,17,18]

5. Vestibular and Vestibulo-Ocular Dysfunction After Sport-Related Concussion

Vestibular and vestibulo-ocular dysfunction should be considered clinically relevant domains in athletes with persistent symptoms after SRC, especially when dizziness, imbalance, blurred vision, visual motion sensitivity, difficulty focusing, reading intolerance, or symptoms provoked by head or eye movement are present. These symptoms may reflect peripheral vestibular involvement, central vestibular dysfunction, oculomotor impairment, visual-vestibular mismatch, cervical contribution, or overlapping mechanisms. Therefore, vestibular and vestibulo-ocular findings should not be interpreted in isolation, but as part of a multidomain assessment in athletes whose recovery is delayed. [5-8]

Vestibular and oculomotor symptoms are common after concussion and may include dizziness, nausea, vertigo, blurred vision, visual instability, difficulty reading, diplopia, headache, difficulty tracking, and discomfort in visually busy environments. Kontos et al. emphasized that vestibular and oculomotor impairments after SRC are clinically relevant because they may contribute to symptom burden and delayed recovery, while Kaae et al. reviewed evidence that vestibulo-ocular dysfunction can occur in acute, post-acute, and chronic phases after concussion [7-8].

Several pediatric studies suggest that vestibular and vestibulo-ocular findings are associated with prolonged recovery, although these data should be interpreted in the context of clinical referral populations. Ellis et al. analyzed pediatric patients with acute SRC and post-concussion syndrome and reported that vestibulo-ocular dysfunction at initial consultation was associated with longer recovery and was an independent predictor of post-concussion syndrome [5]. Master et al. reported that vision and vestibular problems were common in children with concussion and that provocable symptoms with vestibulo-ocular reflex and smooth pursuits, abnormal balance, and accommodative amplitude predicted prolonged recovery time [6]. These findings support early screening for vestibular and oculomotor involvement, but they should not be read as proof that vestibulo-ocular dysfunction is the sole cause of delayed recovery.

The Vestibular/Ocular Motor Screening assessment is one practical tool for identifying athletes who may require more detailed vestibular or oculomotor evaluation. VOMS typically evaluates symptom provocation during smooth pursuits, saccades, near point of convergence, vestibulo-ocular reflex testing, and visual motion sensitivity. Kontos et al. described VOMS as clinically useful for screening and guiding referral after SRC, while Kaae et al. emphasized that VOMS may help clinicians identify deficits and facilitate referral to vestibular physical therapy or vision-related care [7-8]. However, VOMS should be treated as a screening tool rather than a stand-alone diagnostic endpoint; abnormal findings require interpretation alongside cervical examination, symptom behavior, balance/gait assessment, and clinical history.

Peripheral vestibular disorders may also be present in selected patients after SRC. Reimer et al. reported a retrospective case series of pediatric SRC patients referred for comprehensive vestibular physiotherapy assessment, in whom 12 of 115 were diagnosed with benign paroxysmal positional vertigo. In that selected sample, BPPV resolved after targeted particle repositioning maneuvers [20]. Because this was a small case series from a referred pediatric population, the findings should not be generalized to all athletes with SRC. Nevertheless, the study illustrates an important clinical point: positional vertigo after SRC should prompt appropriate vestibular assessment rather than being assumed to represent nonspecific post-concussion dizziness.

Vestibular and oculomotor dysfunction can also have functional implications beyond symptom reporting. Smulligan et al. found that adolescents with postconcussion dizziness demonstrated impaired tandem-gait performance compared with those without dizziness, whereas poor sleep quality was more closely related to total symptom severity [21]. In a chronic mTBI sample that was not limited to sport-related injury, D'Silva et al. reported poorer Functional Gait Assessment performance in individuals with persistent symptoms, especially during walking with horizontal head turns, vertical head movements, eyes closed, and stair climbing; FGA performance correlated with PCSS and DHI scores [14]. These findings suggest that dynamic balance and gait tasks may capture clinically relevant impairment that is not fully represented by global symptom scores alone, although direct extrapolation to all SRC athletes should be cautious.

These functional findings link vestibular and vestibulo-ocular assessment to RTP. Athletes in visually dynamic sports often need to tolerate rapid head movement, visual tracking, body rotation, dual-task demands, and sudden changes in direction. Therefore, symptom absence at rest should be complemented by assessment of VOMS tasks, dynamic gait, balance, exertion, and sport-specific visual-motor activities when these domains were previously symptomatic. [14,21]

Additional clinical reviews provide broader context for vestibular and balance assessment after concussion, including sport-related concussion, adult mTBI physical therapy, and military medicine; however, these sources remain supportive or indirect for SRC-specific RTP decisions [22-25].

6. Targeted Cervicovestibular Rehabilitation and Timing of Vestibular Therapy

Targeted rehabilitation after SRC is most clinically defensible when it is linked to identified impairments rather than delivered as a generic protocol for all athletes with persistent symptoms. The most direct interventional evidence is available for selected patients whose delayed recovery includes dizziness, neck pain, headache, and/or clinical findings suggesting cervical or vestibular involvement. In this context, cervicovestibular rehabilitation should be understood as an impairment-based approach that combines cervical spine physiotherapy, vestibular rehabilitation, balance training, gaze stabilization, habituation, and selected oculomotor or sensorimotor interventions according to the patient's clinical profile. [9-12]

The strongest direct interventional evidence comes from the randomized controlled trial by Schneider et al. In this study, 31 patients (18 male, 13 female) aged 12–30 years with persistent symptoms of dizziness, neck pain, and/or headache for more than 10 days after SRC were randomized to an intervention group receiving cervical spine physiotherapy and vestibular rehabilitation or a control group; 15 and 14 participants, respectively, were included in the analysis. Both groups received weekly physiotherapy sessions, postural education, range-of-motion exercises, rest until asymptomatic, and graded exertion; the intervention group additionally received individualized cervical and vestibular treatment. The primary outcome was time to medical clearance for return to sport, assessed by a blinded sports medicine physician. Within 8 weeks, 73% (11/15) of participants in the intervention group were medically cleared compared with 7% (1/14) in the control group, and the intervention group was 3.91 times (95% CI 1.34 to 11.34) more likely to be medically cleared by 8 weeks [9].

These findings support the clinical relevance of combined cervical and vestibular physiotherapy in a selected subgroup of youth and young adults with persistent dizziness, neck pain, or headache after SRC. However, the study should not be interpreted as proof that every athlete with persistent symptoms requires the same intervention. The trial enrolled a specific clinical population with symptoms suggesting cervical and/or vestibular involvement, and the intervention combined several components. Therefore, the results support an impairment-based cervicovestibular approach in appropriately selected patients, but they do not isolate the independent effect of cervical therapy, vestibular therapy, or any single exercise component. [9]

Evidence from observational studies suggests that earlier vestibular therapy or earlier referral may be associated with faster recovery-related outcomes in selected athletes with vestibular dysfunction after SRC. Ahluwalia et al. conducted a small retrospective cohort study of 23 patients aged 5-23 years with SRC who initiated vestibular rehabilitation therapy. Patients starting therapy within 30 days were compared with those starting later. The late therapy group had longer median time to RTP and symptom resolution, while earlier therapy was associated with reduced risk of delayed symptom resolution after adjustment for age and initial symptom score [10]. Because the study was small and retrospective, these findings should be interpreted as preliminary and hypothesis-generating rather than causal proof.

Ferry et al. similarly performed a retrospective cohort study of 282 patients with SRC and vestibular dysfunction referred within a sports medicine concussion clinic. In their analysis, each additional day from injury to initial vestibular therapy was associated with an increase in geometric mean time from injury to RTP [11]. This supports an association between delay to vestibular therapy and delayed RTP in that clinical cohort. However, because referral timing may reflect access to care, symptom persistence, clinician practice patterns, or unmeasured confounders, the result should not be framed as definitive evidence that earlier vestibular therapy independently shortens RTP in all athletes.

Zargari et al. evaluated athletes aged 12-23 years with SRC who were referred for vestibular therapy in a regional multidisciplinary concussion center. Earlier vestibular therapy referral was associated with shorter time to symptom resolution and RTP, but not return-to-learn [12]. The authors also noted important limitations, including the retrospective single-center design, relatively small sample of patients referred for vestibular therapy, absence of a non-vestibular-therapy control group, and incomplete information on the actual start and dose of vestibular therapy for some patients. These limitations reinforce the need to present this literature as supportive observational evidence rather than definitive treatment timing guidance.

Integrated rehabilitation models may be especially relevant because cervical, vestibular, and oculomotor deficits often coexist. Wong et al. described a retrospective longitudinal cohort of 38 patients with post-concussion symptoms due to sport and non-sport mechanisms who were treated with a pragmatic protocol addressing cervical dysfunction and benign paroxysmal positional vertigo within the first three weeks of injury, followed by integrated vision and vestibular therapy. After an average of 10.4 sessions over 57.6 days, patient-reported outcomes improved on the PCSS, DHI, Convergence Insufficiency Symptom Scale, Activities-specific Balance Confidence scale, and Brain Injury Vision Symptom Survey; clinical measures such as cervical range of motion, BPPV symptoms, Brock string convergence, and BESS also improved [26]. Because this study was retrospective and uncontrolled, its main value is illustrating a clinically plausible integrated model rather than establishing independent treatment effects.

Clinically, targeted cervicovestibular rehabilitation can be conceptualized as a staged process. First, the clinician identifies whether the athlete's persistent symptoms are dominated by cervical pain or range-of-motion limitation, vestibular symptom provocation, oculomotor deficits, balance impairment, exertional intolerance, or a mixed profile. Second, therapy is matched to the identified impairments and progressed according to symptom response. Third, reassessment should include both global symptom burden and domain-specific measures such as cervical range of motion, VOMS/NPC, DHI, NDI, balance/gait testing, and exertional tolerance. Finally, RTP progression should be considered only when the athlete can tolerate sport-relevant head, neck, visual, vestibular, and exertional demands without clinically meaningful symptom exacerbation. [9,13,18,26]

Supportive rehabilitation literature is broader than cervicovestibular therapy alone. Pediatric and adolescent studies and critically appraised summaries suggest that vestibular rehabilitation or active rehabilitation may be helpful in selected slow-to-recover patients, but many are observational, small, or multimodal and should not be treated as equivalent to randomized evidence [27-32]. Broader reviews and case series support individualized management while remaining indirect for SRC-specific RTP criteria [33-36]. A systematic review and meta-analysis of physical interventions after concussion reported a small-to-moderate effect of subthreshold aerobic exercise on symptom scores but not on days to symptom recovery, limited evidence for stand-alone cervical, vestibular, and oculomotor therapies, and imprecise findings for individually tailored multimodal interventions [37].

7. Clinical Implications for Return-to-Play Decision-Making

RTP decisions after SRC are usually based on clinical recovery, symptom resolution, graded exertional progression, and medical clearance. In uncomplicated recovery, this approach may be sufficient. In athletes with persistent symptoms, however, global symptom improvement does not necessarily indicate recovery across all relevant domains; cervical pain, dizziness, vestibulo-ocular symptom provocation, balance impairment, visual intolerance, or exertional symptom exacerbation may persist even when the overall symptom score has improved. [1-2]

For this reason, RTP clearance in delayed recovery should include reassessment of the domains that were abnormal during the persistent-symptom phase. This does not require every athlete to undergo every possible test, but it does require that prior cervical, vestibular, vestibulo-ocular, balance, or exertional deficits are not ignored once global symptoms improve. [1-2,7-8]

The cervical domain is particularly important in athletes whose symptoms include neck pain, cervicogenic headache features, dizziness with neck movement, or restricted cervical range of motion. Cervical symptoms have been associated with persistent post-concussion symptoms, and clinical studies suggest that cervical findings may identify a potentially treatable subgroup, although this evidence remains largely observational [3,17]. For RTP, the practical implication is that athletes should tolerate sport-specific head and neck movements, contact preparation, visual tracking, and rapid changes in direction without clinically meaningful reproduction of neck pain, headache, or dizziness.

The vestibular and vestibulo-ocular domains should also be included when the athlete has dizziness, imbalance, visual motion sensitivity, blurred vision, reading difficulty, abnormal VOMS findings, or symptom provocation during gaze-stability tasks. Pediatric cohort studies suggest that vestibulo-ocular dysfunction and selected vision/vestibular findings are associated with prolonged recovery, but these studies do not prove that these abnormalities independently cause delayed RTP in all athletes [5-6]. The RTP implication is that persistent VOMS provocation, abnormal near point of convergence, impaired gaze stabilization, or visual motion sensitivity should prompt further evaluation and consideration of targeted rehabilitation or specialist referral before unrestricted sport exposure.

Outcome measures can support RTP-related monitoring, but they should not replace clinical judgment. Langevin et al. found that the PCSS was responsive to change in patients with persistent post-concussive symptoms and also reported responsiveness of measures such as the Neck Disability Index, Headache Disability Inventory, Dizziness Handicap Inventory, and pain ratings [13]. This supports the use of both global and domain-specific measures during rehabilitation. However, an improved PCSS score alone should not be treated as proof of full functional recovery, particularly if cervical, vestibular, oculomotor, balance, or exertional deficits remain.

A practical RTP framework for athletes with persistent symptoms after SRC should therefore combine symptom-based and domain-based checkpoints. Before unrestricted RTP, the athlete should demonstrate stable or resolved global symptoms, adequate cervical range of motion and head/neck loading tolerance, absence of clinically meaningful dizziness or visual symptoms during vestibular and oculomotor tasks, acceptable balance and dynamic gait performance, tolerance of graded exertion, and successful progression through sport-specific drills without symptom exacerbation. This framework is intended as clinical reasoning support, not as a validated RTP prediction rule. [13-14,21]

A practical domain-informed assessment and rehabilitation framework derived from the narrative synthesis is presented in Table 2.

Table 2. Practical assessment framework for athletes with persistent symptoms after SRC. Suggested assessments and management directions should be individualized and interpreted in clinical context; this framework is not a validated RTP algorithm.

Domain to reassess	When to suspect it	Suggested assessment	Possible management direction	RTP checkpoint
Cervical	Neck pain, occipital/cervicogenic headache, dizziness with neck movement, reduced ROM	Cervical ROM, pain provocation, manual segmental examination, NDI	Cervical physiotherapy, manual therapy when appropriate, ROM/strength/proprioceptive work	Tolerates sport-specific head/neck movement without

				symptom flare.
Vestibular	Dizziness, vertigo, nausea, imbalance, symptoms with head motion	VOMS/VOR, DHI, tandem gait, BESS/mBESS, positional testing if vertigo	Vestibular rehabilitation, gaze stabilization, habituation, balance/gait therapy; repositioning if BPPV	Tolerates head motion, visual complexity, and dynamic balance tasks.
Oculomotor / visual	Blurred vision, diplopia, eye strain, reading difficulty, focusing problems	NPC, saccades, smooth pursuit, accommodation, VOMS	Oculomotor/vision therapy or specialist referral when indicated	Tolerates visual tracking, rapid gaze shifts, and reading/screen demands.
Cervicovestibular overlap	Dizziness plus neck pain and headache; mixed provocation pattern	Combined cervical exam, VOMS, DHI/NDI/HDI, balance/gait	Integrated cervical plus vestibular/ocular rehabilitation; sequence by symptom irritability	Both cervical and vestibulo-ocular domains reassessed before unrestricted RTP.
Balance / dynamic mobility	Postural instability, impaired tandem gait, difficulty with head turns	Tandem gait, FGA, BESS/mBESS, dual-task gait if feasible	Dynamic balance/gait training, head-turn and visual-motion exposure	Performs sport-specific movement demands without imbalance or dizziness.

Exertional/autonomic	Symptom flare with exercise, poor exertional tolerance	Graded exertional testing, HR/symptom threshold	Sub-symptom aerobic exercise, graded return-to-activity	Tolerates progressive exertion; other domains should also be reassessed if previously abnormal.
Mood/sleep/fatigue modifiers	Poor sleep, fatigue, anxiety, irritability, reduced quality of life	Clinical interview, symptom scales, sleep/mood screening	Multidisciplinary management when indicated	Modifiers are controlled enough not to amplify symptoms during RTP progression.

A proposed domain-informed clinical pathway summarizing reassessment, targeted rehabilitation, and return-to-play progression for athletes with persistent symptoms after SRC is shown in Figure 1.

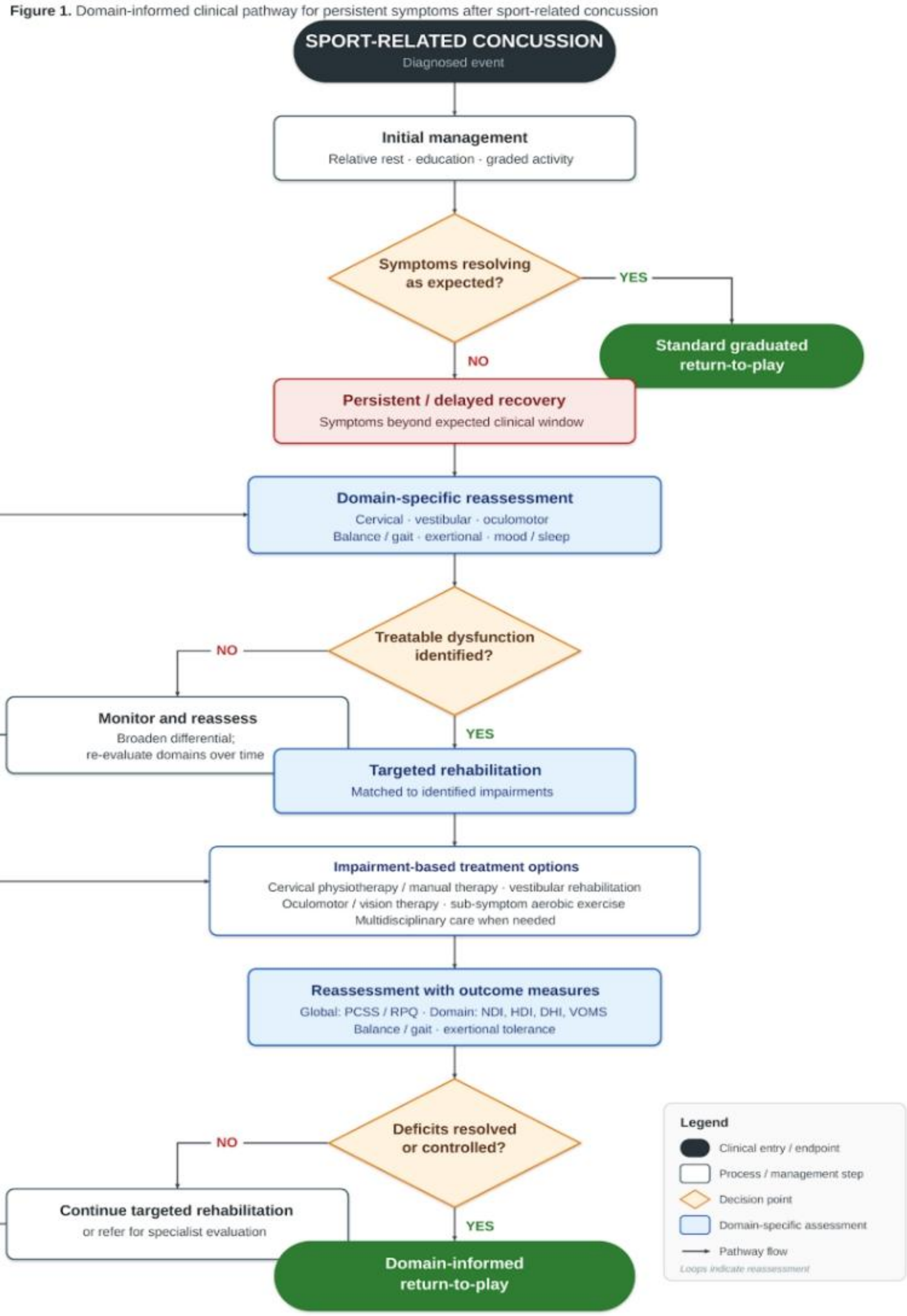

Figure 1. Domain-informed clinical pathway for persistent symptoms after sport-related concussion. The pathway summarizes structured reassessment, impairment-matched rehabilitation, reassessment with outcome measures, and domain-informed return-to-play. It is intended as a clinical reasoning framework, not as a validated prediction rule or mandatory return-to-play algorithm.

8. Limitations and Evidence Gaps

The available evidence supports the clinical relevance of cervical, vestibular, and vestibulo-ocular assessment in selected athletes with persistent symptoms after SRC, but it remains heterogeneous. The strongest direct interventional evidence is a single small randomized trial of combined cervical spine physiotherapy and vestibular rehabilitation in youth and young adults with persistent dizziness, neck pain, and/or headache after SRC [9]. Most evidence linking vestibular or vestibulo-ocular findings, cervical symptoms, referral timing, and recovery outcomes comes from observational or retrospective studies, and should therefore be interpreted as associative rather than causal [3,5-6,10-12]. Definitions of persistent or prolonged symptoms also vary across studies, which limits direct comparison of treatment timing, referral thresholds, and RTP outcomes.

Another important limitation is that cervical, vestibular, and oculomotor domains often overlap clinically. This is useful for real-world assessment, but it makes it difficult to determine which domain drives symptoms and which treatment component is most important. For example, neck and vestibulo-ocular treatment were frequently recommended together in a selected PPCS clinical service [18]. In addition, systematic review evidence suggests that the rehabilitation literature remains uneven: subthreshold aerobic exercise has shown some association with lower symptom scores, whereas evidence for stand-alone cervical, vestibular, and oculomotor therapies remains limited and estimates for multimodal interventions are imprecise [37].

Finally, many included studies involve pediatric, adolescent, specialty-clinic, non-sport, military, or broader mTBI populations. These studies are clinically informative, but they provide indirect evidence when applied to sport-specific RTP decisions [38-43]. Current evidence supports a domain-informed RTP approach, but validated thresholds for cervical examination, VOMS, balance/gait testing, exertional tolerance, or sport-specific visual-motor tasks are still lacking. Future prospective studies should define referral criteria, treatment timing and dose, sequencing of cervical and vestibular interventions, and clinically meaningful RTP endpoints.

Priority research gaps are summarized in Table 3.

Table 3. Priority research gaps.

Research gap	Practical relevance
Limited number of RCTs	Stronger trials are needed to confirm which athletes benefit most from cervicovestibular rehabilitation.

Unclear contribution of individual treatment components	Combined interventions are clinically realistic, but cervical, vestibular, and ocular components are difficult to separate.
Uncertain timing and dose of VRT	Earlier referral appears promising, but optimal timing, frequency, and duration remain unclear.
Variable definitions of persistent symptoms	Different time cutoffs make studies difficult to compare.
Limited adult and elite-athlete data	Much evidence comes from pediatric, adolescent, or specialty-clinic samples.
Limited sport-specific RTP outcomes	Future studies should include dynamic visual, vestibular, cervical, exertional, and sport-specific endpoints.
No validated domain-specific RTP algorithm	Current frameworks support clinical reasoning but should not be treated as validated clearance rules.

9. Conclusions

Persistent symptoms after SRC should not be interpreted as a single homogeneous post-concussion syndrome. In athletes with delayed recovery, symptoms such as headache, dizziness, visual discomfort, imbalance, neck pain, fatigue, sleep disturbance, and cognitive complaints may reflect overlapping cervical, vestibular, vestibulo-ocular, exertional, headache-related, psychological, or sleep-related contributors. This review therefore supports a domain-informed approach in which persistent symptoms prompt structured reassessment rather than passive observation or reliance on global symptom scores alone. [1-2]

Cervical spine dysfunction appears clinically relevant in selected athletes with persistent symptoms, particularly when neck pain, cervicogenic headache features, dizziness with neck movement, or restricted cervical range of motion are present. Observational evidence suggests an association between cervical symptoms and persistent post-concussion symptoms, but causality should not be assumed. Similarly, pediatric cohort studies suggest that vestibulo-ocular dysfunction, abnormal balance, accommodative deficits, and symptom provocation during vestibular or oculomotor testing are associated with prolonged recovery [3-8].

These findings support structured cervical, vestibular, and oculomotor assessment in delayed recovery, while recognizing that screening results should be interpreted within a broader clinical examination. VOMS and related tests may help identify athletes who need targeted referral, but they should not be used as stand-alone diagnostic or RTP endpoints [7-8].

Targeted cervicovestibular rehabilitation appears clinically promising for selected athletes with persistent dizziness, neck pain, headache, or vestibulo-ocular findings. The strongest direct evidence comes from a randomized controlled trial of 31 participants showing that combined cervical spine physiotherapy and vestibular rehabilitation increased the likelihood of medical clearance within 8 weeks (73% vs 7%) in youth and young adults with persistent symptoms after SRC. However, this evidence applies to a selected subgroup, the sample was small, and the combined intervention does not isolate the independent effects of cervical and vestibular treatment components [9].

Observational studies further suggest that earlier vestibular therapy or earlier referral may be associated with shorter symptom resolution or RTP timing in selected athletes with vestibular dysfunction. These findings support early screening and consideration of timely referral when vestibular abnormalities are present, but they should not be interpreted as definitive causal evidence [10-12].

Overall, cervical, vestibular, and vestibulo-ocular dysfunctions should be regarded as clinically identifiable and potentially modifiable domains in selected athletes with persistent symptoms after SRC. A structured approach combining symptom monitoring, cervical assessment, vestibular and oculomotor screening, balance/gait evaluation, exertional testing when appropriate, and targeted rehabilitation may improve clinical decision-making. Higher-quality prospective studies are needed to define referral criteria, treatment timing and dose, sequencing of cervical and vestibular interventions, and validated domain-specific RTP criteria.

Disclosure

Author Contributions

Conceptualization, J.G. and J.J..; methodology, J.G. and M.P. and M.Ł.; literature screening and evidence mapping, M.P., J.G., M.Ł. and J.N.; writing - original draft preparation, M.P., J.G., J.J., J.N., and M.Ł.; writing - review and editing, M.P., J.G., J.J., J.N., and M.Ł.; visualization, M.P. and J.G.; supervision, M.P. All authors have read and agreed to the submitted version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest

The authors declare no conflicts of interest.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

In preparing this work, the authors used Claude (Anthropic) for the purpose of supporting language editing, manuscript organization, formatting assistance, linguistic flow, and bibliographic consistency checks. After using this tool/service, the author(s) have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

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Appendix 1. PubMed search string

(("sport-related concussion"[Title/Abstract] OR "sports concussion"[Title/Abstract] OR "athletic concussion"[Title/Abstract] OR "mild traumatic brain injury"[MeSH Terms] OR "mild traumatic brain injury"[Title/Abstract] OR "mTBI"[Title/Abstract] OR "concussion"[MeSH Terms] OR "concussion"[Title/Abstract]) AND ("persistent symptoms"[Title/Abstract] OR "prolonged recovery"[Title/Abstract] OR "delayed recovery"[Title/Abstract] OR "post-concussion syndrome"[MeSH Terms] OR "post-concussion syndrome"[Title/Abstract] OR "postconcussion symptoms"[Title/Abstract] OR "protracted concussion"[Title/Abstract]) AND ("cervical spine"[MeSH Terms] OR "cervical spine"[Title/Abstract] OR "cervicogenic"[Title/Abstract] OR "neck pain"[MeSH Terms] OR "neck pain"[Title/Abstract] OR "whiplash"[MeSH Terms] OR "whiplash"[Title/Abstract] OR "vestibular"[Title/Abstract] OR "vestibulo-ocular"[Title/Abstract] OR "oculomotor"[Title/Abstract] OR "vestibular diseases"[MeSH Terms] OR "ocular motility disorders"[MeSH Terms] OR "dizziness"[MeSH Terms] OR "dizziness"[Title/Abstract] OR "balance"[Title/Abstract] OR "postural balance"[MeSH Terms] OR "vertigo"[MeSH Terms] OR "vertigo"[Title/Abstract]) AND ("rehabilitation"[MeSH Terms] OR "rehabilitation"[Title/Abstract] OR "physical therapy"[MeSH Terms] OR "physical therapy modalities"[MeSH Terms] OR "manual therapy"[Title/Abstract] OR "vestibular rehabilitation"[Title/Abstract] OR "cervicovestibular rehabilitation"[Title/Abstract] OR "sensorimotor training"[Title/Abstract] OR "proprioceptive training"[Title/Abstract] OR "oculomotor exercises"[Title/Abstract] OR "exercise therapy"[MeSH Terms]) AND ("return to play"[Title/Abstract] OR "return to sport"[Title/Abstract] OR "medical clearance"[Title/Abstract] OR "symptom resolution"[Title/Abstract] OR "symptom burden"[Title/Abstract] OR "recovery"[Title/Abstract] OR "post-concussion symptoms"[Title/Abstract]))