[Primary Care]

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A Practical Concussion Physical Examination Toolbox: Evidence-Based Physical Examination for Concussion

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Context: With heightened awareness of concussion, there is a need to assess and manage the concussed patient in a consistent manner. Unfortunately, concussion physical examination has not been standardized or supported by evidence. Important questions remain about the physical examination.

Evidence Acquisition: Review of ClinicalKey, Cochrane, MEDLINE, and PubMed prior to July 2015 was performed using search terms, including *concussion, mTBI, physical examination, mental status, cranial nerves, reflexes, cervical, vestibular*, and *oculomotor*. The references of the pertinent articles were reviewed for other relevant sources.

Study Design: Clinical review.

Level of Evidence: Level 3.

Results: The pertinent physical examination elements for concussion include evaluation of cranial nerves, manual muscle testing, and deep tendon reflexes; inspecting the head and neck for trauma or tenderness and cervical range of motion; Spurling maneuver; a static or dynamic balance assessment; screening ocular examination; and a mental status examination that includes orientation, immediate and delayed recall, concentration, mood, affect, insight, and judgment. Other examination elements to consider, based on signs, symptoms, or clinical suspicion, include testing of upper motor neurons, cervical strength and proprioception, coordination, pupillary reactivity, and visual acuity; examination of the jaw, temporomandibular joint, and thoracic spine; fundoscopic evaluation; orthostatic vital signs; assessment of dynamic visual acuity; and screening for depression, anxiety, substance abuse disorders, and preinjury psychiatric difficulties.

Conclusion: Various elements of the physical examination, such as screening ocular examination, cervical musculoskeletal examination, static and/or dynamic balance assessment, and mental status examination, appear to have utility for evaluating concussion; however, data on validity are lacking.

Keywords: concussion; mTBI; physical examination

Several recent publications summarized the pathophysiology, signs, and symptoms of concussion and the relative strengths and weaknesses of sideline and neuropsychological assessments.[33,40,66] The physical examination (PE) performed by the physician when concussion is suspected or diagnosed, however, has not been standardized or supported by evidence.

There are, unfortunately, no data on the validity or reliability of most PE tests for the concussed patient. A toolbox for assessment is presented that includes PE elements from domains most often affected by concussion and findings that may prompt further investigation or when early intervention is indicated.

Several PE elements have historically been performed in the concussed patient despite low yield (eg, fundoscopy, manual muscle testing [MMT], deep tendon reflexes [DTRs]). Their diagnostic utility remains controversial so physicians must decide which examination elements to include; however, some

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elements may be needed to satisfy documentation requirements (eg, billing or performance measures).

The proposed examination is primarily intended for the still-symptomatic concussion patient.

METHODS

A systematic search strategy identified articles on the PE and/or recommendations after concussion published prior to July 2015. Articles were identified through keyword searches of ClinicalKey, Cochrane, MEDLINE, and PubMed. Search terms included *concussion, mTBI, physical examination, mental status, cranial nerves, reflexes, DTR, cervical, vestibular, ocular, oculomotor, vital signs, orthostasis, autonomic dysregulation, intracranial pressure, focal neurology, focal neurologic deficits, manual muscle testing, MMT, balance, coordination, depression, anxiety*, and *fundoscopy*.

Articles that provided clinically appropriate elements of the PE were synthesized and used to construct a PE template with accompanying instructions (Appendix 1, available at http://sph.sagepub.com/content/by/supplemental-data). The attached algorithm (Figure 1) highlights findings that may prompt further investigation or indicate when early intervention may be clinically relevant.

Differential Diagnosis

The treating clinician must consider the differential diagnosis for concussion and comorbid, concurrent, and confounding diagnoses when evaluating an athlete with a suspected concussion or an athlete with persistent postconcussive symptoms (PCS) (Table 1).[56]

Physical Examination Domains/Elements

Vital Signs

- Autonomic dysregulation, including abnormal blood pressure (BP) control, temperature regulation, and disruption of endocrine, analgesic, and circadian functions may occur after head injury.[89]
- Autonomic dysregulation may manifest as exercise intolerance with symptom exacerbation,[55] dizziness or vestibular dysfunction,[50] orthostatic hypotension,[21] postural orthostatic tachycardia syndrome (POTS),[50] or altered heart rate (HR) and BP response to submaximal exercise.[52]
- Reduced exercise tolerance may be an indicator of autonomic dysregulation and can help distinguish concussion from other diagnoses.[7,31]
- Testing may include orthostatic vital signs (OVS), heads up tilt table testing (HUT), or exercise tolerance testing with vital sign (VS) monitoring.

Orthostatic hypotension is defined as a 20–mm Hg or greater reduction in systolic BP (SBP) or a 10–mm Hg decrease in diastolic BP after 3 minutes of standing, with or without symptoms.[16] HR change is not required to define a positive orthostatic response. HR response is useful since a rise in HR with a drop in BP usually indicates hypovolemia, whereas lack of HR response is more consistent with a neurogenic cause.[69] In POTS, there is a tachycardic HR response without a drop in BP. The recommended test for OVS is the supine to standing orthostatic stress test (OST) (Table 2). (Note: While often performed, there is no indication to obtain VS in the seated position.[16]) If seated position is substituted for supine, orthostatic hypotension may be missed in two-thirds of patients.[18] Potential sources of error include not maintaining the cuffed arm position at the level of the heart, using an inappropriately sized cuff, and rapid cuff deflation in those with a slow HR.[69]

The Defense Centers of Excellence for Psychological Health and Traumatic Brain Injury has recommended evaluating head-injured patients with OVS, especially when dizziness is present.[21] Compared with the HUT as a reference test (there is no gold standard test[69]), OVS has good specificity (0.75-0.9), but sensitivity as low as 0.21; therefore, consider HUT if strong clinical suspicion persists despite negative OST.[25]

Mental Status Examination

Mental Status

- Most concussion assessment tools (eg, Standardized Assessment of Concussion [SAC][63] and the SCAT series[66]) have addressed cognitive aspects of mental status (eg, orientation, immediate and delayed memory, and concentration).
- Brief concussion assessment tools (eg, SCAT) appear to normalize quickly (many within 2 days) and have undetermined applicability for the office setting.[65]
- Mood and affect may be impaired after concussion.
- A multidisciplinary approach targeted to traumatic brain injury (TBI) patients with preexisting psychiatric difficulty was successful at reducing the rate of depression.[28]

A recommended cognitive assessment is included for reference in the online supplement (Appendix 2, Table 1; available at http://sph.sagepub.com/content/by/supplemental-data).

There are many psychogenic conditions that predate or arise after concussion. Depression is one significant cause of morbidity that can present acutely after the injury or several months afterward.[10] Studies show individuals with preexisting psychogenic or mental health conditions may have prolonged recovery from concussion and are at greater risk of developing PCS.[24,46] There is good evidence for screening for psychiatric conditions, specifically affective disorders, post-traumatic stress, and substance use disorder, even acutely after concussion.[22]

The Patient Health Questionnaire–9 (PHQ-9; Appendix 3, available at http://sph.sagepub.com/content/by/supplemental-data) has been validated in concussed adult and pediatric patients and may be considered if the clinician suspects depression or affective disorders. It is easily self-administered; is useful in multiple settings, populations, and medical conditions[75,82]; is free to use and reproduce; and has been translated into multiple languages. This instrument has been used to screen for depression in concussed military personnel[76] and to assess adolescents with TBI for depression.[70] Other validated

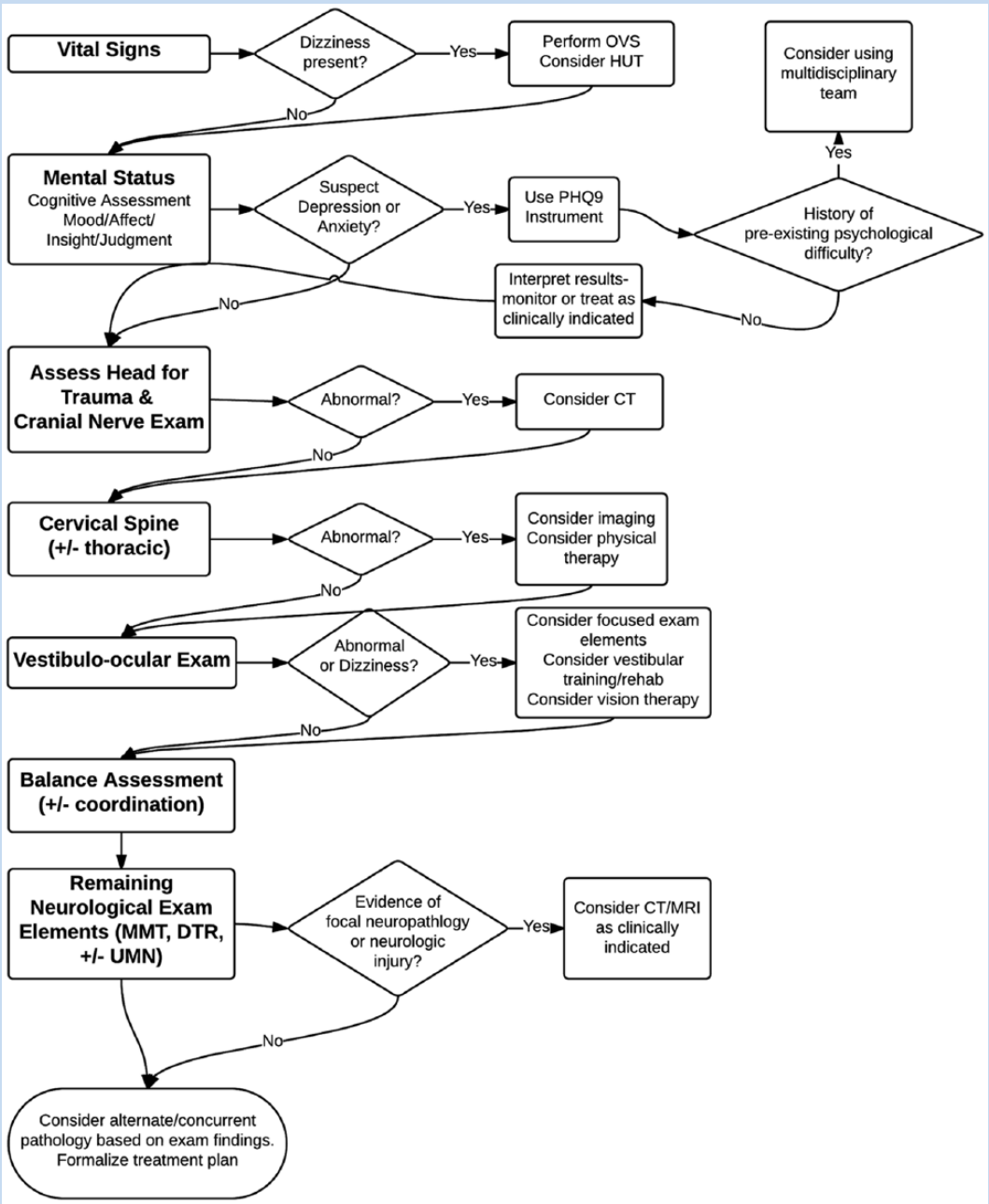

Figure 1. Examination algorithm. CT, computed tomography; DTR, deep tendon reflex; HUT, heads up tilt table test; MMT, manual muscle testing; MRI, magnetic resonance imaging; OVS, orthostatic vital signs; PHQ-9, Patient Health Questionnaire–9; UMN, upper motor neuron.

instruments include the Hospital Anxiety and Depression Scale–Depression Subscale (HADS-D)[75,82] and the Beck Depression Inventory II.[74]

Neurological Examination Elements

- A screening neurological examination has a sensitivity of 0.61 and a specificity approaching 1.0 for detecting a focal neurologic deficit.[4]
- A screening neurological examination is more specific but less sensitive than a focused, hypothesis-driven neurological examination.[49]

Cranial Nerve Assessment

- Injuries occur to single or multiple cranial nerves (CNs) with even minor head trauma/mild head injury[15] and may be underrecognized in concussion.[15,73]

Table 1. Differential diagnosis and concurrent pathology of concussion[a]

Moderate or Severe TBI	Isolated Cranial Nerve Injury
Cerebral hemorrhage (epi- or subdural, intracerebral, subarachnoid)	Symptomatic or communicating arachnoid cyst
Migraine/headache disorder	Syncope
Seizure disorder	Altered mental status from substance or medical disorder
Vestibular system injury	Psychogenic (malingering, PTSD, depression, anxiety, stress/somatization/conversion, gain, hypochondriasis/factitious)
Cervical spine injury (cervicogenic)	
Vestibular injury of cervical origin	
Cervical vascular injury	

PTSD, posttraumatic stress disorder; TBI, traumatic brain injury.
[a]Adapted from Patel et al.[73]

Table 2. Procedure for obtaining orthostatic vital signs[a]

Orthostatic vital signs
1. Patient lies down for 2 minutes. Document blood pressure (BP) and heart rate (HR).
2. Have the patient stand. Wait 1 minute and document BP and HR.
3. Wait 2 more minutes with patient standing and document BP and HR.
4. A *positive* test is defined as a decrease in systolic BP by at least 20 mm Hg or a decrease in diastolic BP by 10 mm Hg, if either is associated with symptoms.
5. If a HR change of 20 bpm accompanies the changes in BP, it is more likely to be a hypovolemic response, whereas absence of a HR response is more consistent with a neurogenic cause.

[a]Adapted from the The Consensus Committee of the American Autonomic Society and the American Academy of Neurology.[16]

In one investigation, 12.6% of head-injured patients (half with mild TBI [mTBI]) had cranial nerve injuries,[73] with CN VII, CN III, and CN II most often injured.[73] In patients with mild injuries, CN I was most often injured followed by CNs VII, III, and IV, while greater than 20% of patients with CN injury had multiple CN injuries.[15] More than 80% of patients with CN injury demonstrate computed tomography scan abnormalities.[15] Since CN V and the lower cranial nerves (IX-XII) are rarely affected, particularly in mTBI or minor head trauma,[15,73] these may prove less important to examine.

Examination of isolated CN injury for focal impairment has poor sensitivity (0.22) but high specificity (0.95)[4] and is an indication for advanced imaging.[15] CN I function historically has been often omitted during CN examination, yet up to 30% of head-injured patients experience anosmia or dysosmia, and there is evidence of high rates of CN I injury in mild TBI.[13,15] It is unclear whether this has any effect on gustation, nausea, or appetite[22]; however, given the frequency of computed tomography abnormality,[15] examination of CN I by testing olfaction should be performed.

The examination of CNs is often recorded as a unit; however, in concussion, a number of the CNs are assessed in more focused ophthalmologic and vestibular examinations. The CN examination portion of the instrument contains only those nerves not assessed elsewhere. A recommended test for each CN is included (see Appendix 1).

Manual Muscle Testing/Reflexes

- There is a lack of data to suggest MMT or DTRs are affected by concussion.
- The primary purpose of the assessment of MMT, DTRs, or upper motor neuron (UMN) lesions is to evaluate for more significant pathology.

Focal muscle weakness (sensitivity, 0.20-0.30; specificity, 1.0)[4] or absent, hypoactive, or pendular DTRs may suggest cerebellar

or brainstem injury. Hyperreflexia (sensitivity, 0.11; specificity, 1.0),[4] especially with unilateral brisk reflexes or clonus, is indicative of upper motor neuron injury in the cerebral cortex.

Finger rolling (sensitivity, 0.33; specificity, 1.0),[4] pronator drift (sensitivity, 0.22; specificity, 1.0),[4] Hoffman sign in the upper extremities (sensitivity, 0.04; specificity, 1.0),[4] and Babinski sign in the lower extremities (sensitivity, 0.13; specificity, 1.0)[4] are tests or findings for UMN lesions.

A recommended screening evaluation for MMT, DTRs, and UMN lesions is included online (see Table 2 in Appendix 2). Abnormal findings warrant further investigation.

Musculoskeletal Examination Elements

Head and Cervicothoracic Examination

- Head and neck injuries often occur simultaneously[92] and have overlapping symptoms.[54]
- Cervical injuries can cause persistent dizziness and balance difficulties, result in continuing headaches, and increase the risk of PCS.[23,26]

Neck injury symptoms can closely mimic those of head injury[5,54] with headaches, dizziness, unsteadiness, visual disturbances, and poor postural control.[19,54,90] Whiplash-induced neck injuries and concussion were difficult to differentiate in hockey players.[45] Spurling's test is often used to determine if there is cervical nerve root involvement. Chronic traumatic atlantoaxial subluxation or hypermobility is a potentially treatable cause of PCS.[19] Pain reproduced at the high cervical level with resisted cervical isometrics may prompt investigation with dynamic cervical radiographs and, if positive, treatment with a soft cervical collar.[19]

Cervical proprioception has an important role in neck injury and disequilibrium.[5] Evaluation of cervical proprioception is performed using a "position-matching" task with the patient attempting to relocate to neutral head position with eyes closed with an error of less than 5°.[5] Cervical proprioception abnormalities may delay recovery and lead to persistent symptoms and often require specific rehabilitation protocols.[54]

Temporomandibular joint disorders and thoracic abnormalities are sometimes seen in conjunction with concussion, with overlapping symptoms, including headache, tinnitus, dizziness, and neck pain[71]; scapular winging exacerbated with abduction (CN XI injury)[61]; and thoracic region trigger points.[72]

Balance/Coordination Examination

Postural Control and Motor Coordination

- Concussion may impair static and/or dynamic balance tests.[2,40]

The Balance Error Scoring System (BESS) test and the modified BESS have been used to evaluate the sport-concussed individual[20]; however, there remain important questions about the reliability of the test and its utility in the clinical setting. While the BESS test has the advantages of being easy to administer and inexpensive, it can take 5 to 7 minutes, and the sensitivity of the test (0.34) has been questioned.[64] Additionally, studies have demonstrated limited intra- and inter-rater reliability (0.74 and 0.57, respectively), limited discrimination (minimum detectable change between 7 and 9 points),[27] a high false positive rate (42%),[68] and limited test-retest reliability (0.67), which falls below commonly accepted thresholds for clinical assessment tools.[44] Importantly, clinical utility is unknown because the sensitivity drops quickly over the several days after concussion, with most concussed individuals normalizing within 3 to 5 days.[8]

Tandem gait and coordination tests, such as finger-to-nose tests, have shown good intra-rater reliability and may be considered as part of a concussion assessment.[78] The Timed Up and Go, Gait Speed, Functional Gait Analysis, and Five Times Sit to Stand tests may be appropriate for sport-related concussion.[1] While not yet in common use, dual tasking during gait, for example, solving math problems while performing a timed up and go test, may demonstrate more significant abnormalities than assessment of single-task performance.[57]

The Romberg test, despite widespread clinical use as an office screening test, has not been useful to screen for vestibular impairment[47] or effective at detecting new vestibular disease.[60] Single-leg stability tests have limited reliability, and care must be taken when interpreting results.[78] Options for testing are presented in Table 3.

Vestibulo-ocular Examination

Vestibular System Evaluation

- Vestibular dysfunction is common after TBI, with symptoms of dizziness, vertigo, and altered balance,[14] and has been associated with prolonged symptoms, higher risk of PCS, and more disability.[36,43]
- The majority of those with vestibular dysfunction can be successfully treated with vestibular rehabilitation.[2,34,35]

The differential diagnosis for dizziness and disequilibrium in the concussed patient is extensive (see Table 3). One etiology of vestibular dysfunction that bears attention, though relatively rare, is posttraumatic benign paroxysmal positional vertigo (t-BPPV) because the treatment, recovery, and recurrence rate are all significantly worse than for idiopathic BPPV.[2,59]

The vestibulo-ocular reflex stabilizes images on the retina during head movement. A simple yet effective screening tool for vestibular dysfunction is the Halmagyi (head thrust) test. During this test, the eyes are fixed on a central target while the head is turned rapidly to the left and the right. A normal response results in rapid eye movements in the opposite direction to keep the target in the center of the retina.[15]

Dynamic visual acuity is abnormal in up to 57% of children with dizziness and balance complaints after sports-related concussions.[93] Testing is performed with the head turning at a frequency of 2 Hz while visual acuity is measured using a Snellen chart.[12] A reduction of at least 3 lines is considered pathologic.[12]

The visual and vestibular systems are combined for testing purposes since there is a great deal of overlap in testing and pathophysiology. Table 4 in Appendix 2 provides instructions on performing aspects of the visual/vestibular system evaluation.

Table 3. Differential diagnosis for dizziness or disequilibrium after head injury[a]

Inner ear disorders (peripheral vestibular disorders)	Psychologic/psychogenic disorders
Benign positional vertigo	Depression
Labyrinthine concussion	Anxiety
Posttraumatic endolymphatic hydrops	Somatization
Perilymphatic fistula	Phobic postural vertigo
Bilateral labyrinthine dysfunction	Musculoskeletal disorders
Central disorders	Cervicogenic
Frontal lobe contusion	Temporomandibular dysfunction
Migraine-induced vestibulopathy	Uncommon central disorders
Motion sensitivity/visual vertigo	Brainstem/cerebellar dysfunction
Visual dysfunction	Vertebral-basilar insufficiency
	Temporal bone fracture

[a]Adapted from the Defense Centers of Excellence for Psychological Traumatic Brain Injury.[21]

Ocular/Ophthalmologic Examination

- Up to 40% of TBI patients suffer from vision difficulties or dysfunction, such as reduced near point of convergence, vergence dysfunction, poor accommodation, and oculomotor tracking abnormalities.[37,84]
- Vision difficulties or dysfunction may interfere with return to school because of the high visual demands, especially with reading and computer use.[39]
- Many causes of vision dysfunction can be treated with vision therapy; early identification can help speed recovery and reduce symptom burden.[85-88]

Extraocular motor function evaluation has been gaining popularity in the assessment of concussion and as a predictor for PCS. Fiber tracts that connect the frontal cortex with the cerebellum may suffer shear damage from TBI, resulting in difficulty with eye-target synchronization that can be further exacerbated by cognitive load.[17] The King-Devick test can evaluate eye movements that, reportedly, a layperson or parent can perform.[29,58] This test has been evaluated in adolescent concussion patients, boxers, and ice hockey players and has been proposed as a sensitive and practical sideline screening test for identifying concussion, but further study is required.[30,82]

Persistent abnormalities of saccades and smooth pursuits appear to be sensitive and specific predictors of poor recovery from concussion.[41] Early eye movement was more accurate in predicting the development of PCS than neuropsychological status, arm motor function, or self-reported health condition.[41] Additionally, visual tracking, including smooth pursuits, was worse in PCS patients when compared with controls[41,42] and can distinguish PCS from other conditions and malingering.[42]

Spontaneous and/or positional nystagmus occurs in 46% of children with head trauma, with 20% showing abnormalities for 6 to 12 months after injury.[91] Vertical/asymmetric nystagmus coincident with (or unrelated to) acute head injury may suggest brainstem lesion, and imaging or referral may be indicated.[81]

Concussed individuals demonstrate spasm or dysfunction of visual accommodation or of other visual abnormalities that result in receded near point of convergence (normal, 6-10 cm).[77] This has been associated with reduced reading speed and comprehension and an increased Convergence Insufficiency Symptom Survey score.[88] Convergence insufficiency without simultaneous visual or vestibular dysfunctions occurs in 9% of visually symptomatic brain-injured patients.[3] In a study of adolescents with concussion, 69% had 1 or more vision diagnoses: accommodative disorders (51%), convergence insufficiency (49%), and saccadic dysfunction (29%).[62] In all, 46% of patients had more than 1 vision diagnosis. Visual dysfunction has implications for adolescents returning to the classroom setting.

A recent cross-sectional study[67] presented a brief vestibular/ocular motor screening (VOMS) assessment that included 5 domains: (1) smooth pursuits, (2) horizontal and vertical saccades, (3) near point of convergence (NPC) distance, (4) horizontal vestibulo-ocular reflex, and (5) visual motion sensitivity (VMS). It has good internal consistency and was sensitive for identifying patients with concussions. This promising brief examination tool merits prospective evaluation for identifying vestibular/ocular motor deficits in the office.

Table 4. Recommended and additional physical examination elements by domain with Strength of Recommendation Taxonomy (SORT)

Examination Domain	Recommended Elements (SORT)	Additional Elements (SORT)
Neurological	CNs (C)[13] MMT (C) DTRs (C)	UMN testing (C)
Musculoskeletal	Head and neck for trauma or tenderness (B) ROM (B) Spurling test (B)	Neck isometrics (B) Cervical proprioception (B)[5,71] Jaw and TMJ (C) Thoracic spine (C)
Balance/coordination	Static and/or dynamic balance assessment[a] (B)[33,38,40,79]	Coordination tests[b] (B)[20,44,57,78]
Vestibulo-ocular/ ophthalmologic	Screening ocular examination (A)[37,84] consisting of: Evaluation of the eyes in 8 positions Nystagmus Saccades Smooth pursuits Near point of convergence/ accommodation	Fundoscopic evaluation (C) Pupillary reactivity (C) Visual acuity (C) If dizziness or imbalance present, consider: Orthostatic vital signs (B)[6,21,50] via supine to stand stress test (B)[16,18] Otoscopic evaluation, Dix-Hallpike maneuver, and assessment of dynamic visual acuity (B)[1,2,21,34,36]
Mental status	Orientation, immediate and delayed recall, concentration, mood, affect, insight, judgment (B)[22]	Screening for depression and anxiety (B)[22,70,74,82] Preinjury psychiatric difficulties (A)[28,32] Substance use disorders (C)[22]
Additional elements as clinically indicated		

BESS, Balance Error Scoring System; CNs, cranial nerves; DTRs, deep tendon reflexes; MMT, manual muscle testing; ROM, range of motion; TMJ, temporomandibular joint; UMN, upper motor neuron; SORT, Strength of Recommendation Taxonomy (A, consistent, good-quality patient-oriented evidence; B, inconsistent or limited-quality patient-oriented evidence; C, consensus, disease-oriented evidence, usual practice, expert opinion, or case series).
[a]Options include BESS test, modified BESS, single-leg stance, tandem gait.
[b]Options include finger-to-nose test, rapidly alternating movements, or heel-to-shin test.

Fundoscopy is probably of low yield in concussion. It has been historically performed to assess for papilledema from increased intracranial pressure after head injury, although papilledema occurs in only 3.5% of severe head trauma cases[80] and was uncommon even with acutely elevated intracranial pressure.[80,83] This finding may evolve over time, especially with delayed or slow intracranial hemorrhage.[9] Recognition of papilledema is limited by the skill of the examiner and the tools used. While some evidence suggests family physicians accurately identify papilledema,[48] other evidence shows that even experts have difficulty with it.[51]

Assessments may include visual acuity, fundoscopic evaluation for papilledema, extraocular motor function, smooth pursuits, saccades, spontaneous/gaze-holding nystagmus, accommodation (monocular), near point of convergence (binocular), and the vestibulo-ocular reflex (see Table 3 in Appendix 2). Abnormal findings on the history or examination may prompt further evaluation with otoscopic evaluation, the Dix-Hallpike maneuver, and dynamic visual acuity.[21]

DISCUSSION

There is a significant degree of overlap in symptoms between concussive and nonconcussive injuries. Objective PE findings that determine physiological function affected by concussion should help clinicians better manage patients with concussion. Table 4 summarizes recommended and additional physical examination elements by domain with corresponding Strength of Recommendation Taxonomy.

A standardized PE could enable clinicians in multiple subspecialties to communicate more effectively when comanaging or referring patients. The ultimate goal of a standardized PE is to advance knowledge on concussion evaluation to improve patient outcomes. Prospective evaluation of this instrument is needed to assess its practicality, validity, and reliability for the examination and management of concussed patients.

Clinical Recommendations

SORT: Strength of Recommendation Taxonomy
A: consistent, good-quality patient-oriented evidence
B: inconsistent or limited-quality patient-oriented evidence
C: consensus, disease-oriented evidence, usual practice, expert opinion, or case series

Clinical Recommendation	SORT Evidence Rating
Instead of a comprehensive neurologic examination after concussion, a focused neurologic and physical examination (Table 2) may be performed.	C
Screening ocular examination should include: evaluation of the eyes in 8 positions, nystagmus, saccades, smooth pursuits, and near point of convergence/accommodation.[32,77]	A
Fundoscopy for evaluation of papilledema is probably of low yield in the concussion evaluation and may be reserved for cases where there is clinical concern.	C
If dizziness or imbalance is present, consider orthostatic vital signs.[5,45,62]	B

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