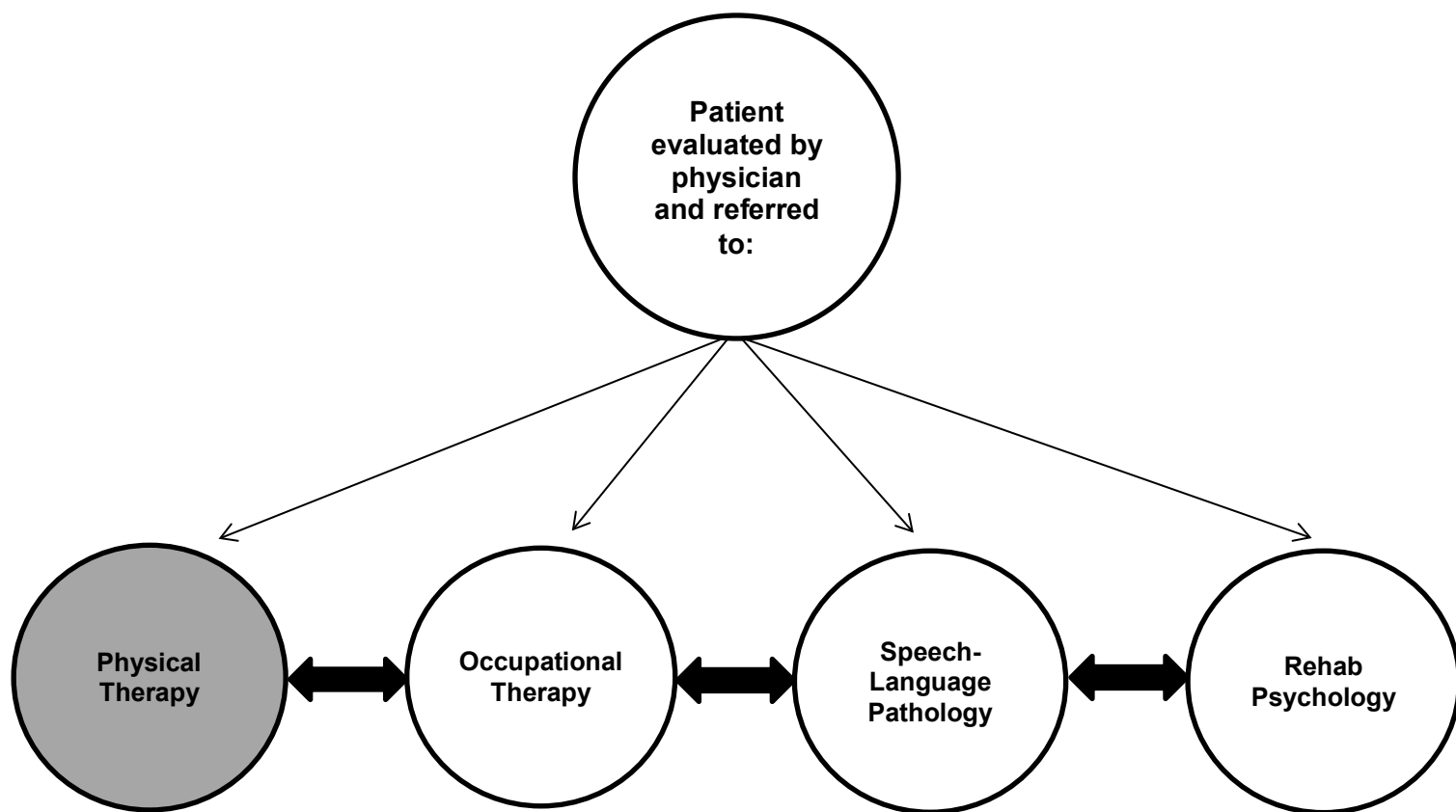


POSTCONCUSSIVE SYNDROME (PCS) CLINICAL PRACTICE GUIDELINE: PHYSICAL THERAPY

Disclaimer

Progression is time and criterion-based, dependent on soft tissue healing, patient demographics and clinician Evaluation.



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Purpose

The primary purpose of this guideline is to improve the diagnosis of impairments related to PCS, improve the quality of care and outcomes for patients with impairments related to PCS, and to decrease variations in the evaluation and management of PCS. This guideline addresses these needs by encouraging accurate and efficient diagnosis and treatment and, when applicable, facilitating patient follow-up to address the management of long-term sequelae or evaluation of new or worsening symptoms not indicative of mTBI/concussion. The guideline is intended for clinicians primarily in an outpatient setting who are likely to diagnose and manage patients with impairments related to PCS; however, these guidelines can provide guidance on symptom projection for the acute management. The target population is inclusive of both adults and adolescents presenting with impairments related to PCS. This guideline is intended to focus on a limited number of quality improvement opportunities deemed most important by the CPG and is not intended to be a comprehensive guide for managing PCS.

The recommendations outlined in this guideline are not intended to represent the standard of care for patient management, nor are the recommendations intended to limit treatment or care provided to individual patients. The guideline is not intended to replace clinical judgment for individualized patient care. The goal is to create a guideline with a specific set of focused recommendations based on an established and transparent process that considers levels of evidence, harm-benefit balance, and expert consensus to resolve gaps in evidence. These specific recommendations are designed to improve quality of care and may be used to develop performance measures.

Background

Concussions are a form of mild traumatic brain injury (TBI) caused by a bump, blow, or jolt to the head or body with resultant bouncing and twisting of the brain within the skull. According to the Centers for Disease Control and Prevention, concussion is a complex pathophysiologic process induced by traumatic forces secondary to direct or indirect forces to the head that disrupts the function of the brain.¹ Concussions results in multiple system impairments including physical, cognitive, emotional and/or sleep-related symptoms which may or may not involve a loss of consciousness.¹ Majority of patients reach full neurologic recovery within 1-2 weeks, however, 15-20% will have persistent signs and symptoms beyond 3 weeks.^{2,3,4,5} Persistent symptoms are referred to as Post-concussion Syndrome (PCS) and is diagnosed according to clinical criteria of physical signs and subjective somatic, cognitive and neurobehavioral symptoms, as there is no gold standard diagnostic test.⁶ The broadest and most sensitive PCS definition is provided by the World Health Organization's International Classification of Diseases (ICD-10), including 3 or more of the following: headache, dizziness, fatigue, irritability, insomnia, concentration difficulty or memory difficulty, refer to Appendix A.^{4,7} Furthermore, PCS has been delineated into subtypes of post-concussion disorders (PCD) of physiologic PCD, vestibulo-ocular PCD and cervicogenic PCD based on clinical history, physical examination and graded exercise testing.³



Summary of Recommendations

Etiology	<ul style="list-style-type: none"> • There are an estimated 1.7-3.8 million sports and recreation-related concussions each year^{4,5,8,9} • Symptoms of acute concussion are believed to be secondary to a global cerebral energy crisis characterized by alterations in cell membrane permeability, ion transport regulation, neurotransmitter release, cellular metabolism and cerebral blood flow (CBF)⁵ • 15-20% patients will have persistent signs and symptoms beyond 3 weeks.^{2,3,4,5} <ul style="list-style-type: none"> ◦ Refer to Appendix B for a proposed algorithm on management of a concussion following the initial MOI • PCS has been delineated into subtypes of post-concussion disorders (PCD) of physiologic PCD, vestibulo-ocular PCD and cervicogenic PCD based on clinical history, physical examination and graded exercise testing⁵ – Appendix C • Current guidelines recommend a period of cognitive and physical rest early post-injury as symptoms/recovery can increase with cognitive and physical exertion^{4,9} <ul style="list-style-type: none"> ◦ Recommended period of cognitive and physical rest is 24-48 hours. No scientific evidence suggests that prolonged rest for more than this time period is beneficial.⁴ ◦ No scientific evidence that medication speeds recovery⁴ • Encouraged to prioritize treatments in a hierarchical fashion that address symptoms that could delay recovery first^{2,7} <ul style="list-style-type: none"> ◦ Primary: depression, anxiety, irritability, sleep disorder, post-traumatic headache ◦ Secondary: Balance, dizziness, vertigo, cognition impairment, fatigue, tinnitus, phonophobia
Factors That Increase Risk For Concussion	<ul style="list-style-type: none"> • Prior h/o concussion(s), previous physical limitations, post-traumatic amnesia (PTA), posttraumatic migraine, skull fracture, dizziness at time of incident, cognitive deficits in first few days, reduced balance or dizziness in acute stage, nausea after injury^{4,7,10,11} • H/o psychiatric disorders, learning disability, migraines or family h/o migraines, PTSD¹⁰ • Female gender or younger age^{4,10} • Decreased cervical strength^{11,12,13} • Involvement in collision sports (e.g. American football, rugby, lacrosse, soccer)^{11,14} • Refer to Appendix B for proposed algorithm of proposed intrinsic and extrinsic variables increasing risk for concussion¹¹
Factors That Play a Role in Prognosis	<ul style="list-style-type: none"> • Psychosocial symptoms such as depression and anxiety² • Poor recovery expectations^{2,15} • Poor pre-injury mental status² • Lower education status²
Examination	<ul style="list-style-type: none"> • Objective examination measures include assessing components of ROM, posture, joint mobility and strength testing of the cervicothoracic spine and shoulder complex • Screening includes neurologic tests, vision, vestibular and c-spine clearance
Outcome Testing	<ul style="list-style-type: none"> • Recommended patient-reported outcome measures include: Concussion Grading Scale, Post-concussion Symptom Inventory (PCSI- SR5, PCSI-SR8, PCSI-SR13), Neck Disability Index (NDI), Headache Disability Index (HDI), Dizziness Handicap Inventory (DHI)¹, Convergence Insufficiency Symptom Survey (CISS)¹⁹, SF-36, SF-12, Rivermead Post Concussion Symptoms Questionnaire (RPQ)³ • Recommended family/support reported outcome measures include: Post-Concussion Symptom Inventory – Parent (PCSI-P) • Recommended balance centered outcome measures include: Balance Error Scoring System(BESS), Mini-BESTest, Dynamic Gait Index (DGI)¹, Functional Gait Assessment (FGA)¹ HiMAT, Timed Up and Go (TUG)¹ TUG Cognitive, Modified Sensory Organization Test (mSOT)¹, 10-meter walk test (10MWT)¹ • Recommended vestibular centered outcome measures include: VOR, VOR cancellation, Head Impulse Test (HIT), Dynamic Visual Acuity (DVA), Dix Hall Pike, Joint Position Error, Motion Sensitivity Quotient (MSQ)



- Recommended cervicogenic centered outcome measures include: joint position error (JPE), postural stability – with vibration to head/neck as indicated, craniocervical flexion test (CCFT), head-neck differentiation test, smooth pursuit neck torsion test (SPNT)
- Recommended physiologic centered outcome measures include: Buffalo Concussion Treadmill Test (BCTT) and Buffalo Concussion Bike Test (BCBT)^{16,17}

Key Interventions	Physiologic PCD^{5,18} <ul style="list-style-type: none"> • Physical and cognitive rest • School/work accommodations • Sub-symptom threshold aerobic exercise programs 	Vestibulo-ocular PCD^{5,20} <ul style="list-style-type: none"> • Vestibular rehabilitation program • Vision therapy program – refer to OT Vision P2P • School/work accommodations • Sub-symptom threshold aerobic exercise program 	Cervicogenic PCD⁵ <ul style="list-style-type: none"> • Cervical spine manual therapy • Head-neck proprioception re-training • Balance and gaze stabilization exercises • Sub-symptom threshold aerobic exercise program
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Recommendations for Outcome Testing

Patient Reported Outcome Measures

Concussion Grading Scale (CGS)	Appendix D
Graded Symptom Checklist ¹⁰	https://sjschools.org/images/Athletics_HS/graded_symptom_checklist.pdf
Rivermead Post-Concussion Symptom Questionnaire ¹⁰	http://www.chiropractor-sacramento.com/wp-content/uploads/2010/02/Rivermeade.pdf
Post-Concussion Symptom Scale ¹⁰	http://www.globalconcussions.org/resources/Post-Concussion-Symptom-Scale.pdf
Post-Concussion Symptom Inventory - Parent ⁷	https://hawaiiconcussion.com/downloads/Post-Concussion-Symptom-Scale.pdf
Neurobehavioral Symptom Inventory (military specific) ¹⁰	https://dvbic.dcoe.mil/sites/default/files/dcoe_dvbic_website-clinical-tools_nsi_v1.0_2017-08-18.pdf
Neck Disability Index (NDI)	https://www.sralab.org/rehabilitation-measures/neck-disability-index
Headache Disability Index (HDI)	https://www.allinahealth.org/-/media/allina-health/files/health-conditions-and-treatments/individual-hct-pages/26headachedisabilityindex.pdf
Dizziness Handicap Index (DHI) ¹	https://www.sralab.org/rehabilitation-measures/dizziness-handicap-inventory
Convergence Insufficiency Symptom Survey (CISS) ¹⁹	http://www.sankaranethralaya.org/pdf/patient-care/Convergence-Insufficiency-Symptom-Survey.pdf
SF-36	https://clinmedjournals.org/articles/jmdt/jmdt-2-023-figure-1.pdf
SF-12	https://www.sralab.org/rehabilitation-measures/short-form-12-item-version-2-health-survey
Patient Health Questionnaire 9-Item Scale ²	https://www.uspreventiveservicestaskforce.org/Home/GetFileByID/218
Generalized Anxiety Disorder 7-Item Scale ²	https://www.integration.samhsa.gov/clinical-practice/gad708.19.08cartwright.pdf

Balance Outcome Measures

Balance Error Scoring System (BESS)	https://www.sralab.org/rehabilitation-measures/balance-error-scoring-system
Mini-BESTest	https://www.sralab.org/rehabilitation-measures/mini-balance-evaluation-systems-test
Dynamic Gait Index (DGI) ¹	https://www.sralab.org/rehabilitation-measures/dynamic-gait-index
Functional Gait Assessment (FGA) ¹	https://www.sralab.org/rehabilitation-measures/functional-gait-assessment
High Level Mobility Assessment Tool (HiMAT)	https://www.sralab.org/rehabilitation-measures/high-level-mobility-assessment-tool
Timed Up and Go (TUG) ¹	https://www.sralab.org/rehabilitation-measures/timed-and-go



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Modified Sensory Organization Test (mSOT) ¹	https://www.sralab.org/rehabilitation-measures/sensory-organization-test https://www.sralab.org/sites/default/files/2017-06/204Lmctsib.pdf
10-meter Walk Test (10MWT) ¹	https://www.sralab.org/rehabilitation-measures/10-meter-walk-test
Physiological Testing	
Buffalo Concussion Treadmill Test ¹⁶	Refer Below – Test and Measures: Activity Tolerance Testing
Balke Protocol ^{18,21}	Refer Below – Test and Measures: Activity Tolerance Testing
Buffalo Concussion Bike Test ¹⁷	https://journals-sagepub-com.proxy.lib.ohio-state.edu/doi/suppl/10.1177/1941738119870189/suppl_file/Buffalo_Concussion_Bike_Test_Manual.pdf
Vestibular Outcome Measures	
VOR	https://www.youtube.com/watch?v=j_R0LcPnZ_w
VOR Cancellation	https://www.youtube.com/watch?v=ExOs7HSHv-c
Head Impulse Test (HIT)	https://www.sralab.org/rehabilitation-measures/head-impulse-test-head-thrust-test https://www.youtube.com/watch?v=DrA4ERU2aG8
Dynamic Visual Acuity (DVA)	https://www.sralab.org/rehabilitation-measures/dynamic-visual-acuity-test-non-instrumented
Vestibulo-oculomotor Screen (VOMS)	https://www.physiotherapyalberta.ca/files/vomstool.pdf
Dix Hall Pike	https://www.sralab.org/rehabilitation-measures/dix-hallpike-maneuver
Joint Position Error	https://www.sralab.org/rehabilitation-measures/cervical-joint-position-error-test
Motion Sensitivity Quotient (MSQ)	https://www.sralab.org/rehabilitation-measures/motion-sensitivity-quotient-test http://www.chartercare.org/uploads/appendix_g_motion_sensitivity_test.pdf
Cervicogenic Outcome Measures	
Joint Position Error (JPE)	https://www.sralab.org/rehabilitation-measures/cervical-joint-position-error-test
Cranio-cervical Flexion Test (CCFT)	https://www.physio-pedia.com/Cranio%E2%80%90cervical_Flexion_Test
Head-Neck Differentiation Test Seated Cervical Rotation Test	https://www.sralab.org/rehabilitation-measures/seated-cervical-rotation-test
Smooth Pursuit Neck Torsion (SPNT)	https://www.youtube.com/watch?v=Yh4W5HoU1AU



Examination^{4,10}

History	<ul style="list-style-type: none">• Age, date of injury (DOI), mechanism of injury (MOI), sport specific – wearing helmet or mouth guard at time of injury, symptoms present at time of injury, loss of consciousness (if yes, how long?), post-traumatic amnesia (PTA – retrograde or anterograde), current school/work status, sport participation, exercise habits, disturbance/change of sleep habits, psychosocial changes, headaches, number of previous concussions (DOI, MOI, symptom type and duration, time off from school/work/sport/activity)• Past medical history significant for: Attention Deficit Hyperactivity Disorder (ADHD), seizures, learning disorder, migraines/headaches, family history of migraines, anxiety, depression, PTSD¹¹• Pharmacological management¹³: sleep dysregulation, headaches, memory, concentration, mood disturbances• Systems review and administration of Concussion Grading Scale (CGS) – current symptoms
Screening	<ul style="list-style-type: none">• Postural alignment in sitting and standing: forward head, head tilt, rounded shoulders, shoulder elevation, scapular winging, pelvic alignment/symmetry• Neurologic screen: sensation/dermatomes, upper and lower extremity myotomes, deep tendon reflexes (DTR), Hoffman's, Babinski's, CN screen• Visual/oculomotor screen: spontaneous nystagmus, gaze holding nystagmus, smooth pursuit, saccades, convergence insufficiency, accommodation insufficiency• Cervical clearing: compression, distraction, spurling's maneuver, alar ligament, sharp-purser, transverse ligament, vertebral artery insufficiency<ul style="list-style-type: none">◦ Sharp-Purser has been used in the past to screen the cervical spine, but new research has shown the test may be inappropriate to use due to inconsistent validity, poor inter-rater reliability and potential to cause harm²²• Vestibular screen:²⁶ Central / peripheral signs, Dix-Hallpike and supine roll tests, VOMS, VOR, VOR Cx, Head impulse test, Dynamic Visual Acuity (DVA), head-shake nystagmus, postural stability with vibration to head/neck as indicated• Screen for psychosocial factors as deemed appropriate: Generalized Anxiety Disorder 7-Item Scale and Patient Health Questionnaire 9-Item Scale²
Tests and Measures	<ul style="list-style-type: none">• Cervical, thoracic and shoulder A/PROM• Palpation• Joint mobility/alignment• Strength testing: cervical flexion, extension, lateral flexion, rotation, deep neck flexor isometric hold / cranial cervical flexion test with biofeedback cuff)• Impairment based outcome measures<ul style="list-style-type: none">• Patient-reported outcome measures: Concussion Grading Scale, Neck Disability Index (NDI), Headache Disability Index (HDI), Dizziness Handicap Inventory (DHI)¹, Convergence Insufficiency Symptom Survey (CISS), SF-36, SF-12, Rivermead Post Concussion Symptoms Questionnaire (RPQ)³• Family/support reported outcome measures include: Post-Concussion Symptom Inventory – Parent (PCSI-P)• Balance outcome measures: Balance Error Scoring System (BESS)⁵, Mini-BESTest, Dynamic Gait Index (DGI)³, Functional Gait Assessment (FGA)⁵, High Level Mobility Assessment Tool (HiMAT), Timed Up and Go (TUG), TUG cognitive, Sensory Organization Test (SOT), 10-meter walk test (10MWT)• Vestibular outcome measures: VOR, VOR cancellation, Head Impulse Test (HIT), Dynamic Visual Acuity (DVA), Dix Hall Pike⁵, Joint Position Error, Motion Sensitivity Quotient (MSQ), Vestibulo-oculomotor Screen (VOMS)• Cervicogenic centered outcome measures: Joint Position Error, Postural Stability- with vibration to head/neck as indicated, craniocervical flexion test (CCFT), head-neck differentiation test, smooth pursuit neck torsion test (SPNT),



- Activity tolerance testing:
 - Degree of exercise intolerance shortly after [1-9 days post] sports related concussion (SRC) strongly predicts time to recovery²³
 - Treadmill testing in patients with symptoms persistent >10 days should not be performed before 3-weeks post-injury with intent to implement Return to Activity Protocol⁴

Buffalo Concussion Treadmill Test (BCTT)^{16,24} – Appendix E

- Treadmill Speed
 - 3.6 mph for patients $\geq 5'5''$
 - 3.2 mph for patients $< 5'5''$
 - Speed may be adjusted +/- .2 mph to 3.4 mph as needed for taller/shorter or athletic/sedentary patients to facilitate a normalized walking speed.
- Patient starts at 0% incline. Incline is increased by 1% at minute 2 and by 1% each minute thereafter until max incline is reached. If patient is able to continue, speed is increased by 0.4 mph until stopping criteria is fulfilled.
- Stopping Criteria
 - PCS symptoms increase per CGS – clinical judgement
 - 20 min time cap
 - RPE of 19-20
- RPE, HR and assessment of new PCS symptoms assessed every 1-minute
- BP assessed every 2-minutes

Balke Protocol^{18,21}

- Treadmill speed set at 3.3 mph at 0% incline. After 1 min, treadmill grade increased to 2.0% maintaining same speed. At the start of the third minute treadmill grade raised by 1%.
- Blood pressure (sphygmomanometer) measured every 2 minutes. Heart rate (HR monitor) and rate of perceived exertion - RPE (Borg scale) measured every minute, as well as patient rating of symptom change and therapist observation.
- Test is terminated at report of exacerbation of PCS symptoms

Buffalo Concussion Bike Test (BCBT)¹⁷

- Power Output
 - RPMs for each stage are calculated using the ACSM walking equation.
 - Measure the patient's body weight in kilograms and enter into excel spreadsheet.
 - The excel spreadsheet will autofill all the power values for each stage according to the ACSM walking equation.
 - Please reach out to alicia.kempton@osumc.edu for a copy of the excel spreadsheet with equation in order to determine the patient's power output for each stage
- When the patient begins biking, adjust the power for the appropriate RPM value according to the excel spreadsheet.
- Power output is increased at the start of each minute based on power values attained from excel spreadsheet.
- RPE, HR and assessment of new PCS symptoms assessed every 1-minute
- BP assessed every 2-minutes
- Stopping Criteria
 - RPE of ≥ 18
 - PCS symptom exacerbation (increase ≥ 3 on the Likert scale compared to baseline)
 - Patient reports inability to continue safely with test

Patient Education

- Several studies demonstrate brief, single session education-oriented treatment is superior to standard procedures and even as effective as more intensive interventions^{5,13}
- Education session can include but not limited to:
 - Common symptoms, reassurance, typical time and course of recovery, how to manage or cope, gradual reintegration to regular activities, how to access further support, regular stress management



- Patient should also be educated on a return to school/work progression – please refer to Appendix F
- Strongly suggested education handouts
 - <https://patienteducation.osumc.edu/Documents/concuss.pdf>
 - http://www.michigan.gov/documents/mdch/TBI_Recovery_Guide_10.8.08_252053_7.pdf



Recommendations for Physiologic PCD Interventions

Etiology

- Persistent alterations in cell membrane permeability, ion transport regulation, neurotransmitter release, cellular metabolism and CBF.^{5,18}
 - Magnetic resonance spectroscopy studies, athletes who report being symptom free at 3-15 days did not have complete metabolic recovery until 30 days post-injury, with mitochondrial metabolism taking an additional 15 days with a second concussion^{4,18}
- Exacerbation of symptoms during cognitive activity and/or physical exercise secondary to persistent cerebral metabolic energy deficiency.⁵
- Autonomic nervous system dysfunction characterized by higher rates of sympathetic nervous system output (resting HRs and HR during cognitive and/or physical activity) proportional to TBI severity and improves during TBI recovery^{4,5}
- Exercise testing and rehab should be employed only if patients have persistent symptoms for 3-6 weeks or more² – Appendix C
 - For sports related concussion (SRC) **OSU's Return to Sport Guidelines** should be followed days 1-14 – Appendix H
 - Treadmill/Bike testing in patients with symptoms persistent >10 days should not be performed before 3-weeks post-injury with intent to implement Return to Activity protocol⁴

Physical and Cognitive Rest	<ul style="list-style-type: none"> • Current guidelines recommend a period of cognitive and physical rest early post-injury as symptoms/recovery can increase with cognitive and physical exertion² <ul style="list-style-type: none"> ○ Recommended period of cognitive and physical rest is 24-48 hours. No scientific evidence suggests that prolonged rest for more than this time period is beneficial^{4,9} ○ No scientific evidence that medication speeds recovery⁴
Prognostic Utility	<ul style="list-style-type: none"> • Exercise intolerance testing may be emerging as one of the best systemic physiological biomarkers in concussion recovery²³ • Degree of exercise intolerance shortly after [19- days post] SRC strongly predicts time to recovery²³ Subjects with a low HR threshold (<135 bpm) are approximately 45x more likely to have prolonged recovery²³
Sub-symptom Threshold Aerobic Exercise Program	<ul style="list-style-type: none"> • Animals with mTBI exposed to exercise 14-21 days post exercise were found to improve cognitive performance and high levels of BDNF^{5,18} <ul style="list-style-type: none"> ○ Exercise-induced BDNF is dependent on injury severity¹⁸ <ul style="list-style-type: none"> ▪ i.e. – moderate TBI = 30-36 days after injury • Sub-symptom threshold programs should be considered in adolescent and adults with symptoms persisting beyond 3 weeks⁵ • Subthreshold aerobic exercise treatment has been shown to restore fMRI brain activation patterns to normal vs a sham (stretching) program¹⁸ • OSU's Return to Activity Protocol – Refer to Appendix G <ul style="list-style-type: none"> ○ Establish sub-symptom threshold with BCTT per physician recommendation <ul style="list-style-type: none"> ▪ % HRmax at which BCTT was terminated ○ Decrease % above by 15-20% = Prescribed HR ○ Correlate Prescribed HR to Phase I-VI of OSU RTA Protocol ○ Progress through phases as indicated by min to no symptom exacerbation <ul style="list-style-type: none"> ▪ Patients who are more fit or athletes generally respond faster¹⁸ • Physiological resolution of concussion = ability to exercise at 85-90% age-predicted HRmax for 20 min without exacerbation of symptoms for several consecutive days¹⁸ <ul style="list-style-type: none"> ○ Athletes must be cleared by their physician of record prior to return to sport based on OHSAA and NCAA legislation • For additional resources/questions contact alicia.kempton@osumc.edu

Recommendations for Vestibulo-ocular PCD Interventions

Etiology

- Vestibular, oculomotor and somatosensory systems consist of special sensory organs with primary processing units that share direct, indirect and reciprocal projections to the spinal cord, autonomic nervous system, brainstem nuclei, cerebellum, thalamus, basal ganglia and cerebral cortex⁵
- Symptoms such as vertigo, dizziness (23-81% in first days, 16-18% at three months, 32.5% at 5 years),^{1,20} nausea, light-headedness, gait instability and postural instability can originate from vestibular dysfunction
 - Vestibulo-ocular reflex (VOR) regulates gaze stabilization during head acceleration^{5,20}
 - Vestibulo-spinal reflex (VSR) coordinates head, neck and trunk positioning during dynamic body movements⁵
 - Post-traumatic benign paroxysmal positional vertigo (BPPV), labyrinthine concussion, perilymphatic fistula, endolymphatic hydrops, otolith disorders and central vestibular disorders⁵
 - >1 of the above mechanisms present in up to 46% concussion patients⁵
- Symptoms such as blurred vision, diplopia, difficulty tracking objects, difficulty reading, motion sensitivity, eye strain brow-ache, trouble focusing or headache can originate from accommodation, version (pursuits, saccades and fixation), convergence insufficiency, photosensitivity and rarely visual field defects and CN palsies⁵
 - Warrants referral to vision specialist/OT - refer to OT Vision P2P
- Consider treatment of impairments of the neck prior to progressing towards treatment of vestibular symptoms as there may be an inability to perform movements required by vestibular treatments due to cervical dysfunction³

BPPV	<ul style="list-style-type: none"> • Repositioning techniques
Eye-Head Coordination	<ul style="list-style-type: none"> • VORx1 and VORx2 (yaw and pitch planes)^{1,5,20} • Modify frequency, BOS, stability of surface and complexity of visual background • Prescribed in 95% of patients²⁰
Sitting Balance	<ul style="list-style-type: none"> • Supported and unsupported sitting, weight shifts, bouncing²⁰
Standing Static Balance	<ul style="list-style-type: none"> • Modifiers refer to Appendix I • Modify base of support (romberg, tandem, single leg stance, etc)^{5,20} • Weight shifting in variable directions²⁰ • Prescribed in 88% of patients²⁰
Standing Dynamic Exercises	<ul style="list-style-type: none"> • Sit to stand²⁰ • Marching, step forward or backward, step to the side, step up or down, turn around²⁰
Ambulation	<ul style="list-style-type: none"> • Walking forward, backwards, tandem, on stairs, with whole body turns and head on body turns, braiding/grape vine, skipping, jogging and running²⁰ • Prescribed in 76% of patients
Sensory Re-integration	<ul style="list-style-type: none"> • Modify stability of surface (foam, rocker board, etc.)^{5,20} • Modify BOS²⁰ • Modify positioning of trunk and arms²⁰ • Incorporate head movements and modify direction of movement²⁰ • Visual Integration (Eyes open, eyes closed, distraction)²⁰ • Dual Tasking²⁰ • Refer to Appendix I for progression of each modifier



Recommendations for Cervicogenic PCD Interventions

Etiology

- Structural and functional injury to the cervical spine can be associated with symptoms such as headache, dizziness, blurred vision and vertigo as rotational forces can effect nerve tracts and proprioceptive fibers⁶
 - Cervical afferents carry proprioceptive information to the cerebellum via spinocerebellar tracts and to the dorsal column nuclei via posterior column-medial lemniscal pathways, which project to the thalamus and primary somatosensory cortex⁵
 - Cervical afferent project to central cervical nucleus, vestibular nuclei and superior colliculi to mediate head and neck position send through coordination of the cervicocollic reflex (CCR), vestibulocollic reflex (VCR) and cervico-ocular reflex (COR) respectively⁵
- Cervicogenic dizziness is a diagnosis of exclusion
 - Neck pain, stiffness, decreased range of motion, dizziness, impaired balance, impaired head-neck position sense
 - No evidence of central or peripheral vestibular involvement
 - Negative BCTT
 - Appendix C
- Difference in cervical muscle strength development, ligamentous laxity, head-body proportions and cervical spine mobility may place children and adolescents at increased risk⁵
 - Neck strength is a significant predictor of concussion among high school athletes; for every one pound increase in neck strength, odds of concussion decrease by 5%¹²

Cervical Mobility and Pain Management⁵	<ul style="list-style-type: none"> • Passive and active range of motion • Soft tissue mobilization • Grade I-IV mobilizations <ul style="list-style-type: none"> ○ Upper cervical spine ○ Cervico-thoracic junction • Minimal evidence to support Grade V manipulations²⁵ • Mulligan techniques – SNAGS²⁶ • Traction/distraction • Muscle energy techniques – contract/relax ²⁶
Cervical Proprioception³	<ul style="list-style-type: none"> • Joint position error training <ul style="list-style-type: none"> ○ Progress to tracing figures and/or complex designs • Gaze stabilization – VORx1 and VORx2 progressions
Cervical Strengthening	<ul style="list-style-type: none"> • Strength and stabilization retraining <ul style="list-style-type: none"> ○ Deep neck flexors ○ Cervical extensors
Postural Retraining	<ul style="list-style-type: none"> • Biofeedback using mirrors • Ergonomic training/education • Movement control training/education <ul style="list-style-type: none"> ○ Sport specific activity, job related tasks, activities of daily living • Abdominal/trunk strengthening • Scapular strengthening

Appendix A: PCS Diagnostic Criteria

Diagnostic Criteria for Post-Concussion Syndrome (ICD-10)

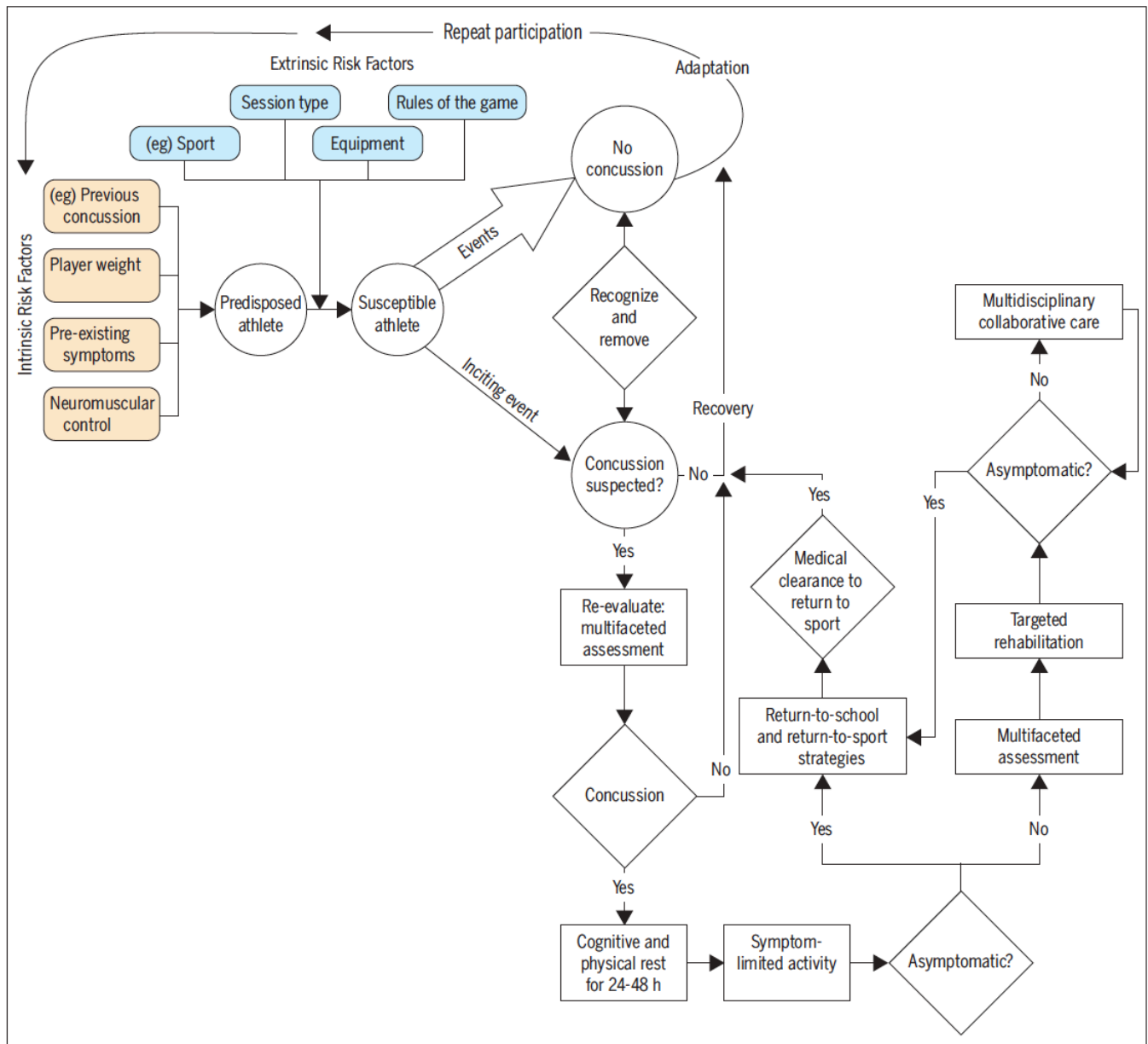
- A. History of head trauma with loss of consciousness preceding symptom onset by a maximum of 4 weeks.
- B. Symptoms in 3 or more of the following symptom categories
- Headache dizziness, malaise, fatigue, noise tolerance
 - Irritability, depression, anxiety, emotional lability
 - Subjective concentration, memory or intellectual difficulties without neuropsychological evidence of marked impairment
 - Insomnia
 - Reduced alcohol tolerance
 - Preoccupation with above symptoms and fear of brain damage with hypochondriacal concern and adoption of sick role

Diagnostic Criteria for Postconcussional Disorder (DSM-IV)

- A. A history of head trauma that has caused significant cerebral concussion.
The manifestations of concussion include loss of consciousness, posttraumatic amnesia, and less commonly, posttraumatic onset of seizures. The specific method of defining this criterion needs to be established by further research.
- B. Evidence from neuropsychological testing or quantified cognitive assessment of difficulty in attention (concentrating, shifting focus of attention, performing simultaneous cognitive tasks) or memory (learning or recall of information).
- C. Three (or more) of the following occur shortly after the trauma and last at least 3 months:
- Becoming fatigued easily
 - Disordered sleep
 - Headache
 - Vertigo or dizziness
 - Irritability or aggression on little or no provocation
 - Anxiety, depression or affective instability
 - Changes in personality (e.g. social or sexual inappropriateness)
 - Apathy or lack of spontaneity
- D. The symptoms in criteria B and C have their onset following head trauma or else represent a substantial worsening of preexisting symptoms.
- E. The disturbance causes significant impairment in social or occupational functioning and represents a significant decline from a previous level of functioning. In school-age children, the impairment may be manifested by a significant worsening in school or academic performance dating from the trauma.
- F. The symptoms do not meet criteria for Dementia Due to Head Trauma and are not better accounted for by another mental disorder (e.g. Amnesic Disorder Due to Head Trauma, Personality Change Due to Head Trauma)



Appendix B: Factors that Increase Risk for Concussion and Proposed Algorithm for Treatment Following Concussion¹¹

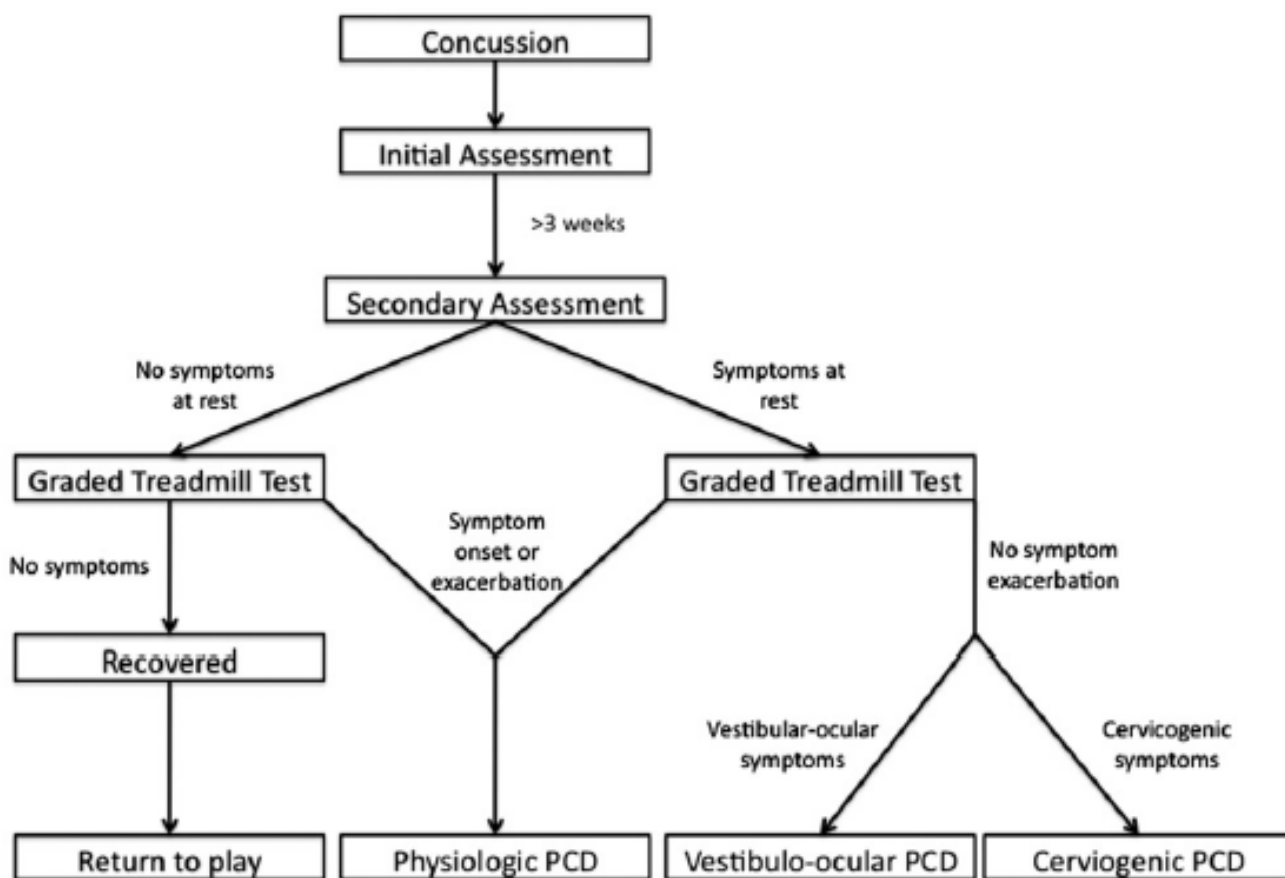


Appendix C: Proposed Algorithm for Differential Diagnosis of PCD Subtypes⁵

Summary of pathophysiology, predominant symptoms, pertinent physical examination findings, graded treadmill test results and treatment options in patients with PCDs

	Physiologic PCD	Vestibulo-ocular PCD	Cerviogenic PCD
Pathophysiology	<ul style="list-style-type: none"> Persistent alterations in neuronal depolarization, cell membrane permeability, mitochondrial function, cellular metabolism and cerebral blood flow 	<ul style="list-style-type: none"> Dysfunction of the vestibular and oculomotor symptoms 	<ul style="list-style-type: none"> Muscle trauma and inflammation Dysfunction of cervical spine proprioception
Predominant Symptoms	<ul style="list-style-type: none"> Headache exacerbated by physical and cognitive activity Nausea, intermittent vomiting, photophobia, phonophobia, dizziness, fatigue, difficulty concentrating, slowed speech 	<ul style="list-style-type: none"> Dizziness, vertigo, nausea, lightheadedness, gait instability and postural instability at rest. Blurred or double vision, difficulty tracking objects, motion sensitivity, photophobia, eye strain or brow-ache, and headache exacerbated by activities that worsen vestibulo-ocular symptoms (i.e. reading) 	<ul style="list-style-type: none"> Neck pain, stiffness and decreased range of motion Occipital headaches exacerbated by head movements and not physical or cognitive activity Lightheadedness and postural imbalance
Physical exam findings	<ul style="list-style-type: none"> No focal neurological findings Elevated resting HR 	<ul style="list-style-type: none"> Impairments on standardized balance and gait testing Impaired VOR, fixation, convergence, horizontal and vertical saccades 	<ul style="list-style-type: none"> Decreased cervical lordosis and range of motion Paraspinal and sub-occipital muscle tenderness Impaired head-neck position sense
Graded treadmill test	<ul style="list-style-type: none"> Often terminated early due to symptom onset or exacerbation 	<ul style="list-style-type: none"> Patients typically reach maximal exertion without exacerbation of vestibulo-ocular symptoms 	<ul style="list-style-type: none"> Patients typically reach maximal exertion without exacerbation of cervicogenic symptoms
Management options	<ul style="list-style-type: none"> Physical and cognitive rest School accommodations Sub-symptom threshold aerobic exercise programs should be considered for adolescent and adult athletes 	<ul style="list-style-type: none"> Vestibular rehabilitation program Vision therapy program School accommodations Sub-symptom threshold aerobic exercise programs should be considered for adolescent and adult athletes 	<ul style="list-style-type: none"> Cervical spine manual therapy Head-neck proprioception re-training Balance and gaze stabilization exercises Sub-symptom threshold aerobic exercise programs should be considered for adolescent and adult athletes





Appendix D: Ohio State Concussion Grading Scale

Patient Name _____

Circle the number in each row that best describes the way you have been feeling relative to the symptom.

Symptom	None	Mild	Moderate	Severe			
Headache	0	1	2	3	4	5	6
“Pressure in Head”	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or Vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred Vision	0	1	2	3	4	5	6
Balance Problems	0	1	2	3	4	5	6
Sensitivity to Light	0	1	2	3	4	5	6
Sensitivity to Noise	0	1	2	3	4	5	6
Feeling Slowed Down	0	1	2	3	4	5	6
Feeling Like “In a Fog”	0	1	2	3	4	5	6
Don’t Feel Right	0	1	2	3	4	5	6
Difficulty Concentrating	0	1	2	3	4	5	6
Difficulty Remembering	0	1	2	3	4	5	6
Fatigue or Low Energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Trouble Falling Asleep	0	1	2	3	4	5	6
More Emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6
Sleeping More Than Usual	0	1	2	3	4	5	6
Sleeping Less Than Usual	0	1	2	3	4	5	6
Difficulty Sleeping Soundly	0	1	2	3	4	5	6
Ringing in Ears	0	1	2	3	4	5	6
Numbness or Tingling	0	1	2	3	4	5	6

- Over the past week, my sleeping pattern has changed. _____ Yes No *If NO, skip to #2*
 - Have you been taking naps during the middle of the day? _____ Yes No
 - Are you waking during the night? _____ Yes No
- Over the past week, my participation in **work** or **school** has been _____ % of what it would be normally.
- Over the past week, my participation in **physical activity** (sports, working out, etc.) has been _____ % of what it would be normally.
- Do you feel like you are putting more effort more effort into maintaining schoolwork/grades and/or work productivity? (Circle corresponding number below)

0	1	2	3	4	5	6
No More Effort			A Lot More Effort			

- Please indicate the type of visual changes you are experiencing:
Eye Fatigue Double Vision Blurry Vision Other _____ h/a
- Do your symptoms get **WORSE** with **physical activity**? _____ Yes No
- Do your symptoms get **WORSE** with **thinking/cognitive activity**? _____ Yes No
- Do your symptoms **IMPROVE** with **physical rest**? _____ Yes No
- Do your symptoms **IMPROVE** with **thinking/cognitive rest**? _____ Yes No



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Appendix E: Buffalo Concussion Treadmill Test

Name _____ Date _____

Symptoms _____

HRmax = $220 - \text{age} =$ _____ Resting HR _____ Resting BP _____ Speed _____

Min	HR	BP	RPE	Symptom Change	Observations
0					
1		-			
Incline increased by 1% at start of minute 2					
2					
3		-			
4					
5		-			
6					
7		-			
8					
9		-			
10					
11		-			
12					
13		-			
14					
15		-			
16					
17		-			
18					
19		-			
20					
2-min post					
5-min post					

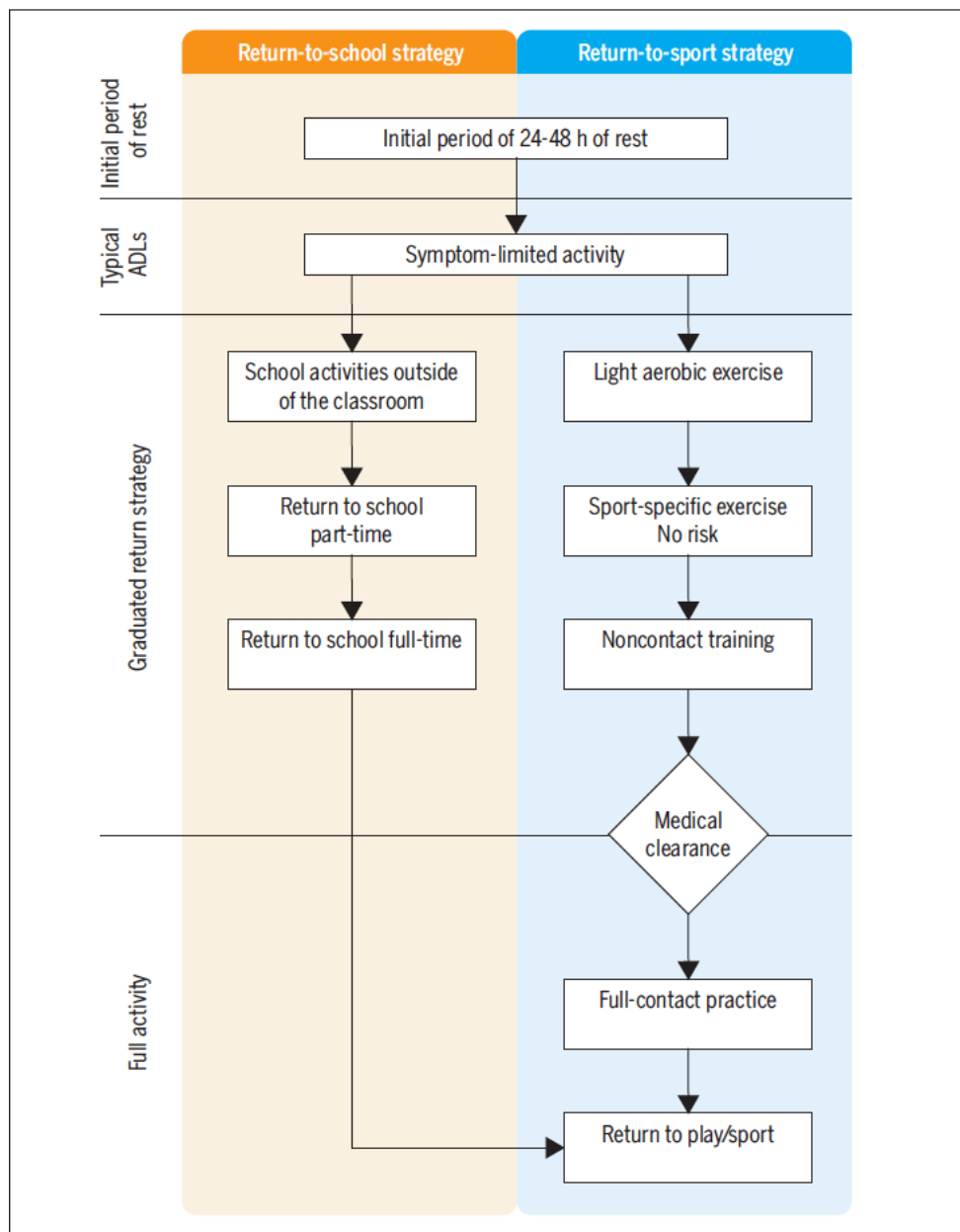
Notes:



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Appendix F: Return-to-School and Return-to-Sport Strategy¹¹



Appendix G: Return to Activity Protocol

Each phase to last 1 to 2 weeks, all phases should be progressed to patient tolerance avoiding all concussion signs and symptoms, patient should participate in monitored home program 6 days per week.

Phase I (no impact)

Cardiovascular Conditioning (elliptical, stationary bike, spinner)

- 30 to 50% max heart rate times 15 to 20 minutes

Strengthening

- 50% max time 3 way plank (prone, right and left)
- Upper and lower body strengthening without resistance with low sets and reps

Phase II (low impact) Cardiovascular Conditioning (elliptical, stationary bike, spinner, walking on treadmill)

- 30 to 50% max heart rate times 20 to 30 minutes
- 10 min at 30 to 50%, 3-5 min at 60 to 80%, 5 min at 30 to 50%, 3-5 min at 60 to 80%, 5-10 min at 30 to 50%
- 60 to 80% max heart rate times 5 to 10 minutes

Strengthening/Balance

- 75 to 100% max time 3 way plank
- Upper and lower body strengthening with body weight at low sets and high reps
- Upper and lower body strengthening with body weight at low sets and low reps
- Initiate static balance activities on firm surface with eyes open per Balance Error Scoring System (BESS)

Phase III (impact)

Cardiovascular Conditioning (initiate running on treadmill to tolerance)

- 60 to 80% max heart rate times 10 to 15 minutes

Strengthening/Balance

- 100% max time 3 way plank, dynamic core strength and stability
- Upper and lower body strengthening with body weight at low sets and high reps
- Upper and lower body strengthening with resistance at low sets and reps
- Progress balance activities to eyes closed per BESS

Phase IV (agility)

Cardiovascular Conditioning (continue treadmill running, initiate running on sport specific surfaces)

- Warm up: 60% max heart rate times 15 minutes
- Circuit training: 60-80% max HR for 30 minutes [Borg 11-14 (light to somewhat hard)]

Each interval should be 30 seconds in duration. May complete extra cycles if time and symptoms allow

	Cardio	LE Strength	Balance	Cardio	UE Strength	Agility	Cardio	Core	Rest
Cycle 1	Jog	Squats	SLS Eyes Closed	Jog	T-band Shoulder Extension	Box Drill	Jog	Prone Plank	2 min
Cycle 2	Jog	Walking Lunges	SLS with UE Chop	Jog	Push-ups (modified)	Pro-Agility (T-drill)	Jog	R side Plank	2-min
Cycle 3	Jog	T-Band Resisted Sidestep	Star Drill	Jog	T-Band Star Pulls	W-Drill	Jog	L side Plank	2-min

Phase V (return to activity)

Cardiovascular Conditioning (continue treadmill running, continue running on sport specific surfaces)

- Warm up: 60 to 80% max heart rate times 20-30 minutes
- Circuit training: 60-80% max HR for 30 minutes [Borg scale 14-18 (Hard to very hard)]

Each Interval should be 30-45 seconds in duration. May complete extra cycles if time and symptoms allow

	Cardio	LE Strength	Balance	Cardio	UE Strength	Agility	Cardio	Core	Rest
Cycle 1	Jog	2-foot Jumps in Place	SLS on Foam + Rebounder	Jog	Med Ball Slams	Box Drill	Jog	Med Ball Twists	2 min
Cycle 2	Jog	Lateral Bench Jump Plyos	SLS with UE Shop	Jog	T-Band Rows	Pro-Agility (T-Drill)	Jog	R side Plank with Rotation	2 min
Cycle 3	Jog	Lunge hops/switch	SLS with Floor Touch	Jog	Med Ball Chest Pass (wall)	W-Drill	Jog	L side Plank with Rotation	2 min

Phase VI (return to full contact practice) - Check in briefly to determine if PT needs persist



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Appendix H: Return to Sport Protocol

Prior to beginning the return to sport progression, the athlete must complete a period of cognitive and physical rest – 24-48 hrs. Length of rest period will be determined by physician or appropriate medical professional.

- Symptom checklist should be completed by athlete before and after each treatment/exercise session
- If symptoms are elevated with exercise beyond permissible criteria, do not progress to next phase. Return athlete to previous phase which did not elevate symptoms.
- Communication with physician required prior to advancing beyond day/phase 3.

If athlete is unable to progress through phase 5 after 14 days, athlete should be referred back to a physician for additional multidisciplinary testing, and a Buffalo Concussion Treadmill Testing (BCTT) may be considered

Day/Phase 1	Light aerobic activity (30-40% max HR) - 5 min warm up - 15 min duration	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;"> Target Heart Rate = ((max HR – resting HR) × %Intensity) </div>										
Day/Phase 2	Moderate aerobic activity (40-60 % max HR) - 5 min warm up - 15 min duration - 15 min circuit based exercise	Each cycle completed one time. Each exercise in cycle 1-2 performed for 30 sec										
		Cycle 1	Jog	Squats	Jog	Push ups	Jog	Lunges	Jog	Bridges	Jog	2 min rest
		Cycle 2	Jog	Squats	Jog	Push ups	Jog	Lunges	Jog	Bridges	Jog	2 min rest
		Cycle 3	Single Leg balance on Right (30 sec)		Single Leg Balance on Left (30 sec)		Prone Plank (30 sec-1 min)					
Day/Phase 3	Higher intensity aerobic activity (60-80% max HR) -5 min warm up -20 min duration -15 min circuit based exercise -Sport specific non-contact drills	Each cycle completed one time. Each exercise in cycle 1-2 performed for 30 sec										
		Cycle 1	Jog	Hops	Jog	Skips	Jog	Lunge hops	Jog	Box Drill	Jog	2 min rest
		Cycle 2	Jog	Hops	Jog	Skips	Jog	Lunge hops	Jog	Box Drill	Jog	2 min rest
		Cycle 3	Single Leg stance with perturbations (30 sec)		Single Leg stance with perturbations (30 sec)		Side plank Left (30 sec)		Side plank Right (30 sec)			
		Non-contact sport specific aerobic drills x 5 min: i.e. – Running, Skating, etc.										
Day/Phase 4	Return to practice Non-contact Drills	Non-contact sport specific drills to tolerance: initiate harder training drills, agility and passing drills. May start to progressive resistance training.										
Communication with physician required before advancing beyond phase 4												
Day/Phase 5: Full Contact Practice												
Day/Phase 6: Return to Sport												



Appendix I: Modifiers for Vestibular Rehabilitation²⁰

Each phase to last 1 to 2 weeks, all phases should be progressed to patient tolerance avoiding all concussion signs and symptoms, patient should participate in monitored home program 6 days per week.

Modifier	Choices
Posture	1: Sitting, 2: Standing, 3: Walking, Not applicable/Not specified (NA/NS)
Surface	1: Level, 2: Firm, 3: Uneven, 4: Obstacle, 5: Stairs, 6: Ramps, NA/NS)
Base of support	1: Feet apart, 2: Feet together, 3: Semi-tandem, 4: Tandem, NA/NS
Trunk position	1: Upright, 2: Leaning, 3: Rotated, NA/NS
Arm position	1: Weight-bearing, 2: Close to body, 3: Away from body, 4: Reaching, 5: Carrying, 6: Picking up objects, 7: Juggling, NA/NS
Head movement direction	1: Still, 2: Yaw, 3: Pitch, 4: Roll, NA/NS
Direction of whole body movements	1: Anterior-posterior, 2: Medial-lateral, 3: Multi-directional, NA/NS
Visual movement	1: Eyes closed, 2: Eyes open, 3: Complex patterns, NA/NS
Cognitive dual task	1: Yes, 2: No
Special circumstances	For example, note if the VORx1 exercise was performed with near or far target



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