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SYSTEMATIC REVIEW

The Role of Cervical Symptoms in Post-concussion Management: A Systematic Review

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Abstract

Background Patients with cervicogenic symptoms following a concussion have shown a disproportionate rate of delayed symptom resolution. However, the prevalence of cervicogenic symptoms in the acute stages following a concussion and the percentage of those patients who continue on to suffer delayed symptom resolution is poorly described in the literature.

Objectives To provide a comprehensive report on the clinical prevalence, diagnostic methods, and potential treatment options for cervicogenic symptoms that are elicited during acute and chronic phases following a concussion.

Methods Electronic searches were conducted in PubMed, SPORTDiscus, ICL, CINAHL and PEDro, from inception to May 2020, to identify original research articles on concussion involving cervicogenic symptoms. We assessed each included article for risk of bias, methodological quality, level of evidence and evidence quality. The articles were categorized into three topics: (1) prevalence of post-concussion cervicogenic symptoms; (2) diagnostic testing for cervicogenic symptoms, and (3) treatment techniques for cervicogenic symptoms.

Results The initial review resulted in 1443 abstracts, of which 103 abstracts met the inclusion criteria of our research. After the review of full text, 80 articles were excluded, which resulted in a total of 23 articles for this systematic review. Prevalence of cervicogenic symptoms in the acute stages ranged from 7 to 69% and increased to 90% in patients experiencing persistent post-concussive symptoms. Neck pain at initial evaluation increased risk of developing persistent post-concussive symptoms (PPCS) by 2.58–6.38 times. Patient-reported outcome measures (e.g., Neck Disability Index, Dizziness Handicap Inventory, and Rivermead Post-Concussion Questionnaire) can identify patients with cervicogenic symptoms that should be further differentiated by clinical testing. Lastly, treatment using graded cervical manual therapy has shown to reduce time to symptom resolution and medical clearance.

Conclusions Cervicogenic symptoms are prevalent in the acute and chronic stages following concussion, which if not diagnosed appropriately increase the likelihood of PPCS. Several clinical tests are available to help differentiate cervicogenic symptoms; however, lack of awareness and hesitation by practitioners limits their use. More randomized controlled trials are necessary to evaluate the effectiveness of cervical specific treatment programs for PPCS.

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1 Introduction

Concussion and its potential long-term neurologic consequence are a serious public health concern and a growing epidemic that is known to negatively impact tens of millions of people's social, economic, and academic wellbeing across the world each year [1–3]. According to the most recent sports concussion consensus statement a concussion can be defined as representing the immediate and transient symptoms of traumatic brain injury. However, it subsequently noted:

> such operational definitions, however, do not give any insights into the underlying process through which the brain is impaired, nor do they distinguish differ-

Key Points

Cervicogenic symptoms at the time of initial evaluation lead to a higher incidence of persistent post-concussive symptoms (PPCS).

Lack of knowledge among clinicians with respect to appropriate clinical test and diagnostic criteria limits understanding of the true prevalence of comorbid cervical pathology following a concussion.

While several evidence based therapeutic modalities have been widely accepted as treatments for cervicogenic symptoms, the extent to which those treatments translate to treating PPCS patients with a cervical symptom profile is poorly described throughout the literature.

ent grades of severity, nor reflect newer insights into the persistence of symptoms and/or abnormalities on specific investigational modalities[1].

While approximately 70–90% of all concussion cases follow a typical trajectory of symptom resolution within 14 days for adults and 27 days for adolescents and children [1, 4], there is a growing body of literature suggesting a comorbid injury may be associated with a delay in symptom resolution and lead to the development of persistent post-concussive symptoms (PPCS) [5–7, 22]. Specifically, patients suffering from cervicogenic symptoms (e.g., headache and or dizziness originating at the occiput, neck pain) often experience delayed symptom resolution [8–12]. The hallmark characteristics of a cervical clinical profile are described in Table 1. The need for a comprehensive multifaceted post-concussion assessment aimed at differentiating cervicogenic, oculomotor, and vestibular symptoms from symptoms originating from central nervous system injury has emerged and been widely recommended [9, 13, 14]. This clinical assessment should include a comprehensive set of clinical tests and neurologic outcome measures (e.g., symptom reports, neurological screen, balance, visual, vestibulo-ocular, cervical spine and cognitive assessment) that can differentiate the origin of associated symptoms [9, 14, 15]. It has been suggested that this may be the solution to holistically gauge whether, and to what extent, symptoms may be attributed to central nervous system injury and/or comorbid pathology [16].

In considering potential preventive and interventional measures for the treatment of PPCS, particularly for those who manifest with an array of cervicogenic symptoms, it is imperative to understand the prevalence of concussed patients with cervical symptoms, potential causes, and effectiveness of preventive and treatment measures [17]. While cervicogenic symptoms have been implicated in contributing to delayed recovery following a concussion, little is known about what percentage of concussed individuals suffer from this comorbid pathology both in the acute and chronic stages. Moreover, it remains unclear how many clinicians take the time to screen for cervicogenic symptoms, which further complicates efforts to understand the true prevalence of these symptoms. Lastly, while therapeutic modalities such as massage, cervical spine proprioception retraining, vibration, manual manipulations, stretching and traction are widely accepted treatments for cervicogenic symptoms, the nature of how effective those treatments and other active rehabilitation techniques translate into the treatment of PPCS patients with a cervical symptom profile is poorly described throughout the literature.

The aim of this study was to perform a systematic review of the literature pertaining to the prevalence and evaluation of cervicogenic symptoms following a concussion, and to inform the potential interaction between the pathophysiology of PPCS and comorbid cervical pathology. High-level evidence and data were synthesized to provide a comprehensive report on (1) the frequency with which patients suffer from cervicogenic symptoms in both the chronic and acute phases following a concussion; (2) the methodologies that

Table 1 Hallmark traits of a cervical clinical profile following a concussion

Neck pain	Numerous pain-sensitive structures exist in the cervical and occipital regions. Pain generating structures include the joint ligaments, cervical nerve roots and vertebral arteries passing through the cervical vertebral bodies and may be compromised during a concussion due to quick acceleration and deceleration of the head
Cervicogenic dizziness	Cervicogenic dizziness is characterized by the presence of imbalance, unsteadiness, disorientation, neck pain, limited cervical range of motion (ROM), and may be accompanied by a headache. The cervical spine is typically considered the cause of the dizziness when all other potential causes of dizziness are excluded
Cervicogenic headache	Cervicogenic headache is a secondary headache due to a disorder of the cervical spine. Cervicogenic headaches are often characterized by reduced range of neck motion and worsening headache with certain movements or pressure applied to certain points on the neck. The headaches are often unilateral and the pain may radiate from the neck/back of the head up to the front of the head or behind the eye. The headache may or may not be associated with a complaint of neck pain

are effective in identifying cervicogenic symptoms following a concussion, and (3) potential treatments for patients who are diagnosed as having a cervical clinical profile following a concussion.

2 Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [18].

2.1 Data Sources and Search Strategy

A systematic review of the current literature was performed by two independent reviewers using the electronic databases PubMed, SportDiscus, Index to Chiropractic Literature (ICL), Cochrane Library databases and Physiotherapy Evidence Database (PEDro) from January 1st, 1990 to May 26th, 2020. The following keywords were used in different combinations: concussion, neck, cervical, post-concussion syndrome, physical therapy, athletic training, treatment, chiropractic, and manual therapy. For the complete list of combinations, see Table 2. Reference lists of articles meeting the selection criteria were also collected. Searches were limited to human participants and English language publications. All records of literature search were examined by title and abstract to exclude irrelevant records. All abstracts that are related to concussion involving cervicogenic symptoms were selected for a full reading of the article.

2.2 Eligibility Criteria

This systematic review included original research articles on concussion that involve cervicogenic symptoms. Exclusion criteria were foreign origin papers other than English, abstracts, case studies, editorials, magazine articles, and papers that did not fall within the three main topics listed below. Review articles were considered separately and incorporated into the discussion for context. The selection of articles is shown in Fig. 1. Following this search, the articles were categorized into three main topics:

(1) Prevalence of cervicogenic symptoms following a concussion and potential complications associated with a cervicogenic symptom profile.
(2) Diagnostic and classification criteria for the differential diagnosis of cervicogenic symptoms and classification of a cervical clinical profile following a concussion.
(3) Evidence-based treatment for cervicogenic symptoms following a concussion.

2.3 Study Selection

Two authors (KC and KK) performed independently the identification, screening, eligibility and inclusion of studies (Appendix a), with disagreement settled by consensus judgement. The following were recorded: first author, year of publication, study design, age of patients, time since concussion, diagnostic methodology, treatment methodology, main outcome, and relevant results with respect to our aims. When included studies referenced previous papers for details of their methods, full texts of

Table 2 Detailed literature search (January 1, 1990–May 27, 2020)

Database	Keywords	Total	Abstracts reviewed	Articles included
PubMed	Concussion, neck	455	51	14
PubMed	Concussion, Chiropractic	38	5	2
PubMed	Concussion, athletic training, cervical	126	5	1
PubMed	Concussion, pcs, physical therapy	37	8	1
PubMed	Concussion, cervical, treatment	300	13	1
SportDiscus	Concussion, neck	41	1	0
SportDiscus	Concussion, neck, treatment	1	0	0
SportDiscus	Concussion, cervical	27	1	1
SportDiscus	Concussion, physical therapy	11	1	0
SportDiscus	Concussion, cervical, PCS	57	7	1
ICL	Cervical, concussion	17	3	0
Cochrane	Concussion	2	0	0
PEDro	Concussion, cervical	3	0	0
PEDro	Concussion, treatment	14	3	1
PEDro	Concussion, physical therapy	314	6	1
Total		1443	103	23

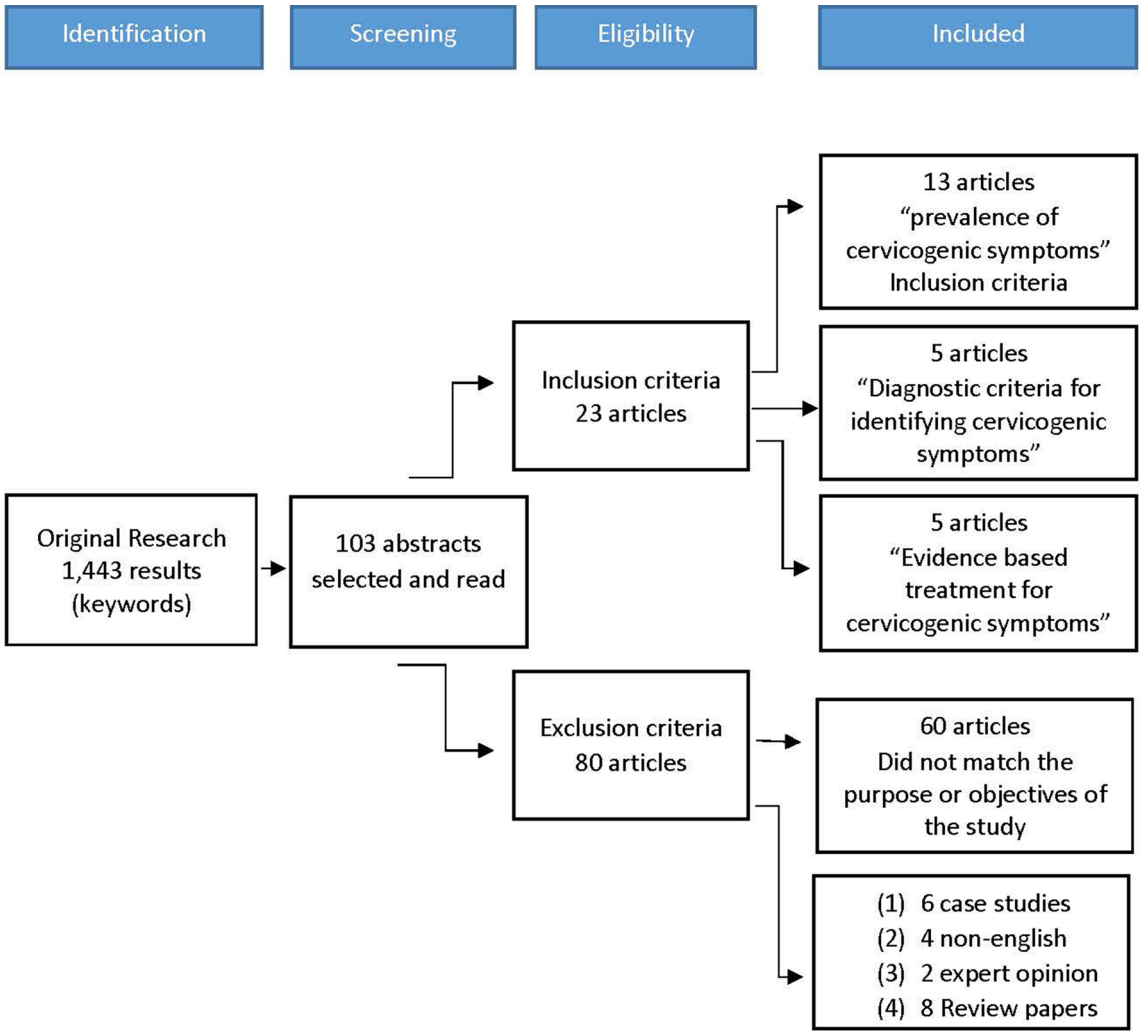

Fig. 1 PRISMA flow diagram

these references were screened, and available data were extracted. In addition, data listed in supplementary documents were also extracted in an attempt to present a fully comprehensive review of the literature.

2.4 Risk of Bias Selection

Two reviewers (KC and KK) independently assessed the risk of bias of the included studies using the Quality in Prognostic Studies (QUIPS) tool, which grades six separate study domains (selection of participants, study attrition, prognostic factor measurement, outcome measurement, study confounding and statistical analyses) according to their risk of bias (low, medium or high risk of bias).

3 Results

3.1 Study Characteristics

The literature search yielded 1443 abstracts after removal of duplicates for initial review, and 103 abstracts met the inclusion criteria of our research (Fig. 1). The full text of all 103 articles were analyzed. Eighty articles were excluded for the following reasons: the main topic did not match the three topics of this study ($n=60$), were case studies ($n=6$), in a foreign language ($n=4$), expert opinion ($n=2$), or a literature review ($n=8$). In total 23 articles met the inclusion criteria for this systematic review. The selected articles are described in Tables 3, 4 and 5.

Table 3 Prevalence of cervicogenic symptoms following a concussion and potential complications associated with a cervicogenic symptom profile

References	Risk of bias	Study objective	Population	Time since concussion	Methods	Main outcomes findings
Treleaven [48]	Medium	Investigate parameters of cervical muscle and joint function in a group of patients with post-concussion headache (PCH) without a history of premorbid headache or neck condition	12 PCH patients aged 15–47 12 age/ gender matched controls	6–29 months	Cross-sectional observational study	10 of the 12 PCH patients had symptomatic joint movement dysfunction—PCH group demonstrated greater forward head posture Higher incidence of moderate neck muscle tightness in PCH group
Smith [29]	High	Report reference values for deep cervical flexor endurance Examine differences with and without a history of concussion	122 High school football players	n/a	Cross-sectional observational study	No significant differences in deep cervical flexor endurance or active range of motion were seen in high school football players with a history of concussion
Hides [28]	Medium	To explore changes in cervical sensorimotor function in the acute phase following sports concussion	54 rugby players 14 sustained concussions	3–5 days	Prospective cohort study	Large inter-individual variation of cervical proprioception was observed
Cnossen [22]	Low	Assess the quality and clinical value of prediction models for PCS and create a new model	591 emergency room patients	6-month follow up survey	Prospective cohort study	241 developed PCS at 6-month Neck pain at time of injury increased the risk of PCS (OR 2.58, 1.39–4.73) Neck pain was present in 18.6% of patients when first evaluated and was the strongest predictor of PCS at 6 months
Ellis [11]	Low	Examine prevalence of cervical spine dysfunction (CSD) among children and adolescents with suspected sports-related concussion and the effect on clinical recovery	266 patients (6–19 years) 80 (32.5%) met clinical criteria for CSD	Not reported	Retrospective cohort study	CSD was defined as the presence of neck pain, headache or dizziness with abnormal spine examination Patients with CSD took longer to recover (28.5 days vs 17 days) and were 3.95 times more likely to experience delayed recovery
Sutton [21]	Low	Identify sex differences in the rate of neck injury comorbidity among patients with a concussion diagnosis in an emergency department	90,175 concussion patients in emergency room	Immediate emergency room post-injury evaluation	Retrospective chart review	Females had higher rate of comorbid neck injury (4333 vs 2995/100,000) Comorbid neck injury was 2.89 times higher in motor vehicle crash then SRC This risk is age dependent

Table 3 (continued)

References	Risk of bias	Study objective	Population	Time since concussion	Methods	Main outcomes findings
Tiwari [24]	Medium	Characterize the type, frequency and severity of cervical impairments in children and adolescents referred for physical therapy after concussion	73 patients following a concussion aged 8–18	6–380 days	Retrospective descriptive study	90% of patients had impairment in 3 categories, while 55% demonstrated 4 Impartments included posture (99%), myofascial impairments (98%), joint mobility (86%), muscle strength (62%), and cervical joint proprioception
Vargo [23]	Low	Assess factors associated with referral disciplines in following concussion	262 patients suffering with a concussion	Mean 67 ± 59 days	Retrospective study	32 patients (12%) were referred to physical therapy for neck pain
Baker [27]	High	Determine relationship between cervical muscle endurance and either concussion incidence, or concussion recovery	University student athletes	n/a	Longitudinal observational study	A moderate correlation between deep-neck flexor endurance test and concussion recovery ($R = 0.47$, $p = 0.001$)
King [19]	Low	Determine the frequency of neck pain overall and relative to other symptoms in patients presenting to emergency department with a concussion	95 patients reporting to emergency room for a concussion	< 3, 8, 15 ,45 days	Repeated measures cohort study	The frequency cervicogenic symptom was 68.4%, 50.6%, 49% and 41.9% at 3, 8, 15, and 45 days, respectively The frequency of neck pain that was equal or worse than other symptoms was 35, 34, 37, and 39 percent across the 4 time points Participants in a motor vehicle collision had a higher rate of primary neck pain
Carmichael [20]	Low	Investigate the epidemiology of diagnosed neck injury in non-SRC vs SRC by age, sex and sport	3,040 participants with non-SRC and 2,775 SRC in youth age 5 to 21	No reported data captured at first evaluation	Cross-sectional epidemiologic study	Prevalence of comorbid neck pathology among SRC was significantly lower than SRC (7.2% vs. 12.1% $p < 0.001$) Females were 6.1% more likely to suffer comorbid neck injury Prevalence of neck pain with concussion increased with age

Table 3 (continued)

References	Risk of bias	Study objective	Population	Time since concussion	Methods	Main outcomes findings
Provance [26]	Low	Examine the effect of current neck or shoulder pain on concussion outcomes	580 concussed; 312 (53.7%) reported shoulder or neck pain	Median 9 days	Retrospective review	Neck or shoulder pain was associated with longer symptom resolution time (beta = 6.38, 95% CI 2.14, 10.31; $p = 0.002$), more severe symptoms (beta = 7.06, 95% CI 1.23, 2.93; $p = 0.004$), and post-injury sleep problems (OR = 2.20, CI 1.51, 3.21; $p < 0.001$)
Van der Walk [25]	Low	To explore how often neck and or vestibulo-ocular treatment is received or recommended in people with PCS	147 patients	Median 39 days Mean 46 ± 51 days	Retrospective chart review	Physical therapy for neck treatment was recommended in 80 cases (54%) Vestibulo-ocular treatment in 106 cases (72%) 59 cases (40%) received treatment or recommendation for both

3.2 Prevalence of Cervicogenic Symptoms Following a Concussion and Potential Complications Associated with a Cervicogenic Symptom Profile.

The present review identified 13 original articles that explored the prevalence of cervicogenic symptoms following concussion and potential complications. First, four articles examined the frequency of neck pain in the acute stages following a concussion [19–22]. Prevalence of comorbid neck pain at time of initial assessment following a concussion ranged from 7.2 to 68.4%. The prevalence of cervicogenic symptoms in patients with PPCS was described in five articles and ranged from 12 to 90% with neck pain and dizziness being the most prevalent symptoms [11, 19, 23–25]. Lastly, six articles demonstrated potential consequences of cervicogenic symptoms such as delayed symptom resolution (e.g., persisted 10 days longer than those without) [7], where the presence of neck pain at time of initial evaluation increased the risk of developing PPCS by 2.58–6.38 times [11, 22, 26–29].

3.3 Diagnostic and Classification Criteria for the Differential Diagnosis of Cervicogenic Symptoms and a Cervical Clinical Profile Following a Concussion

The criteria for multifaceted diagnostic evaluations to differentiate cervicogenic symptoms following concussion was the topic of five original research articles [9, 30–33]. These articles revealed how post-concussive symptoms (e.g., headache, dizziness and neck pain) can be derived from the Neck Disability Index, Dizziness Handicap Inventory, Rivermead Post-Concussion Questionnaire, and single item severity scores may be used to identify those at risk of cervical dysfunction necessitating a more thorough cervical exam [1, 33–35]. Numerous clinical tests such as: cervical strength testing, neck palpation, cervical joint position error test, cervical flexion-rotation test, head and neck differentiation test, and smooth pursuit neck torsion test were identified throughout the literature search and may be useful when differentiating cervical dysfunction [34, 36]. Despite these findings, it became clear that many clinicians are unfamiliar with the process of identifying cervical dysfunction; therefore, cervical tests are not ubiquitously employed in clinical practice [30, 31, 37].

Table 4 Diagnostic and classification criteria for the differential diagnosis of cervicogenic symptoms and a cervical clinical profile following a concussion

References	Risk of bias	Study objective	Population	Time Since concussion	Methods	Main outcomes findings
Reneker [30]	Medium	Identify proper clinical tests to differentiating between cervicogenic and other causes of dizziness after a SRC	25 experts in concussion and dizziness	n/a	Delphi Method survey	The majority of clinical tests identified as having strong clinical utility originate from the vestibular or central nervous system Expert option between and within each medical profession widely diverged regarding the utility of clinical tests to assess cervical dysfunction
Yorke [31]	Low	Describe the current attitudes and beliefs and practice of physical therapists in the treatment of patients with concussion	1272 physical therapists	n/a	Electronic survey	Physical therapist indicate their need in treatment concussion patients, but lack confidence in making diagnostic and return-to-play decisions Large gaps were identified in physical therapy practice in understanding concussion severity scales, conservative treatment techniques, and need for referral for vestibular or manual therapy
Taylor [32]	High	Assess the self-reported concussion knowledge, recognition and treatment by chiropractic practitioners	61 Chiropractic physicians	n/a	Survey	Despite reporting moderate confidence in concussion diagnosis, the average concussion knowledge and recognition score was only 27% Chiropractors < 1 PPCS patient/month Primary action of chiropractors who suspected concussion was referral to neurologist (76%) while only a small percentage provided treatment

Table 4 (continued)

References	Risk of bias	Study objective	Population	Time Since concussion	Methods	Main outcomes findings
Kennedy [33]	High	Evaluate the potential of the neck to contribute to persistent symptoms following a concussion and determine whether the neck has also been injured	20 concussed patients	Mean 7.5 Median 5 weeks	Prospective descriptive case series	Clinicians utilized Rivermead post-concussion symptoms questionnaire, Neck Disability Index, Dizziness handicap inventory as well as patient-reported measures of headache, and neck pain Moderate-to-severe neck disability index scores (33.4 ± 9.5), neck pain (85%) and point tenderness Flexion–rotation test was positive in 45% of patients and muscle tenderness in (50–55%)
Kontos [9]	Low	To develop and test the reliability and validity of a new concussion clinical profile screening tool (CP Screen)	121 concussed athletes and 127 controls	< 30 days	Reliability and validity study	Moderate to high correlations were seen between CP Screen and PPCS factors and VOMS items AUCs for identifying concussed from controls were excellent for migraine (.93), Ocular (.88), vestibular (.85), and cognitive (.81) factors

Table 5 Evidence-based treatment for cervicogenic symptoms following a concussion

References	Risk of bias	Study objective	Population	Time since concussion	Methods	Main outcomes findings
Schneider [10]	Low	Determine if a combination of vestibular rehabilitation and cervical spine physiotherapy decreased time until medical clearance following a concussion	31 PPCS patients (15 therapy and 16 control)	Treatment group 8–276 days Control group mean 31–142 days	Randomized controlled trial	The treatment group saw a significantly greater percentage (73% vs 7%) of the participants reach medical clearance within 8 weeks of starting therapy Individuals in treatment group were 3.91(95% CI 1.34–11.34) times more likely to be medically cleared by 8 weeks
Marshall [38]	High	Review the existing literature surrounding the numerous proposed theories of PPCS and introduce cervical spine dysfunction as a potential and very treatable cause	5 patients diagnosed with PPCS	5 weeks to 31 months	Literature Review and case series	All five patients had very favorable outcomes following cervical treatment Effective treatments included ART®, vibration, active deep-neck flexor endurance
Reneker [39]	Medium	Assess the feasibility of recruitment/retention of early rehabilitation in PPCS Estimate the size of the effect between experimental and control groups	41 concussed patients (10–23 years old)	Mean 12 days		The median days to medical clearance was lower in the intervention group (15.5 vs 26) Median days to symptomatic recovery was shorter in the intervention group (13.5 vs 17) It's feasible and safe to engage in intervention prior to symptomatic recovery

Table 5 (continued)

References	Risk of bias	Study objective	Population	Time since concussion	Methods	Main outcomes findings
Kennedy [40]	High	Describe the cervical spine findings and outcomes of treatment in a series of patients with persistent post-concussion symptoms, and describe the clinical characteristics of a cervicogenic component when it is present	46 patients to a physical therapist for cervical spine assessment	5 groups 29 patients = 1–3 months 3 patients = 4–6 months 4 patients = > 6 months 3 patients = Unclear	Retrospective chart review	32 identified cervicogenic component, 14 had no cervicogenic component Patients were differentially diagnosed by pain on manual segmental examination Patients who underwent physiotherapy treatment achieved improvement in function (mean increase of 3.8 on patient-specific functional scale) and pain (mean decrease of 4.6 in numeric pain-rating scale) Highlight the value of physiotherapy assessment and treatment of the cervical spine following a concussive injury
Hammerle [41]	Medium	Assess the outcomes of 2 treatments for patients with dizziness after concussion who demonstrate abnormal cervical spine proprioception	48 patients 22 vestibular rehabilitation therapy 26 cervical retraining		Retrospective chart review	Patients who received CSPR were 30 times more likely to report improvement compared to VRT

3.4 Evidence-Based Treatment for Cervicogenic Symptoms Following a Concussion

A total of five original research articles [10, 38–41] were used to make the clinical recommendations surrounding the treatment effect on cervicogenic symptoms following a concussion. The present systematic review revealed that active rehabilitation is both feasible and productive in patients suffering from Cervicogenic PPCS following a thorough physical exam to identify signs of a cervical clinical profile and rule out any red flags (e.g., cervical instability). Schneider et al. [10] demonstrated PPCS patients who received therapy were 3.91 times more likely to resolve cervicogenic symptoms within 8 weeks. Similarly, a randomized controlled trail by Reneker et al. [39] showed a reduction in time to medical clearance (15.5 vs 26 days) and median days to symptomatic recovery (13.5 vs 17 days) in patients who received individualized progressive manual therapy such as massage, traction, joint mobilizations and joint reposition training compared to those who received a sham treatment. The authors of these studies reported no complications throughout their treatment protocols further demonstrating the utility and safety of introducing therapy early in patients with cervicogenic symptoms.

4 Discussion

Several decades of concussion research have advanced our knowledge in concussion pathophysiology, diagnosis, and prognostic outlook. Recent research indicates that the mechanism that produces concussion can induce both neural injury in the brain parenchyma and also neck/cervical injury [11, 27, 34]. Symptoms elicited by CNS injury and cervical injury are surprisingly similar but broadly classified as concussion symptoms devoid of a differential diagnosis. This systematic review aimed to uncover the acute and chronic response profile of cervicogenic symptoms following a concussion, determine effective diagnostic tools for cervical dysfunction, and examine the effectiveness of treatment for post-concussive cervical dysfunction. Our review revealed that as many as 68% of patients suffer cervical symptoms during the acute stages following a concussion, while as many as 90% of PPCS patients complain of one or more cervical symptoms. Moreover, a lack of knowledge and clinical experience limited the use of a cervical differential diagnosis by clinicians following a concussion, which significantly hinders true prevalence of comorbid cervical pathology. Furthermore, without proper differential diagnosis, cervical symptoms such as neck pain, tension headache, or dizziness, can be misattributed to vestibular or oculomotor deficits. Lastly, it became evident that patients who were identified as suffering from cervicogenic symptoms may benefit from immediate intervention, including a graded increase in manual therapy and aerobic exercise, which may reduce the risk of developing PPCS.

4.1 What are Cervicogenic Symptoms and What do they Mean Following a Concussion?

While cervicogenic symptoms were first noted following concussion as early as 70 years ago [42], it has only been within the past 5 years that widespread effort has been made to understand the implications of comorbid cervical pathology after a concussion [16, 43]. Several studies have since revealed that as high as 90% of PPCS patients suffer from cervicogenic symptom such as neck pain, cervicogenic headache, and dizziness [11, 21, 22]. The prevalence of comorbid neck pain acutely, or at time of concussion, ranged from 7 to 68% and appeared to be driven by age, sex, reporting/research site and mechanism of injury [19–22]. In young patients, ranging in age from 5 to 21, the highest incidence of comorbid neck pain was seen in 21-year-olds and increased as age increased [21]. Additionally, there was disproportionate reporting of neck pain acutely following a concussion in females (4333/100,000 incidents) compared to males (2995/100,000 incidents) [21]. This result was replicated by Carmichael et al. who found females were more likely to suffer comorbid neck pain than males [20]. This may be partially explained by reports that suggest increased neck strength may decrease linear acceleration of the head in response to sports-related impacts [44–46]. Additionally, neck stiffness and anticipation have been reported to play a role in rate of head acceleration in response to sports-related impacts [47]. Lastly, the mechanism of injury was shown to alter prevalence where sports-related concussions were associated with a lower rate of comorbid neck pain when compared to non-sports-related concussion [19–21]. While the findings of these preliminary studies give clinicians some insight into the prevalence of acute cervicogenic symptoms following a concussion, previous studies were cohort studies utilizing data from emergency room visits, which represents only a subset of concussive injuries [19–22]. Many individuals who sustain a sports-related concussion do not seek care from an emergency room and instead report to an athletic trainer or other health care provider. Moreover, there may be a higher likelihood of an individual seeking medical help at an emergency room if neck pain is present due to the widely documented and publicized risk of cervical spine injury.

The prevalence of cervicogenic symptoms ranged from 12 to 90% of patients referred to specialty clinics due to chronic and/or delayed symptom recovery. Across the PPCS patient populations, it appeared that the presence of identified cervical symptoms was highly dependent on the type of referral. Only 12% of all patients referred to a neuropsychologist specializing in concussion management were referred to physical therapists for neck pain or suspected comorbid cervical pathology [23], while physical therapists specializing in cervicogenic dysfunction identified comorbid cervical pathology in 84–90% of patients seen following physician referral [24, 48]. This finding perhaps suggests that individual clinicians trained in the differential diagnosis of cervical pathology may be more adept at identifying comorbid cervical pathology rather than misattributing these symptoms to other origins. In addition, several articles identified the potential implications of comorbid cervical pathology, such as delayed symptom resolution, delayed return to activity, risk of future injury, and sensorimotor deficits [11, 22, 26].

Overall, the presence of neck pain at first evaluation increased the risk of developing PPCS by 2.58–6.38 times [11, 22, 26], and patients with acute neck pain have more severe overall post-concussion symptoms, as well as post-concussion sleep disturbances [26]. Concussive impacts to the head or neck have also been hypothesized to predispose athletes to a risk of future injury, due to altered cervical sensorimotor function such as decreases in cervical flexor endurance and strength as well as decreased cervical kinesthesia [27–29]. Changes in deep cervical musculature endurance, strength, and kinesthesia vary across concussed patients, and this large inter-subject variation precludes whether and to what extent cervical musculature plays a role in developing cervicogenic dysfunction after a concussion [49]. Additional research is needed to explore what factors may be modifying cervical resiliency and vulnerability to concussive injury.

4.2 How to Identify a Cervical Clinical Profile Following a Concussion?

Understanding the mechanisms, causes and underlining pathophysiology of cervicogenic symptoms following a concussion is the next critical step to the prevention of PPCS patients suffering from cervical symptoms. Ellis et al. [16] first proposed the theory that PPCS patients can be divided into specific post-concussion disorders (PCDs) that could be characterized by features of clinical history, symptom profile, physical exam, and treadmill exercise testing [16]. These PCDs include: global brain metabolism (physiologic PCD), or neurological sub-system dysfunction of either vestibulo-ocular PCD and/or cervicogenic PCD. Since the emergence of this three part classification system, Kontos et al. [9] released an alternative clinical screening protocol that includes five clinical domains based on symptom clusters: (1) anxiety/mood, (2) cognitive/fatigue, (3) migraine, (4) ocular, and (5) vestibular. This protocol uses neck pathology as a modifying, or contextual, factor that may alter each clinical domain in a unique way [9].

Although a multifaceted concussion assessment is widely recommended, it remains unclear what percentage of clinicians are abiding by these recommendations. This complicates an accurate understanding of the prevalence of cervical involvement following a concussion, as certain symptoms may be misdiagnosed and/or attributed to other underlining mechanisms. A partial explanation for the limited clinical use of cervical testing was offered by Reneker et al. [30]. In their survey of expert medical professionals, no consensus was reached on the utility of cervical testing after a concussion, despite demonstrated high sensitivity in differentiating cervical dysfunction [30]. In contrast, a strong-to-moderate consensus was reached by the expert panel for each method presented to differentiate vestibular and/or ocular motor dysfunction following a concussion. The experts identified a lack of familiarity with these cervical tests as the largest obstacle to implementing them in their clinical practice. Similar studies since have explored the attitudes and beliefs of physical therapists [31] and chiropractors [32] only to reveal that they often lack the general knowledge pertaining to conservative treatment protocols and symptom profiles to recognize and conservatively treat concussions. Additionally, many of these practitioners reported an overall hesitancy to provide cervical treatment after a concussion.

Despite disagreement and knowledge barriers between clinicians, there is substantial evidence to suggest patient-reported outcome measures such as the Neck Disability Index, Dizziness Handicap Inventory, Rivermead Post-Concussion Questionnaire, along with single item severity scores can identify cervical symptoms such as headache, dizziness, and neck pain, which can be indicators of a cervical clinical profile following a concussion [1, 33–35]. These measures can provide valuable insight into the necessity for a more thorough cervical exam, while also providing a means for assessment in tracking progress. Moreover, a differential physical exam designed to identify comorbid cervical pathology following a concussion should include tests such as range of motion, cervical strength, neck palpation to explore for point tenderness, joint position error test, flexion-rotation test, head and neck differentiation test, and smooth pursuit neck torsion test [34, 36]. Overall our findings suggest that practitioners who perform an acute physical examination of patients

immediately following a concussion may be able to identify one or more potentially treatable post-concussion symptoms that could then be addressed through active rehabilitation.

4.3 What Should be Done Once a Cervical Clinical Profile has been Identified?

The final step to the prevention of PPCS in patients suffering from cervical symptoms following a concussion is to identify evidence-based treatment strategies and explore the effectiveness of those strategies. Several active treatments such as stretching, manual traction, cervical and/or vestibular physical therapy, cervical manipulation, and subthreshold aerobic exercise, have been proposed to improve symptom resolution in both the acute and chronic stages after a concussion, if implemented at the appropriate time [10, 38–41, 50–53]. The findings of this systematic review outline a three-phased approach that can be followed to identify and treat comorbid cervical pathology following a concussion. The steps to this process are as follows: (1) complete a physical exam that identifies any potentially treatable post-concussion disorder signs or symptoms including cervical symptomology, while simultaneously clearing any red flags that might prohibit progression; (2) if a cervicogenic component is identified in the absence of any red flags, begin graded cervical manual therapy with conservative treatment measures and progress to more aggressive techniques as symptoms permit, and (3) introduce graded aerobic exercise as appropriate.

To start the physical exam of a patient with suspected cervical clinical profile the first step is to rule out injuries such as a cervical fracture, dislocation and/or an otherwise unstable cervical spine, which may result in a more complicated injury if not treated appropriately [53]. This can be done utilizing the purser test, alar ligament stress test, and physical palpation [36, 54]. While palpating, signs of fracture or instability, such as muscle guarding, extreme point tenderness and/or sharp radiating pain should be identified [53]. Stability and strength should also be addressed by measuring deep cervical musculature using the cranio-cervical flexion test. Signs of neurological insufficiencies can also be measured utilizing the smooth pursuit neck torsion and cervical joint position error tests [34]. The patient-reported outcome measures mentioned in the previous section may also be beneficial in establishing a baseline level of dysfunction as well as any signs that the patient may not be ready to progress to the next stage of the intervention plan. Lastly, graded aerobic exercise testing protocols such as the Buffalo Concussion Treadmill Test (BCTT) may be beneficial in identifying deficits due to altered cerebral blood flow regulation, which is useful in the differential diagnosis of one or more post-traumatic disorders after concussive head injury [51, 52]. While a complete review of the BCTT is beyond the scope of this review, cervicogenic symptoms are typically not provoked or worsened dearly during the treadmill exercise test. Sometimes neck pain can develop when the patient is nearing exhaustion on the treadmill or hours after the test is over (from straining of the cervical muscles). Symptom exacerbation in the early stages of the BCTT, conversely, is thought to represent physiological dysfunction of the central autonomic nervous system.

Following a physical exam in which no red flags are raised, manual therapy should begin immediately starting conservatively and progressing to more aggressive treatment techniques based on the clinician's educational training and scope of practice. A referral may be necessary in some instances, especially for more aggressive manual modalities such as cervical manipulation or integrated cervical physical therapy. However, several conservative techniques such as gentle stretching, position release therapy, vibration, light manual traction, and cervical joint position error training have been shown to be effective starting points for any qualified clinician [10, 39–41]. In exploring the role of active physical therapy in PPCS, expedited return to play and symptom resolution have been seen in concussed patients who received treatment compared with those who did not. Schneider et al. [10] reported PPCS patients who received therapy were 3.91 times more likely to be medically cleared in 8 weeks. Furthermore, Reneker et al. [39] demonstrated a reduction in time to medical clearance (15.5 vs 26 days) and median days to post-concussion symptom recovery (13.5 vs 17 days) following targeted manual therapy, as compared to those who received a sham treatment. These results demonstrate the utility and safety of introducing physical therapy early in patients with cervicogenic symptoms after a concussion. Moreover, patients who undergo physiotherapy treatments such as stretching, muscle strengthening and manual traction, achieved improvements on patient-specific functional scales and reduced complaints of pain [40]. It is important to note that these patients received non-specific physical therapy treatments including both vestibular and cervical components.

Although not included in this review, several case studies and case series have shown a significant reduction in PPCS symptoms following highly specialized and targeted intervention techniques such as cervical manual manipulations and mobilizations [8, 55]. Moreover, Hammerle et al. compared the use of vestibular vs cervical specific therapy

by incorporating proprioceptive retraining and therapeutic exercises in PPCS patients suffering from dizziness. In this study, those in the cervical treatment group were 30 times more likely to report improvement in dizziness severity compared to a vestibular treatment group [41]. These preliminary findings serve as a critical data when attempting to design future randomized controlled trials to elucidate the effectiveness of targeted cervical specific interventions on cervicogenic PCS.

Finally, in conjunction with graded manual therapy, graded aerobic exercise may commence where deemed appropriate [16]. While initially a major concern in the acute stages following a concussion due to the threat of symptom provocation and delaying of symptom resolution, direct evidence shows that graded aerobic exercise can be safely integrated into the rehabilitation plan including the treatment of patients with cervicogenic symptom profile [39, 40, 52]. The present systematic review of the literature did not identify any studies in which aerobic exercise was incorporated as a treatment protocol specifically for patients suffering from cervical profiles. However, several studies have revealed the benefits of early graded aerobic exercise in the treatment of patients suffering from post-concussion symptoms [50, 51].

5 Conclusions

Concussion is a multifaceted injury that can be further complicated by comorbid cervical pathology that requires a careful diagnosis and treatment plan. The high prevalence rates and potential implications of cervical pathology in association with a concussion necessitate the inclusion of a cervical spine differential diagnosis when signs of a clinical symptom profile exist. The results from this systematic review suggest that the prevalence of neck pain following a concussion is dependent on several factors such as age, sex, mechanism, and clinician's proficiency in cervical diagnostic measures. Further studies are needed to explore the role each of these modifying factors play in the prevalence of comorbid cervical pathology following a concussion. Furthermore, additional research is warranted to identify the barriers clinicians face when implementing cervical spine differential diagnosis into their clinical treatment of concussion. Lastly, rigorous randomized controlled trials should be conducted to determine the effectiveness of highly specialized treatments on the cervical symptomology.

Appendix

See Table 6.

Table 6 Checklist to guide the selection of studies based on inclusion criteria

Item	Question	Action
1	Did the study discuss cervical symptoms /cervical profile following a concussion?	Yes, move to next questions No, study is excluded
2	Is the full manuscript of the article available and published in English?	Yes, Move to next questions No, study is excluded
3	Did the study utilize one of the eligible study designs?	Yes, move to next questions No, study is excluded
4	Did the study discuss 1 of the following criteria? (1) Prevalence of cervicogenic symptoms following a concussion and potential complications associated with a cervicogenic symptom profile (2) Diagnostic and classification criteria for the differential diagnosis of cervicogenic symptoms and classification of a cervical clinical profile following a concussion (3) Evidence-based treatment for cervicogenic symptoms following a concussion	Yes, move to next questions No, study is excluded
5	Did the study discuss the prevalence of cervicogenic symptoms following a concussion and or potential complications associated with a cervicogenic symptom profile?	Yes, move to question 6 No, move to question 8
6	Did the study discuss the prevalence of cervicogenic symptoms in the acute or chronic stages following a concussion?	Yes, include study No, move to question 7
7	Did the study discuss a complication associated with the presence of cervicogenic symptoms following a concussion?	Yes, include study No, study is excluded
8	Did the article discuss a classification criteria or clinical test used for the identification and differentiation of cervicogenic symptoms following concussion?	Yes, include study No, Move to the next question
9	Did the study describe a treatment protocol that was utilized for the treatment of cervicogenic symptoms following a concussion?	Yes, include study No, study is excluded

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