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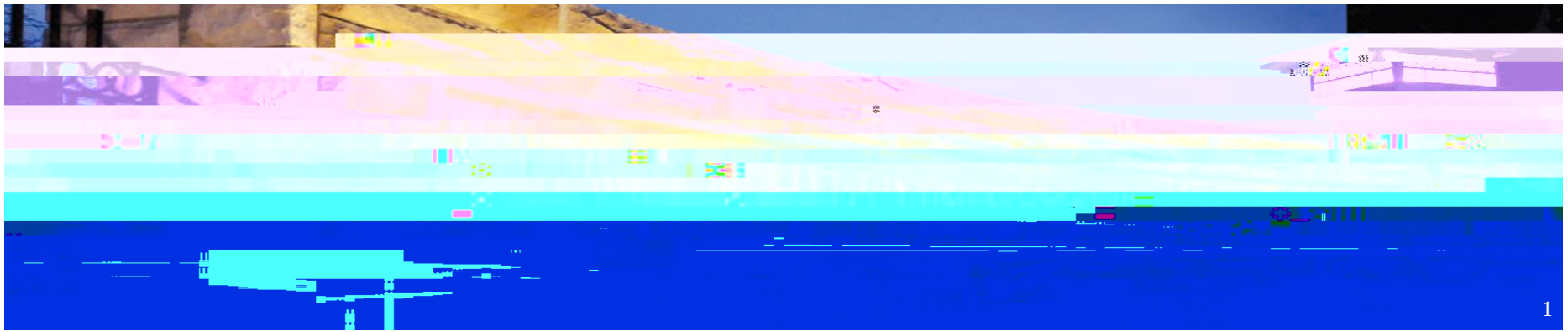

Concussion Overview

- 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 echa/MCIecha/MCIecha/M

Symptoms

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

Signs

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

Post-Concussion Subtypes

- 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

- 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]

McMaster All-out Progressive Continuous Cycling Test

- 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
- CINHAL
- 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

Records Identified through database searching (n = 4,320)

Additional records identified through other sources (n = 5)

Records after duplicates removed (n = 4,252)

Records screened
(n = 1045)
Screened title and abstract for concussion, clinical management, and exercise testing

Studies included in qualitative synthesis (n = 13)

Records excluded (n = 978)
Excluded articles without keywords in title or abstract

Full-text articles excluded with reasons (n = 54)

Systematic Review - 25

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

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 planning[11]

Article Citation	Graded Exercise Test	Diagnosis	Prognosis	RTP	Treatment
Cordingly et al.[3]	BCTT/Modified Balke Protocol	X	X	X	X

- 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]

- 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

- Further research is needed to assess how graded exercise testing can be utilized as a standardized approach
- Future studies for standardization should include
  -

- Graded exercise testing can be utilized to
  - Diagnose concussion subtypes
  - Determine treatment at subsymptom threshold
  - Predict recovery time
  - Guide return to play decision making
-

1. Barkhoudarian G, Hovda DA, Giza CC. The molecular pathophysiology of concussive brain injury. *Clin Sports Med.* 2011;30:33

9. Leddy JJ, Kozlowski K, Donnelly JP, et al. A preliminary study or subsymptom threshold exercise training for refractory post-concussion syndrome. *Clin J Sport Med.* 2010;20(1):21-27. doi: 10.1097/JSM.0b013e3181c6c22c

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