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Physical Therapy Evaluation and Treatment After Concussion/ Mild Traumatic Brain Injury

Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability and Health From the Academy of Orthopaedic Physical Therapy, American Academy of Sports Physical Therapy, Academy of Neurologic Physical Therapy, and Academy of Pediatric Physical Therapy of the American Physical Therapy Association

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Summary of Recommendations*

SCREENING AND DIAGNOSIS

Diagnosis

A Physical therapists must screen all individuals who have experienced a potential concussive event and document the presence or absence of symptoms, impairments, and functional limitations that may relate to a concussive event.

Screening for Indicators of Emergency Conditions

A Physical therapists must screen patients who have experienced a recent potential concussive event for signs of medical emergency or severe pathology (eg, more serious brain injury, medical conditions, or cervical spine injury) that warrant further evaluation by other health care providers. Referral for further evaluation should be made as indicated (**FIGURE 1**).

Differential Diagnosis

A Physical therapists must evaluate for potential signs and symptoms of an undiagnosed concussion in patients who have experienced a concussive event but have not been diagnosed with concussion. Evaluation should include triangulation of information from patient/family/witness reports, the patient's past medical history, physical observation/examination, and the use of an age-appropriate symptom scale/checklist (see **FIGURE 1** for diagnostic criteria).

F For patients who have experienced a concussive event and do not report or demonstrate signs and symptoms consistent with a concussion diagnosis, physical therapists should evaluate for other potential diagnoses and follow standard-of-care procedures in accordance with their findings.

F For patients who have experienced a concussive event and report or demonstrate signs and symptoms consistent with a concussion diagnosis, physical therapists should determine whether a comprehensive physical therapy evaluation is appropriate using information from a comprehensive intake interview and clinical judgment (see **FIGURE 1** for potential considerations).

A Physical therapists should screen patients who have experienced a concussive event for mental health, cognitive impairment, and other potential coinciding diagnoses and refer for additional evaluation and services as indicated.

F For patients not deemed appropriate for a comprehensive physical therapy examination (ie, those who present with severe mental health concerns or health conditions that require medical clearance prior to comprehensive physical examination), physical therapists should provide education regarding concussion symptoms, prognosis, and self-management strategies and refer for consultation with other health care providers as indicated.

Comprehensive Intake Interview

A Physical therapists must conduct and document a comprehensive intake of past medical history, review of mental health history, injury-related mechanisms, injury-related symptoms, and early management strategies for patients who have experienced a concussive event.

EXAMINATION

Systems to Be Examined

B For patients identified as safe and appropriate for a comprehensive examination, physical therapists must determine and document a need for physical therapy to facilitate recovery from a concussive event, based on findings from a comprehensive multisystem physical therapy examination and evaluation. Examination procedures should include examination for impairments in the domains of cervical musculoskeletal function, vestibulo-oculomotor function, autonomic dysfunction/exertional tolerance, and motor function through foundational standard-of-care screening strategies (**FIGURE 2**).

Sequencing of Examination Based on Levels of Irritability

F Prior to initiating a comprehensive physical examination for patients who have experienced a concussive event, physical therapists should determine probable levels of irritability for movement-related symptoms and impairments and plan to strategically sequence and/or delay examination procedures as needed, based on patients' symptom types and probable levels of irritability. Physical therapists are encouraged to first triage for neck pain irritability and then for dizziness and/or headache (**FIGURE 2**).

F For patients who have experienced a concussive event and have high neck pain irritability but exhibit no signs of serious neck or systemic pathology, physical therapists should first examine the cervical and thoracic spines for sources of musculoskeletal dysfunction and address findings appropriately to promote symptom relief (eg, stretching, soft tissue mobilization, therapeutic exercise, modalities) and to support tolerance of examination of other body systems.

F For patients who have experienced a concussive event and report dizziness, vertigo, and/or headache, physical therapists should thoroughly examine for sources of cervical and thoracic spine dysfunction, vestibular and oculomotor dysfunction, and orthostatic hypotension/autonomic dysfunction that may contribute to the emergence or exacerbation of these symptoms (**FIGURE 2**). Physical therapists should start with the tests that are anticipated to be the least irritable and proceed with the tests anticipated to be the most irritable, based on patient tolerance.

F After triaging and screening for neck pain, dizziness, and headache, physical therapists should proceed with multisystem comprehensive examination of any untested domains of cervical musculoskeletal function, vestibulo-oculomotor function, autonomic dysfunction/exertional tolerance, and motor function by sequencing tests and measures based on clinical judgment as indicated (**FIGURE 2**).

Cervical Musculoskeletal Impairments

C Physical therapists should examine the cervical and thoracic spines for potential sources of musculoskeletal dysfunction for patients who have experienced a concussive event with reports of any of the following symptoms: neck pain, headache, dizziness, fatigue, balance problems, or difficulty with visually focusing on a target. Recommended cervical musculoskeletal tests and measures include range of motion, muscle strength and endurance, tenderness to palpation of cervical and scapulothoracic muscles, passive cervical and thoracic spine joint mobility, and joint position error testing.

F Physical therapists may examine the cervical spine, thoracic spine, and temporomandibular joint for potential sources of musculoskeletal dysfunction for patients who do not report the symptoms listed to determine whether subtle impairments are present and may be contributing to symptoms.

Vestibulo-oculomotor Impairments

B Physical therapists should examine vestibular and oculomotor function for patients who have experienced a concussive event with reports of any of the following symptoms: headache, dizziness, vertigo, nausea, fatigue, balance problems, visual motion sensitivity, blurred vision, or difficulty with focusing on stable or moving targets.

B Physical therapists should examine vestibular and oculomotor function related to the following: ocular alignment, smooth pursuits, saccades, vergence and accommodation, gaze stability, dynamic visual acuity, visual motion sensitivity, light-headedness caused by orthostatic hypotension, and vertigo caused by benign paroxysmal positional vertigo (BPPV).

A If BPPV is suspected, physical therapists should assess the patient using a Dix-Hallpike test or other appropriate positional test(s).

F Physical therapists may examine patients who have experienced a concussive event for vestibulo-oculomotor function, even if vestibulo-oculomotor symptoms are not reported, to identify potential subtle impairments that may be contributing to symptoms.

Autonomic/Exertional Tolerance Impairments

B Physical therapists should test for orthostatic hypotension and autonomic dysfunction (eg, resting and postural tachycardia or fast rise in heart rate with positional changes) by evaluating heart rate and blood pressure in supine, sitting, and standing positions.

B Physical therapists should conduct a symptom-guided, graded exertional tolerance test for patients who have experienced a concussive event and report exertional intolerance, dizziness, headache, and/or a desire to return to high-level exertional activities (ie, sports, active military duty, jobs that entail manual labor). Timing, modality, and protocol should be tailored to optimize safety and individual appropriateness. For patients who are highly symptomatic at rest, the symptom-guided, graded exertional tolerance test should be delayed until symptoms are stable and more tolerable at rest. Likewise, physical therapists may decide to postpone graded exertional testing until later in the course of care if the clinical judgment is that other symptoms and impairments are of higher priority. Testing modality (eg, treadmill versus stationary bicycle) and protocol selection should be based on clinical judgment, patient comfort, and the availability of necessary equipment. Heart rate and blood pressure should be monitored periodically throughout the test and afterward to identify any significant concerns for atypical responses to exercise testing.

C If vestibulo-oculomotor or cervical spine impairments or symptoms are present, physical therapists should use a stationary bicycle for testing to reduce the risk of exacerbating impairments or compromising the validity of the test results.

C Physical therapists may use assessments for orthostatic hypotension/autonomic dysfunction and symptom-guided, graded exertional tolerance tests for patients who do not report exertional intolerance to help determine the role that autonomic dysfunction, deconditioning, or general fitness may play in symptoms (eg, headache, fatigue, fogginess).

F Physical therapists may conduct exertional tests for patients who have experienced a concussive event and do not report symptoms indicative of exertional intolerance in order to rule out subtle autonomic dysfunction in response to exertion, establish initial postconcussion performance level, and identify exertional targets for aerobic exercise training that may be incorporated to promote brain health and healing.

Motor Function Impairments

B Physical therapists should examine patients who have experienced a concussive event for motor function impairments, including static balance, dynamic balance, motor coordination and control, and dual/multitasking (eg, having the patient perform motor tasks along with cognitive tasks or complex tasks with multiple subtasks involved). Selection and timing of motor performance assessments should be based on clinical judgment about which evaluation strategies are most appropriate for the patient's age and ability and will provide the most insight into current functional levels relative to goal levels.

Classification of Examination Findings Into Impairment Profiles

E Physical therapists should establish and document the presence or absence of all impairments and their levels of irritability to support the selection of treatment priorities and strategies for patients who have experienced a concussive event.

B For patients who have experienced a concussive event and report headache as a symptom, physical therapists should determine and document the potential headache type in accordance with the International Classification of Headache Disorders.

Psychological and Sociological Factors

E Physical therapists should elicit, evaluate, and document factors related to self-efficacy and self-management abilities, potential psychological and sociological factors that may significantly influence recovery processes and outcomes for physical therapy interventions. Examples of factors to consider include (1) the patient's expression and demonstration of good, healthy coping strategies in response to stressful situations, (2) the type of support system the patient has to enable self-management of her or his symptoms and impairments, (3) the number and type of potential risk factors that may contribute to delayed or complicated recovery (eg, history of mental health or substance use disorders), (4) the patient's understanding and attitude toward recovery (eg, the patient expresses a positive outlook for recovery versus a more negative mindset or high anxiety toward recovery), and (5) the patient's access to resources and equipment that may facilitate recovery (eg, access to athletic trainer or other health care providers to support recovery).

E When evaluating self-efficacy and self-management factors, physical therapists should explain and emphasize that most symptoms and impairments after concussion do improve.

Outcome Measure Selection

F Physical therapists should determine and document a plan for outcome measurement for patients who have experienced a concussive event for any impairment domains that will be targeted with physical therapy interventions and/or were previously untested due to poor tolerance.

INTERVENTIONS

Communication and Education

B Physical therapists must educate patients who have experienced a concussive event about self-management of symptoms, the importance of relative rest (rest as needed) instead of strict rest, the benefits of progressive re-engagement in activities, the importance of sleep, safe return-to-activity pacing strategies, and potential signs and symptoms of the need for follow-up care with a physician, physical therapist, or other health care provider.

A Physical therapists must educate patients who have experienced a concussive event and their families/caregivers about the various symptoms, impairments, and functional limitations that are associated with concussion, and stress that most patients with concussion recover relatively quickly. Providing this information can help avoid inadvertent reinforcement of poorer recovery expectations.

Movement-Related Impairments

F Physical therapists should use findings from the examination to triage patients who have experienced a concussive event into 1 of 2 categories: (1) patients with movement-related impairments and dysfunction who are good candidates for physical therapy interventions, or (2) patients with no identified movement-related impairments or dysfunction (**FIGURE 3**). Time since injury may influence level of irritability of symptoms, but should not be a primary determinant for decisions regarding when physical therapy interventions are appropriate. Evidence indicates that physical therapy early after concussion is safe, and that earlier initiation of physical therapy interventions may facilitate a faster recovery.

B Physical therapists should design a personalized intervention plan for patients who have experienced a concussive event and have movement-related impairments that aligns interventions with the patient's identified impairments, functional limitations, participation limitations, self-management capabilities, and levels of irritability.

B Physical therapists should refer patients who have experienced a concussive event for further consultation and follow-up with other health care providers as indicated. Of specific note, high-quality clinical practice guidelines recommend referral for specialty evaluation and treatment in cases of persistent migraine-type and other chronic headaches, vision impairments (including ocular alignment), auditory impairments, sleep disturbances, mental health symptoms, cognitive problems, or any other potential medical diagnosis that may present with concussion-like symptoms or coincide with concussion symptoms (eg, lesions/tumors or endocrine abnormalities such as posttraumatic diabetes insipidus).

Cervical Musculoskeletal

B Physical therapists should implement interventions aimed at addressing cervical and thoracic spine dysfunction, such as strength, range of motion, postural position, and/or sensorimotor function (eg, cervicocephalic kinesthesia, head position control, cervical muscle dysfunction) exercises and manual therapy to the cervical and thoracic spines, as indicated, for patients who have experienced a concussive event.

Vestibulo-oculomotor

A If BPPV is identified as a potential impairment, physical therapists should use canalith repositioning interventions.

B Physical therapists with appropriate expertise in vestibular and oculomotor rehabilitation should implement an individualized vestibular and oculomotor rehabilitation plan for patients who have experienced a concussive event and exhibit vestibular and/or oculomotor dysfunction. If visual vertigo/visual motion sensitivity (dizziness provoked by repetitive or moving visual environments) is identified, an individualized visual-motion habituation program may also be beneficial. Patients with neck pain or other cervical impairments may exhibit worsening of cervical impairments due to repetitive head movement as part of vestibular rehabilitation. Therefore, the implications of head-rotation interventions on the possible concomitant cervical impairments should also be considered and addressed.

F Physical therapists who lack appropriate training in vestibular and oculomotor rehabilitation should refer patients who exhibit vestibular and/or oculomotor impairments to a clinician with appropriate expertise.

Exertional Tolerance and Aerobic Exercise

A Physical therapists should implement a symptom-guided, progressive aerobic exercise training program for patients who have experienced a concussive event and exhibit exertional intolerance and/or are planning to return to vigorous physical activity levels. Selection of modality and protocol for training with a specific focus on the patient's goals, comfort level, lifestyle, and access to equipment is encouraged. Timing of the initiation of the aerobic exercise training program may vary by patient, but as soon as the patient's symptoms have stabilized to a moderate or lower level of irritability may be used as a guiding criterion.

E Physical therapists may implement progressive aerobic training for all patients who have experienced a concussive event, including those who do not exhibit exertional intolerance and those who do not intend to engage in vigorous physical activity, in order to reduce risk for deconditioning, promote functional brain healing, and provide a nonpharmaceutical option to improve mental health.

Motor Function

C Physical therapists should implement motor function interventions that address identified or suspected motor function impairments and help progress the patient toward higher-level functional performance goals. Motor function interventions that target the following impairments are strongly encouraged: static balance, dynamic balance, motor coordination and control, and dual/multitasking. Additionally, interventions that directly help improve motor function for work/recreation/activity-specific tasks are strongly encouraged.

Monitoring and Progressing Patients

F Physical therapists should regularly document symptoms, provide reassessments of movement-related impairments, and administer selected outcome measures as needed or indicated for patients with movement-related impairments post concussion.

*These recommendations and clinical practice guidelines are based on the scientific literature accepted for publication prior to January 2019.

List of Abbreviations

ADHD: attention-deficit hyperactivity disorder
AGREE II: Appraisal of Guidelines for Research and Evaluation II instrument
APTA: American Physical Therapy Association
BPPV: benign paroxysmal positional vertigo
CDC: Centers for Disease Control and Prevention
CPG: clinical practice guideline
CT: computed tomography
DHI: Dizziness Handicap Inventory
DVAT: dynamic visual acuity testing
ED: emergency department
GDG: Guideline Development Group
HiMAT: High-level Mobility Assessment Tool
ICD: International Classification of Diseases
ICF: International Classification of Functioning, Disability and Health
mTBI: mild traumatic brain injury
PECARN: Pediatric Emergency Care Applied Research Network
RCT: randomized controlled trial
VOMS: Vestibular/Ocular Motor Screening

Introduction

AIM AND PURPOSE OF THE GUIDELINE

The American Physical Therapy Association (APTA) and the various academies associated with the APTA encourage the creation of clinical practice guidelines (CPGs) for physical therapy management of patients with physical impairments and functional limitations described in the World Health Organization's International Classification of Functioning, Disability and Health (ICF).[224]

The purpose of this endeavor by the APTA and its associated academies is to produce clinical guidelines that

- Describe evidence-based physical therapy practice, including diagnosis, prognosis, intervention, and assessment of outcome approaches for disorders commonly managed by physical therapists
- Classify these conditions using World Health Organization terminology related to impairments of body structure and function, activity limitations, and participation restrictions
- Identify interventions supported by current best evidence to address impairments of body function and structure, activity limitations, and participation restrictions associated with common conditions
- Identify appropriate outcome measures to assess changes resulting from physical therapy interventions in body function and structure as well as in activity and participation of the individual
- Provide a description to policy makers, using internationally accepted terminology, of the practice of physical therapists
- Provide information for payers and claims reviewers regarding the practice of physical therapy for common neurologic and musculoskeletal conditions
- Create a reference publication for physical therapy clinicians, academic instructors, clinical instructors, students, interns, residents, and fellows regarding the best current practice of physical therapy

STATEMENT OF INTENT

This CPG is not intended to be construed or to serve as a standard of medical care. Standards of care are determined on the basis of all clinical data available for an individual patient and are subject to change as scientific knowledge and technology advance and patterns of care evolve. These parameters of practice should be considered as guidelines only. Adherence to them will not ensure a successful outcome in every patient, nor should they be construed as including all proper methods of care or excluding other acceptable methods of care aimed at the same results. The ultimate judgment regarding a particular clinical procedure or treatment plan must be made based on clinician experience and expertise in light of the clinical presentation of the patient; the available evidence; the available diagnostic and treatment options; and the patient's values, expectations, and preferences. However, we suggest that significant departures from strong recommendations should be documented in the patient's medical records at the time the relevant clinical decision is made.

SCOPE

For the purposes of this CPG, the term *concussion* is used synonymously with *mild traumatic brain injury* (mTBI) and is defined as a traumatic injury that affects the brain, induced by biomechanical forces transmitted to the head by a direct blow to, or forces exerted on, the body,[141,153,159] but that does not result in an extended period of unconsciousness, amnesia, or other significant neurological signs indicative of a more severe brain injury. Concussions occur via many different mechanisms and in a variety of contexts, including but not limited to falls, motor vehicle crashes, blast exposures, sporting and recreational injuries, or assault. The nature of such mechanisms and contexts constitutes a concussive event. Considering an injury of this nature as a *concussive* event is useful because the forces that induce concussion may result in damage to brain function (justifying the classification of the injury as a "mild traumatic brain injury") but also concomitant injury to other body structures and functions, especially areas in close proximity to the brain, such as the cervical spine and vestibular system. The Guideline Development Group (GDG) embraced the perspective that all concussions stem from a concussive event to ensure a broader consideration of the other structures, tissues, and body systems that may be involved when a physically traumatic incident occurs.

The intended scope of this CPG is to guide physical therapist clinical decision making for individuals who have experienced a concussive event resulting in movement-related symptoms, impairments, and functional limitations. It is important to acknowledge that there is potential for an individual to have experienced a concussive event but to have never been evaluated for a medical diagnosis of concussion prior to a physical therapy encounter. Therefore, the starting criterion for implementation of this CPG is a physical therapy encounter with a patient who has sustained a potential concussive event, regardless of whether or not the patient has a medical diagnosis of concussion. The CPG may be implemented whether the potential injury occurred recently or in the more distant past. Implementation adjustments for the CPG should not be based on time since injury (or acuity), but rather on clinical judgment of patient presentation, examination results, and response to interventions in alignment with the recommendations and decision trees provided.

Recommendations in this CPG are focused on the evaluation and treatment of individuals 8 years of age and older, with no more than mild cognitive impairment prior to or after the concussive event. Theoretically, the recommendation statements provided in this document may be able to be applied to children under the age of 8 years and individuals with more severe cognitive impairments. However, current management strategies for concussion rely heavily on reliable patient reports of their symptom responses to provocation tests and interventions. There are limited data available on symptom assessment in children under the age of 8 years,[70,141,142] which may limit the applicability of these recommendations for clinical decision making with young children.

It is not the intent of this CPG to address acute concussion screening or diagnosis (eg, sideline assessment), neurocognitive/neuropsychological management, or pharmacological management. These issues are well covered in consensus statements and CPGs that are published by various professional groups and associations (eg, the Ontario Neurotrauma Foundation,[153] Centers for Disease Control and Prevention [CDC],[141] US Department of Veterans Affairs and Department of Defense[149]). We encourage physical therapists to become familiar with other CPGs to enrich their understanding of postconcussion assessments and interventions that are often used but may fall outside the scope of physical therapy care.

CPG Framework

The complexity of concussion-related symptoms and impairments often necessitates the involvement of multidisciplinary teams that include a variety of medical and rehabilitation professionals.[34,107,108,159] The conventional approach to managing individuals with concussion was to encourage rest until symptom resolution.[34,192] One rationale in support of prescribing rest, especially in the first few days after a concussion, is that it may help alleviate symptoms and ease the discomfort individuals with concussion often experience.[66,166,167] It has also been hypothesized that rest may facilitate the brain's recovery by reducing energy demands and attenuating the acute neurometabolic and inflammatory responses to a concussive injury.[133,192] Moreover, concerns over potential risk for catastrophic injury from another head injury occurring prior to recovery from the first concussion have led to cultural and policy shifts designed to prevent individuals from returning to high-risk activities too soon.[159]

Recently, authors have questioned the value of rest until symptom resolution and suggest that an earlier, gradual return to activity may be beneficial.[34,192] Observational and experimental studies have demonstrated that both extremes of strict rest and intense bouts of cognitive or physical activity acutely after injury may be associated with delayed recovery trajectories.[23,33,36,39,45,50,62,63,69,73,76,88,98,117,127,132,145,146,157,158,167,168,175,192,194,197,204,208] Prolonged rest, specifically, may lead to development of secondary effects that are similar to common postconcussion symptoms (eg, deconditioning with exertional intolerance, anxiety or depression due to social isolation and/or reduced participation), making it difficult to discern whether the source of ongoing symptoms is the prescribed rest or the injury itself.[76,192]

Most recent CPGs and guidance documents include recommendations to encourage 24 to 48 hours of complete rest or "relative rest" (gradual reintegration of usual activity with the recommendation to "rest as needed"), followed by phased activity progressions based on symptom response to increasing activity.[141,153,159] While randomized controlled trials (RCTs) in this area are sparse, current clinical recommendations typically advocate for the resumption of low levels of activity in the presence of mild symptoms, as long as symptom exacerbation does not occur.[141,153,159,160]

Another emerging paradigm that contrasts with the rest-focused "wait-and-see" approach leverages active interventions, often referred to as "active rehabilitation." Many of these active intervention strategies incorporate skilled rehabilitation techniques within physical therapists' scope of practice.[4,5,9,18,34,38,47,51,53,54,62,98,117,125,132,133,137,145,152,178,191,192,194,220,225,226] Consequently, physical therapists are increasingly involved as key members in an interdisciplinary approach to caring for individuals with concussion.[53,159,192]

This CPG addresses active rehabilitation for management of patients who have experienced a concussive event using an overarching framework comprising 3 components: (1) a process for determining appropriateness of physical therapy concussive event examination, (2) physical therapy examination and evaluation processes for patients who have experienced a concussive event, and (3) developing and implementing a physical therapy plan of care for patients who have experienced a concussive event. Recommendations are broken down into sections that directly align with each component, and visual decision trees are provided to support implementation of the recommendations within the components. Within components 2 and 3, examination and treatment strategies are further broken down into primary impairment domains. Based on a synthesis of the literature, the GDG identified 4 overarching impairment domains that align with physical therapists' scope of practice: (1) cervical musculoskeletal impairments, (2) vestibulo-oculomotor impairments, (3) exertional tolerance impairments, and (4) motor function impairments. These impairment domains are described in a later section and serve as focal points for the examination and intervention recommendations provided in this CPG.

Examination and intervention strategies for movement-related impairments often require procedures that are intended to provoke symptoms to determine whether an impairment is present, and, in some cases, to treat the impairment. *Irritability* is a term used by rehabilitation practitioners to reflect the tissue or body system's ability to handle physical or physiological stress,[170] and is presumably related to physical status and the extent of injury and inflammatory activity. The GDG concluded that information gleaned during the intake interview can be used to help determine probable levels of irritability for the affected systems, which in turn can be used to help identify priorities and sequencing for examination procedures to allow for a greater number and accuracy of assessments. Determining probable levels of irritability may also help clinicians plan for modifications to examination procedures that would address safety concerns, patient comfort, and/or patient and family goals and preferences. Likewise, irritability levels for specific impairments can guide prioritization and selection of physical therapy interventions. Therefore, the concept of irritability is applied throughout this CPG to guide the sequence of screening, examination, and management of individuals who have experienced a concussive event. The GDG has also published a related clinical commentary article that provides more details on the rationale for and potential clinical approaches to using irritability to guide physical therapy treatments for individuals who have experienced a concussive event.[1]

CPG Rationale

Over the last decade, numerous concussion evidence-based CPGs, consensus statements, and clinical guidance documents have been published.[19,34,61,141,149,153,159,160] These documents have typically focused on the diagnosis of concussion and medical management of individuals post concussion, but provide little specific guidance for physical therapy management of concussion and its associated impairments. Further, many of these guidance documents have targeted specific populations (eg, athletes and military personnel) in specific care contexts (eg, sideline assessments and return-to-activity decision making).[34,159] The lack of guidance for management of a wider scope of patients is particularly problematic for physical therapists, as they may encounter patients with concussions from a variety of injury mechanisms and contexts (eg, children injured in recreational activities, military personnel in active-duty service, older adults after falls, or passengers in motor vehicle collisions). Practice settings also vary across the continuum of care, from acute inpatient settings to ambulatory outpatient clinics.

The growing body of evidence for using active rehabilitation strategies for postconcussion impairments[192] prompts the need for recommendations regarding how physical therapists should approach the management of individuals who have experienced a potential concussive event. Furthermore, a CPG for physical therapists may be useful in informing other health professionals and stakeholders about the expertise and services physical therapists can provide to patients diagnosed with a concussion. The primary purpose of this CPG is to provide a set of evidence-based recommendations for physical therapist management of the wide spectrum of patients who have experienced a concussive event.

Specific objectives of this CPG are to

- Systematically review the available scientific evidence pertaining to physical therapist management of patients who have experienced a concussive event
- Provide evidence-based recommendations to guide physical therapist treatment
- Educate all stakeholders regarding physical therapy strategies for management of patients who have experienced a concussive event

Secondary objectives are to

- Identify current gaps in knowledge related to physical therapist management of concussion
- Provide consensus-based recommendations for physical therapist management where evidence is lacking

Special Considerations for Physical Therapist Management of a Concussive Event

This CPG is the first to provide a comprehensive set of evidence-based recommendations for examination, evaluation, treatment, and outcome measurement strategies for physical therapist management of patients who have sustained a potential concussive event. Many of the symptoms, impairments, and functional limitations often reported after concussion are conditions and functional limitations that physical therapists are specifically trained to evaluate and treat (eg, vestibular impairments causing dizziness and imbalance; cervical impairments resulting in neck pain, headache, and cardiorespiratory deconditioning). However, the treatment for these conditions is supported, in large part, by CPGs derived from evidence that is not specific to concussion. The complex and multifactorial nature of concussion requires that physical therapists use clinical reasoning to apply CPGs and evidence for common complaints (eg, headache, dizziness, neck pain, and chronic pain management) that were developed without a specific focus on concussion. More research is needed to evaluate the appropriateness and feasibility of using guidelines that were developed for impairments common after a concussive event but have not been tested for use with people who have experienced a concussive event.

CPG Limitations

The recommendations provided in this CPG were based on a critical appraisal of the studies published and/or available as an electronic publication through December 31, 2018. The literature on concussion/mTBI is rapidly expanding. There have been many studies pertinent to the CPG since the end of 2018. Given the GDG's systematic search time frame, there are a number of 2019 articles that are highly relevant but were not integrated. Additionally, external reviewers raised a number of important suggestions for future topics that are relevant to physical therapy care but were outside the search processes and scope of the current CPG. Therefore, revision/updated versions of this CPG should begin critical appraisal from January 1, 2019 and consider inclusion of the following topics in the literature search: explicit headache management approaches, primary concussion prevention strategies, and self-management assessments and interventions.

Barriers and Facilitators to Implementation

A potential barrier to implementation of this CPG is that physical therapist management of patients who have experienced a concussive event may require evaluation and treatment strategies that are typically provided by physical therapy specialists. Therefore, effective physical therapist management of concussion may necessitate referral to physical therapy specialists or other health care providers with necessary expertise appropriate across the continuum of management. For example, an individual with complex neck pain or cervical spine dysfunction may normally be treated by a physical therapist with expertise in orthopaedic manual therapy techniques, while an individual with dizziness may typically be managed by physical therapists who specialize in vestibular rehabilitation. After a concussive event, however, a patient may need both types of interventions. These challenges are compounded by the practice of having patients with brain injuries managed by physical therapists who specialize in more severe neurologic conditions that may not commonly progress to a level where advancement in high physical performance is needed (eg, sports, military, tactical professions such as police, fire, or other emergency medical personnel). Therapists in outpatient orthopaedic and sports settings may be more familiar with progressing people to high performance levels, but have less expertise in managing patients with brain injuries. Therefore, it is important for physical therapists to be mindful of their clinical strengths and limitations and refer to and/or consult with other physical therapist colleagues as needed to help ensure their patients receive the necessary care. Physical therapists who plan to treat patients with concussion regularly are encouraged to seek specialized training and coursework that prepare them to manage the unique and multifactorial nature of postconcussive symptoms and impairments.

Additional barriers to implementation may include costs associated with training clinicians, lack of equipment, cultural barriers with local practice coordination or patterns that contrast with recommendations, and the additional time needed to examine, evaluate, and treat patients who have experienced a concussive event and have multiple impairments. Physical therapists are encouraged to use this CPG to support collaboration with the other care providers managing patients with concussion in their local practice settings. The contents of this CPG may also be useful to inform discussions with clinic managers and administrators on how to set up infrastructure to ensure adequate time and resources, and to ensure that referral sources are dedicated to provide optimal care for patients who have experienced a concussive event.

Facilitators to implementing this CPG may include a local practice culture that embraces evidence-based practice and physical therapists who are trained to specifically manage patients who have experienced a concussive event. Another facilitator to implementation may be access to a multidisciplinary clinic or network of health care providers who can work together to help manage patients who have experienced a concussive event. Last, the complexity of concussive injuries may lead to highly variable care-delivery processes. Clinical pathways that support optimal patient referral and treatment flows that align with the recommendations proposed in this CPG are encouraged to facilitate direct integration into local practice settings.

Methods

GUIDELINE DEVELOPMENT OVERVIEW

The composition of the GDG was strategically designed to ensure representation of diverse perspectives and experiences within the profession of physical therapy. Representatives from the APTA, Academy of Orthopaedic Physical Therapy, American Academy of Sports Physical Therapy, Academy of Neurologic Physical Therapy, and Academy of Pediatric Physical Therapy were recruited to ensure a GDG composed of people with sufficient and complementary clinical and research expertise to address the wide range of neurologic, orthopaedic, age-related, and functional impairments that are commonly present among individuals who have experienced a concussive event. The CPG development process was guided by a trained methodologist who was an integral part of the team, using standards consistent with the Institute of Medicine[101] and subsequently outlined in the 2018 edition of the APTA's Clinical Practice Guideline Process Manual.[6] In addition, the authors received methodological guidance and support from leading methodologists in the field. See the Affiliations and Contacts section at the end of the CPG for a full list of acknowledgments.

The authors declared relevant relationships and conflicts of interest and submitted a conflict-of-interest form to the Academy of Orthopaedic Physical Therapy. Articles identified for review that were authored by GDG members or volunteer reviewers were assigned to alternate reviewers. Throughout the CPG development process, the GDG received support through an APTA grant and sponsorship from the Academy of Orthopaedic Physical Therapy, the American Academy of Sports Physical Therapy, and the Academy of Neurologic Physical Therapy for training, travel, software, and librarian assistance. The funding bodies did not have any influence over the recommendations proposed.

Background Information Resources

Due to the large volume of background literature on concussion, the heterogeneity of the available literature, and the lack of specific relevance to physical therapy techniques and strategies, the GDG judged systematic review and critical appraisal to be outside the intended scope of this CPG for the following topics: incidence, risk, and clinical course. Therefore, these sections are provided as background information, using recent articles with the highest level of evidence as key informational sources.

Systematic Literature Searches

The recommendations provided in this CPG are based on the scientific literature published in print or as an electronic publication ahead of print prior to December 31, 2018. **APPENDICES A** through **H** (available at www.jospt.org) provide details about the search strategies, database search results, inclusion/exclusion criteria, critical appraisal tools, a flow chart of included articles, and appraisal syntheses. The review of the evidence for this CPG encompassed a range of physical impairments that may be relevant when making a differential diagnosis after a concussive event, with the goal of determining the underlying cause(s) of presenting signs and symptoms and matching them with intervention priorities. The GDG worked with a librarian from the University of North Carolina at Chapel Hill to engage in the 2 phases of the literature search process (preliminary searches and systematic searches), as recommended by the APTA Clinical Practice Guideline Process Manual.[6] EndNote X8 (Clarivate Analytics, Philadelphia, PA) and DistillerSR software (Evidence Partners, Ottawa, Canada) were used to manage the literature searches, coordinate evidence selection, carry out critical appraisals, and store notes and information about the evidence sources.

Evidence Selection

Title and Abstract Screening

Potential original research studies were initially screened independently by at least 2 GDG members by title and abstract. Screening criteria for this phase were that the document appeared to have potential relevance to inform physical therapists' examination or intervention processes. In cases where the screeners disagreed or the abstract was not clear enough to make a determination, the article was carried forward to the full-text-review stage.

Full-Text Review

Each article carried forward from the title and abstract screen was independently reviewed by 2 GDG members using previously established inclusion and exclusion criteria (**APPENDIX C**). Reviewers were given the option to identify and retain an article that was not in direct alignment with the inclusion/exclusion criteria if it might prove relevant for background information. The articles identified in this category could then be reviewed and considered level V (expert opinion) evidence to help inform the GDG's drafting of action statements and research recommendations when higher-level evidence was lacking. In cases of disagreement on inclusion, the reviewers were asked to resolve the conflict through discussion. If needed, a third reviewer was consulted to help make a final determination.

Critical Appraisals of Evidence

Each article was critically appraised by 2 independent, trained reviewers who were either GDG members or volunteers (Eugene Boeglin, Katherine Lynch), using a designated critical appraisal tool based on study type in accordance with the APTA Clinical Practice Guideline Process Manual.[6] All reviewers were trained in the use of the critical appraisal tools by appraising test articles to establish interrater reliability. When a study arose that was authored by a member of the GDG, the article was appraised by other GDG members. Each dyad compared scores for agreement and resolved conflicts through discussion, and submitted a single critical appraisal form for determination of the level of evidence. In cases where the appraisers were unable to agree, the GDG discussed the article as a group to achieve consensus. The final step entailed the GDG's assessment of the identified risks of bias and relative importance of those risks to the procedures or specific outcome of interest to designate the article into 1 of 4 quality ratings: (1) high quality, (2) acceptable quality, (3) low quality, and (4) unacceptable quality. If a study was deemed as unacceptable quality, it was removed from consideration for inclusion for recommendations related to that area.

Conceptual, Theoretical, and Expert Consensus Documents

Given the rapidly evolving practice standards and relatively new treatment paradigm of active concussion rehabilitation, a number of conceptual models, theory-focused commentaries, and expert consensus documents have emerged in the literature. Systematic critical appraisal for such types of documents is challenging and largely subjective in nature. However, several manuscripts and documents identified through the search process provided valuable strategies for framing how to approach physical therapy examination and intervention processes, for which evidence is currently lacking. Two GDG members independently reviewed conceptual, theoretical, and expert consensus documents identified during the systematic searches, and determined the appropriateness for inclusion in the CPG based on the criteria provided in **APPENDIX C**.

Strength of Evidence

Using the critical appraisal ratings, each article was assigned a level of evidence in accordance with the designations and procedures described in **APPENDIX F.** An abbreviated version of the level-of-evidence rating system is provided below. An individual article or recommendation statement from a previously published CPG could be assigned multiple levels of evidence if it was linked to more than 1 outcome of interest.

I	Evidence obtained from high-quality diagnostic studies, prospective studies, randomized controlled trials, or systematic reviews
II	Evidence obtained from lesser-quality diagnostic studies, prospective studies, systematic reviews, or randomized controlled trials (eg, weaker diagnostic criteria and reference standards, improper randomization, no blinding, less than 80% follow-up)
III	Case-control studies or retrospective studies
IV	Case series
V	Expert opinion

Development of Recommendations

The GDG developed recommendations based on the strength and limitations of the body of evidence, including how directly the studies addressed the clinical questions posed. Additionally, the authors considered potential health benefits, side effects, and risks of tests and interventions. The GDG used BRIDGE-Wiz Version 3.0 (Yale University, New Haven, CT) to write implementable and transparent recommendations that meet the Institute of Medicine CPG standards.[101] The GDG worked with the editors and staff of the target journal for publication and APTA CPG leaders to refine the recommendations and supporting documentation structure into a publishable format.

Selection and Adaptation of Recommendations From Previously Published CPGs

Numerous evidence-based CPGs and expert consensus guidance documents on concussion have been published. Likewise, several CPGs applicable to physical therapy examination and intervention strategies relevant to impairments and functional limitations common with concussive events have been developed and endorsed by the APTA and its associated academies. The GDG determined it was important to minimize redundancy in the literature and avoid replication of general practice recommendations by using a process of critical appraisal to adapt recommendations from previously published, high-quality CPGs relevant to general management of patients who have experienced a concussive event. As CPGs are often reviewed and updated, the group continued to monitor publication of updates and releases of new CPGs through December 31, 2018 for potential inclusion in this document. This ensured the inclusion of existing guidelines appropriate for endorsement and integration in this CPG.

Recommendations from previously published CPGs were eligible for inclusion if they met the following criteria: (1) published on January 1, 2015 or later, (2) included a multidisciplinary team for authorship, (3) based on a systematic review and appraisal of the literature, (4) included recommendations that pertained to movement-related impairments, and (5) rated as acceptable quality based on critical appraisal by 2 trained independent reviewers using the Appraisal of Guidelines for Research and Evaluation II (AGREE II) tool.[22] The AGREE II instrument consists of 23 items categorized under 6 domains, rated using a 7-point scale. A rating of 7 represents the highest possible score. Three CPGs were identified that met these criteria: (1) guidelines produced by a working group for the Ontario Neurotrauma Foundation in 2015,[153] (2) guidelines produced by a working group for the US Department of Veterans Affairs and Department of Defense in 2016,[149] and (3) guidelines for pediatric patients produced by a working group for the CDC in 2018.[141] Recommendations in this CPG that were developed based on an adaptation of previously published CPGs were assigned a level of evidence in accordance with the table below.

LEVEL	EVIDENCE LEVEL RATING FOR RECOMMENDATIONS ADAPTED FROM PREVIOUSLY PUBLISHED CPGS ON CONCUSSION MANAGEMENT
I	The recommendation being adapted was generated from level I evidence
II	The recommendation being adapted was generated from level II evidence
III	The recommendation being adapted was generated from level III evidence
IV	The recommendation being adapted was generated based on expert consensus of the authors of the published CPG

GRADES OF RECOMMENDATION

Grades for each recommendation were assigned through a consensus-generation process in accordance with the recommended grades and definitions provided below. The wording of the clinician level of obligation used in the recommendations was designed to align with the recommended language for linking evidence, grades of recommendation, and strength of obligation (Level of Obligation column). Unanimous agreement among all GDG members was required to include recommendations adapted from previously published CPGs. The GDG determined the grade of recommendation based on synthesis of the relevant recommendations.

AGREE II Review

To ensure the CPG was of high quality and implementable, the complete draft of the CPG was reviewed by members of the Academy of Neurologic Physical Therapy evidence-based Practice Committee, using the AGREE II instrument.[22] Domain scores for the CPG were strong overall, with individual ratings ranging from 5 to 7 on all domains. Scores and comments provided by the AGREE II reviewers were discussed by the GDG. When deemed feasible and appropriate, the GDG edited the CPG to address reviewer concerns and suggestions.

External Stakeholder Review Processes

Guideline development methods, policies, and implementation processes are reviewed at least yearly by the Academy of Orthopaedic Physical Therapy, APTA, Inc's ICF-based Clinical Practice Guideline Advisory Panel, which includes consumer/patient representatives, external stakeholders, and experts in physical therapy practice guideline methodology. This CPG underwent multiple formal reviews. The complete draft was reviewed by invited stakeholders representing CPG methodology and a variety of clinical perspectives, including physical therapists, physicians, athletic trainers, neuropsychologists, occupational therapists, and speech language pathologists. Acknowledgments for specific reviewers are provided at the end of the CPG. The draft was also posted for public comment in September 2019 on websites for the components of the APTA that supported the development process (the Academy of Orthopaedic Physical Therapy, the American Academy of Sports Physical Therapy, and the Academy of Neurologic Physical Therapy). Notices encouraging contributions to the request for public comment were sent via e-mail and electronic newsletter to members of APTA components

GRADES OF RECOMMENDATION		STRENGTH OF EVIDENCE	LEVEL OF OBLIGATION
A	Strong evidence	A preponderance of level I and/or level II studies support the recommendation. This must include at least 1 level I study	Must: benefits substantially outweigh harms Should: benefits moderately outweigh harms May: benefits minimally outweigh harms or benefit-harm ratio is value dependent Should not: harms minimally or moderately outweigh benefits or evidence of no effect Must not: harms largely outweigh benefits
B	Moderate evidence	A single high-quality randomized controlled trial or a preponderance of level II studies support the recommendation	Should: benefits substantially outweigh harms May: benefits moderately or minimally outweigh harms or benefit-harm ratio is value dependent Should not: evidence that harms outweigh benefits or evidence of no effect
C	Weak evidence	A single level II study or a preponderance of level III and IV studies, including statements of consensus by content experts, support the recommendation	Should: benefits substantially outweigh harms May: benefits moderately or minimally outweigh harms or benefit-harm ratio is value dependent Should not: harms minimally or moderately outweigh benefits
D	Conflicting evidence	Higher-quality studies conducted on this topic disagree with respect to their conclusions. The recommendation is based on these conflicting studies	May: conflicting evidence; the benefit-harm ratio is value dependent
E	Theoretical/foundational evidence	A preponderance of evidence from animal or cadaver studies, from conceptual models/principles, or from basic sciences/bench research support this conclusion	May: in the absence of evidence from clinical studies, theoretical and/or foundational evidence supports benefit Should not: in the absence of evidence from clinical studies, theoretical and/or foundational evidence suggests risk of harms
F	Expert opinion	Best practice based on the clinical experience of the GDG	Must: strongly supported by consensus-based best practice/standard of care Should: moderately supported by best practice/standard of care May: supported by expert opinion in the absence of consensus Should not: best practice/standard of care indicates potential harms Must not: potential harms are strongly supported by consensus-based best practice/standard of care

for orthopaedics, sports, neurology, pediatrics, and geriatrics, as well as to individuals who inquired about the CPG during its development. Comments, concerns, and suggestions from each round of reviews were considered by the GDG with each successive draft of the document.

ORGANIZATION OF THE GUIDELINE

This CPG covers topics related to concussion incidence, risk factors for prolonged recovery, physical therapist examination strategies, and physical therapist intervention strategies. At the end of the document, decision trees are provided that align with the recommendations and address the flow of decisions for triage (process to help determine priorities) and sequencing of activities.

CLASSIFICATION

The primary International Classification of Diseases, 10th revision (ICD-10) code associated with concussion is **S06.0 Concussion**. Additional codes that may be directly associated with the brain injury aspect of concussive events include **S06.9X Unspecified intracranial injury**, **S06.2X Diffuse traumatic brain injury**, and **F07.81 Postconcussional syndrome**. Due to its complex nature, there are many ICD-10 codes related to physical impairments that may result from a concussive event. Studies have defined core sets of ICF indicators following concussion, spine trauma, or vestibular complaints.[61,75,206] Issues that would reasonably be addressed by physical therapy were identified from these sources, and consensus of the GDG confirmed their inclusion, resulting in the lists summarized in **TABLES 1** and **2**.

TABLE 1 ICD-10 Codes Related to Physical Impairments Associated With Concussive Events

Code	Description
G43	Migraines
G43.909	Headache, migraine
G44.209	Headache, tension type
G44.309	Headache, posttraumatic
G44.319	Headache, posttraumatic, acute
G44.329	Headache, posttraumatic, chronic
G44.84	Headache, exertional
G89.11	Pain, due to trauma
G89.21	Pain, chronic due to trauma
G89.29	Pain, chronic
G89.4	Pain, chronic pain syndrome
G96.9	Central nervous system disorder

Table continues in next column.

TABLE 1 ICD-10 Codes Related to Physical Impairments Associated With Concussive Events (continued)

Code	Description
H51.1	Convergence insufficiency and excess
H81.1	Benign positional vertigo
H81.3	Other peripheral vertigo
H81.39	Vertigo, peripheral
H81.4	Vertigo of central origin
H81.8	Unspecified disorder of vestibular function
H81.9	Vestibular function disorder
H82	Vertiginous syndromes
H83.2	Imbalance, labyrinth
M24.28	Vertebral ligament disorder
M25.60	Joint stiffness
M26.62	Pain, temporomandibular joint
M26.69	Derangement, temporomandibular joint
M46.01	Enthesopathy, spinal, occiput-atlas-axis
M46.02	Enthesopathy, spinal, cervical region
M50.90	Cervical disc disorder
M53.1	Pain, cervicobrachial; cervical root syndrome
M53.2	Instability, joint, posttraumatic, spine
M53.82	Dorsopathy, cervical region
M54.2	Cervicalgia
M79.1	Pain, myofascial
R26.8	Other abnormalities of gait and mobility
R29.3	Imbalance, postural
R42	Dizziness and giddiness
R51	Headaches
R52	Pain, acute
R53.83	Fatigue
S04.6	Injury, acoustic nerve
S06.06	Concussion
S06.2X	Diffuse traumatic brain injury
S06.9X	Unspecified intracranial injury
S09.31	Injury, blast, ear
S10	Superficial injury of neck
S10.9	Injury, superficial neck, unspecified part
S12.9	Fracture, cervical
S13.4	Sprain of ligaments of cervical spine
S13.4	Whiplash injury
S16	Injury of muscle, fascia, and tendon at neck level
S16.9	Injury, neck muscle, unspecified
S19.9	Injury, neck, unspecified

TABLE 2 ICF Codes for Physical Impairments Associated With Concussive Events

Code	Description
Body functions	
b130	Energy and drive functions
b134	Sleep functions
b140	Attention functions
b147	Psychomotor functions
b156	Perceptual functions
b210	Seeing functions
b215	Functions of structures adjoining the eye/oculomotor function
b235	Vestibular functions
b240	Sensations associated with hearing and vestibular function
b260	Proprioceptive functions
b280	Sensation of pain, headache, neck pain/other pain
b455	Exercise tolerance functions
b710	Mobility of joint functions
b730	Muscle power functions
b735	Muscle tone functions
b740	Muscle endurance
b760	Control of voluntary movement functions
b770	Gait pattern functions
Body structures	
s110	Structure of brain
s260	Structure of inner ear
s410	Structure of cardiovascular system
s710	Structure of head and neck region
Activities and participation	
d220	Undertaking multiple tasks
d410	Changing basic body positions
d415	Maintaining a body position
d430	Lift and carry objects
d450	Walking
d455	Moving around (includes running, jumping)
d460	Moving around in different locations
d469	Walking and moving, other specified and unspecified
d475	Driving
d640	Doing housework
d810-839	Education
d840-859	Work and employment
d910	Community life
d920	Recreation and leisure

Postconcussive Event Impairment Domains

The GDG identified 4 domains that are relevant to physical therapist examination and intervention processes and may be useful to identify specific patient needs and develop treatment plans. These domains should not be treated as mutually exclusive classifications, as patients may exhibit impairments that fall into more than 1 category. The 4 domains are presented below, with specific rationales about the associations between impairments and concussive events.

Cervical Musculoskeletal Impairments

Cervical musculoskeletal impairments can lead to a variety of symptoms that are also commonly reported by individuals with a diagnosis of concussion (eg, neck pain, headache with or without neck pain, dizziness, and diminished balance/postural control).[57,98,106,152,165,195] Currently, the incidence of cervical musculoskeletal impairment associated with concussive events has not been comprehensively studied or well reported. However, given the biomechanical mechanism of many concussive injuries, it is hypothesized that cervical musculoskeletal impairments may be present.[35,54,217] In patients with neck pain in the absence of concussion, there is strong evidence that impairments such as diminished range of motion, poor strength, and insufficient muscle endurance and control exist.[16] There is also evidence that sensorimotor control deficits may originate from alterations in cervical afferent input.[64,83,84,114,209-212] These deficits may include impaired cervical reflex responses and cervical proprioception that can affect the visual and vestibular systems and lead to dizziness, visual dysfunction, balance problems, and difficulties with head and eye movement control.[58,83] Therefore, even when neck pain is not present in a patient who has experienced a concussive event, cervical musculoskeletal impairments may serve as an underlying source driving other symptoms, particularly dizziness, imbalance, and headache. This overlapping of symptoms can make determining symptom origin difficult in patients after a concussive event.

Vestibulo-oculomotor Impairments

Numerous studies indicate that vestibular and oculomotor deficits are common after concussion.[165] Such deficits can contribute to many postconcussion symptoms, impairments, and functional limitations, including dizziness, balance problems, vertigo, blurred vision, headaches, nausea, sensitivity to light, sensitivity to sound, mental fogginess, difficulty reading, difficulty concentrating, anxiety, and fatigue.[82] Precise incidence rates for these impairments remain unclear, and they may be driven by different factors and/or multiple factors.[82,103,165,186,198] Physical therapy examination and intervention strategies for both the vestibular and oculomotor systems are linked, especially relative to the literature pertaining to concussions/mTBIs. Therefore, it is practical to view these as a single impairment domain for examination and treatment purposes. Regardless, it is important for physical therapists to consider the interplay and overlap between cervical and vestibular causes of dizziness, oculomotor dysfunction, and imbalance.

Autonomic Dysfunction and Exertional Intolerance

Mounting evidence indicates that reduced tolerance of physical exertion is common after concussion, with many individuals reporting an increase in a variety of concussion-related symptoms with physical exertion.[47,53,54,66,85,104,123,126,133,152,159,192] Poor tolerance of physical exertion may also be associated with higher reports of fatigue, as the effects of physical exertion may not occur during actual exercise but may emerge later.[47,118] The extent to which physical exertion intolerance is present among individuals with concussion has not been systematically studied, nor are the specific mechanisms that drive exertion intolerance fully understood. However, autonomic dysfunction resulting from the brain injury itself may be a contributing factor.[9,15,33,123,133] It has been hypothesized that concussions can lead to an uncoupling of the central autonomic nervous system and the heart, leading to a reduced ability to maintain and adjust cerebral blood flow, blood pressure, and/or heart rate in response to increases and decreases in physical exertion.[15,53,66,85,133] While confirmatory studies for these hypotheses are needed, preliminary work in this area suggests that concussions may be associated with altered autonomic regulation.[17,65,66,85] This autonomic dysregulation has been linked to higher perceived rates of exertion after concussion in comparison to individuals who have not recently sustained a concussion,[85] and may be captured by assessments for orthostatic hypotension.[187] Another potential source of poor tolerance of physical exertion is general deconditioning or secondary physical inactivity/lifestyle changes that may be recommended or occur as a result of the concussive injury.[191,192,204]

Motor Function Impairments

A variety of studies have reported that individuals who have experienced a concussive event may present with altered motor function abilities, including static and dynamic balance/postural control impairments, changes in dual/multitasking impairments, delayed motor reaction time, and increased difficulty with motor coordination (especially with more complex environments or tasks).[43,44,64,111] These motor function impairments may be relatively subtle and difficult to capture without laboratory equipment.[28-30,91,93,136] Studies also suggest that these underlying impairments may persist for months to years and may be present even when symptoms have seemingly resolved.[13,44] The extent to which such subtle motor function impairments may interfere with daily function and activity participation is unclear, and the prevalence of these impairments remains unknown. However, these types of impairments may lead to increased risk for future concussions and other injuries among athletes and those in high-activity/high-risk jobs (eg, active-duty military, firefighters, and police officers).[87,162,185]

DISSEMINATION AND IMPLEMENTATION PLANS AND TOOLS

In addition to the publication of this document, this CPG will be freely available on APTA Academy websites, including www.orthopt.org, and posted in a searchable CPG database hosted by the APTA. The initial presentation of the CPG draft was presented January 24, 2019 at the APTA Combined Sections Meeting in Washington, DC. Additional plans are in place for ongoing presentation of this CPG at educational conferences and webinars for clinicians. Planned implementation tools include a patient-oriented guideline summary, read-for-credit continuing education units, and suggestions for common data elements and minimal data sets for contribution to the Physical Therapy Outcomes Registry.

Plan for Updating the Guideline

The plans for updating this CPG include monitoring the evidence on a monthly basis and publishing a revision in approximately 5 years. If evidence of sufficient quality becomes available that directly contradicts or would result in substantial changes to the recommendations in this CPG prior to the planned 5 years, a revised CPG may be needed sooner.

CLINICAL PRACTICE GUIDELINES

Impairment/Function-Based Diagnosis

INCIDENCE

Evidence Summary

Concussion is increasingly recognized as a major public health concern due to high incidence rates and the potential for long-term effects.[4,107,108,141,159] Overall incidence rates for concussion have varied greatly across studies. The CDC estimates that 1.6 to 3.8 million concussions occur during sports and recreational activities annually.[121] For 2008, the Agency for Healthcare Research and Quality reported 43 802 emergency department (ED) visits for sports-related concussion, and more than 12 times as many reported non–sports-related concussions during the same period.[227] However, it may be that this ratio is different for non-ED contexts. Even so, it illustrates that while media reports have often focused on the high incidence and dangers of concussion in sports, it is important to recognize that the mechanisms and contexts of concussive events vary greatly, and frequently occur outside of sports contexts (ie, falls, motor vehicle crashes, and military injuries).[25,37,227] Furthermore, recent epidemiological reports indicate that incidence rates for concussions have been on the rise, likely as a direct result of the increases in research and media coverage indicating the substantial impact of concussive events and mild brain injuries.[25,41]

A commonly acknowledged limitation of incidence estimates is that not all individuals who experience a concussive event seek medical care.[41,46,55,56,107,120,121] Additionally, many concussive events go unrecognized or unreported,[41] and the symptoms, impairments, and functional limitations associated with concussion can be subtle, vary in presentation, and be easily confused with other common illnesses or injuries.[34,41,107] For example, headaches, fatigue, and dizziness commonly occur after a concussive event; however, they are also associated with other injuries and illnesses.[141,142,149,153] Collectively, these factors are significant challenges to providing accurate estimates of the incidence and prevalence of concussion.[34,107,142,159]

Gaps in Knowledge

Future research should investigate the prevalence of patients participating in physical therapy who do not have a medical diagnosis of concussion yet experienced a concussive event and exhibit signs and symptoms indicative of a concussion. Research in this regard would help provide estimates for undiagnosed concussion among individuals referred to physical therapy.

RISK FACTORS

Evidence Summary

There is growing recognition that concussion recovery trajectories are complex, highly variable, and influenced by a range of factors (eg, age, sex, prior history of concussion, premorbid diagnoses).[34,102,107,108] A recent systematic review highlighted preinjury factors, injury-related factors, and postinjury factors associated with prolonged recovery after a concussion.[102] It has been suggested that preinjury factors such as history of concussion, female sex, younger age, attention-deficit hyperactivity disorder (ADHD), history of migraine, and genetics may all be associated with prolonged recovery from concussion.[102] Injury-related factors associated with prolonged recovery include loss of consciousness, anterograde amnesia, retrograde amnesia, and delayed removal from sports participation.[102] Postinjury factors associated with prolonged recovery include symptoms of dizziness, headache, migraine, or depressive symptoms.[102] However, studies have also documented a lack of association between prolonged recovery and many of the aforementioned factors.[102] Consequently, definitive characterization of risk factors associated with poor concussion recovery remains unclear.[102,107,108]

Two emerging areas of research highlight additional factors that may influence recovery outcomes: (1) psychosocial factors (eg, perceived competence, tenacity, tolerance of negative affect, and positive acceptance of change)[107,119,138-140,176] and (2) early concussion management factors (eg, strict rest versus relative rest versus active rehabilitation).[34,107,137] Identification of risk factors and implementation of management approaches have continued to evolve quickly as new knowledge is gained and alternative strategies are proposed. This fast-paced evolution of evidence likely contributes to variation in care, which in turn adds to the difficulty in defining natural concussion recovery trajectories and the extent to which various strategies directly affect outcomes.[107,108]

Gaps in Knowledge

More research is needed to determine risk factors related to poor recovery from concussion and how timing and utilization of physical therapy services may affect recovery.

CLINICAL COURSE

Evidence Summary

Concussions are associated with a wide array of complaints, including headache, dizziness, balance problems, neck pain, sensitivity to light and sound, fatigue, disorientation, mental fogginess, sleep disturbances, and difficulty regulating emotions, among others.[41,107,142] Many studies report that most individuals who sustain a concussion "recover" within a relatively short period of time (approximately 7-14 days post injury).[34,41,102] However, definitions for concussion and the strategies to measure recovery have been inconsistent.[102,107] In recent years, the notion that most individuals recover fully from concussion within a few days or weeks has been increasingly challenged.[34,102,159] Studies have demonstrated that as many as 5% to 58%[96,107] of individuals who sustain a concussion have persistent symptoms, impairments, and/or limitations that affect daily function. The timing of these complaints ranges from a few days to a few weeks or longer.[96,144,151,196]

Although it is often reported that symptoms, impairments, and functional limitations follow a gradual pattern of improvement, the trajectory may not be linear.[197] Rather, many patients experience symptom exacerbations during their recovery period.[197] In some cases, these exacerbations may be an immediate reaction to a specific mechanism (eg, change of position or intense bout of physical or cognitive exertion),[47] or delayed reaction associated with activities over the preceding 24-hour period.[197] Some studies indicate that subtle, underlying impairments may continue to be present after concussion[43,44,144] and put individuals at risk for additional injuries[105,162] or more chronic/long-term sequelae (eg, chronic pain, persistent motor control deficits).[43,44,74,151]

Since approximately 2007, clinical commentaries and studies have supported postconcussion assessment, management, and skilled rehabilitation techniques that fall within physical therapists' scope of practice (eg, progressive aerobic exercise, vestibular and oculomotor interventions, manual therapy and exercises targeting the cervical spine, balance training).[4,5,9,18,34,38,47,51,53,54,62,98,125,132,133,145,152,178,191,192,194,220,225] Systematic reviews support active rehabilitation strategies for concussions under the direction of a physical therapist as a promising management approach for facilitating recovery.[178,192] Consequently, physical therapists have become key members in an interdisciplinary approach to caring for individuals with concussion.[53,159]

Gaps in Knowledge

Despite a growing body of evidence on the safety and primarily positive outcomes for physical therapy interventions, additional research is needed to provide more specific insight into factors that affect patient responsiveness to physical therapy for concussion-related symptoms, impairments, functional limitations, and participation restrictions. Additionally, studies evaluating the prevalence of the different types of movement-related impairments would be informative.

CLINICAL PRACTICE GUIDELINES

Screening and Diagnosis

DIAGNOSIS

I Two high-quality CPGs strongly emphasize the need to recognize and diagnose a concussion as soon as possible to promote positive health outcomes and mitigate poor health outcomes and secondary effects of concussion.[149,153]

Evidence Synthesis

High-quality concussion CPGs and consensus-based guidance documents consistently acknowledge (1) the importance of identifying and diagnosing a potential concussion as early as possible, (2) the importance of the involvement of a trained medical professional for determining the concussion diagnosis, and (3) common signs and symptoms that should be used to diagnose a concussion. Given the known problems of underreporting and underrecognition of concussions, physical therapists may encounter patients who have experienced a concussive event and exhibit concussion-related symptoms, impairments, and functional limitations, yet have not been diagnosed with a concussion. The benefits of identifying an undiagnosed concussion and associated impairments may outweigh the potential costs of time, resources, and overidentification that may occur with more expansive screening efforts.

Recommendation

A Physical therapists **must** screen all individuals who have experienced a potential concussive event and document the presence or absence of symptoms, impairments, and functional limitations that may relate to a concussive event.

SCREENING FOR INDICATORS OF EMERGENCY CONDITIONS

I Two high-quality CPGs included recommendations emphasizing the importance of screening for more serious neurological or musculoskeletal conditions that may require emergency evaluation and treatment.[141,153]

Evidence Synthesis

Although incidence is relatively low, there is potential for an individual with an initial presentation of mild brain injury to develop signs of decline that may be indicative of more moderate to severe brain pathology. In many cases, physical therapists are likely to encounter patients who are outside the most vulnerable period for signs of moderate to severe injury, so screening for indicators of emergency will align with standard-of-care practice patterns for general systems review. However, in some cases, physical therapists may be the patient's first health care providers (eg, through direct access, sideline coverage for certified sports specialists, providing coverage in an ED, or other contexts). In these cases, more in-depth screening procedures may be needed. Clinical practice guidelines for concussion/mTBI provide specific guidance on this type of screening.[141,153]

FIGURE 1 provides a synthesis of key signs and symptoms in screening to determine the need for emergency evaluation. The use of the Glasgow Coma Scale and the Canadian computed tomography (CT) head rule may be useful to support screening of individuals for brain injury of greater severity than concussion.[149,153] If patients demonstrate relatively normal mental status (alertness/behavior/cognition) at least 4 hours post injury, do not report severe headache, do not have signs of focal neurological deficit, and do not demonstrate high-risk factors for further imaging/scans (eg, Glasgow Coma Scale score of less than 13 two hours after injury, suspected open skull fracture or sign of base skull fracture, vomiting more than twice, and younger than 65 years of age), then concern for more severe brain injury requiring neurosurgical intervention is low. For patients aged 8 to 18 years presenting within the first 24 hours of head injury, the Pediatric Emergency Care Applied Research Network (PECARN) has developed a validated prediction rule to help identify children at very low risk of needing acute-care intervention, versus those who are showing signs of more moderate or severe brain injury.[116] Signs that CT imaging and other acute monitoring are not likely needed include normal mental status, no loss of consciousness, no vomiting, nonsevere injury mechanism, no signs of basilar skull fracture, and no severe headache.[116]

Additionally, given the mechanisms of a concussive event, screening for potential cervical spine pathology is also warranted, regardless of presence of neck pain. When screening for significant cervical spine pathology, signs indicative of infection, cancer, cardiac involvement, arterial insufficiency (ie, dizziness in combination with neurologic signs), upper cervical ligamentous insufficiency (ie, positive transverse or alar ligament testing), unexplained cranial nerve dysfunction, signs of central cord compression (ie, positive upper motor neuron tests), or fracture (ie, findings suggesting imaging is required based on the Canadian cervical spine rules and/or the National Emergency X-Radiography Utilization

Study criteria) warrant further assessment and referral for consultation with physicians or other members of the health care team (**FIGURE 1**).[10,16,201,202]

Recommendation

A Physical therapists **must** screen patients who have experienced a recent potential concussive event for signs of medical emergency or severe pathology (eg, more serious brain injury, medical conditions, or cervical spine injury) that warrant further evaluation by other health care providers. Referral for further evaluation should be made as indicated (**FIGURE 1**).

DIFFERENTIAL DIAGNOSIS

I Evidence and recommendations from a high-quality CPG emphasized a need to conduct a comprehensive intake on various aspects of the patient's past medical history, review of mental health history, injury-related mechanisms, injury-related symptoms, and early management strategies.[153]

I Evidence and recommendations from high-quality CPGs did not support the use of imaging for immediate diagnosis in the absence of more severe brain injury concerns.[141,149,153] The use of biomarkers and the consideration of helmet-based measurement devices for diagnosing concussion are not recommended outside the context of research studies.[141,149,153]

I Evidence and recommendation from 2 high-quality CPGs support using a symptom checklist or symptom rating scale to help evaluate/assess for concussion signs and symptoms and multisystem evaluations.[141,153] However, there are no clear evidence-based endorsements to support specific symptom scales or system measures.

I Evidence indicates that computerized neurocognitive assessments are an option to complement diagnostic evaluation for concussion, but the reliability, validity, and utility across patient populations remain unclear.[2,3,149]

II Evidence from a high-quality CPG further supports that multiple tools should be used to assess children with concussion, but does not provide endorsement of any specific tools.[141]

II Evidence from the CDC CPG, providing recommendations specific to children, indicates that age-appropriateness may be an important consideration for selection of concussion symptom scales, as there are different scales developed for specific age ranges.[141]

II Evidence and recommendations from 1 high-quality CPG support evaluation for cognitive difficulties through focused clinical interviews and symptom checklists.[153] Evidence and recommendations from a high-quality CPG recommend against the use of comprehensive and focused neurocognitive assessments in the first 30 days, instead encouraging general screening until symptoms appear to be persistent.[149]

IV Evidence from expert consensus documents and case studies provides further support for a comprehensive intake for factors that may affect or be affected by recovery from concussion.[61,159,160]

Evidence Synthesis

Available guidance documents indicate the multidimensional factors that should be considered and that triangulation of information sources should be used to identify concussion as the likely cause of the presenting signs and symptoms (**FIGURE 1**). As recognized by high-quality CPGs and numerous epidemiological studies, memory problems and confusion are common symptoms associated with concussion. Reports from individuals who know a patient well can be used to help verify and expand upon information the patient provides. Symptom scales or checklists are commonly used and cited. However, there is no clear gold standard for the most appropriate diagnostic tools based on previously published guidelines, and comparative studies between tools are limited.

A comprehensive systematic review of all potential diagnostic tools for concussion was outside the scope of the GDG goals for this CPG. Based on the evidence that was identified within the searches that were performed, the GDG determined that there is insufficient evidence to specifically endorse any of these assessments due to uncertain reliability, validity, and utility for the wide array of types of patients physical therapists may encounter.

Recommendations

A Physical therapists **must** evaluate for potential signs and symptoms of an undiagnosed concussion for patients who have experienced a concussive event but have not been diagnosed with concussion. Evaluation should include triangulation of information from patient/family/witness reports, the patient's past medical history, physical observation/examination, and the use of an age-appropriate symptom scale/checklist (see **FIGURE 1** for diagnostic criteria).

F For patients who have experienced a concussive event and do not report or demonstrate signs and symptoms consistent with a concussion diagnosis, physical therapists **should** evaluate for other potential diagnoses and follow standard-of-care procedures in accordance with their findings.

F For patients who have experienced a concussive event and report or demonstrate signs and symptoms consistent with a concussion diagnosis, physical therapists **should** determine whether a comprehensive physical therapy evaluation is appropriate using information from a comprehensive intake interview and clinical judgment (see **FIGURE 1** for potential considerations).

A Physical therapists **should** screen patients who have experienced a concussive event for mental health, cognitive impairment, and other potential coinciding diagnoses and refer for additional evaluation and services as indicated.

F For patients not deemed appropriate for a comprehensive physical therapy examination (ie, they present with severe mental health concerns or health conditions that require medical clearance prior to comprehensive physical examination), physical therapists **should** provide education regarding concussion symptoms, prognosis, and self-management strategies and refer for consultation with other health care providers as indicated.

COMPREHENSIVE INTAKE INTERVIEW

I Evidence and recommendations from a high-quality CPG emphasized the need to conduct a comprehensive intake on various aspects of the patient's past medical history, reviewing mental health history, injury-related mechanisms, injury-related symptoms, and early management strategies.[153]

II Evidence from a high-quality CPG further supports that multiple tools should be used to assess children with concussion, but does not provide endorsement of any specific tools.[141]

IV Evidence from expert consensus documents and case studies provides further support for a comprehensive intake for factors that may affect or be affected by recovery from concussion.[61,159,160]

Recommendation

A Physical therapists **must** conduct and document a comprehensive intake of past medical history, reviewing mental health history, injury-related mechanisms, injury-related symptoms, and early management strategies for patients who have experienced a concussive event.

CLINICAL PRACTICE GUIDELINES

Examination

SYSTEMS TO BE EXAMINED

II Evidence and recommendations from a high-quality CPG[153] and moderate-quality systematic review[147] consistently emphasize the importance of a multisystem physical examination to help discern specific impairments that may need to be monitored or targeted with rehabilitation strategies. Systems to be evaluated included neurological (including specific screens for vision, auditory, sensory processing, cognition, and motor control and coordination impairments), cardiovascular/autonomic, musculoskeletal, and vestibular systems.

IV Four recent expert consensus statements provide robust evaluation of potential physical examination techniques and domains, with varying strengths of recommendation based on clinical expertise.[19,61,159,160] Recommendations for examination approaches most relevant to this CPG included assessments for musculoskeletal function (especially in the cervical spine), vestibular and oculomotor function, exertional tolerance, gait, balance, and dual/multitasking.

Evidence Synthesis

There is strong evidence to support high risk for concussive events to result in multiple system impairments that affect and are affected by movement. There are no well-validated, evidence-based approaches or tools to guide how the multiple systems should be evaluated. Recent expert consensus statements provide insight into what may be considered best practice at this time.[19,61] However, it should be acknowledged that these recommendations were meant for more global management of concussion and are not specific to physical therapy management of concussion. Recent evidence offers some potential screening options that include screening for movement-related impairments (eg, Buffalo Concussion Physical Examination[77,124]). There is also insufficient evidence to support the validity, reliability, and utility of these screening tools for physical therapy purposes. Therefore, while there is moderate to strong evidence to suggest that it is important to assess the domains identified, the recommendations in this CPG are intentionally vague with regard to which assessments should be used. As previously mentioned in the Clinical Course section, the GDG identified 4 overarching system domains that align with movement-related impairments pertinent to physical therapists' scope of practice: (1) cervical musculoskeletal impairments, (2) vestibulo-oculomotor impairments, (3) autonomic dysfunction/exertional tolerance impairments, and (4) motor function impairments. Identifying impairments in each of these domains will help in the development of treatment plans tailored to the needs of each patient.[31]

Gaps in Knowledge

Future research to develop, test, and optimize a specific battery of physical therapy examination strategies for individuals who have sustained a concussive event is needed.

Recommendation

B For patients identified as safe and appropriate for a comprehensive examination, physical therapists **must** determine and document a need for physical therapy to facilitate recovery from a concussive event, based on findings from a comprehensive multisystem physical therapy examination and evaluation. Examination procedures should include examination for impairments in the following domains: cervical musculoskeletal function, vestibulo-oculomotor function, autonomic dysfunction/exertional tolerance, and motor function, through foundational standard-of-care screening strategies (**FIGURE 2**).

SEQUENCING OF EXAMINATION BASED ON LEVELS OF IRRITABILITY

Evidence Synthesis

No evidence was identified to address sequencing of physical therapy examination of patients who have experienced a concussive event. However, screening and examination for movement-related impairments often require procedures that are intended to provoke symptoms to determine whether an impairment is present. The consensus of the GDG was that transient increases in symptoms are expected in response to physical therapy examination processes. Because of the multisystem effects, it is possible that examination procedures for one system may increase symptoms to a level that may make it difficult to proceed or could compromise the validity of additional tests for other systems. The extent to which symptoms are provoked, and their duration, can be assessed and a level of irritability assigned.

FIGURE 2 provides a triage system (a process to help determine priorities) to guide examination sequencing that is based solely on the GDG's consensus of expert opinion. The focus is on using anticipated levels of irritability to strategically sequence exam procedures. Recommended irritability considerations with regard to symptom reports and examination procedures include (1) frequency of symptom provocation, (2) vigor of movement required to reproduce symptom(s),

(3) severity of symptoms once provoked, (4) how easily symptoms are provoked, (5) which factors ease the symptoms, and (6) how much, how quickly, and how completely the symptoms resolve (**FIGURE 2**).

Gaps in Knowledge

Future research is needed to test the utility and value of this triage strategy.

Recommendations

F Prior to initiating a comprehensive physical examination for patients who have experienced a concussive event, physical therapists **should** determine probable levels of irritability for movement-related symptoms and impairments and plan to strategically sequence and/or delay examination procedures as needed, based on patients' symptom types and probable level of irritability. Physical therapists are encouraged to first triage for neck pain irritability and then for dizziness and/or headache (**FIGURE 2**).

F For patients who have experienced a concussive event and have high neck pain irritability but exhibit no signs of serious neck or systemic pathology, physical therapists **should** first examine the cervical and thoracic spines for sources of musculoskeletal dysfunction and address findings appropriately to promote symptom relief (eg, stretching, soft tissue mobilization, therapeutic exercise, modalities) and to support tolerance of examination of other body systems.

F For patients who have experienced a concussive event and report dizziness, vertigo, and/or headache, physical therapists **should** thoroughly examine for sources of cervical and thoracic spine dysfunction, vestibular and oculomotor dysfunction, and orthostatic hypotension/autonomic dysfunction that may contribute to the emergence or exacerbation of these symptoms (**FIGURE 2**). Therapists should start with the tests that are anticipated to be the least irritable and proceed with the tests anticipated to be the most irritable, based on patient tolerance.

F After triaging and screening for neck pain, dizziness, and headache, physical therapists **should** proceed with multisystem comprehensive examination of any untested domains of cervical musculoskeletal function, vestibulo-oculomotor function, autonomic dysfunction/exertional tolerance, and motor function by sequencing tests and measures based on clinical judgment as indicated (**FIGURE 2**).

EXAMINATION FOR CERVICAL MUSCULOSKELETAL IMPAIRMENTS

IV Multiple consensus documents and lower-level studies emphasize that cervical musculoskeletal dysfunction is complex and may contribute to variable types of symptoms.[115,152,186,188,217] However, evidence and consensus statements encourage attempts to differentiate between the sources that may be causing the symptoms when possible.[186,188,217] When there is a report of neck pain with concussion, the potential for cervical spine musculoskeletal dysfunction is high. However, the potential for dizziness to be caused by cervical dysfunction post concussion is less clear.[188] Low-level evidence indicates that examination of cervical musculoskeletal, vestibulo-oculomotor, and autonomic functions may help clinicians differentiate between dizziness caused by cervical spine dysfunction and other sources.[188]

IV Several level IV studies, including a Delphi study, provide examples of cervical musculoskeletal assessments that may be useful to identify impairments that may contribute to neck dysfunction and cervicogenic dizziness.[106,187,188] Proposed examination techniques include active range of motion of the neck, testing for the presence of pain during active range of motion, manual passive joint mobility assessment, active trigger point assessment and tenderness to palpation, the cranial cervical flexion test, cervical flexion-rotation test, smooth pursuit neck torsion test, head-neck differentiation test, vibration tests, and motor control assessment of deep cervical flexors and extensors. Results of a Delphi study indicated a consensus of strong clinical utility for the following tests in patients with sports-related concussion: the Dix-Hallpike test, orthostatic hypotension testing, spontaneous nystagmus, head impulse test, roll test, gaze-hold nystagmus, saccade testing, vestibulo-ocular reflex cancellation, head-shake test, and smooth pursuit testing.[188] The authors noted that these tests identify dizziness originating from the vestibular or central nervous system. This Delphi study also achieved consensus categorizing the following tests as having weak clinical utility: the cervical flexion-rotation test, neck torsion test, vibration tests, head-neck differentiation test, and motor control assessments of deep cervical flexors and extensors. There was no clear consensus on the clinical utility of static and dynamic balance tests, convergence assessment, dynamic visual acuity testing (DVAT), reproduction of dizziness through manual passive joint mobility, the joint position error test, neck pain and related dizziness, or reproduction of dizziness through palpation of cervical musculature.

V A number of expert opinions, narrative reviews, and theoretical/conceptual papers have provided rationales and theoretical support for the potential role and relatively high prevalence of cervical musculoskeletal impairments that may coincide with symptom reports of dizziness and headache with proposed assessment strategies.[31,54,152,165]

Evidence Synthesis

There is clear evidence to suggest that the cervical spine should be examined after a concussive event, but there is limited evidence on examination procedures for cervical musculoskeletal dysfunction specific to patients who have experienced a concussive event. Low-level evidence suggests that a concussive event can cause cervical injury, and that cervical musculoskeletal impairments can cause symptoms that are often reported after a concussive event. Given the postulated connection between cervical musculoskeletal impairments and concussive events, the GDG consensus was that examination to detect impairments is useful for patients who have experienced a concussive event. Recommended tests and measures include passive and active range of motion of the neck, muscle strength and endurance for cervical and scapulothoracic muscles, tenderness to palpation of cervical and scapulothoracic muscles, passive cervical and thoracic spine joint mobility, and cervical joint position error. When dizziness is reported, the cervical spine should be examined to determine the potential for musculoskeletal dysfunction as a source of the dizziness. The GDG also agreed that the 2017 revision of the Academy of Orthopaedic Physical Therapy neck pain CPG[16] may be used as a resource for guiding physical therapist examination procedures. Musculoskeletal evaluations are part of all physical therapy curricula and are standard-of-care procedures for patients with suspected musculoskeletal dysfunction. Therefore, the GDG decided to set the level of obligation as "should" instead of "may," despite the relatively weak state of the evidence.

Gaps in Knowledge

Future research is needed to test the direct utility and implementability of the neck pain CPG[16] for patients who have experienced a potential concussive event. Although the scope of the systematic search process did not specifically cover the role of neck strength in mitigating subsequent concussion risk, numerous studies and expert opinion reports have hypothesized and demonstrated a potential link between concussion risk and neck strength and control.[152] Given the theoretical and hypothesized linkages between concussion risk, the potential dangers of subsequent concussions, and the expertise of physical therapists to address cervical spine dysfunction, the benefit of identifying potential cervical spine musculoskeletal impairments outweighs the potential costs and burden of examining the spine, even among those patients who do not report neck pain, headache, or dizziness. Future research to evaluate the value of examining neck strength and control among individuals in physical therapy when headache, neck pain, and dizziness are not reported would be beneficial.

Recommendations

C Physical therapists **should** examine the cervical and thoracic spines for potential sources of musculoskeletal dysfunction for patients who have experienced a concussive event with reports of any of the following symptoms: neck pain, headache, dizziness, fatigue, balance problems, or difficulty with visually focusing on a target. Recommended cervical musculoskeletal tests and measures include range of motion, muscle strength and endurance, tenderness to palpation of cervical and scapulothoracic muscles, passive cervical and thoracic spine joint mobility, and joint position error testing.

F Physical therapists **may** examine the cervical spine, thoracic spine, and temporomandibular joint for potential sources of musculoskeletal dysfunction for patients who do not report the symptoms listed to determine whether subtle impairments are present and may be contributing to symptoms.

EXAMINATION FOR VESTIBULO-OCULOMOTOR IMPAIRMENTS

I One CPG specific to concussion and a CPG not directly addressing individuals who have experienced a concussive event indicate that benign paroxysmal positional vertigo (BPPV) may be present and support the use of the Dix-Hallpike test/positional tests to assess for BPPV.[14,153]

II Evidence from a CPG specific to concussion provides strong support for examination to detect vestibular and oculomotor dysfunction that may contribute to postconcussive symptoms.[153] A moderate-quality systematic review reported the following as examination techniques that have been used in research to detect postconcussive oculomotor impairments: saccadic eye movement, smooth pursuits, vergence, and accommodation.[99]

II A prospective cohort study comparing preinjury baseline data and postinjury scores for 63 athletes indicated that both total and change scores on the Vestibular/Ocular Motor Screening (VOMS) may help identify vestibular and oculomotor impairments in athletes who have experienced a concussive event.[52]

II A cross-sectional study comparing 64 athletes with concussion and 78 healthy controls provided preliminary support for adequate internal consistency, sensitivity, and utility of the VOMS assessment.[169]

III Evidence from CPGs and systematic reviews using level III studies, as well as additional level III studies, further supports the use of vestibular and oculomotor evaluations to identify potential sources of postconcussive symptoms.[26,32,82,103,141,149,155,173,198]

IV A retrospective chart review of 167 youth patient records indicated that poorer scores on the VOMS in any of the domains except for near-point convergence may be predictive of delayed recovery after sport-related concussion.[8]

IV Expert consensus from 2 Delphi studies and preliminary evidence from other studies indicate that the following tests may have clinical utility for investigating various sources of dizziness after a concussive event, including dizziness of vestibular or oculomotor origin: ocular alignment, the Dix-Hallpike test, orthostatic hypotension testing, spontaneous nystagmus, head impulse test, roll test, gaze-hold nystagmus, saccade testing, vestibulo-ocular reflex testing, vestibulo-ocular cancellation testing, head-shake test, smooth pursuit testing, motion sensitivity, optokinetic stimulation, and DVAT.[27,71,161,187,188,228]

IV A retrospective chart review indicated that pediatric patients who showed signs of vestibular abnormality on initial clinical examination at a sports medicine clinic took a significantly longer time to return to school or be fully cleared for return to sport.[38]

IV Multiple descriptive cohort studies indicate that dizziness, which is often tied to vestibulo-oculomotor dysfunction, is likely multifactorial and that it may be difficult to differentiate the specific impairments leading to the reports of dizziness.[38,82,152,186-188]

V A number of expert opinions, narrative reviews, and theoretical/conceptual papers have provided rationales and theoretical support for the potential role and relatively high prevalence of vestibular and oculomotor impairments that may coincide with symptom reports of dizziness and headache and proposed assessment strategies.[31,54,135,152,156,219]

Evidence Synthesis

Although evidence is available regarding evaluation for vestibular and oculomotor dysfunction, there is limited evidence specifically derived from patients who have experienced a concussive event. Various strategies to assess for impairments in vestibular and oculomotor function have been proposed. The VOMS is a vestibular and oculomotor functional screening tool that is commonly cited in the literature and was developed and has been tested for use specifically in athletes with concussion. Preliminary study of the VOMS supports its use for diagnosing sport-related concussions and predicting prolonged recovery. The VOMS captures self-reported symptom provocation with assessment of 5 areas: smooth pursuit, horizontal and vertical saccades, convergence, horizontal and vertical vestibular-oculomotor reflex, and visual motion sensitivity. The VOMS has demonstrated strong internal consistency and significant correlation with the Post-Concussion Symptom Scale, and has potential to help differentiate individuals with concussion from healthy controls. However, it is important to emphasize that the VOMS was not designed as a comprehensive tool for vestibular and oculomotor function and may not encompass all of the screening strategies necessary to examine all aspects of vestibular and oculomotor dysfunction. Therefore, it may be useful as a screening tool, but is not appropriate as a replacement for a comprehensive vestibular and oculomotor assessment.

The GDG determined that the following examination strategies may be useful for patients who have experienced a concussion: ocular alignment, head impulse testing, smooth pursuits, saccades, vergence and accommodation, gaze stability, dynamic visual acuity, and visual motion sensitivity. When symptoms indicate it, the use of positional tests (eg, the Dix-Hallpike test) may help to identify BPPV. Additionally, the CPGs for vestibular hypofunction[80] and BPPV[14] and their associated implementation tools may be useful to help guide examination and evaluation procedures.

Gaps in Knowledge

Various strategies to examine vestibular and oculomotor function have been proposed. At this time, there is limited evidence to support one strategy over others for examining patients who have experienced a concussive event. More research is needed to determine the utility and implementability of the CPGs for vestibular hypofunction[80] and BPPV[14] and other oculomotor-vestibular assessment protocols for use in individuals who have experienced a concussive event.

Recommendations

B Physical therapists **should** examine vestibular and oculomotor function for patients who have experienced a concussive event with reports of any of the following symptoms: headache, dizziness, vertigo, nausea, fatigue, balance problems, visual motion sensitivity, blurred vision, or difficulty with focusing on stable or moving targets.

B Physical therapists **should** examine vestibular and oculomotor function related to the following: ocular alignment, smooth pursuits, saccades, vergence and accommodation, gaze stability, dynamic visual acuity, visual motion sensitivity, light-headedness caused by orthostatic hypotension, and vertigo caused by BPPV.

A If BPPV is suspected, then physical therapists **should** assess the patient using the Dix-Hallpike test or other appropriate positional test(s).

F Physical therapists **may** examine patients who have experienced a concussive event for vestibulo-oculomotor function, even if vestibulo-oculomotor symptoms are not reported, to identify potential subtle impairments that may be contributing to symptoms.

EXAMINATION FOR AUTONOMIC/EXERTIONAL TOLERANCE IMPAIRMENTS

I A high-quality systematic review appraised the evidence on strategies for evaluating responses to physical exertion after mTBI/concussion for clinical and research purposes.[177] Findings indicate that testing may identify impairments that would not otherwise be detected based on symptom reports or physiologic measures taken with the patient at rest. Additionally, patient responses to exertional tests may result in a slight, short-term exacerbation of symptoms.

I Evidence from an RCT indicates that evaluation of exercise tolerance testing for adolescents within 1 week of sports-related concussion did not affect recovery, and that the extent of early exercise intolerance may be strongly associated with prolonged recovery time.[131]

II Evidence from a scoping review of the literature for postconcussion assessment strategies indicates that graded exercise tests are becoming more prominent in research and clinical practice, and they may provide valuable insight into concussion recovery trajectories and potential impairments.[78]

II Two cohort studies indicate that treadmill and stationary bicycle graded exercise testing could be useful tools for capturing impairment after concussion and while monitoring recovery.[47,174]

III A mildly blunted heart rate response, altered heart rate variability, and higher ratings of perceived exertion have been observed among individuals who have experienced a concussive event during graded exercise testing, suggesting potential autonomic dysfunction.[65,66,85,174] Findings indicated that exertional testing may identify impairments that would not otherwise be detected based on symptom reports or physiologic measures taken with the patient at rest,[65,85] and that results may be predictive of recovery trajectory.[79,174]

IV A variety of case series and other lower-level study designs indicate that graded exertional tests are safe, tolerable, and can be clinically valuable for assessing individuals who have experienced a concussive event.[36,42,112] Additionally, graded exertional tests have become recognized as an option for assessment via expert consensus documents and workgroups.[19,159]

V The use of graded exertional tests is further supported by numerous theoretical papers, clinical commentaries, and narrative review papers describing the potential value of postconcussive exertional tests.[53,54,123,126,128,133,134,156]

Evidence Synthesis

Collectively, the evidence suggests that evaluating symptoms and physiological metrics at rest (eg, heart rate, respiration rate, and blood pressure) is not sufficient to effectively detect lingering postconcussion exertional intolerance. Strong evidence indicates that (1) exertional assessments using symptom thresholds can provide important insights into recovery, and (2) exertional tolerance tests are a key assessment strategy for individuals with concussion with persistent symptoms and who desire to return to high-exertion activities (eg, sports, active military duty). Common outcome measures used with exertional tests include self-reported symptom exacerbation, heart rate, and blood pressure. Potential risks, harms, and implementation considerations related to exertional intolerance examinations include (1) exacerbation of concussion-related symptoms, (2) varying comfort levels and preferences of patients for exercise in general or with certain exercise modalities,[150,163,177] (3) a general lack of fitness that may limit the utility of an exertional assessment for identifying specific injury-related impairment, and (4) for some patients with cardiovascular, orthopaedic, or vestibular conditions or impairments, inability to tolerate certain types of exertional modalities or protocols. Emerging evidence suggests that exertional tests are safe and may be beneficial for athletes to help make return-to-play decisions, and may be administered within the first week of injury. Additionally, given the growing body of evidence supporting aerobic exercise training for promoting brain healing and health after concussion (evidence reported in the Interventions section), the GDG group consensus was that exertional tests may be useful for providing initial postconcussion measures and setting target exertion levels for promoting brain healing and health, regardless of whether exertional intolerance is suspected.

Gaps in Knowledge

Additional studies are needed to help clarify optimal testing modes, protocols, and interpretation for exertional tests with individuals who have experienced a concussive event. Another important knowledge gap is that a majority of the exertion testing studies for individuals who have experienced a concussive event have been conducted with athletes and/or individuals diagnosed with sport-related concussion. More research is needed to determine whether there is the same type of need for testing and whether the same type of testing protocols are appropriate for individuals who are not athletes.

Recommendations

B Physical therapists **should** test for orthostatic hypotension and autonomic dysfunction (eg, resting and postural tachycardia or rapidly accelerating heart rate with positional changes) by evaluating heart rate and blood pressure in supine, sitting, and standing positions.

B Physical therapists **should** conduct a symptom-guided, graded exertional tolerance test for patients who have experienced a concussive event and report exertional intolerance, dizziness, headache, and/or a desire to return to high-level exertional activities (ie, sports, active military duty, jobs that entail manual labor). Timing, modality, and protocol should be tailored to optimize safety and individual appropriateness. For patients who are highly symptomatic at rest, the symptom-guided, graded exertional tolerance test should be delayed until symptoms are stable and more tolerable at rest. Likewise, physical therapists may decide to postpone graded exertional testing until later in the course of care if clinical judgment deems that other symptoms and impairments are of higher priority. Testing modality (eg, treadmill versus stationary bicycle) and protocol selection should be based on clinical judgment, patient comfort, and the availability of necessary equipment. Heart rate and blood pressure should be monitored periodically throughout the test and afterward to identify any significant concerns for atypical responses to exercise testing.

C If vestibulo-oculomotor or cervical spine impairments or symptoms are present, physical therapists **should** use a stationary bicycle for testing to reduce risk for exacerbating impairments or compromising the validity of the test results.

C Physical therapists **may** use assessments for orthostatic hypotension/autonomic dysfunction and symptom-guided, graded exertional tolerance tests for patients who do not report exertional intolerance to help determine the role that autonomic dysfunction, deconditioning, or general fitness may play in symptoms (eg, headache, fatigue, fogginess).

F Physical therapists **may** conduct exertional tests for patients who have experienced a concussive event and do not report symptoms indicative of exertional intolerance in order to rule out subtle autonomic dysfunction in response to exertion, establish initial postconcussion performance level, and identify exertional targets for aerobic exercise training that may be incorporated to promote brain health and healing.

EXAMINATION FOR MOTOR FUNCTION IMPAIRMENTS

I A high-quality cohort study demonstrated that concussion may affect postural control during gait as far as 2 months post injury and that a dual-task assessment may help capture these deficits.[92]

III A low-quality systematic review provided foundational evidence that response times and postural control deficits are greater and gait strategies are less efficient under divided-attention tasks among individuals who have experienced a concussion.[183]

III Multiple cohort and case-control studies and systematic reviews of moderate-quality evidence found potential motor function impairments that may be present after a concussive event, including impairments in static and dynamic balance, dual-task/multitasking gait activities, and motor coordination with complex movement tasks, which may or may not correlate with symptom reports.[11,13,20,21,44,49,58,59,68,86,89,90,93-95,100,144,154,183,190,195,218,221,223]

III Studies indicate that the measurement properties for evaluation of motor tasks are uncertain, with numerous potential limitations in the reliability, validity, utility, and interpretability of the various measures currently in the literature, especially with regard to age and complexity of task used for assessments.[11,12,24,40,172,182,183] Several studies indicate that examination techniques most sensitive for detecting concussion-related motor function impairments may necessitate special equipment (eg, force plates or accelerometers) and/or advanced analyses (eg, entropy analyses or complexity metric analyses), thus limiting clinical implementability and practicality.[93,172,173,180,199]

IV Additional case series and case-control studies indicate that age/developmental factors and the presence of headache (versus no headache) may influence motor function assessment scores for individuals with concussion.[97,179,184]

IV Multiple case series and retrospective analyses indicate that subtle, subclinical motor function impairments (eg, postural control/sway metrics or sensory integration ability) may persist beyond the presence of easily observable and detectable impairments (eg, balance tests).[28,180,200,207,221]

IV Multiple evidence-based expert consensus documents based on lower-level study designs encourage the use of motor function assessments for motor function abilities such as dual task/multitask, balance, and motor coordination for individuals who have experienced a concussive event.[19,60,94,109,141,159,160,181,190]

Evidence Synthesis

A variety of tools and assessment strategies for motor function impairments related to concussion are available, some of which are cited more often than others. However, most have been designed for sideline and clinical evaluation for symptoms and impairments that may indicate a probable concussion. Many studies pertaining to this topic did not meet the relevance or inclusion/exclusion criteria set forth by the GDG. Consequently, at this time, there is insufficient evidence to support a clear set of motor function measures for individuals who have experienced a concussive event. For patients with lower-level function, the CPG titled "A Core Set of Outcome Measures for Adults With Neurologic Conditions Undergoing Rehabilitation"[164] may be useful. However, for patients with higher motor function abilities, the recommended measures are likely to have limited clinical utility, as their motor impairments may be too subtle. There is a growing set of evidence looking into dual/multitask assessments to identify subtle motor impairments after concussion. However, these studies have primarily used laboratory-grade motion-analysis equipment and more complex protocols that are not easily implemented in clinical contexts. There are inherent challenges in determining how useful, valid, and reliable a given test is when used by a physical therapist to inform plan of care, monitor progress, and determine episode-of-care end points for discharge from physical therapy. These challenges are compounded by an ever-growing body of new technologies or approaches that have only been tested in laboratory conditions and/or with healthy participants. In fact, the US Food and Drug Administration recently released a safety communication in March 2019 warning that products marketed for the assessment, diagnosis, or management of head injuries often lack validity and are not appropriately validated or vetted for accuracy and safety.[216] Current research suggests that more advanced and sophisticated assessment and analytic techniques (eg, complex analyses of postural sway, accelerometry, or other technologically advanced instrumentation) may improve the capacity to detect subtle motor function impairments in the future.

Gaps in Knowledge

Due to insufficient evidence to inform selection of motor function assessments specific to physical therapy needs and purposes for individuals who have suffered a concussive event, GDG consensus for motor function assessments is to use standard-of-care practices for testing these hypothesized motor function impairments. More research is needed to identify specific tests and measures that would inform clinical decision making and physical therapy intervention selection for individuals who have experienced a concussive event.

Recommendation

B Physical therapists **should** examine patients who have experienced a concussive event for motor function impairments, including static balance, dynamic balance, motor coordination and control, and dual/multitasking (eg, motor tasks along with cognitive tasks or complex tasks with multiple subtasks involved). Selection and timing of motor performance assessments should be based on clinical judgment about which evaluation strategies are most appropriate for the patient's age and ability and will provide the most insight into current functional levels relative to goal levels.

CLASSIFICATION OF EXAMINATION FINDINGS INTO IMPAIRMENT PROFILES

III Recommendations from 2 CPGs for patients who have experienced a concussion and report headache encourage clinicians to align evaluation and treatment planning based on headache phenotype (International Classification of Headache Disorders).[149,153]

IV A cross-sectional study of athletes between the ages of 10 and 23 years with a diagnosis of concussion found that many of the patients with a complaint of dizziness post concussion demonstrated deficits in a variety of tests that indicate that dizziness was not attributable to one main type of dysfunction, but rather was multifactorial in nature.[187]

IV An expert consensus document indicated that there was strong agreement among participating experts that "matching targeted and active treatments to clinical profiles may improve recovery trajectories after concussion," and that "[t]here is growing empirical support for the heterogeneity of this injury and clinical profiles, but additional research in these areas is warranted.[34]

V Several conceptual schemas promote the idea that although patients who experience concussions have variable clinical presentations and recovery trajectories, it may be possible to identify specific clinical profiles of diagnoses associated with concussion that can be targeted with specific rehabilitation techniques.[35,53,54,143]

Evidence Synthesis

Historically, individuals who experienced a concussion were conceptualized as a homogeneous patient population with similar responses to the trauma and relatively parallel recovery experiences and trajectories. There are several clinical commentaries and expert opinion documents that propose new conceptual schemas suggesting that individuals with concussion should be viewed in a more heterogeneous way through clustering or characterizing patients into phenotypic profiles. The current proposed schemas vary in the specific profile groups they suggest and the methods for determining which profile or profiles a patient fits best. However, these classification models have also not been thoroughly validated and tested. Additionally, there is growing expert consensus that patients may not directly fit any one classification but rather exhibit a profile that incorporates patterns consistent with multiple classifications.

Gaps in Knowledge

Although clinically important and conceptually compelling, current classification models have not been thoroughly validated and tested. At this time, there is insufficient evidence to support the endorsement of one classification system over others. The GDG consensus was to encourage physical therapists to identify all potential impairments that could be addressed with physical therapy interventions, as well as their levels of irritability, to formulate a treatment plan that is individualized to each patient. A comprehensive description of the GDG consensus and rationale for the profile is outside the scope of this CPG. However, the GDG team published a manuscript detailing this perspective and its collective opinions on this topic that clinicians may refer to for further clarification and context.[1] Future research is needed to identify an optimal classification or profiling system for patients who have experienced a concussive event and are experiencing movement-related impairments and symptoms.

Recommendations

E Physical therapists **should** establish and document the presence or absence of all impairments and their levels of irritability to support the selection of treatment priorities and strategies for patients who have experienced a concussive event.

B For patients who have experienced a concussive event and report headache as a symptom, physical therapists **should** determine and document the potential headache type in accordance with the International Classification of Headache Disorders.

PSYCHOLOGICAL AND SOCIOLOGICAL FACTORS

Evidence Synthesis

No studies directly related to physical therapy and psychological and sociological implications were identified. However, there is theoretical and foundational epidemiological evidence indicating that psychological and sociological resilience (personal qualities and social factors that enable one to thrive in the face of adversity) and psychological and social vulnerabilities (psychological and social factors that may put one at risk for poor recovery) may play important roles in recovery.[107,119,138-140,205] These theoretical and foundational studies also suggest that various preinjury and postinjury psychological and sociological variables may contribute to who recovers well naturally as well as to who may respond well to specific interventions. For example, positive, healthy coping skills and a good social support system may facilitate recovery, whereas an absence of these factors may be detrimental to recovery (eg, increased use of alcohol or other substances to cope with stress and symptoms). These studies are further supported by a number of theoretical and conceptual expert opinion documents highlighting the likelihood of psychological and sociological factors as important considerations for prognosis and intervention selection.[107,176] Specific assessments and evaluative decisions based on these factors have not been thoroughly tested.

Gaps in Knowledge

More research is needed to help apply available measures and/or develop specific evaluation measures for identifying potential psychological and sociological factors that may influence optimal physical therapy intervention and dosing selection.

Recommendations

E Physical therapists **should** elicit, evaluate, and document factors related to self-efficacy and self-management abilities, potential psychological and sociological factors that may significantly influence recovery processes and outcomes for physical therapy interventions. Examples of factors to consider include (1) the patient's expression and demonstration of good, healthy coping strategies in response to stressful situations; (2) the type of support system the patient has to enable self-management of symptoms and impairments; (3) the number and type of potential risk factors that may contribute to delayed or complicated recovery (eg, history of mental health or substance use disorders); (4) the patient's understanding and attitude toward recovery (eg, expressing a positive outlook on recovery versus a more negative mindset or high anxiety toward recovery); and (5) the patient's access to resources and equipment that may facilitate recovery (eg, access to an athletic trainer or other health care providers to support recovery).

E When evaluating self-efficacy and self-management factors, physical therapists **should** explain and emphasize that most symptoms and impairments after concussion do improve.

OUTCOME MEASURE SELECTION

II Evidence from high-quality CPGs informed by moderate-level evidence indicates that postconcussion symptom assessments/checklists should be used to monitor recovery, with perhaps more comprehensive outcome measures to specifically evaluate certain symptoms (eg, dizziness, headache, fatigue, and neck pain).[141,142,149,153]

III Evidence from a moderate-quality cohort study indicates that the Dizziness Handicap Inventory (DHI) and DVAT may be useful as outcome measures for individuals who have experienced a concussion and exhibit vestibular impairments.[72]

III A moderate-quality diagnostic study provided preliminary reliability, validity, and responsiveness of the High-level Mobility Assessment Tool (HiMAT) for individuals who have experienced a concussive event and reported balance problems 3 months post injury.[110]

IV Two recent expert consensus documents provide recommendations for a variety of outcome measures that may be useful for monitoring postconcussion recovery.[19,61]

Evidence Synthesis

Systematic and repeated outcome assessments provide a mechanism to evaluate the end results of care at the patient and population levels. Many outcome measures have been proposed for use with patients who have experienced a concussive event. However, the utility and appropriateness of these measures for physical therapy purposes are unclear. Many comparative studies related to postconcussion outcome measurement had insufficient quality and uncertain relevance for use in physical therapy contexts. Moderate-level evidence was available to support the ongoing use of symptom checklists or scales; however, there was no consensus on the most appropriate symptom assessment method for outcome measurement. There is weak evidence to support the use of the HiMAT; however, there is a large ceiling effect, and it may not be useful for detecting outcomes related to more subtle movement-related impairments. Expert consensus recommendations have proposed a variety of data elements that would be worth collecting, but the clinical utility and implementability for physical therapy purposes have not been tested. There was also weak evidence to support the DHI and DVAT; however, additional research is needed to evaluate the validity and reliability of these measures for patients diagnosed with concussion.

The GDG did not find sufficient evidence to endorse any specific outcome measures for use with patients with concussions. Ongoing measurement of symptoms using an age-appropriate scale or checklist may be valuable to help monitor for progress in postconcussion symptom presentation. Measures recommended in the Academy of Neurologic Physical Therapy's core set CPG,[164] the Academy of Orthopaedic Physical Therapy's neck pain CPG,[16] and the Academy of Neurologic Physical Therapy's peripheral vestibular hypofunction CPG[80] may be useful for some patients. Additionally, given the challenge of making sure interventions meet the individual needs and goals of younger and older patients, goal attainment scaling may be an option to help individualize outcome tracking while still retaining the ability to compare achievement levels across patients.[81,113,148,213-215,229] However, the utility and implementability for patients who have experienced a concussive event also remain untested. The GDG consensus at this time is that selection of specific outcome measure use should be based on clinician judgment of best fit for the patient's functional status, age, goals, needs, and prognosis.

Gaps in Knowledge

Future studies are strongly encouraged to develop, test, and optimize a battery of outcome measures that may include self-report measures, observation/performance-based measures, and clinically useful technology for patients who have experienced a concussive event. Self-management may be a key element for concussion recovery. Research into specific outcome measures for self-management and concussion for use as part of physical therapy examination and monitoring would be beneficial. Additionally, decision tools for selection of appropriate outcome measures given various impairment profiles may also be investigated.

Recommendation

F Physical therapists **should** determine and document a plan for outcome measurement for patients who have experienced a concussive event for any impairment domains that will be targeted with physical therapy interventions and/or were previously untested due to poor tolerance.

CLINICAL PRACTICE GUIDELINES

Interventions

COMMUNICATION AND EDUCATION

I Evidence from high-quality CPGs highlights the importance of educating and providing assurance to patients who have experienced a concussion that most people recover well and typically do not have significant difficulties that last more than 1 to 3 months post injury.[141,153]

III High-quality CPGs based on moderate-level evidence and other studies indicate that after an initial period of rest for the first 24 to 48 hours, patients with concussion should be encouraged to avoid activities that have a high risk for another concussion but gradually resume normal activity, based on their tolerance.[141,142,153,159,192]

IV Consensus-based recommendations from a panel of experts indicate that patients with concussion can benefit from education on lifestyle and self-management of symptoms to decrease the impact of symptoms on quality of life and to facilitate recovery.[160]

Evidence Synthesis

Several guidance documents stressed the importance of how the diagnosis of concussion is communicated to patients and their families. The rationale for clear communication and education about concussion diagnosis and prognosis is to establish an expectation for recovery and to avoid unintentional reinforcement of insecurities, fears, or a trajectory of catastrophizing about the injury. Published guidelines for concussion management also consistently emphasize the importance of patient education regarding the risks for subsequent injury during high-risk activities, management strategies, and return-to-activity progressions.

Recommendations

B Physical therapists **must** educate patients who have experienced a concussive event about self-management of symptoms, the importance of relative rest (rest as needed) instead of strict rest, the benefits of progressive re-engagement in activities, the importance of sleep, safe return-to-activity pacing strategies, and potential signs and symptoms of the need for follow-up care with a physician, physical therapist, or other health care providers.

A Physical therapists **must** educate patients who have experienced a concussive event and their families/caregivers about the various symptoms, impairments, and functional limitations that are associated with concussion, and stress that most patients with concussion recover relatively quickly. Providing this information can help physical therapists avoid inadvertent reinforcement of poorer recovery expectations.

INTERVENTIONS FOR MOVEMENT-RELATED IMPAIRMENTS

II Two systematic reviews of moderate-quality study designs indicate that personalized physical therapy interventions targeting movement-related impairments (eg, therapeutic exercises for cervical spine impairments, vestibulo-oculomotor impairments, and aerobic exercise training) are safe and result in clinical improvement (ie, reduced symptoms, improved ability to return to preinjury activities) after an initial period of relative rest, and potentially biological and physiological improvement.[178,192]

II A randomized controlled feasibility study that compared a group of adolescents with concussion and dizziness up to 14 days after injury who received early personalized physical therapy to a control group demonstrated a shorter recovery time in the experimental group.[189] The median number of days to medical clearance for the experimental group was 15.5 (versus 26 for the controls), and the median number of days to symptomatic recovery was 13.5 for the experimental group (versus 17 for the controls).

II Recommendations from high-quality CPGs based on moderate-quality evidence indicate that in addition to movement-related impairments, patients may also experience a range of other persistent postconcussion symptoms and impairments that may require treatment from other health care professionals.[141,142,149,153]

IV Numerous retrospective cohort studies and case series provide further support for the potential for multimodal physical therapy approaches to safely facilitate recovery after concussion.[48,62,63,73,98,137] Further, several of these studies indicate that these interventions can be safely introduced within a few days to weeks post injury, with earlier initiation potentially resulting in better outcomes for patients.[48,122,137]

Evidence Synthesis

Timing of initiation of physical therapy services is highly variable, with many earlier studies and guidelines focusing on individuals who experienced persistent symptoms lasting 2 or more weeks. Recent studies support considering the initiation of physical therapy interventions as early as the first week of injury. Studies have not found that early physical therapy contributes to significant safety concerns or worse outcomes. This is not surprising, as study designs and clinical practice patterns are often guided by theoretical and clinical judgments that are based on minimizing the potential for adverse events. Collectively, these studies suggest that time since injury should not independently drive decisions about the appropriateness and potential benefit of physical therapy for individuals who have experienced a concussive event. Additionally, some impairments may require specialized treatment that is not within physical therapists' scope of practice, including auditory impairments, vision impairments (including impairments of ocular alignment), cognitive impairments, sleep problems, and migraine and other chronic headache symptoms.

Gaps in Knowledge

Despite evidence of safety and positive outcomes for physical therapy interventions targeting postconcussion symptoms, impairments, functional limitations, and participation restrictions, there are limited data regarding specific patient and injury characteristics impacting responsiveness to physical therapy interventions. Given the large volume of patients who recover naturally or with general education about activity progression, there are presumably some individuals who may be able to self-manage mild movement-related impairments with education and a home exercise program. We propose a triaging plan in **FIGURE 3** to help differentiate patients who may be able to self-manage their symptoms and impairments from those who would benefit from skilled physical therapy care. Research investigating the proposed triaging system would be beneficial. Additionally, more research is needed to develop a system for identifying those patients who can optimally benefit from physical therapy interventions to facilitate recovery after experiencing a concussive event.

Recommendations

F Physical therapists **should** use findings from the examination to triage patients who have experienced a concussive event into 1 of 2 categories: (1) patients with movement-related impairments and dysfunction who are good candidates for physical therapy interventions, or (2) patients with no identified movement-related impairments or dysfunction (**FIGURE 3**). Time since injury may influence level of irritability of symptoms, but should not be a primary determinant for decisions regarding when physical therapy interventions are appropriate. Evidence indicates that physical therapy early after concussion is safe, and that earlier initiation of physical therapy interventions may facilitate a faster recovery.

B Physical therapists **should** design a personalized intervention plan for patients who have experienced a concussive event and have movement-related impairments that aligns interventions with the patient's identified impairments, functional limitations, participation restrictions, self-management capabilities, and levels of irritability.

B Physical therapists **should** refer patients who have experienced a concussive event for further consultation and follow-up with other health care providers as indicated. Of specific note, high-quality CPGs recommend referral for specialty evaluation and treatment in cases of persistent migraine-type and other chronic headaches, vision impairments (including ocular alignment), auditory impairments, sleep disturbances, mental health symptoms, cognitive problems, or other potential medical diagnoses that may present with concussion-like symptoms or coincide with concussion symptoms (eg, lesions/tumors or endocrine abnormalities such as posttraumatic diabetes insipidus).

CERVICAL MUSCULOSKELETAL INTERVENTIONS

II Evidence from RCTs indicates that physical therapy interventions that address the cervical spine can independently, and in combination with other therapies (eg, vestibular interventions), lead to improvement in symptoms, function, and return to activity after concussion.[189,194] Individuals receiving a combined cervical and vestibular intervention were 3.91 times more likely to be medically cleared for return to sport by 8 weeks than those in the control group.[194]

IV Retrospective chart reviews and case series provide further support for cervical musculoskeletal interventions to improve symptoms and function for individuals who have experienced a concussive event.[73,98,106,152,193]

V A narrative systematic review of studies related to the cervical spine and concussion highlighted several low-quality studies and theoretical papers emphasizing the potential for stronger neck muscles and anticipatory cervical muscle activation to reduce risk for future concussions.[165]

Evidence Synthesis

Few studies have been dedicated specifically to the study of physical therapy interventions for cervical musculoskeletal impairments in patients who have experienced a concussive event or been diagnosed with a concussion. The treatment studies identified typically incorporated interventions to address cervical musculoskeletal impairments in combination with other types of interventions (eg, aerobic exercise training and/or oculomotor-vestibular interventions). Regardless of the underlying mechanisms leading to these symptoms, several studies indicate that patients with concussion who exhibit signs of cervical musculoskeletal impairment may respond well to physical therapy interventions for cervical spine dysfunction alone and in combination with other active rehabilitation strategies. Additionally, neck strength and muscle strength imbalances have been shown to be associated with concussion risk. Therefore, even when cervical spine impairments are not present as a result of concussion, it may be valuable for physical therapists to provide cervical spine musculoskeletal interventions, with the goal of decreasing a patient's risk for subsequent concussive injuries. Evidence guiding specific postconcussion cervical spine interventions for patients who have experienced a concussive event is limited at this time. The consensus of the GDG is to use best-practice standards for selecting and implementing cervical musculoskeletal interventions. The neck pain CPG[16] guiding general management of cervical spine dysfunction may be useful to inform intervention strategies.

Gaps in Knowledge

Future research is needed to determine, test, and optimize cervical musculoskeletal interventions for individuals who have experienced a concussive event and exhibit cervical musculoskeletal impairments.

Recommendation

B Physical therapists **should** implement interventions aimed at addressing cervical and thoracic spine dysfunction, such as strength, range of motion, postural position, and/or sensorimotor function (eg, cervicocephalic kinesthesia, head position control, cervical muscle dysfunction) exercises and manual therapy to the cervical and thoracic spine, as indicated, for patients who have experienced a concussive event.

VESTIBULO-OCULOMOTOR INTERVENTIONS

I A CPG supported by level I evidence recommended that if BPPV is identified as a potential source of dizziness, then canalith repositioning maneuvers should be used.[153]

II A systematic review including 2 RCTs provided weak-to-moderate evidence that vestibulo-oculomotor rehabilitation improved outcomes.[171] Evidence from a moderate-quality RCT indicates that rehabilitation strategies targeting vestibulo-oculomotor impairments, independently and in combination with other physical therapy interventions, may be feasible even within the first 10 days after a concussive injury and can be effective in reducing symptoms, reducing time to recovery, and improving function.[189] For 1 RCT, individuals in the treatment group who received cervical and vestibular rehabilitation were 3.91 times more likely to be medically cleared for return to sport by 8 weeks.[194]

IV Multiple clinician survey studies, case series, and retrospective cohort studies without comparators indicate that vestibular rehabilitation, including canalith repositioning maneuvers for BPPV, is commonly used by physical therapists to treat individuals who have experienced a concussive event[5] and may help reduce dizziness and improve gait and balance dysfunction for these patients.[4,103,163,193,203]

Evidence Synthesis

Studies suggest that physical therapists commonly integrate vestibular and oculomotor rehabilitation strategies when working with patients who have experienced a concussive event. Vestibulo-oculomotor rehabilitation, when prescribed in isolation or in conjunction with other rehabilitation interventions, is associated with reduced dizziness, improved balance, and faster return to sport. It is expected that vestibulo-oculomotor rehabilitation exercises cause a mild transient increase in symptoms. The American Academy of Otolaryngology–Head and Neck Surgery recommends that patients with posterior and lateral canal BPPV should be treated with canalith repositioning procedures (a series of head maneuvers that can help correct BPPV).[14] Although repositioning maneuvers can be effective in treating BPPV, a patient may require additional interventions in the presence of concomitant vestibular hypofunction.[14]

Evidence guiding specific vestibulo-oculomotor intervention protocols for patients who have experienced a concussive event is limited at this time. However, the Academy of Neurologic Physical Therapy's peripheral vestibular hypofunction CPG[80] may provide some guidance for treatment strategies. Additionally, the American Academy of Otolaryngology–Head and Neck Surgery's CPG for BPPV may also be a useful resource for physical therapists.[14]

Gaps in Knowledge

More research is needed to evaluate the implementation of these guidelines in patients who have experienced a concussive event.

Recommendations

A If BPPV is identified as a potential impairment, then physical therapists **should** use canalith repositioning interventions.

B Physical therapists with appropriate expertise in vestibular and oculomotor rehabilitation **should** implement an individualized vestibular and oculomotor rehabilitation plan for patients who have experienced a concussive event and exhibit vestibular and/or oculomotor dysfunction. If visual vertigo/visual motion sensitivity (dizziness provoked by repetitive or moving visual environments) is identified, an individualized visual-motion habituation program may also be beneficial. Patients with neck pain or other cervical impairments may exhibit worsening of cervical impairments due to repetitive head movement as part of vestibular rehabilitation. Therefore, the implications of head-rotation interventions on the possible concomitant cervical impairments should also be considered and addressed.

F Physical therapists who lack appropriate training in vestibular and oculomotor rehabilitation **should** refer patients who exhibit vestibular and/or oculomotor impairments to a clinician with appropriate expertise.

EXERTIONAL TOLERANCE AND AEROBIC EXERCISE INTERVENTIONS

I A high-quality systematic review that included 5 RCTs provides strong evidence that monitored, progressive, symptom-guided aerobic exercise training is feasible, safe, and may accelerate symptom resolution and neurologic recovery after a concussive event.[118] The exertion training protocols varied by exercise mode, exertion protocols, and dosage of training. Despite these discrepancies in the studies, the meta-analysis results indicated that exercise resulted in significant decreases in symptom scores as measured by Post-Concussion Symptom Scale score (mean difference, –13.06; 95% confidence interval: –16.57, –9.55; $P \leq .001$), reaction time score among RCTs that used the Immediate Post-Concussion Assessment and Cognitive Testing (mean difference, –0.43; 95% confidence interval: –0.90, –0.06; $P = .02$), number of days off work (17.7 days versus 32.2 days, $P < .05$), and percent of patients with full function at the end of the study period (72% versus 17%, $P = .02$).

I A high-quality RCT comparing adolescent athletes who followed an aerobic exercise program in the first 10 days after a sports-related concussion to a group that followed a progressive stretching program found that early aerobic exercise may help speed recovery (interquartile ranges, 10-18.5 days for the aerobic group versus 13 to 23 days for the stretching group).[129]

II A quasi-experimental study provided evidence indicating that aerobic exercise training among males with sport-related concussion initiated within the first few days after injury may reduce total time to recovery compared to relative rest.[130] A second quasi-experimental study provided evidence of improved quality of life and less anger among youths who are slow to recover after concussion and who follow an exercise-based active rehabilitation intervention.[67]

IV Numerous case series and small pilot studies provide further support for the safety, feasibility, and potential benefits of aerobic training among individuals who have experienced a concussive event.[7,48,73,98,112,132,137] Additionally, a recent retrospective case series with propensity scoring analysis indicated that earlier time to aerobic exercise training may facilitate faster recovery for athletes and help mitigate prolonged recovery from concussion for athletes and nonathletes.[137]

Evidence Synthesis

Both alone and coupled with other impairment-specific active rehabilitation interventions, aerobic exercise training has been linked to faster symptom resolution and rate of return to sport and enhanced neurologic recovery. Many of the efficacy studies have been performed with patients who were 4 to 6 weeks post injury. However, preliminary evidence from case series with propensity scoring analysis provides some initial support that introducing physical exertion activities earlier after injury may be safe, feasible, and potentially advantageous. An RCT with adolescent athletes indicated that implementation of an aerobic training protocol early after injury may result in faster recovery.[129]

There is limited evidence for the best mode, protocol, progression parameters, dosing, and timing of initiation for aerobic exercise training after concussion. Currently available studies have utilized multiple modes, including treadmill training, bicycling, elliptical training, and multimodal training (eg, resistance training coupled with cardiovascular training and/or sport-specific training). However, there are no studies directly comparing modes or protocols. Additionally, protocols across studies have varied in terms of progression parameters. Some studies used systematic progressions guided by heart rate or ratings of perceived exertion. Others were time based, with more generic specifications about intensity. A common assertion from experts in consensus statements and commentaries has been that aerobic training interventions should be guided by symptoms, in that significant exacerbation of symptoms beyond a mild degree should result in exercise termination for the session, and an absence of symptom exacerbation can provide support for progressing exercise intensity and duration.[159,192] Symptom exacerbations may occur with aerobic activity, but they should be mild and temporary in nature.[9,47]

Gaps in Knowledge

Research is needed to determine optimal protocols for timing, progressing, and dosing strategies for exertion and aerobic exercise interventions for individuals who have experienced a concussive event.

Recommendations

A Physical therapists **should** implement a symptom-guided, progressive aerobic exercise training program for patients who have experienced a concussive event and exhibit exertional intolerance and/or are planning to return to vigorous physical activity levels. Selection of modality and protocol for training with a specific focus on the patient's goals, comfort level, lifestyle, and access to equipment is encouraged. Timing of the initiation of the aerobic exercise training program may vary by patient, but the stabilization of the patient's symptoms to a moderate or lower level of irritability may be a guiding criterion.

E Physical therapists **may** implement progressive aerobic training for all patients who have experienced a concussive event, including those who do not exhibit exertional intolerance and those who do not intend to engage in vigorous physical activity in order to reduce risk for deconditioning, promote functional brain healing, and provide a nonpharmaceutical option to improve mental health.

MOTOR FUNCTION INTERVENTIONS

IV Expert consensus from CPGs based on weak evidence from case series studies and expert opinion consensus documents suggest that interventions that target motor function impairments after concussion may be beneficial.[34,98,149,153,160]

V An expert opinion article provides guidance for physical therapy interventions for armed service members with mTBI that includes suggestions for balance and dual-task activities.[222]

Evidence Synthesis

At this time, there is limited evidence regarding the efficacy and effectiveness of interventions to target motor function impairments. Given the volume of evidence indicating the potential for motor function impairments, the GDG consensus was that motor function interventions are likely to be beneficial, even if the impairments are subclinical and difficult to identify as part of the clinical examination process. Expert consensus and low-level studies indicate that gradual, progressive return to higher-level motor function tasks and challenges, including return to work and return to physical activity/sport, could be supported through physical therapy interventions and progressions directly targeting motor function.

Gaps in Knowledge

Research is needed to evaluate the outcomes and value of interventions that target motor function.

Recommendation

C Physical therapists **should** implement motor function interventions that address identified or suspected motor function impairments and help progress the patient toward higher-level functional performance goals. Motor function interventions that target the following impairments are strongly encouraged: static balance, dynamic balance, motor coordination and control, and dual/multitasking. Additionally, interventions that directly help improve motor function for work/recreation/activity-specific tasks are strongly encouraged.

MONITORING AND PROGRESSING PATIENTS

Evidence Synthesis

The systematic search did not yield any evidence to specifically inform recommendations for how to make decisions regarding monitoring and progressing physical therapy interventions for patients who have experienced a concussive event. Studies that informed the Clinical Course section of this CPG indicate that it is important for clinicians to understand that patients' symptoms, impairments, and functional limitations may change and/or become more apparent during episodes of care. Thus, continual monitoring and re-evaluation of patients' responses to treatment and emerging clinical presentation are critical for providing an optimal match of interventions throughout each patient's episode of care. It is important to appreciate that patients may present differently at various points in the recovery process and may experience exacerbations and setbacks as they reintegrate and introduce new activities into their daily routines. Follow-up with physical therapy and referrals for follow-up with other health care providers should be encouraged as needed or indicated.

Gaps in Knowledge

Studies specifically designed to help inform intervention dosing parameters, monitoring and reassessment strategies, and criteria for progressions and discharge would be beneficial.

Recommendation

F Physical therapists **should** regularly document symptoms, provide reassessments of movement-related impairments, and administer selected outcome measures as needed or indicated for patients with movement-related impairments post concussion. The following data elements and monitoring frequencies are recommended.

Symptoms

- Age-appropriate symptom scale/checklist at least weekly until discharge

Cervical Spine Musculoskeletal Impairments

- Active neck range of motion, pain with active neck range of motion, and other cervical spine measures as determined by the physical therapist at the initial visit and at least every

2 weeks until discharge
- Cervical flexor and extensor strength and endurance at the initial visit and approximately every 4 weeks until impairments are resolved
- Joint position error or cervical proprioception assessments at the initial visit and approximately every 4 weeks until discharge
- Self-report outcome scales/measures (eg, Neck Disability Index, Headache Disability Inventory) as indicated at the initial visit and at least every 2 weeks until discharge

Vestibulo-oculomotor Impairments
- If BPPV is present, the Dix-Hallpike test should be performed at the initial visit and at least weekly until BPPV is resolved
- Vestibular and oculomotor tests and measures as indicated at the initial visit and at least every 2 weeks until impairments are resolved
- Self-report outcome scales/measures (eg, DHI) as indicated at the initial visit and at least every 2 weeks until discharge

Exertional Test
- Graded exertion test completed during at least 1 visit for individuals reporting symptoms related to exertional intolerance
- Graded exertion test completed during at least 1 visit and as needed to determine readiness to return to play or work for athletes and/or individuals with high-exertion activity needs

Motor Function
- Age- and functional-level tests and measures as indicated at the initial visit and at least every 2 weeks until impairments are resolved

Self-management
- Qualitative assessment of the patient's ability to self-manage symptoms and adhere to physical therapy recommendations at the initial visit and every visit until discharge

Physical Therapy Management Decision Trees

Visual decision tree models can provide valuable guidance for how physical therapists plan and make decisions during a patient's episode of care after a concussive event. The proposed decision tree model is depicted in **FIGURES 1** through **3** and broken down into the following components: (1) process for determining the appropriateness of physical therapy concussive-event examination, (2) physical therapy examination and evaluation processes for patients who have experienced a concussive event, and (3) developing and implementing a physical therapy plan of care for patients who have experienced a concussive event. Recommendations are broken down into sections that directly align with each component, such that clinicians can use the component narrative overviews below, the figures, and the recommendations together to inform their decision-making processes. The ovals in the decision trees indicate start and end points in that component. Rectangular boxes indicate a process or procedure to be implemented. Diamonds indicate a decision point that will lead to one pathway (versus another pathway).

COMPONENT 1: PROCESS FOR DETERMINING APPROPRIATENESS OF PHYSICAL THERAPY CONCUSSIVE-EVENT EXAMINATION

A triaging process may help determine whether a patient who has experienced a concussive event is appropriate for a more comprehensive examination to identify potential movement-related symptoms and impairments related to that event (**FIGURE 1**). The starting point for component 1 is a physical therapy encounter with a patient who has experienced a potential concussive event. Physical therapists should screen all patients who have experienced a potential concussive event for the possibility of a concussion, regardless of previous screening for a diagnosis of concussion related to that event. The first step in this component is observation and interview to evaluate for indicators of potential medical emergency and need for referral (**FIGURE 1**). Next, the physical therapist will determine whether the patient is presenting with signs and symptoms that align with the diagnostic criteria for a concussion (**FIGURE 1**). This screening may be useful even if the concussive event was not recent, as residual symptoms could be the result of an undiagnosed concussion injury. If the patient's history and presenting criteria are consistent with a diagnosis of concussion, the physical therapist will then decide whether the patient is appropriate for a comprehensive physical therapy examination, based on a multifaceted interview (**FIGURE 1**).

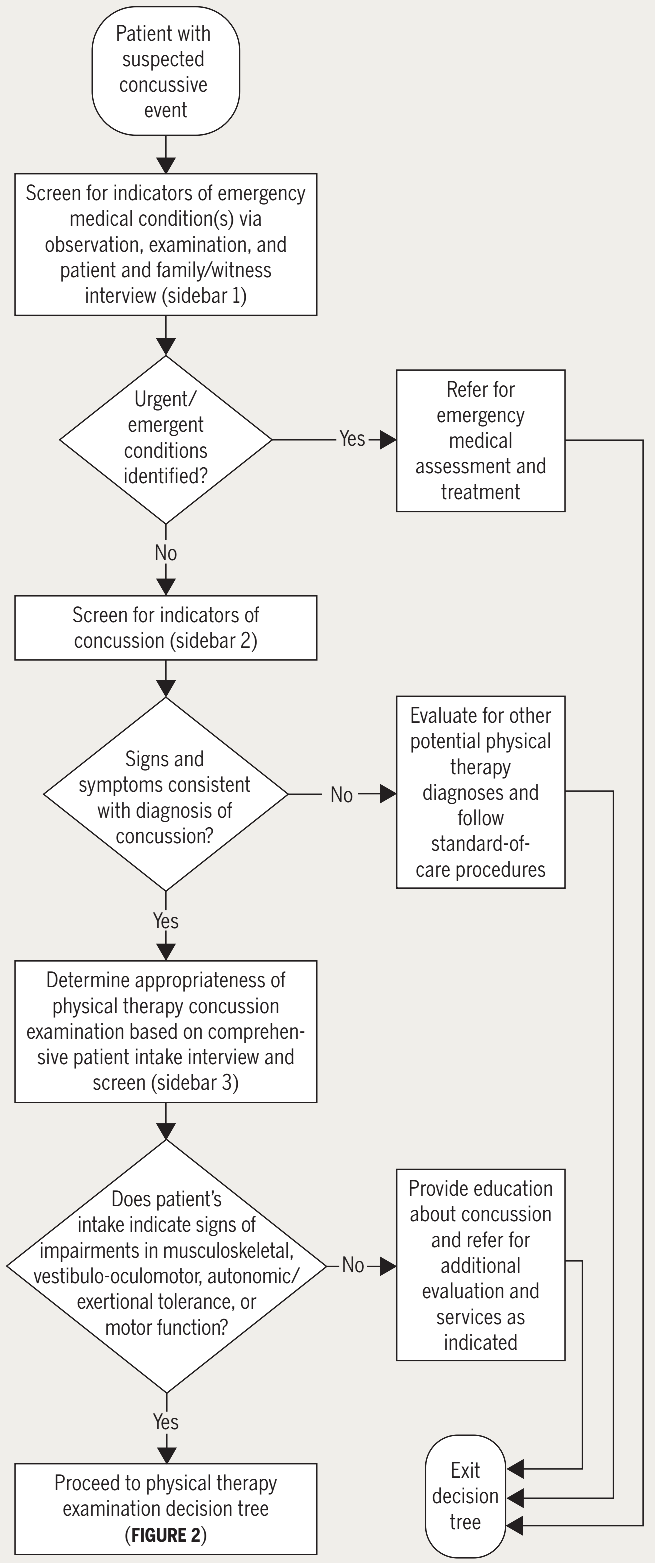
COMPONENT 2: PHYSICAL THERAPY EXAMINATION AND EVALUATION PROCESSES FOR PATIENTS WHO HAVE EXPERIENCED A CONCUSSIVE EVENT

Differential evaluation of clinical findings from patient interviews and physical examination can help determine the most relevant and key physical impairments associated with the diagnosis of concussion and also identify existing functional limitations. Determining probable movement-related impairments and levels of irritability (**FIGURE 2**) may help clinicians plan the examination, including the selection, sequencing, and modification needs to address safety concerns, patient comfort, and/or patient and family goals and preferences. Targeted follow-up questions from findings obtained during the intake can help clinicians determine which examination tests and measures are most appropriate for a patient. Neck pain is the first priority for sequencing, as neck pain irritated by movement limits the feasibility and accuracy of other tests, particularly vestibulo-oculomotor tests. If neck pain is present, pain relief interventions could be provided to potentially support tolerability and accuracy for additional tests. Dizziness and headache are symptoms that require more complex assessments and clinical reasoning to identify potential sources of impairment that may contribute to complaints. When dizziness and/or headache are reported, physical therapists are encouraged to conduct tests that are expected to be the least irritable for the patient first, then progress to tests expected to be most irritable per patient tolerance. Sequencing in this way should help increase the likelihood of patient tolerance for testing of all domains and improve the utility of the results obtained. If no specific reports of neck pain, dizziness, or headache are identified, clinical judgment should be used to determine optimal sequencing based on reported levels of irritability and disability, patient needs and preferences, and patient ability to tolerate tests. Therapists are encouraged to identify and document a complete set of impairments that physical therapy interventions could potentially address. Identification and consideration of psychological and sociological facilitators and vulnerabilities and the potential need for follow-up testing are also encouraged. As part of the examination process, the physical therapist should determine and document a plan for follow-up testing and outcome measure administration.

COMPONENT 3: DEVELOPING AND IMPLEMENTING A PHYSICAL THERAPY PLAN OF CARE FOR PATIENTS WHO HAVE EXPERIENCED A CONCUSSIVE EVENT

Development and implementation of a plan of care should be based on findings from the physical therapy clinical examination, in combination with patient and family needs and preferences (**FIGURE 3**). Education regarding the risks and prognosis for patients, self-management, and activity-related recommendations and potential signs of the need for follow-up care are important for patients who have experienced a concussive event. Movement-related impairments may not be identified for patients who have experienced a concussive event. In these cases, educate patients about potential signs and symptoms that may emerge and encourage them to follow up for further physical therapy evaluation and treatment as indicated. Intervention strategies for patients may vary depending on their impairment diagnosis profiles and level of irritability. Dosing parameters (frequency, intensity, timing, and type of intervention) for each impairment domain should be adjusted in accordance with the patient's level of irritability. Additionally, it is important for clinicians to understand that patients' symptoms, impairments, and functional limitations often change and/or become more apparent during an episode of care. Thus, continual monitoring and re-evaluation of the patient's response to treatment and emerging clinical presentation are critical for providing optimal matching of interventions throughout a patient's episode of care.

Process for Determining Appropriateness of Physical Therapy Concussive Event Examination



Sidebar 1
Indicators for immediate emergency medical evaluation
- Declining level or loss of consciousness, cognition, or orientation (Glasgow Coma Scale score of less than 13)
- New onset of pupillary asymmetry, seizures, repeated vomiting, or other focal neurologic signs
- Severe or rapidly worsening headache or neurologic deficits
- Signs/symptoms indicating undiagnosed skull fracture
- Serious cervical spine fracture, dysfunction, or pathology (eg, vertebrobasilar artery insufficiency, cervical ligamentous instability, signs of central cord compression)

Sidebar 2
Concussion diagnosis criteria
A direct blow to the head, face, or neck, or an impulsive force elsewhere on the body that is transmitted to the head, followed by any of the following:
- Any period of decreased orientation or loss of consciousness
- Posttraumatic amnesia
- Any alteration in cognition or mental state immediately related to the concussive event: confusion, disorientation, slowed thinking/processing, problems with attention/concentration, forgetfulness, decreased executive control
- Physical symptoms: headache, dizziness, balance disorders, nausea, vomiting, fatigue, sleep disturbance, blurred vision, sensitivity to light, hearing difficulties, tinnitus, sensitivity to noise, seizure, transient neurological abnormalities, numbness, tingling, neck pain, exertional intolerance
- Emotional/behavioral symptoms: depression, anxiety, agitation, irritability, impulsivity, aggression
- Glasgow Coma Scale (best available score in first 24 hours) of 13-15
- Brain imaging (if available) is normal
- Signs/symptoms not otherwise explained by drug, alcohol, or medication
- Symptoms are present that cannot be explained by preinjury history of medical diagnoses. If preinjury diagnoses were present, the patient reports or is observed to demonstrate an exacerbated state of symptoms

Sidebar 3
Patient intake process and interview
- Type, severity, frequency, and irritability of concussion-related symptoms
- Preinjury medical history with emphasis on previous concussions or brain injuries, medical conditions that could result in/present with symptoms similar to concussion-related symptoms (eg, learning challenges or disabilities, mood or emotional disorders, depression, frequent headaches), history of personal or familial migraine, sleep quality/history
- Any conditions or diseases that would limit or serve as a contraindication to comprehensive physical therapy evaluation or interventions
- Details regarding injury, including mechanism of injury and early signs and symptoms associated with the injury
- Medical/pharmacologic strategies implemented since the injury; reflection on things that seem to result in worsening or improvement of symptoms
- Physical function goals, priorities, and perceived limitations
- Mental health and substance use screens for referral needs

FIGURE 1. Process for determining appropriateness of physical therapy concussive-event examination.

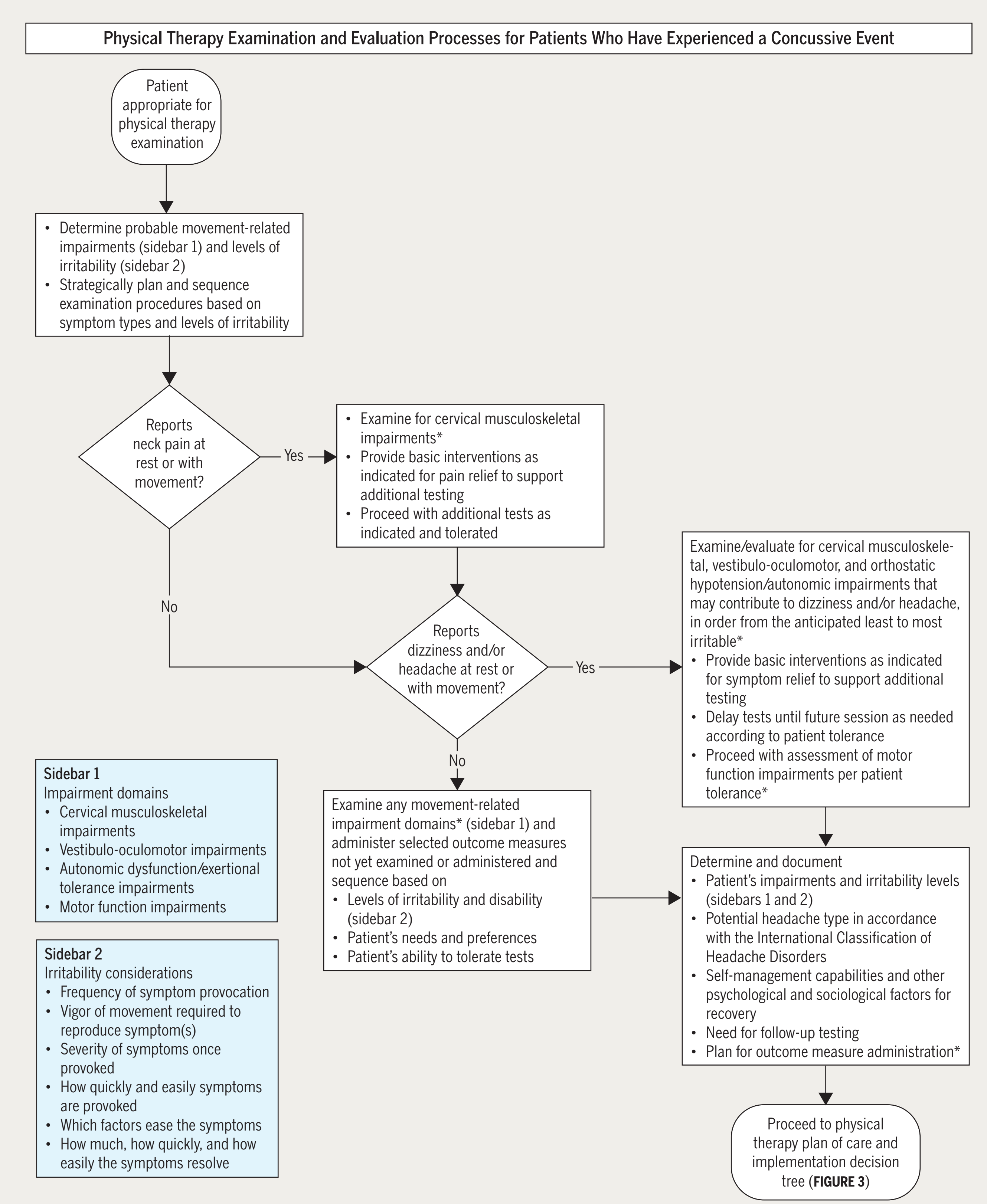


FIGURE 2. Physical therapy examination and evaluation processes for patients who have experienced a concussive event. *The vagueness regarding specific examination/assessment procedures is intentional, as evidence is lacking to endorse specific tests and measures in some cases and too complex to describe in others. Readers are encouraged to review the body of the text for examination/assessment strategies and the degree of evidence supporting them.

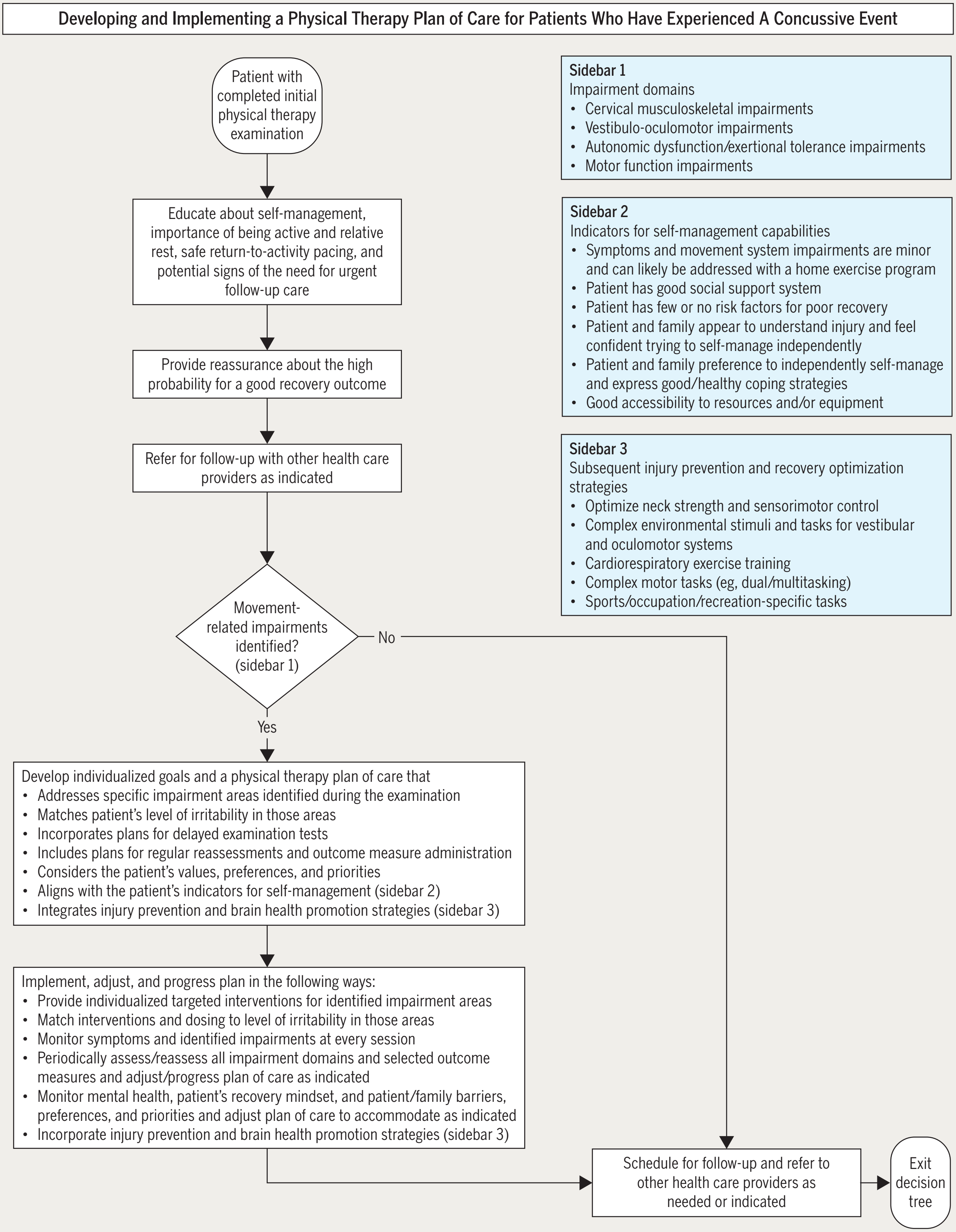


FIGURE 3. Developing and implementing a physical therapy plan of care for patients who have experienced a concussive event.

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APPENDIX A

LITERATURE SEARCH DETAILS

The review of the evidence for this clinical practice guideline (CPG) encompassed a consideration of the range of physical impairments that may be relevant when making a differential diagnosis after a concussive event, with the goal of determining the underlying cause(s) of presenting signs and symptoms and matching them with intervention priorities. The Guideline Development Group (GDG) worked with a librarian from the University of North Carolina at Chapel Hill to engage in the 2 phases of the literature search process (preliminary searches and systematic searches), as recommended by the American Physical Therapy Association's Clinical Practice Guideline Process Manual.[6] EndNote X8 (Clarivate Analytics, Philadelphia, PA) and DistillerSR software (Evidence Partners, Ottawa, Canada) were used to manage the literature searches, coordinate evidence selection, carry out critical appraisals, and store notes and information about the evidence sources.

The first phase of the literature search process was conducted in October 2014 and entailed preliminary searches to help determine the extent to which a reasonable body of evidence was present to support the development of a guideline, and to identify existing guidelines and systematic reviews available at the time on concussion management. The preliminary searches explored the use of the following key words separately and in various combinations: "concussion," "mild traumatic brain injury," "mild closed head injury," "rehabilitation," "physical therapy," "physiotherapy," and "exercise." Databases searched included PubMed, SPORTDiscus, and PsycINFO. The preliminary searches helped identify previously published CPGs, systematic reviews, and meta-analyses pertaining to the topic of concussion. From these preliminary searches, the GDG refined the scope and plan for the CPG and developed a formal strategy for the second phase.

The second phase entailed iterative systematic searches performed for studies through April 30, 2015; May 1, 2015 to October 31, 2015; November 1, 2016 to March 31, 2017; April 1, 2017 to December 31, 2018. The second-phase searches entailed the high-level key word searches from phase 1 and added the following additional search terms, separately and in combination, to ensure a wide breadth and comprehensive search process to capture impairments in vestibular, cervical, physical exertion, and functional mobility. The electronic systematic searches were supplemented through manual searching of journals and bibliographies, Google and Google Scholar searches, and word of mouth.

Search Strategies for All Databases Searched

Database	Search Terms
MEDLINE, CINAHL, Embase	("Brain Injuries"[MeSH] AND (mild[tiab] OR moderate[tiab] OR minor[tiab] OR concussion[tiab] OR concussions[tiab] OR concussive[tiab] OR mtbi[tiab] OR "posttraumatic"[tiab] OR posttraumatic[tiab] OR postconcussion[tiab] OR postconcussive[tiab] OR "postconcussion"[tiab] OR "postconcussive"[tiab] OR "postconcussional"[tiab] OR postconcussional[tiab])) AND ("Physical Therapy Modalities"[mesh] OR "Rehabilitation"[mesh] OR "Physical and Rehabilitation Medicine"[mesh] OR "Exercise"[mesh] OR "Disability Evaluation"[mesh] OR "Recovery of Function"[mesh] OR "physical therapy"[all fields] OR ("rehabilitation"[Subheading] OR "rehabilitation"[All Fields] OR "rehabilitation"[MeSH Terms]) OR physiotherapy[tiab] OR "rehabilitation"[Subheading] OR neurorehabilitation[all fields] OR "neuro-rehabilitation"[all fields]) AND (Randomized Controlled Trial[ptyp] OR ("Meta-analysis"[pt] OR "Practice Guideline"[pt] OR "Randomized Controlled Trial"[pt] OR "Longitudinal Studies"[MeSH] OR systematic[ti] or "Follow-up Studies"[mh] OR "Retrospective Studies"[mh] OR "Clinical Trial"[pt])AND ("2000/01/01"[PDAT]: "2018/12/31"[PDAT]) AND English[lang])
	("Brain Injuries"[MeSH] OR brain[ti]) AND (mild[tiab] OR moderate[tiab] OR minor[tiab] OR concussion[tiab] OR concussions[tiab] OR concussive[tiab] OR mtbi[tiab] OR "posttraumatic"[tiab] OR postconcussion[tiab] OR postconcussive[tiab] OR "postconcussion"[tiab] OR "postconcussive"[tiab]) AND ("Physical Therapy Modalities"[mesh] OR "Rehabilitation"[mesh] OR "Physical and Rehabilitation Medicine"[mesh] OR "Exercise"[mesh] OR "Disability Evaluation"[mesh] OR "Recovery of Function"[mesh] OR "physical therapy"[tiab] OR rehabilitation[tiab] OR physiotherapy[tiab] OR "rehabilitation"[Subheading] OR ("neurological rehabilitation"[MeSH Terms] OR ("neurological"[All Fields] AND "rehabilitation"[All Fields]) OR "neurological rehabilitation"[All Fields] OR "neurorehabilitation"[All Fields])) AND ("2000/12/01"[PDAT]: "2018/12/31"[PDAT])

Table continues on page CPG51.

APPENDIX A

Database	Search Terms
SPORTDiscus, PsycINFO	Cervical and dizziness, cervical and concussion, cervical and mTBI, cervicogenic dizziness and concussion, cervicogenic and mTBI Balance and concussion, balance and mTBI, balance and cervical Dizziness and concussion, dizziness and mTBI, vertigo and concussion, vertigo and mTBI Concussion and fatigue, concussion and mTBI, concussion and exertion, exertion and mTBI Dual task and concussion, dual task and mTBI Vision and concussion, vision and mTBI, ocular motor and concussion, ocular motor and mTBI Cervical complications: ("Brain Concussion"[mh] OR concussion[tw] OR concussions[tw] OR mtbi[tw] OR "mild traumatic brain"[tw] OR concussive[tw] OR "postconcussion"[tw] OR "postconcussive"[tw] OR postconcussion[tw]) AND ("Neck"[mh] OR "Neck Pain"[mh] OR "Cervical Vertebrae"[mh] OR "neck"[tw] OR "cervical"[tw] OR cervicogenic[tw]) AND English[lang] AND ("2000/01/01"[PDAT]: "2016/12/31"[PDAT]) NOT (Case Reports[ptyp] OR "case report"[ti]) Balance: ("Brain Concussion"[mh] OR concussion[tw] OR concussions[tw] OR mtbi[tw] OR "mild traumatic brain"[tw] OR concussive[tw] OR "postconcussion"[tw] OR "postconcussive"[tw] OR postconcussion[tw]) AND ("Postural Balance"[Mesh] OR "Proprioception"[Mesh] OR "Gait"[mh] OR balance[ti] OR equilibrium[ti]) AND English[lang] AND ("2000/01/01"[PDAT]: "2016/12/31"[PDAT]) NOT (Case Reports[ptyp] OR "case report"[ti]) Dizziness/vertigo: ("Brain Concussion"[mh] OR concussion[tw] OR concussions[tw] OR mtbi[tw] OR "mild traumatic brain"[tw] OR concussive[tw] OR "postconcussion"[tw] OR "postconcussive"[tw] OR postconcussion[tw]) AND ("Dizziness"[Mesh] OR "Vertigo"[Mesh] OR dizzy[ti] OR dizziness[ti] OR vertigo[ti]) AND English[lang] AND ("2000/01/01"[PDAT]: "2016/12/31"[PDAT]) NOT (Case Reports[ptyp] OR "case report"[ti]) Fatigue/exertion: ("Brain Concussion"[mh] OR concussion[tw] OR concussions[tw] OR mtbi[tw] OR "mild traumatic brain"[tw] OR concussive[tw] OR "postconcussion"[tw] OR "postconcussive"[tw] OR postconcussion[tw]) AND ("Fatigue"[Mesh] OR "Physical Exertion"[Mesh] OR "Exercise"[Mesh] OR fatigue[ti] OR fatigued[ti] OR exertion[ti] OR exercise[ti]) AND English[lang] AND ("2000/01/01"[PDAT]: "2016/12/31"[PDAT]) NOT (Case Reports[ptyp] OR "case report"[ti]) Dual task: ("Brain Concussion"[mh] OR concussion[tw] OR concussions[tw] OR mtbi[tw] OR "mild traumatic brain"[tw] OR concussive[tw] OR "postconcussion"[tw] OR "postconcussive"[tw] OR postconcussion[tw]) AND ("dual task" OR "divided attention" OR "Stroop Test"[mh] OR Stroop[tw]) AND English[lang] AND ("2000/01/01"[PDAT]: "2016/12/31"[PDAT]) NOT (Case Reports[ptyp] OR "case report"[ti]) Vision/ ocular motor: ("Brain Concussion"[mh] OR concussion[tw] OR concussions[tw] OR mtbi[tw] OR "mild traumatic brain"[tw] OR concussive[tw] OR "postconcussion"[tw] OR "postconcussive"[tw] OR postconcussion[tw]) AND ("Vision, Ocular"[Mesh] OR "Visual Perception"[Mesh] OR vision[ti] OR visual[ti] OR "ocular motor"[ti] OR oculomotor[ti]) AND English[lang] AND ("2000/01/01"[PDAT]: "2016/12/31"[PDAT]) NOT (Case Reports[ptyp] OR "case report"[ti])

APPENDIX B

SEARCH RESULTS

Search	Result
April 30, 2015	210
October 31, 2015	823
March 31, 2017	103
December 31, 2018	1136
Hand searches	76
Total[a]	2348

[a] *All databases and hand searches combined, with duplicates removed.*

APPENDIX C

ARTICLE INCLUSION AND EXCLUSION CRITERIA

Inclusion Criteria

CPGs

- Published on January 1, 2015 or later
- Included a multidisciplinary team for authorship
- Recommendations based on a systematic review and appraisal of the literature
- Included recommendations that pertained to movement-related impairments
- Determined to be acceptable based on critical appraisal by 2 trained, independent reviewers using criteria on the AGREE II tool

Original Studies and Systematic Reviews

- Included human participants with clear designation of a concussion or history of concussive event
- Two trained, independent reviewers appraised the study as relevant to the scope of the CPG
- Critical review of the document by 2 trained, independent reviewers appraised it as having an acceptable level of quality for inclusion

Expert Consensus Documents

- Two trained, independent reviewers appraised the document as relevant to the scope of the CPG
- Based on a systematic search of the literature OR a Delphi study methodology
- Described sound methods for consensus generation
- Adequate evidence of applicable expertise of participants/authors was provided
- Critical review of the document by 2 trained, independent reviewers appraised it as having an acceptable level of quality for inclusion

Conceptual and Theoretical Documents

- Two trained, independent reviewers appraised the document as relevant to the scope of the CPG
- Source was perceived as trustworthy
- Critical review of the document by 2 trained, independent reviewers appraised it as having an acceptable level of quality for inclusion

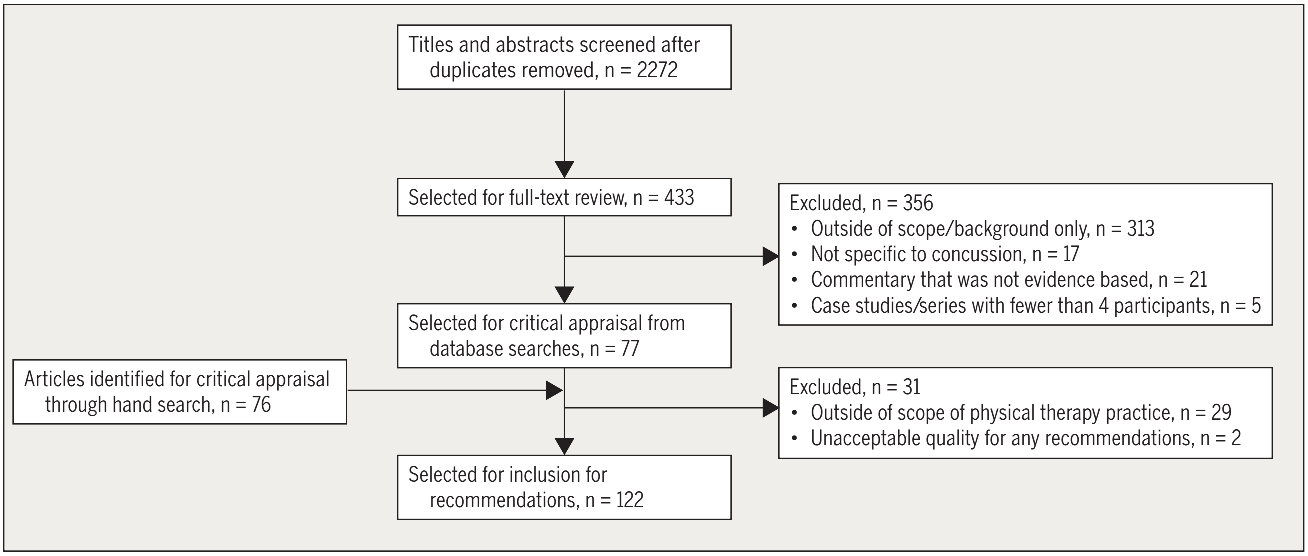
Exclusion Criteria

- Not available in English
- Determined to not be relevant to the CPG scope by 2 independent reviewers
- Inclusion of only healthy participants (no participants with history of concussive event)
- No clear delineation of outcomes specific to individuals with concussion/mild traumatic brain injury when the study also included participants with more severe brain injury
- Participant or target population mean age was younger than 8 years
- Case study/series with fewer than 4 participants
- Commentary that was not evidence based
- Critical appraisal that resulted in a rating of unacceptable quality

Abbreviations: AGREE II, Appraisal of Guidelines for Research and Evaluation II instrument; CPG, clinical practice guideline.

APPENDIX D

FLOW CHART OF ARTICLES



APPENDIX E

ARTICLES INCLUDED IN RECOMMENDATIONS BY TOPIC

Component 1: Process for Determining Appropriateness of Physical Therapy Concussive-Event Examination

Diagnosis

Management of Concussion-mild Traumatic Brain Injury Working Group. VA/DoD Clinical Practice Guideline for the Management of Concussion-Mild Traumatic Brain Injury. Washington, DC: US Department of Veterans Affairs/Department of Defense; 2016.

Marshall S, Bayley M, McCullagh S, et al. Updated clinical practice guidelines for concussion/mild traumatic brain injury and persistent symptoms. *Brain Inj*. 2015;29:688-700. https://doi.org/10.3109/02699052.2015.1004755

Screening for Indicators of Emergency Conditions

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Differential Diagnosis

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Comprehensive Intake Interview

Gagnon I, Friedman D, Beauchamp MH, et al. The Canadian Pediatric Mild Traumatic Brain Injury Common Data Elements project: harmonizing outcomes to increase understanding of pediatric concussion. *J Neurotrauma*. 2018;35:1849-1857. https://doi.org/10.1089/neu.2018.5887

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Component 2: Physical Therapy Examination and Evaluation Processes for Patients Who Have Experienced a Concussive Event

Systems to Be Examined

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Component 3: Developing and Implementing a Physical Therapy Plan of Care for Patients Who Have Experienced a Concussive Event

Communication and Education

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Motor Function Interventions

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APPENDIX F

LEVELS OF EVIDENCE TABLE[a]

Level	Intervention/Prevention	Pathoanatomic/Risk/Clinical Course/Prognosis/Differential Diagnosis	Diagnosis/Diagnostic Accuracy	Prevalence of Condition/Disorder	Exam/Outcomes
I	Systematic review of high-quality RCTs High-quality RCT[b]	Systematic review of prospective cohort studies High-quality prospective cohort study[c]	Systematic review of high-quality diagnostic studies High-quality diagnostic study[d] with validation	Systematic review, high-quality cross-sectional studies High-quality cross-sectional study[e]	Systematic review of prospective cohort studies High-quality prospective cohort study
II	Systematic review of high-quality cohort studies High-quality cohort study[c] Outcomes study or ecological study Lower-quality RCT[f]	Systematic review of retrospective cohort study Lower-quality prospective cohort study High-quality retrospective cohort study Consecutive cohort Outcomes study or ecological study	Systematic review of exploratory diagnostic studies or consecutive cohort studies High-quality exploratory diagnostic studies Consecutive retrospective cohort	Systematic review of studies that allows relevant estimate Lower-quality cross-sectional study	Systematic review of lower-quality prospective cohort studies Lower-quality prospective cohort study
III	Systematic reviews of case-control studies High-quality case-control study Lower-quality cohort study	Lower-quality retrospective cohort study High-quality cross-sectional study Case-control study	Lower-quality exploratory diagnostic studies Nonconsecutive retrospective cohort	Local nonrandom study	High-quality cross-sectional study
IV	Case series	Case series	Case-control study		Lower-quality cross-sectional study
V	Expert opinion	Expert opinion	Expert opinion	Expert opinion	Expert opinion

Abbreviation: RCT, randomized clinical trial.

[a]*Adapted from Phillips B, Ball C, Sackett D, et al. Oxford Centre for Evidence-based Medicine - Levels of Evidence (March 2009). Available at: http://www.cebm.net/index.aspx?o=1025. Accessed August 4, 2009. See also* **APPENDIX G**.

[b]*High quality includes RCTs with greater than 80% follow-up, blinding, and appropriate randomization procedures.*

[c]*High-quality cohort study includes greater than 80% follow-up.*

[d]*High-quality diagnostic study includes consistently applied reference standard and blinding.*

[e]*High-quality prevalence study is a cross-sectional study that uses a local and current random sample or censuses.*

[f]*Weaker diagnostic criteria and reference standards, improper randomization, no blinding, and less than 80% follow-up may add bias and threats to validity.*

APPENDIX G

PROCEDURES FOR ASSIGNING LEVELS OF EVIDENCE

- Level of evidence is assigned based on the study design using the Levels of Evidence table (**APPENDIX F**), assuming high quality (eg, for intervention, randomized clinical trial starts at level I)
- Study quality is assessed using the critical appraisal tool, and the study is assigned 1 of 4 overall quality ratings based on the critical appraisal results
- Level of evidence assignment is adjusted based on the overall quality rating:
  - High quality (high confidence in the estimate/results): study remains at assigned level of evidence (eg, if the randomized clinical trial is rated high quality, its final assignment is level I). High quality should include:
    - Randomized clinical trial with greater than 80% follow-up, blinding, and appropriate randomization procedures
    - Cohort study includes greater than 80% follow-up
    - Diagnostic study includes consistently applied reference standard and blinding
    - Prevalence study is a cross-sectional study that uses a local and current random sample or censuses
  - Acceptable quality (the study does not meet requirements for high quality and weaknesses limit the confidence in the accuracy of the estimate): downgrade 1 level
    - Based on critical appraisal results
  - Low quality: the study has significant limitations that substantially limit confidence in the estimate: downgrade 2 levels
    - Based on critical appraisal results
  - Unacceptable quality: serious limitations—exclude from consideration in the guideline
    - Based on critical appraisal results

APPENDIX H

APPRAISALS

AGREE II Appraisal Scores

	Domain[a]						
Study	**1**	**2**	**3**	**4**	**5**	**6**	**Overall Score[b]**
Marshall et al[153]	92%	92%	84%	69%	77%	50%	5
Lumba-Brown et al[141]	94%	69%	79%	86%	42%	84%	5
MCMTBIWG[149]	92%	75%	69%	92%	44%	50%	5

Abbreviations: AGREE II, Appraisal of Guidelines for Research and Evaluation II instrument; MCMTBIWG, Management of Concussion-mild Traumatic Brain Injury Working Group.

[a]Domains: (1) scope and purpose, (2) stakeholder involvement, (3) rigor of development, (4) clarity of presentation, (5) applicability, (6) editorial independence.

[b]A quality judgment based on the average of the 2 Guideline Development Group members who performed the appraisal using a range of 1 to 7, where 1 represents the lowest rating and 7 represents the highest rating.

AMSTAR[a] Scores for Systematic Reviews

	Item[b]											
Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Quality[c]**
Alsalaheen et al[2]	Y	Y	Y	Y	N	Y	Y	Y	NA	N	N	Acceptable
Alsalaheen et al[3]	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	High
Bell et al[11]	Y	N	Y	N	Y	Y	N	N	N	N	N	Low
Broglio and Puetz[20]	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	High
Fino et al[59]	Y	Y	Y	N	Y	N	Y	Y	N	N	N	Acceptable
Haider et al[78]	Y	Y	Y	Y	N	Y	Y	Y	NA	N	N	Acceptable
Hunt et al[99]	Y	Y	Y	N	N	Y	NA	Y	NA	N	Y	Acceptable
Lal et al[118]	Y	Y	Y	N	N	Y	Y	Y	Y	N	N	Acceptable
Lumba-Brown et al[142]	Y	Y	Y	N	N	N	Y	Y	N	N	Y	Acceptable
Makdissi et al[147]	Y	Y	Y	N	N	Y	Y	Y	NA	N	N	Acceptable
Murray et al[171]	Y	N	Y	Y	N	Y	Y	Y	N	N	N	Acceptable
Quatman-Yates et al[178]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	N	High
Quatman-Yates et al[177]	Y	Y	Y	Y	N	Y	Y	Y	NA	N	N	Acceptable
Register-Mihalik et al[183]	Y	Y	Y	N	N	Y	N	N	N	N	N	Low
Schneider et al[192]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	High

Abbreviations: AMSTAR, A MeaSurement Tool to Assess systematic Reviews; N, no; NA, not applicable; Y, yes.

[a]Criteria from Shea BJ, Grimshaw JM, Wells GA, et al. Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. BMC Med Res Methodol. 2007;7:10. https://doi.org/10.1186/1471-2288-7-10

[b]Yes/no. Items: 1, Was an a priori design provided? 2, Was there duplicate study selection and data extraction? 3, Was a comprehensive literature search performed? 4, Was the status of publication (ie, gray literature) used as an inclusion criterion? 5, Was a list of studies (included and excluded) provided? 6, Were the characteristics of the included studies provided? 7, Was the scientific quality of the included studies assessed and documented? 8, Was the scientific quality of the included studies used appropriately in formulating conclusions? 9, Were the methods used to combine the findings of studies appropriate? 10, Was the likelihood of publication bias assessed? 11, Was the conflict of interest included?

[c]Scores of 8 or greater were considered high, 6 or 7 acceptable, 4 or 5 low, and 3 or below very low.

Diagnosis: Clinical Practice Guidelines

Study	**Appraisal Level[a]**	**Quality[b]**
Marshall et al[153]	I	Acceptable
Management of Concussion-mild Traumatic Brain Injury Working Group[149]	I	Acceptable

[a]Based on the critical appraisal tool and review results.

[b]Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).

APPENDIX H

Screening for Indicators of Emergency Conditions: Clinical Practice Guidelines

Study	Appraisal Level[a]	Quality[b]
Marshall et al[153]	I	Acceptable
Lumba-Brown et al[141]	I	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

Differential Diagnosis

Study	Study Type	Appraisal Level[a]	Quality[b]
Alsalaheen et al[2]	Systematic review	I	Acceptable
Alsalaheen et al[3]	Systematic review	I	High
Gagnon et al[61]	Expert opinion	IV	Acceptable
Lumba-Brown et al[141]	Clinical practice guideline	I-II	Acceptable
Marshall et al[153]	Clinical practice guideline	I	Acceptable
McCrory et al[159]	Expert opinion	IV	Acceptable
McCulloch et al[160]	Expert opinion	IV	Acceptable
Management of Concussion-mild Traumatic Brain Injury Working Group[149]	Clinical practice guideline	I-II	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

Comprehensive Intake Interview

Study	Study Type	Appraisal Level[a]	Quality[b]
Gagnon et al[61]	Expert opinion	IV	Acceptable
Lumba-Brown et al[141]	Clinical practice guideline	II	Acceptable
Marshall et al[153]	Clinical practice guideline	I	Acceptable
McCulloch et al[160]	Expert opinion	IV	Acceptable
McCrory et al[159]	Expert opinion	IV	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

Systems to Be Examined

Study	Study Type	Appraisal Level[a]	Quality[b]
Broglio et al[19]	Expert opinion	IV	Acceptable
Gagnon et al[61]	Expert opinion	IV	Acceptable
Makdissi et al[147]	Systematic review	II	Acceptable
Marshall et al[153]	Clinical practice guideline	II	Acceptable
McCrory et al[159]	Expert opinion	IV	Acceptable
McCulloch et al[160]	Expert opinion	V	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

APPENDIX H

Examination for Cervical Musculoskeletal Impairments

Study	Study Type	Appraisal Level[a]	Quality[b]
Cheever et al[31]	Expert opinion	V	Acceptable
Ellis et al[54]	Expert opinion	V	Acceptable
Kennedy et al[106]	Case series	IV	Low
Kuczynski et al[115]	Case series	IV	Acceptable
Marshall et al[152]	Case series	IV	Acceptable
Morin et al[165]	Expert opinion	V	Acceptable
Reneker et al[186]	Case series	IV	Acceptable
Reneker et al[187]	Cohort study	IV	Acceptable
Reneker et al[188]	Expert opinion	IV	Acceptable
van der Walt et al[217]	Case series	IV	Acceptable
Leddy et al[c]	Cohort study	...	Unacceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*
[c]*Leddy JJ, Baker JG, Merchant A, et al. Brain or strain? Symptoms alone do not distinguish physiologic concussion from cervical/vestibular injury. Clin J Sport Med. 2015;25:237-242. https://doi.org/10.1097/JSM.0000000000000128*

Examination for Vestibulo-oculomotor Impairments

Study	Study Type	Appraisal Level[a]	Quality[b]
Anzalone et al[8]	Case series	IV	Acceptable
Capó-Aponte et al[26]	Case-control study	III	Acceptable
Capó-Aponte et al[27]	Case-control study	IV	Acceptable
Corwin et al[38]	Case series	IV	Acceptable
Cheever et al[31]	Expert opinion	V	Acceptable
Cheever et al[32]	Cohort study	III	Acceptable
Elbin et al[52]	Cohort study	II	Acceptable
Ellis et al[54]	Expert opinion	V	Acceptable
Goodrich et al[71]	Expert opinion	IV	Acceptable
Heyer et al[82]	Cohort study	III-IV	Acceptable
Hunt et al[99]	Systematic review	II	Acceptable
Józefowicz-Korczyńska et al[103]	Cohort study	III	Acceptable
Lei-Rivera et al[135]	Expert opinion	V	Acceptable
Lumba-Brown et al[141]	Clinical practice guideline	III	Acceptable
Marshall et al[153]	Clinical practice guideline	I	Acceptable
Marshall et al[152]	Case series	IV	Acceptable
Master et al[155]	Cross-sectional study	III	Acceptable
Matuszak et al[156]	Expert opinion	V	Acceptable
McDevitt et al[161]	Case-control study	IV	Acceptable
Mucha et al[169]	Cross-sectional study	II	Acceptable
Murray et al[173]	Cohort study	III	Acceptable
Reneker et al[186]	Case series	IV	Acceptable
Reneker et al[187]	Cohort study	IV	Acceptable
Reneker et al[188]	Expert opinion	IV	Acceptable
Skóra et al[198]	Cohort study	III	Acceptable
Management of Concussion-mild Traumatic Brain Injury Working Group[149]	Clinical practice guideline	III	Acceptable
Ventura et al[219]	Clinical practice guideline	V	Acceptable
Zhou and Brodsky[228]	Case series	IV	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

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Examination for Autonomic/Exertional Tolerance Impairments

Study	Study Type	Appraisal Level[a]	Quality[b]
Broglio et al[19]	Expert opinion	IV	Acceptable
Cordingley et al[36]	Case series	IV	Acceptable
Darling et al[42]	Case series	IV	Acceptable
Dematteo et al[47]	Cohort study	II	Acceptable
Ellis et al[54]	Expert opinion	V	Acceptable
Ellis et al[53]	Expert opinion	V	Acceptable
Gall et al[66]	Case-control study	III	Acceptable
Gall et al[65]	Case-control study	III	Acceptable
Haider et al[78]	Systematic review	II	Acceptable
Haider et al[79]	Case-control study	III	Acceptable
Hinds et al[85]	Cohort study	III	Acceptable
Kozlowski et al[112]	Case-control study	IV	Acceptable
Leddy et al[133]	Expert opinion	V	Acceptable
Leddy et al[123]	Expert opinion	V	Acceptable
Leddy et al[126]	Expert opinion	V	Acceptable
Leddy et al[129]	Randomized controlled trial	I	High
Leddy et al[128]	Expert opinion	V	Acceptable
Leddy et al[134]	Expert opinion	V	Acceptable
Matuszak et al[156]	Expert opinion	V	Acceptable
McCrory et al[159]	Expert opinion	IV	Acceptable
Orr et al[174]	Cohort study	II	Acceptable
Quatman-Yates et al[177]	Systematic review	I	High

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

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Examination for Motor Function Impairments

Study	Study Type	Appraisal Level[a]	Quality[b]
Bell et al[11]	Systematic review	III	Low
Benedict et al[12]	Cross-sectional study	III	Acceptable
Berkner et al[13]	Case-control study	III	Acceptable
Broglio et al[19]	Expert opinion	IV	Acceptable
Broglio and Puetz[20]	Systematic review	III	High
Broglio et al[21]	Cohort study	III	Acceptable
Buckley et al[24]	Cohort study	III	Acceptable
Cavanaugh et al[28]	Case series	IV	Acceptable
Cossette et al[40]	Case-control study	III	Acceptable
De Beaumont et al[44]	Case-control study	III	Acceptable
Dorman et al[49]	Case-control study	III	Acceptable
Findling et al[58]	Cohort study	III	Acceptable
Fino et al[59]	Systematic review	III	Acceptable
Furman et al[60]	Case-control study	IV	Acceptable
Gera et al[68]	Case-control study	III	Acceptable
Howell et al[93]	Cohort study	III	Acceptable
Howell et al[92]	Cohort study	I	High
Howell et al[95]	Cohort study	III	Acceptable
Howell et al[86]	Cohort study	III	Acceptable
Howell et al[89]	Case-control study	III	Acceptable
Howell et al[94]	Case-control study	IV	Acceptable
Hugentobler et al[97]	Cross-sectional study	IV	Acceptable
Inness et al[100]	Cross-sectional study	III	Acceptable
King et al[109]	Case series	IV	Acceptable
Lumba-Brown et al[141]	Clinical practice guideline	IV	Acceptable
Lynall et al[144]	Cross-sectional study	III	Acceptable
Massingale et al[154]	Case-control study	III	Acceptable
McCrory et al[159]	Expert opinion	IV	Acceptable
McCulloch et al[160]	Expert opinion	IV	Acceptable
Murray et al[173]	Case-control study	III	Acceptable
Murray et al[172]	Systematic review	III	Acceptable
Quatman-Yates et al[180]	Case-control study	III	Acceptable
Quatman-Yates et al[179]	Case-control study	IV	Acceptable
Radomski et al[181]	Case-control study	IV	Acceptable
Register-Mihalik et al[183]	Systematic review	III	Low
Register-Mihalik et al[184]	Case series	IV	Acceptable
Sambasivan et al[190]	Cross-sectional study	III-IV	Acceptable
Schneider et al[195]	Cohort study	III	Acceptable
Solomito et al[199]	Case-control study	III	Acceptable
Sosnoff et al[200]	Case series	IV	Low
Teel et al[207]	Case-control study	IV	Acceptable
Vartiainen et al[218]	Case-control study	III	Acceptable
Walker et al[221]	Cross-sectional study	III-IV	Acceptable
Wilkerson et al[223]	Cohort study	III	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

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Classification

Study	Study Type	Appraisal Level[a]	Quality[b]
Collins et al[34]	Expert opinion	IV	Acceptable
Collins et al[35]	Expert opinion	V	Acceptable
Ellis et al[53]	Expert opinion	V	Acceptable
Ellis et al[54]	Expert opinion	V	Acceptable
Lundblad[143]	Expert opinion	V	Acceptable
Marshall et al[153]	Clinical practice guideline	III	Acceptable
Reneker et al[187]	Cohort study	IV	Acceptable
Management of Concussion-mild Traumatic Brain Injury Working Group[149]	Clinical practice guideline	III	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

Outcome Measure Selection

Study	Study Type	Appraisal Level[a]	Quality[b]
Broglio et al[19]	Expert opinion	IV	Acceptable
Gagnon et al[61]	Expert opinion	IV	Acceptable
Gottshall et al[72]	Cohort study	III	Acceptable
Kleffelgaard et al[110]	Cohort study	III	Acceptable
Lumba-Brown et al[141]	Clinical practice guideline	II	Acceptable
Lumba-Brown et al[142]	Systematic review	II	Acceptable
Marshall et al[153]	Clinical practice guideline	II	Acceptable
Management of Concussion-mild Traumatic Brain Injury Working Group[149]	Clinical practice guideline	II	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

Communication and Education

Study	Study Type	Appraisal Level[a]	Quality[b]
Lumba-Brown et al[141]	Clinical practice guideline	I-III	Acceptable
Lumba-Brown et al[142]	Systematic review	III	Acceptable
Marshall et al[153]	Clinical practice guideline	I-III	Acceptable
McCulloch et al[160]	Expert opinion	IV	Acceptable
McCrory et al[159]	Expert opinion	IV	Acceptable
Schneider et al[192]	Systematic review	III	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

APPENDIX H

Physical Therapy Interventions for Movement-Related Impairments

Study	Study Type	Appraisal Level[a]	Quality[b]
Dobney et al[48]	Case series	IV	Acceptable
Hugentobler et al[98]	Case series	IV	Acceptable
Grabowski et al[73]	Case series	IV	Acceptable
Gagnon et al[62]	Case series	IV	Acceptable
Gagnon et al[63]	Case series	IV	Acceptable
Lawrence et al[122]	Case series	IV	Acceptable
Lennon et al[137]	Case series	IV	Acceptable
Lumba-Brown et al[141]	Clinical practice guideline	II	Acceptable
Lumba-Brown et al[142]	Systematic review	II	Acceptable
Marshall et al[153]	Clinical practice guideline	II	Acceptable
Quatman-Yates et al[178]	Systematic review	II	Acceptable
Reneker et al[189]	Randomized controlled trial	II	Acceptable
Schneider et al[192]	Systematic review	II	Acceptable
Management of Concussion-mild Traumatic Brain Injury Working Group[149]	Clinical practice guideline	II	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

Cervical Musculoskeletal Interventions

Study	Study Type	Appraisal Level[a]	Quality[b]
Grabowski et al[73]	Case series	IV	Acceptable
Hugentobler et al[98]	Case series	IV	Acceptable
Kennedy et al[106]	Case series	IV	Acceptable
Marshall et al[152]	Case series	IV	Acceptable
Morin et al[165]	Expert opinion	V	Acceptable
Reneker et al[189]	Randomized controlled trial	II	Acceptable
Schneider et al[194]	Randomized controlled trial	II	Acceptable
Schneider et al[193]	Case series	IV	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

Vestibulo-oculomotor Interventions

Study	Study Type	Appraisal Level[a]	Quality[b]
Alsalaheen et al[4]	Case series	IV	Acceptable
Alsalaheen et al[5]	Expert opinion	IV	Acceptable
Józefowicz-Korczyńska et al[103]	Cohort study	IV	Acceptable
Marshall et al[153]	Clinical practice guideline	I	Acceptable
Moore et al[163]	Cohort study	IV	Low
Murray et al[171]	Systematic review	II	Acceptable
Reneker et al[189]	Randomized controlled trial	II	Acceptable
Schneider et al[194]	Randomized controlled trial	II	Acceptable
Schneider et al[193]	Case series	IV	Acceptable
Storey et al[203]	Cohort study	IV	Acceptable
Gottshall and Hoffer[c]	Cohort study	...	Unacceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*
[c]*Gottshall KR, Hoffer ME. Tracking recovery of vestibular function in individuals with blast-induced head trauma using vestibular-visual-cognitive interaction tests. J Neurol Phys Ther. 2010;34:94-97. https://doi.org/10.1097/NPT.0b013e3181dead12*

APPENDIX H

Exertional Tolerance and Aerobic Exercise Interventions

Study	Study Type	Appraisal Level[a]	Quality[b]
Anderson et al[7]	Case-control study	IV	Acceptable
Dobney et al[48]	Case series	IV	Acceptable
Gauvin-Lepage et al[67]	Case-control study	II	Acceptable
Grabowski et al[73]	Case series	IV	Acceptable
Hugentobler et al[98]	Case series	IV	Acceptable
Kozlowski et al[112]	Case-control study	IV	Acceptable
Lal et al[118]	Systematic review	I	High
Leddy et al[132]	Case series	IV	Acceptable
Leddy et al[129]	Randomized controlled trial	I	High
Leddy et al[130]	Cohort study	II	Acceptable
Lennon et al[137]	Case series	IV	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*

Motor Function Interventions

Study	Study Type	Appraisal Level[a]	Quality[b]
Collins et al[34]	Expert opinion	IV	Acceptable
Hugentobler et al[98]	Case series	IV	Acceptable
Marshall et al[153]	Clinical practice guideline	IV	Acceptable
McCulloch et al[160]	Expert opinion	IV	Acceptable
Management of Concussion-mild Traumatic Brain Injury Working Group[149]	Clinical practice guideline	IV	Acceptable
Weightman et al[222]	Expert opinion	V	Acceptable

[a]*Based on the critical appraisal tool and review results.*
[b]*Overall assessment of the methodological quality of the study (high, acceptable, low, unacceptable).*