

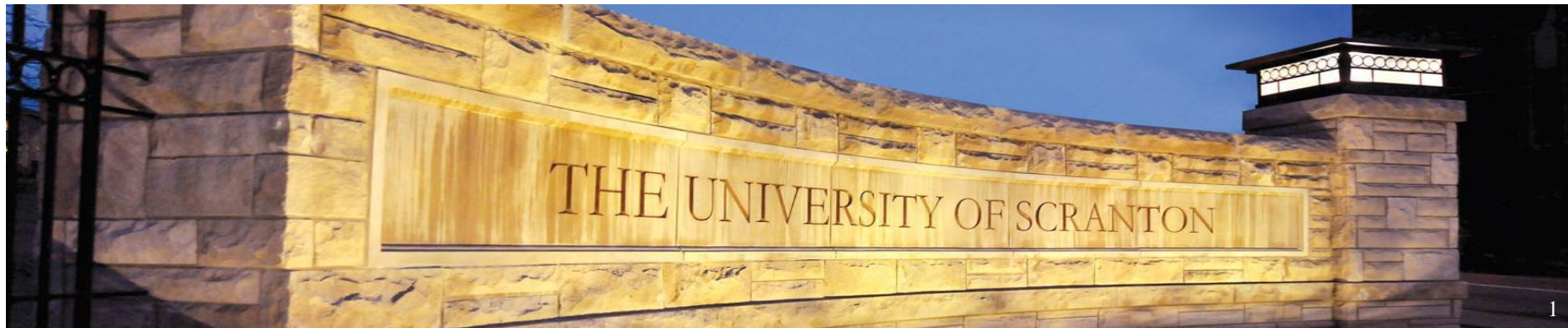
How Graded Exercise Testing is Being Utilized in the Clinical Management of Concussion: A Systematic Review

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Overview



- Introduction
- Purpose
- Database
- Search Terms
- Sackett Level
- PRISMA
- Results
- Discussion
- Clinical Relevance



Concussion Overview¹

- Impact to the head or body
- Diffuse axonal injury caused by acceleration/deceleration of gray and white matter
 - Shearing effect of axons creating a mechanical stretch of cell membrane
- Leads to a multitude of effects - metabolic cascade
 - Ionic influx
 - Diffuse depolarization
 - Calcium influx
 - Mitochondrial swelling
- Region mainly affected is subcortical areas of the brain
 - Confirmed by imaging studies using Diffuse Tensor Imaging observing the lack of water diffusion deep to the cerebral cortex



Introduction



Symptoms^{1,2}

- Headache
- Nausea/Vomiting
- Balance and/or gait disturbance
- Dizziness
- Tinnitus
- Photophobia
- Difficulties focusing
- Slowed speech
- Lightheadedness
- Extreme fatigue
- Memory/cognitive dysfunction

Signs^{1,2}

- Retrograde amnesia
- Anterograde amnesia
- Disorientation
- Confusion
- Gait imbalance
- Memory deficits





Post-Concussion Subtypes^{2,3}

- Physiologic
 - Cerebral blood flow
 - Cellular metabolism
 - Ion transport regulation
- Vestibulo-ocular
 - Disruption of vestibulo-ocular reflex
 - Disruption of vestibulo-spinal reflex
 - Visual dysfunction
- Cervicogenic
 - Dysfunction of the cervical spine somatosensory system
 - Disruption of proprioception





Buffalo Concussion Treadmill Test (BCTT)/Modified Balke Protocol^{3,4}

- Equipment: Treadmill or cycle ergometer
- Objective measures: heart rate (HR), post-concussion symptom scale (PCSS), rate of perceived exertion (RPE)
- Start at 0% incline and 3.2-3.6 mph increasing 1% incline each minute
- Test is terminated after total exhaustion or symptom exacerbation of 3 or greater
- Each minute objective measures were assessed
- Inter rater reliability (95%), Retest reliability (79%)⁵
- Sensitivity (99%) and Specificity (89%)⁵

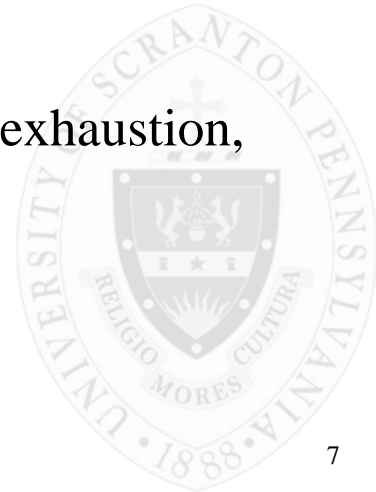


Graded Exercise Testing



McMaster All-out Progressive Continuous Cycling Test⁶

- Equipment: cycle ergometer
- Objective measures: HR, PCSS, and RPE
- Begin at 25-85W pedaling at 60 rpm with progressive increase in work rate every 2 minutes
- Test terminated if pedaling rate dropped below 50 rpm for 3 s, exhaustion, increase in concussion like symptoms
- Objective measures were assessed every 2 minutes





The purpose of this study was to determine how graded exercise testing (GET) is being utilized in the clinical management of individuals following a concussion.





Databases

- PubMed
- CINAHL
- Google Scholar
- ProQuest Central



Search Terms

(“Concussion” **OR** “mTBI” **OR** “mild traumatic brain injury)

AND

(“Buffalo” **OR** “Balke” **OR** “graded exercise testing”)





Search Limits

- English language
- Human subjects
- Peer-reviewed



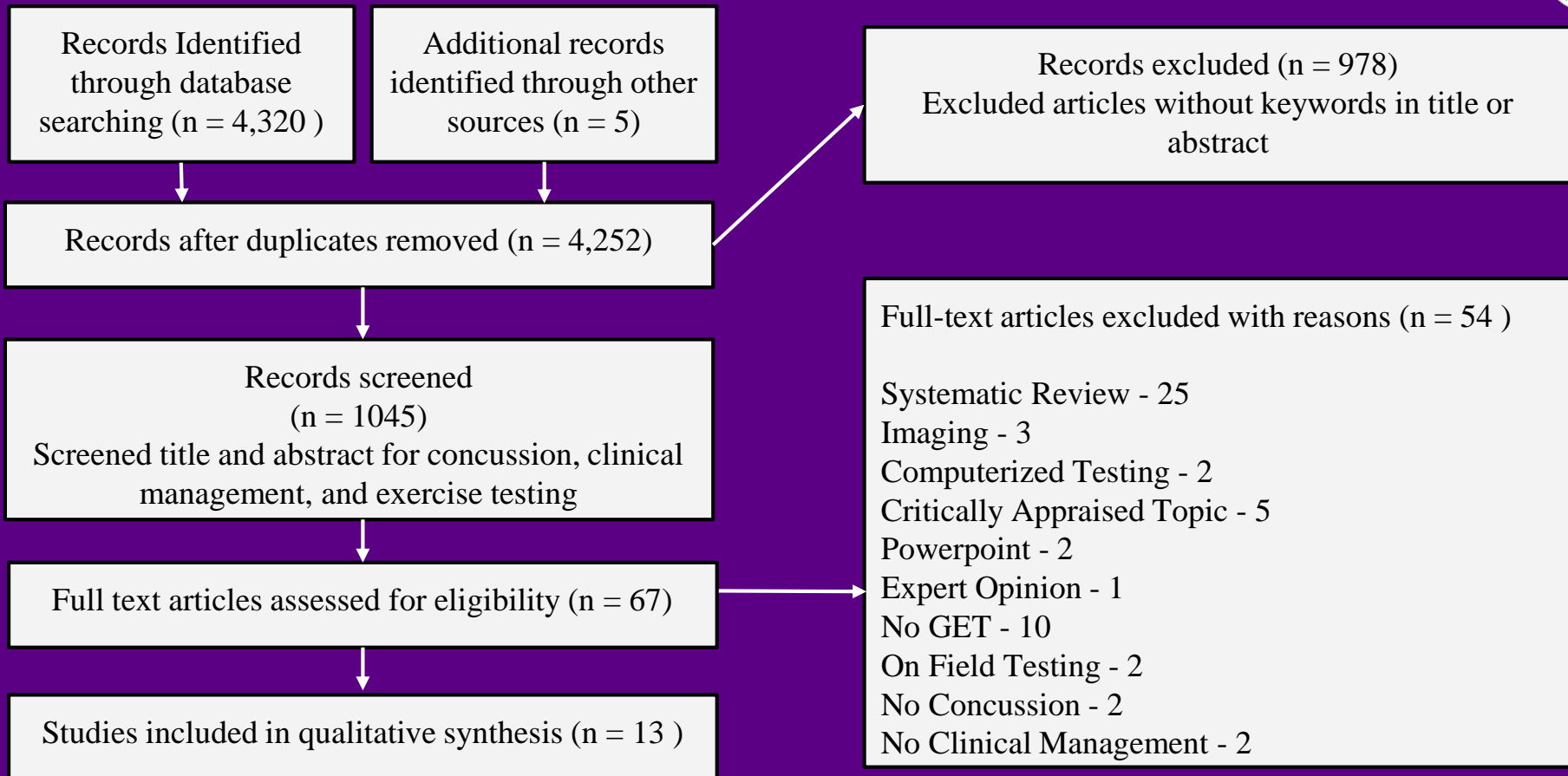


Selection Criteria

- Original research
- Individuals with concussion or post concussion syndrome
- Graded exercise testing
- PT clinical management



PRISMA



Sackett Levels



Article Citation	Study Design	Sackett Score
Cordingly et al. ³	Retrospective chart review	4
Leddy JJ et al. ⁴	Prospective randomized controlled trial	1b
Dematteo et al. ⁶	Cross-sectional study	2b
Darling SR et al. ⁷	Retrospective chart review	4
Kozlowski et al. ⁸	Cross-sectional study	2b
Leddy et al. ⁹	Prospective case series	4
Baily NF ¹⁰	Case Report	4
Moore BM et al. ¹¹	Prospective Longitudinal Design	2c
Manikas et al. ¹²	Pre-Post Prospective Design	4
Chrisman et al. ¹³	Retrospective Cohort Study	4
Grabowski et al. ¹⁴	Retrospective Cohort study	4
Gunter et al. ¹⁵	Case Report	4
Anderson V et al. ¹⁶	Case-Controlled Study	3b

Results



- Total of 613 subjects with an age range of 10-72 years old were included
- Mechanism of injury varied
 - 10 articles Sports Related Concussion (SRC)^{3,4,7-9,11-15}
 - 5 articles MVA/falls^{8-11,13}
 - 2 not specified^{6,16}
- Time since injury was not clearly defined
 - 5 articles acute concussion^{3,4,7,15,16}
 - 10 articles chronic concussion^{3,6-14}





Clinical Management

- Diagnosis
 - Determine subtype involvement
- Prognosis
 - Length of recovery correlated with heart rate upon symptom exacerbation
- Return to Play (RTP)
 - Decision making and timeline
- Treatment Plan
 - Subsymptom threshold and subtype management





- Buffalo Concussion Treadmill Test/Modified Balke Protocol was utilized in 10 articles^{3,4,7-10,11,13-15}
 - 5 used the BCTT as a diagnostic tool^{3,8,10,14,15}
 - 2 as a prognostic tool^{3,4}
 - 7 for treatment planning^{3,9,10,11,13,14,15}
 - 2 for RTP decision making^{3,7}
- McMaster All-out Progressive Continuous Cycling Test was used in 3 articles^{6,12,16}
 - All 3 articles the MAPCCT was used for RTP and prognosis
- Modified cycle ergometer protocol used for diagnosis and treatment planning¹¹



Results



Article Citation	Graded Exercise Test	Diagnosis	Prognosis	RTP	Treatment
Cordingly et al. ³	BCTT/Modified Balke Protocol	X	X	X	X
Leddy JJ et al. ⁴	BCTT/Modified Balke Protocol		X		
Dematteo et al. ⁶	McMaster All-Out Progressive Continuous Cycle Test		X	X	
Darling SR et al. ⁷	BCTT/Modified Balke Protocol			X	
Kozlowski et al. ⁸	BCTT/Modified Balke Protocol	X			
Leddy et al. ⁹	BCTT/Modified Balke Protocol				X
Baily NF ¹⁰	BCTT/Modified Balke Protocol	X			X
Moore BM et al. ¹¹	Modified Cycle Ergometer Protocol				X
Manikas et al. ¹²	McMaster All-Out Progressive Continuous Cycle Test	X			
Chrisman et al. ¹³	BCTT/Modified Balke Protocol				X
Grabowski et al. ¹⁴	BCTT/Modified Balke Protocol	X			X
Gunter et al. ¹⁵	BCTT/Modified Balke Protocol	X			X
Anderson V et al. ¹⁶	McMaster All-Out Progressive Continuous Cycle Test		X		

Results



- All 13 articles assessed HR and used a symptom exacerbation scale as objective measures^{3,4,6-16}
- 4 used blood pressure^{3,8,9,11} and 7 used RPE to monitor patients throughout testing^{3,6,8,9,11,13,16}
- Safety in clinical management was assessed in 6 out of 13 articles^{3,4,7,9,13,14}



Discussion



- Articles reviewed suggest that graded exercise testing is utilized for multifactorial clinical management of concussion
- Graded exercise testing may be safely implemented in the acute and chronic stages of concussion management



Limitations



- Limited number of strong evidence studies
- The developer of the BCTT, Dr. John Leddy, as the primary author and/or contributor of the majority of articles reviewed
- Lack of standardization in the use of graded exercise testing amongst researchers and clinicians



Future Research



- Further research is needed to assess how graded exercise testing can be utilized as a standardized approach
- Future studies for standardization should include
 - Testing vs. stage of recovery
 - Physical therapy concussion evaluation
 - Utilization of treadmill compared to cycle ergometer
 - Psychometric values of special populations



Clinical Relevance



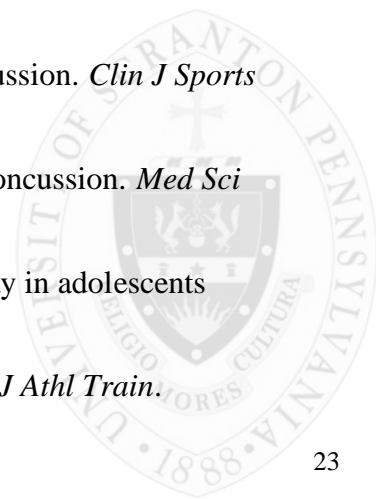
- Graded exercise testing can be utilized to
 - Diagnose concussion subtypes
 - Determine treatment at subsymptom threshold
 - Predict recovery time
 - Guide return to play decision making
- Graded exercise testing can be safely and feasibly implemented in PT clinical examination and management of concussion



References



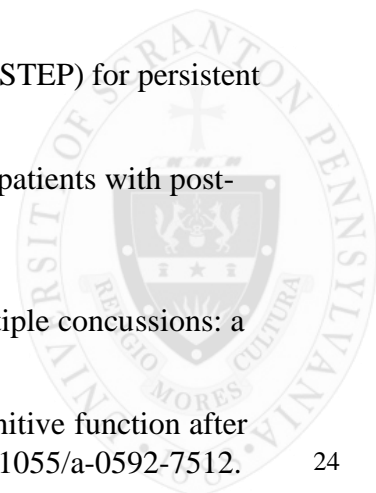
1. Barkhoudarian G, Hovda DA, Giza CC. The molecular pathophysiology of concussive brain injury. *Clin Sports Med.* 2011;30:33-48. doi: 10.1016/j.csm.2010.09.001
2. Ellis MJ, Leddy JJ, Willer B. Physiological, vestibulo-ocular and cervicogenic post-concussion disorders: an evidence-based classification system with directions for treatment. *Brain Injury.* 2015;29(2):238-248. doi: 10.3109/02699052.2014.965207
3. Cordingley D, Girardin R, Reimer K, et al. Graded aerobic treadmill testing in pediatric sports-related concussion: safety, clinical use, and patient outcomes. *J Neurosurg Pediatr.* 2016;18(6):693-702. doi:10.3171/2016.5.PEDS16139
4. Leddy JJ, Hinds AL, Miecznikowski et al. Safety and prognostic utility of provocative exercise testing in acutely concussed adolescents: a randomized trial. *Clin J Sport Med:* 2017;0:1-8 doi: 10.1097/JSM.0000000000000431
5. Leddy JJ, Baker JG, Kozlowski K, et al. Reliability of a graded exercise test for assessing recovery from concussion. *Clin J Sports Med.* 2011;21(2):89-94
6. Dematteo C, Volterman KA, Breithaupt PG, et al. Exertion testing in youth with mild traumatic brain injury/concussion. *Med Sci Sports Exerc.* 2015;47(11):2283-2290. doi: 10.1249/MSS.0000000000000682
7. Darling SR, Leddy JJ, Baker JG, et al. Evaluation of the zurich guidelines and exercise testing for return to play in adolescents following concussion. *Clin J Sport Med.* 2014;24(2):128-133. doi:10.1097/jsm.0000000000000026
8. Kozlowski KF, Graham J, Leddy JJ, et al. Exercise intolerance in individuals with post concussion syndrome. *J Athl Train.* 2013;48(5):627-635. doi:10.4085/1062-6050-48.5.02



References



9. Leddy JJ, Kozlowski K, Donnelly JP, et al. A preliminary study of subsymptom threshold exercise training for refractory post-concussion syndrome. *Clin J Sport Med.* 2010;20(1):21-27. doi: 10.1097/JSM.0b013e3181c6c22c
10. Bailey NF. Unique physical therapy management of a young adult with post-concussion symptoms: a case report. *IJSSPT.* 2015;1:1-11.
11. Moore BM, Adams JT, Barakatt E. Outcomes following a vestibular rehabilitation and aerobic training program to address persistent post-concussion symptoms. *J Allied Health.* 2016;45(4):e59-e68.
12. Manikas V, Babl FE, Hearps S, et al. Impact of exercise on clinical symptom report and neurocognition after concussion in children and adolescents. *J Neurotrauma.* 2017;34:1932-1938. doi: 10.1089/neu.2016.4762
13. Chrisman SPD, Whitlock KB, Somers E, et al. Pilot study of the sub-symptom threshold exercise program (SSTEP) for persistent concussion symptoms in youth. *NeuroRehabil.* 2017;40:493-499. doi: 10.3233/NRE-161436
14. Grabowski P, Wilson J, Walker A, et al. Multimodal impairment-based physical therapy for the treatment of patients with post-concussion syndrome: a retrospective analysis on safety and feasibility. *Phys Ther Sport.* 2017;23:22-30. doi: 10.1016/j.ptsp.2016.06.001
15. Gunter KB, Shields CJ, Ott SD, et al. Rehabilitation of an adolescent equestrian athlete with a history of multiple concussions: a case report describing an adapted return to sport protocol. *JOSPT.* 2018;1-31. doi: 10.2519/jospt.2018.8214
16. Anderson V, Manikas V, Babl FE, et al. Impact of moderate exercise on post-concussive symptoms and cognitive function after concussion in children and adolescents compared to healthy controls. *Int J Sport Med.* 2018;39:696-703. doi: 10.1055/a-0592-7512.



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Questions?



Appendix



Subject ID _____

Rate Your Overall Condition

0	1-2	3-4	5-6	7-8	9-10
Feel terrific, no symptoms	Feel some symptoms but quite tolerable	Symptoms a little worse	Symptoms much worse	Feeling quite symptomatic	Feel terrible, worst I ever felt

Min	HR	RPE	Likert Scale	New Symptom?	Comments/Observations
Rest					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

