Matthew J. Morahan, III
Health Assessment Center for Athletes
RWJBarnabas Health

Retraining your Brain to Move: An Active Return Towards Brain Health following Head Injury

Diana Toto, M.S.
Program Director
Matthew J. Morahan III Health Assessment Center for Athletes
Sports Medicine and Business Development

RWJBarnabas HEALTH

Encouraging an Active Return

What is included in Active Brain Healing?

The Launch of active recovery

What's new?

- Deconditioning the body post brain injury can slow recovery.
- Prolonged brain rest beyond 48 hours is controversial.

KEEP MOVING!!!!!

Create a cross-disciplinary approach for academic and functional, and physical return.

- Acutely refer and Assess!
- Lost time means lost recovery!
- Quicker intervention with rehabilitation where needed for PCS patients.

Acute Diagnosis Decision Making

Sideline and Subjectivity

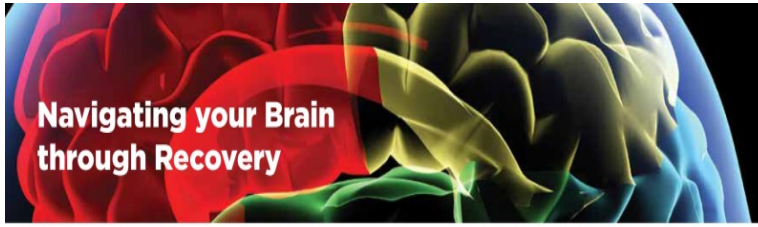
- VOMS
- KD
- Scat 5
- C-spine

The eyes don't lie! Induce acutely. Don't wait!

Impact is becoming more of a subacute testing mechanism for accuracy.

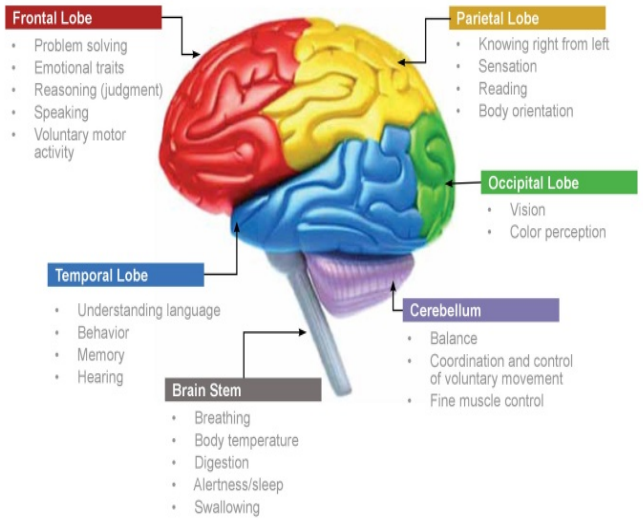
Determine- How do we categorize concussion severity? (Grading Vs. Pillar system)

What's in your tool kit; Inducing vs Reducing Symptomatology



Navigating your Brain through Recovery

Without a true diagnostic tool, blood biomarker or special imaging (MRI, CT) that can diagnose concussion, clinicians have to rely on tools to assess different areas of the brain to determine any potential functions of the brain that can be compromised. Your brain supports every movement and major function in life including functions as crucial as the ability to breathe. Each lobe of the brain is responsible for different roles such as speech, reading, distinguishing between colors, balance, coordination, sleep, memory, behavior, and hearing. At the Morahan Center see how we are combating second impact syndrome by assessing every aspect of your brain.



Every brain heals at a different pace and over a different time span. Some brains can take weeks or months to heal, while others can experience long term symptoms that last years and even decades. The rate of recovery can be altered by psychological issues, Attention Deficit Hyperactivity Disorder (ADHD), gender, and other variable factors. Recovery is generally extended with every repeat injury or with a multiple concussion history as well as with patients or athletes that fail to report symptoms honestly or follow school accommodations or restrictions. It is very important to report symptoms honestly for this reason. Avoiding long term issues following a brain injury is largely dependent on ensuring the first concussion heals correctly. During a concussion one or several areas of the brain can be affected. Each area of the brain controls different functions for movement, motor skills, coordination, vision and daily function. Our colored brain map addresses each area of your brain and the ability to assess, track improvement, and map recovery of every brain injury with an individualized plan of care.

Areas of the Brain Testing Targets	Testing Type	Appropriate Ages	Testing Facts
Frontal Lobe Occupital Lobe Parietal Lobe Cerebellum	King-Devick Testing	5 and up	50% of the brain's pathways are tied to vision. Following a suspected brain injury, the King- Devick (KD) Test tracks Saccadic Eye Movements and asks participants to read numbers from left to right. Baseline testing prior to an injury, includes several timed trials measuring eye speed as the participant verbalizes numbers aloud. The total time of all three cards (cards two through 4) without errors becomes the participant's baseline. Significant delay in eye movement speed and an increase in errors recorded is a significant change that can be found post -concussion when compared to baseline. This deficit may be detected in the acute phase following a suspected Brain Injury. The KD can also assess difficulty reading or with screen use following a concussion.
Frontal Lobe Occupital Lobe Temporal Lobe	ImPACT Testing	5 and up	ImPACT (Immediate Post Concussion Assessment and Cognitive Testing) is an interactively administered computerized exam. This software program was developed by The University of Pittsburgh Medical Center's (UPMC) Sports Concussion program. It challenges the brain and tracks information such as memory, reaction time, processing speed, and concentration. A baseline, pre-injury ImPACT test is recommended every two years. If the athlete later suffers a brain injury, she/he can then retake this test. Any changes since the baseline test was taken may help determine the severity of the injury and the pace at which it is healing.
Cerebellum Occupital Lobe	Vestibular Ocular Motor Screening (VOMS)	10 and up	Ocular-Motor dysfunction occurs when muscles in the eye are not properly coordinated for eye movement. This dysfunction is common following concussion and can be a large contributing cause to visual disturbances during recovery and frequent headaches or symptoms. The VOMS can assess if ocular-motor dysfunction exists as well as issues with balance or vestibular issues. It is completed by a clinician or physician in both the baseline and post-concussion setting to help assist the clinical team in returning deficits back to normal prior to returning to the field. This issue can effect hand and eye coordination in sports as well as concentration and reading in school.
Frontal Lobe Cerebellum Brain Stem	Treadmill Testing	10 and up	Treadmill testing is a valuable tool for clinicians to determine physical function sooner after an injury. A child that becomes symptom free more quickly can be taken through a basic treadmill test to see if they are eligible for the Return to Play protocol to begin. This becomes especially important for children that do not have an ImPACT baseline to compare to or for children that struggle with successfully completing neuro-cognitive tests. Treadmill testing is also valuable in determining exercise tolerance as well as determining whether the body's response to exercise is normal when a child is still experiencing symptoms. Symptomatic treadmill testing is a significant help to our physical therapy team in determining an appropriate plan of care and gradual return to sports.

BLAST FROM THE PAST

OLD SCHOOL

- Cognitive rest/removal from school until symptom free (no graduated return)
- Prolonged symptomatology (≥ 3 weeks)prior to rehabilitative intervention.
- Impact test- highest weighted assessment
- No visual testing
- 100% asymptomatic before physical intervention

NEW SCHOOL

- 48 hours ***complete*** brain rest then gradual re-introduction of stimulus.
- 14 days- rehab intervention (or earlier based on symptomatology)
- Ocular-motor/physiologic response- highest weighted assessment
- Visual testing from sideline through complete resolve
- Symptom threshold based intervention with pillar focus

BERLIN ON BRAINS

5TH INTERNATIONAL CONCUSSION CONFERENCE IN SPORT (Berlin)

Newest changes

- **Complete cognitive rest not validated after 48 hours**
- **Symptom threshold through activity/cognition in acute phase**
- **Focus on pillars for recovery (ocular-motor/cognitive/exercise threshold/cervical)**
- **Defining PCS in children (>4 weeks with symptoms)**

****Having a low level of a person's initial symptoms in the first day or initial few days after injury is a favorable prognostic indicator.**

**** Children with a pre-injury history of mental health problems or migraines appear to be at somewhat greater risk of having symptoms >1 month**

**** ADHD- challenging intervention with return to school but no relevant data showing persistent symptoms > 1 month.**

LEDDY LEADS THE CHARGE (University of Buffalo)

Sports Related Concussion(SRC)

- 7-10 days typical for recovery (may be delayed in children/adolescents)
- Recent research accounts for Vestibular-ocular/motor problems that often accompany SRC suggests recovery for adolescents may take 3-4 weeks.

Are you up for the challenge?

- Concussion or secondary factor (Migraines, Cervical injury, depression).
- Assess pillars in depth; take solid medical history.
- SLOWER EXERCISE TOLERENCE=SLOWER RECOVERY

Defining PCS(SRC vs. non SRC)

- Definitions of PCS varies across literature
- SRC > 10 days vs non SRC >3 weeks.

LEDDY LEADS THE CHARGE (University of Buffalo)

The scoop on CBF

- Cerebral blood flow increases during exercise
- Following concussion we typically see a loss of CBF control
- With deconditioning we also see a natural loss of control with CBF causing fatigue, slowed cognition, symptoms, inability to exercise to max capacity and abnormal elevations in CBF; negative effect on autoregulation.

How do we improve CBF?

- Exercise can improve CBF by calculating 80%-90% of symptom threshold or by increasing THR 5-10 bpm every 1-2 weeks.
- SLOWER EXERCISE TOLERENCE=SLOWER RECOVERY

New methods

Activate autonomic NS early on and try to help restore CBF through early activity such as low level movements to maintain conditioning (light walking, jogging, biking). Avoid weight training till final stages of RTP.

New study from UB in 2017 with new improvements with this theory. Low level programs starting days after injury with quicker recovery timelines.

Berlin states, " closely monitored active rehabilitation programs involving controlled sub-symptom threshold, submaximal exercise have been shown to be safe and may be of benefit in facilitating recovery."

What we can learn from studying physiological response to exercise following concussion

What we know

- Athletes have decreased Heart Rate Variability (HRV) when concussed - Indicating Sympathetic Nervous system is taking over
- Increased HRV is a positive response to HR recovery (Improved symptom threshold)
- Increase DBP has been seen in those still recovering from concussion.

Concussion Pillars for Recovery

ALL PILLAR GOALS MUST BE ACCOMPLISHED PRIOR TO CLEARANCE TO RETURN TO FULL ACADEMICS AND SPORT.

CARDIOVASCULAR THRESHOLD AND EXERCISE TOLERANCE

*May require pediatric cardiologist evaluation

Assessments and Evaluation:

- Low Level Home Exercise Programs
- Treadmill Testing
- Physical Therapy Evaluation and Treatment
- Return to Play Progression

Goals and Objectives:

Recovery phase: Improve exercise tolerance and symptom thresholds as well as an increase in exercise intensity and duration.

Prior to Clearance: Complete a high level (90% heart rate goal) of exercise symptom free.

OCULAR-MOTOR & VESTIBULAR FUNCTION (Vision and Balance)

**May require Neuro-ophthalmology evaluation

Assessments and Evaluation:

- Vestibular Ocular Motor Screening (VOMS)/ King-Devick Testing (KD testing)
- Balance Assessment
- Physical Therapy Evaluation and Treatment
- Return to Play Progression
- Return to Learn Progression

Goals and Objectives:

Recovery phase: Improve dynamic multiplane and eye control.

Prior to Clearance: Demonstrates normal balance for age and athletic ability.

Able to perform return to play tasks symptom free. as able to perform return to play tasks symptom free.

CERVICAL/SPINAL

***May require Pediatrician/ Orthopedic evaluation

Assessments and Evaluation:

- Vestibular Ocular Motor Screening (VOMS)
- Treadmill Testing
- Balance Assesement Physical Therapy Evaluation and Treatment
- Return to Play Progression
- Return to Learn Progression

Goals and Objectives:

Recovery phase: Improve neck and spine range of motion, strength, and control.

Prior to Clearance: Demonstrate Full range of motion and normal neck and spine control without the worsening of symptoms or cervical/spinal pain during return to play and return to learn progression.

BEHAVIORAL/ COGNITIVE

**May require cognitive therapy and/or neuropsychological evaluation

Assessments and Evaluation:

- Symptom Log
- Memory, dual tasking, and processing
- Cognitive tasks
- Behavioral Monitoring
- Physical Therapy Evaluation and treatment
- Return to Play Progression
- Return to learn Progression

Goals and Objectives:

Recovery phase: Improve supervised controlled return to previous academic and social environment.

Prior to Clearance: Demonstrates ability to complete full participation in previous level of academia symptom free.

Able to participate in social activity symptom free.

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Let's be healthy together.

Pillar #1
Cardiovascular

- Modified Balke protocol
  - 2 minutes between stages
  - Progressive increase in speed and incline
    - @ 8 minutes this will be variable depending the level of athlete
    - THINK: desired HR
      - RTP: 70%, 80%, 90% resting HR reserve (HRR)

Pillar #1
Cardiovascular

Clinical Pearls

- Some patients will greatly improve when pushed.
- BE VERY AWARE some will Crash.
  - If symptoms increase > 2 levels stop the task (NCAA level athletes can be pushed 3 points).
- Rehabilitation focuses on dual tasking with TM tests as the pillar progresses.
- Typically in active recovery- A large percentage of initial evals will pass TM testing with no symptom change during the acute phase.
- Bike protocol option (All thresholds should always be assessed upon initial evaluation).

New Bike Protocol

BCTT Output Conversion - Microsoft Excel

Stage (%grade)	VO2	METs	BW (KG)	Workload (Watts)
0	13.1	3.74	93	46.5186
1	14.83	4.24		59.71158
2	16.56	4.73		72.90456
3	18.28	5.22		86.02128
4	20.01	5.72		99.21426
5	21.74	6.21		112.40724
6	23.47	6.71		125.60022
7	25.2	7.2		138.7932
8	26.92	7.69		151.90992
9	28.67	8.19		165.25542
10	30.38	8.68		178.29588
11	32.12	9.17		191.56512
12	33.85	9.67		204.7581
13	35.56	10.16		217.79856
14	37.92	10.65		235.79592
15	39.03	11.15		244.26078

Karvonen Review

Age Predicted Maximum Heart Rate (APMHR) 220 – Age = APMHR
MHR x % intensity = Target Heart Rate (THR)

RTP Stage II Sample
Example: 16 year old at 70% intensity
220 – 16 = 204
204x 0.70 = 143 bpm

Karvonen Formula - Heart Rate Reserve (HRR) 220 – Age = MHR
MHR – Resting Heart Rate = HRR
(HRR x % intensity) + RHR

RTP Stage II Karvonen Review
THR Example: 16 year old,
resting heart rate = 62 bpm, at 70% intensity
220 – 16 = 204
204– 62 = 142
142x 0.70 = 99 + 62 = 161 bpm

Why Karvonen? One of the problems with the APMHR equation is that it makes no allowances for individual differences in resting heart rate. By incorporating the heart rate reserve into the equation, in theory a more accurate training zone can be determined.

Pillar # 2 Vestibular/Ocular System

- Vision, Balance, Coordination
  - **Ability to sense, predict and prevent multi-planer movement (Linear, Angular/Rotational, Ve**locity, Gravitational)
  - Balance assessments
  - Baseline Vision

Pillar # 2 Vestibular/Ocular System

- Remember: The Vision system drives function
  - Primary complaints:
    - Head aches all day
    - Blurred vision
    - Double vision
    - Photophobia
    - Eye fatigue
    - Dizziness / Vertigo
  - #1 Trouble with Screens/ School/ Reading

  - Headaches/Dizziness are two key symptoms most frequently reported upon initial injury that we are finding in studies (A high volume correlate with ocular motor dysfunction)

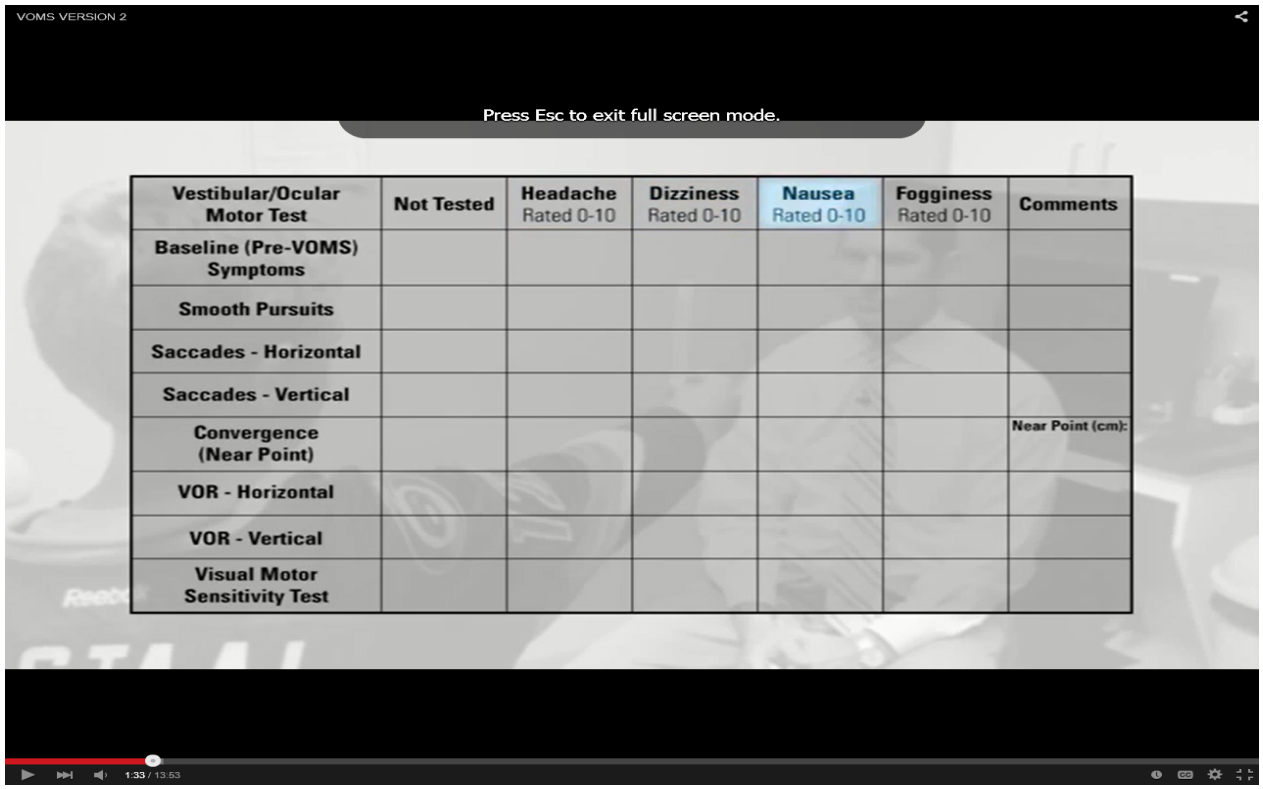
Pillar # 2 Vestibular/Ocular System

- VOMS
  - Pursuit, Saccades, VOR,Con/Div
- Accommodation
- Dynamic Visual Acuity (DVA) (head laser)
  - 2 line difference
- Convergence/ Divergence → Fast or Jumps
- Saccadic Head Turns
- Ocular Misalignment

VOMS

VESTIBULAR OCULAR MOTOR SCREENING

- Physician assessment to help determine neurological dysfunction
- Symptom score of 0-10
- Baseline scoring in the office completed just prior to administration of the VOMS and after each module is completed.
- Any change pre to post after completing the modules may indicate signs of concussion.
- 30 Reps VOR= 5 mins. reading



Vestibular/Ocular Motor Test	Not Tested	Headache Rated 0-10	Dizziness Rated 0-10	Nausea Rated 0-10	Fogginess Rated 0-10	Comments
Baseline (Pre-VOMS) Symptoms						
Smooth Pursuits						
Saccades - Horizontal						
Saccades - Vertical						
Convergence (Near Point)						Near Point (cm):
VOR - Horizontal						
VOR - Vertical						
Visual Motor Sensitivity Test						

*****Endorsed and validated by UPMC***

******Validated for non-healthy controls and healthy controls***

******Taking VOMS research one step further?***

A Brief Vestibular/Ocular Motor Screening (VOMS) Assessment to Evaluate Concussions (American Journal Of Sports Medicine)

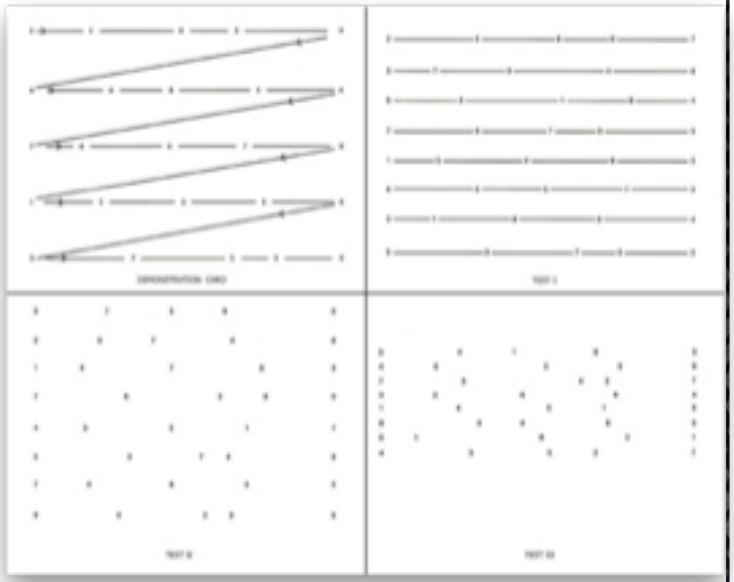
- 2014 study
- Sixty-four patients, aged 13.9 ± 2.5 years and seen approximately 5.5 ± 4.0 days after a sport-related concussion
- Sixty-one percent of patients reported symptom provocation after at least 1 VOMS item.
- All VOMS items were positively correlated to the PCSS total symptom score.
- The VOR and VMS components of the VOMS were most predictive of being in the concussed group.
- An NPC distance ≥5 cm and any VOMS item symptom score ≥2 resulted in an increase in the probability of correctly identifying concussed patients of 38% and 50%, respectively.

Why do VOMS on the sideline??

Assessments at the Forefront: King Devick Test

50% of the brain's pathways are tied to vision

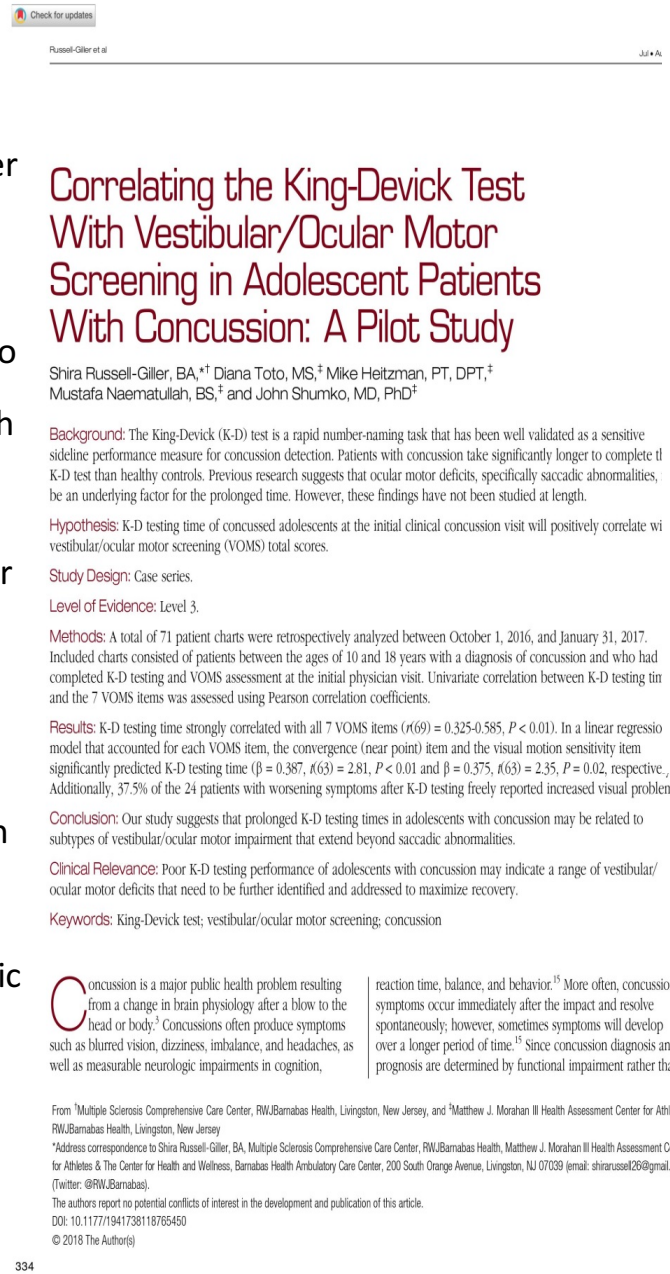
- Sideline assessment or tool to assess suspicion of concussion. Recommended within the first 24 hours of impact.
- Measurement on the speed of rapid number naming.
  - *Timed test for reading single digit numbers on a card from left to right.*
- Evaluate eye movement, attention, and language to assess the baseline brain function, allowing the ability to predict worse outcomes in concussion.
- Baseline obtained; repeat testing done on sideline after injury to determine if a deficit exists at time of injury.
- Method of baseline for younger subjects
- Demo testing



- https://kingdevicktest.com/tutorials

Morahan center research : A focus on Vision

- In 2017 the Morahan Center begins its' retrospective study looking at visual assessment tools for concussion.
- The study was accepted into publication in and can be the Journal of Sports Health in 2018.
- The study looked at 71 patients (between 10-18) and compared ocular-motor dysfunction through basic visual motor assessments including King Devick (K-D) and VOMS (Vestibular Ocular Motor Screening)
- The study found strong clinical correlation between KD testing and VOMS indicating a range of vestibular ocular motor impairment beyond saccadic abnormalities.



Check for updates

Russell-Giller et al

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Correlating the King-Devick Test With Vestibular/Ocular Motor Screening in Adolescent Patients With Concussion: A Pilot Study

Shira Russell-Giller, BA,*† Diana Toto, MS,‡ Mike Heitzman, PT, DPT,‡ Mustafa Naematullah, BS,‡ and John Shumko, MD, PhD‡

Background: The King-Devick (K-D) test is a rapid number-naming task that has been well validated as a sensitive sideline performance measure for concussion detection. Patients with concussion take significantly longer to complete tl K-D test than healthy controls. Previous research suggests that ocular motor deficits, specifically saccadic abnormalities, be an underlying factor for the prolonged time. However, these findings have not been studied at length.

Hypothesis: K-D testing time of concussed adolescents at the initial clinical concussion visit will positively correlate wi vestibular/ocular motor screening (VOMS) total scores.

Study Design: Case series.

Level of Evidence: Level 3.

Methods: A total of 71 patient charts were retrospectively analyzed between October 1, 2016, and January 31, 2017. Included charts consisted of patients between the ages of 10 and 18 years with a diagnosis of concussion and who had completed K-D testing and VOMS assessment at the initial physician visit. Univariate correlation between K-D testing tin and the 7 VOMS items was assessed using Pearson correlation coefficients.

Results: K-D testing time strongly correlated with all 7 VOMS items ($r(69) = 0.325$-0.585, $P < 0.01$). In a linear regressio model that accounted for each VOMS item, the convergence (near point) item and the visual motion sensitivity item significantly predicted K-D testing time ($\beta = 0.387$, $t(63) = 2.81$, $P < 0.01$ and $\beta = 0.375$, $t(63) = 2.35$, $P = 0.02$, respective Additionally, 37.5% of the 24 patients with worsening symptoms after K-D testing freely reported increased visual problems.

Conclusion: Our study suggests that prolonged K-D testing times in adolescents with concussion may be related to subtypes of vestibular/ocular motor impairment that extend beyond saccadic abnormalities.

Clinical Relevance: Poor K-D testing performance of adolescents with concussion may indicate a range of vestibular/ocular motor deficits that need to be further identified and addressed to maximize recovery.

Keywords: King-Devick test; vestibular/ocular motor screening; concussion

Concussion is a major public health problem resulting from a change in brain physiology after a blow to the head or body.[3] Concussions often produce symptoms such as blurred vision, dizziness, imbalance, and headaches, as well as measurable neurologic impairments in cognition, reaction time, balance, and behavior.[15] More often, concussion symptoms occur immediately after the impact and resolve spontaneously; however, sometimes symptoms will develop over a longer period of time.[15] Since concussion diagnosis and prognosis are determined by functional impairment rather than

From †Multiple Sclerosis Comprehensive Care Center, RWJBarnabas Health, Livingston, New Jersey, and ‡Matthew J. Morahan III Health Assessment Center for Athletes, RWJBarnabas Health, Livingston, New Jersey

*Address correspondence to Shira Russell-Giller, BA, Multiple Sclerosis Comprehensive Care Center, RWJBarnabas Health, Matthew J. Morahan III Health Assessment Center for Athletes & The Center for Health and Wellness, Barnabas Health Ambulatory Care Center, 200 South Orange Avenue, Livingston, NJ 07039 (email: shirarussell26@gmail.com) (Twitter: @RWJBarnabas).

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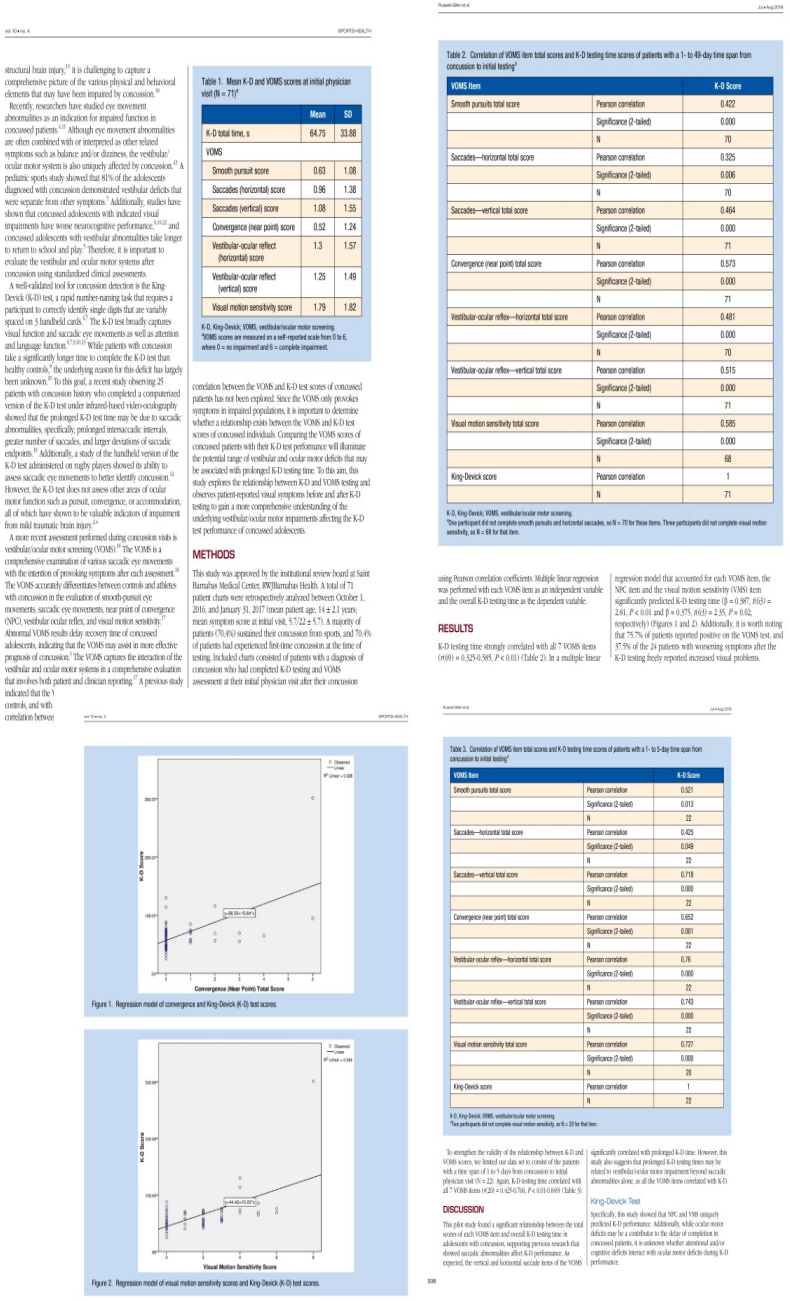


structural brain injury,[15] it is challenging to capture a comprehensive picture of the various physical and behavioral elements that may have been impaired by concussion.[16]

Recently, researchers have studied eye movement abnormalities as an indication for impaired function in concussed patients.[5,17] Although eye movement abnormalities are often combined with or interpreted as other related symptoms such as balance and/or dizziness, the vestibular/ocular motor system is also uniquely affected by concussion.[15] A pediatric sports study showed that 81% of the adolescents diagnosed with concussion demonstrated vestibular deficits that were separate from other symptoms.[5] Additionally, studies have shown that concussed adolescents with indicated visual impairments have worse neurocognitive performance,[5,10-12] and concussed adolescents with vestibular abnormalities take longer to return to school and play.[7] Therefore, it is important to evaluate the vestibular and ocular motor systems after concussion using standardized clinical assessments.

A well-validated tool for concussion detection is the King-Devick (K-D) test, a rapid number-naming task that requires a participant to correctly identify single digits that are variably spaced on 3 handheld cards.[13] The K-D test broadly captures visual function and saccadic eye movements as well as attention and language function.[5,7,9,10,12] While patients with concussion take a significantly longer time to complete the K-D test than healthy controls,[9] the underlying reason for this deficit has largely been unknown.[9] To this goal, a recent study observing 25 patients with concussion history who completed a computerized version of the K-D test under infrared-based video-oculography showed that the prolonged K-D test time may be due to saccadic abnormalities, specifically, prolonged intersaccadic intervals, greater number of saccades, and larger deviations of saccadic endpoints.[17] Additionally, a study of the handheld version of the K-D test administered on rugby players showed its ability to assess saccadic eye movements to better identify concussion.[12] However, the K-D test does not assess other areas of ocular motor function such as pursuit, convergence, or accommodation, all of which have shown to be valuable indicators of impairment from mild traumatic brain injury.[2,4]

A more recent assessment performed during concussion visits is vestibular/ocular motor screening (VOMS).[18] The VOMS is a comprehensive examination of various saccadic eye movements with the intention of provoking symptoms after each assessment.[18] The VOMS accurately differentiates between controls and athletes with concussion in the evaluation of smooth-pursuit eye movements, saccadic eye movements, near point of convergence (NPC), vestibular ocular reflex, and visual motion sensitivity.[17] Abnormal VOMS results delay recovery time of concussed adolescents, indicating that the VOMS may assist in more effective prognosis of concussion.[1] The VOMS captures the interaction of the vestibular and ocular motor systems in a comprehensive evaluation that involves both patient and clinician reporting.[18] A previous study indicated that the V controls, and with correlation betwee

Table 1. Mean K-D and VOMS scores at initial physician visit ($N = 71$)[a]

	Mean	SD
K-D total time, s	64.75	33.88
VOMS		
Smooth pursuit score	0.63	1.08
Saccades (horizontal) score	0.96	1.38
Saccades (vertical) score	1.08	1.55
Convergence (near point) score	0.52	1.24
Vestibular-ocular reflect (horizontal) score	1.3	1.57
Vestibular-ocular reflect (vertical) score	1.25	1.49
Visual motion sensitivity score	1.79	1.82

K-D, King-Devick; VOMS, vestibular/ocular motor screening.
[a]VOMS scores are measured on a self-reported scale from 0 to 6, where 0 = no impairment and 6 = complete impairment.

correlation between the VOMS and K-D test scores of concussed patients has not been explored. Since the VOMS only provokes symptoms in impaired populations, it is important to determine whether a relationship exists between the VOMS and K-D test scores of concussed individuals. Comparing the VOMS scores of concussed patients with their K-D test performance will illuminate the potential range of vestibular and ocular motor deficits that may be associated with prolonged K-D testing time. To this aim, this study explores the relationship between K-D and VOMS testing and observes patient-reported visual symptoms before and after K-D testing to gain a more comprehensive understanding of the underlying vestibular/ocular motor impairments affecting the K-D test performance of concussed adolescents.

METHODS

This study was approved by the institutional review board at Saint Barnabas Medical Center, RWJBarnabas Health. A total of 71 patient charts were retrospectively analyzed between October 1, 2016, and January 31, 2017 (mean patient age, 14 ± 2.1 years; mean symptom score at initial visit, 5.7/22 ± 5.7). A majority of patients (70.4%) sustained their concussion from sports, and 70.4% of patients had experienced first-time concussion at the time of testing. Included charts consisted of patients with a diagnosis of concussion who had completed K-D testing and VOMS assessment at their initial physician visit after their concussion

Figure 1. Regression model of convergence and King-Devick (K-D) test scores.

Figure 2. Regression model of visual motion sensitivity scores and King-Devick (K-D) test scores.

Table 2. Correlation of VOMS item total scores and K-D testing time scores of patients with a 1- to 49-day time span from concussion to initial testing[a]

VOMS Item		K-D Score
Smooth pursuits total score	Pearson correlation	0.422
	Significance (2-tailed)	0.000
	N	70
Saccades—horizontal total score	Pearson correlation	0.325
	Significance (2-tailed)	0.006
	N	70
Saccades—vertical total score	Pearson correlation	0.464
	Significance (2-tailed)	0.000
	N	71
Convergence (near point) total score	Pearson correlation	0.573
	Significance (2-tailed)	0.000
	N	71
Vestibular-ocular reflex—horizontal total score	Pearson correlation	0.481
	Significance (2-tailed)	0.000
	N	70
Vestibular-ocular reflex—vertical total score	Pearson correlation	0.515
	Significance (2-tailed)	0.000
	N	71
Visual motion sensitivity total score	Pearson correlation	0.585
	Significance (2-tailed)	0.000
	N	68
King-Devick score	Pearson correlation	1
	N	71

K-D, King-Devick; VOMS, vestibular/ocular motor screening.
[a]Two participants did not complete smooth pursuits and horizontal saccades, so N = 70 for these items. Three participants did not complete visual motion sensitivity, so N = 68 for that item.

using Pearson correlation coefficients. Multiple linear regression was performed with each VOMS item as an independent variable and the overall K-D testing time as the dependent variable.

RESULTS

K-D testing time strongly correlated with all 7 VOMS items ($r(69) = 0.325$-0.585, $P < 0.01$) (Table 2). In a multiple linear regression model that accounted for each VOMS item, the NPC item and the visual motion sensitivity (VMS) item significantly predicted K-D testing time ($\beta = 0.387$, $t(63) = 2.81$, $P < 0.01$ and $\beta = 0.375$, $t(63) = 2.35$, $P = 0.02$, respectively) (Figures 1 and 2). Additionally, it is worth noting that 75.7% of patients reported positive on the VOMS test, and 37.5% of the 24 patients with worsening symptoms after the K-D testing freely reported increased visual problems.

Table 3. Correlation of VOMS item total scores and K-D testing time scores of patients with a 1- to 5-day time span from concussion to initial testing[a]

VOMS Item		K-D Score
Smooth pursuits total score	Pearson correlation	0.521
	Significance (2-tailed)	0.013
	N	22
Saccades—horizontal total score	Pearson correlation	0.425
	Significance (2-tailed)	0.048
	N	22
Saccades—vertical total score	Pearson correlation	0.718
	Significance (2-tailed)	0.000
	N	22
Convergence (near point) total score	Pearson correlation	0.652
	Significance (2-tailed)	0.001
	N	22
Vestibular-ocular reflex—horizontal total score	Pearson correlation	0.76
	Significance (2-tailed)	0.000
	N	22
Vestibular-ocular reflex—vertical total score	Pearson correlation	0.743
	Significance (2-tailed)	0.000
	N	22
Visual motion sensitivity total score	Pearson correlation	0.727
	Significance (2-tailed)	0.000
	N	28
King-Devick score	Pearson correlation	1
	N	22

K-D, King-Devick; VOMS, vestibular/ocular motor screening.
[a]Two participants did not complete visual motion sensitivity, so N = 20 for that item.

To strengthen the validity of the relationship between K-D and VOMS scores, we limited our data set to consist of the patients with a time span of 1 to 5 days from concussion to initial physician visit ($N = 22$). Again, K-D testing time correlated with all 7 VOMS items ($r(20) = 0.425$-0.76), $P < 0.01$-0.049 (Table 3).

DISCUSSION

This pilot study found a significant relationship between the total scores of each VOMS item and overall K-D testing time in adolescents with concussion, supporting previous research that showed saccadic abnormalities affect K-D performance. As expected, the vertical and horizontal saccade items of the VOMS significantly correlated with prolonged K-D time. However, this study also suggests that prolonged K-D testing times may be related to vestibular/ocular motor impairment beyond saccadic abnormalities alone, as all the VOMS items correlated with K-D

King-Devick Test

Specifically, this study showed that NPC and VMS uniquely predicted K-D performance. Additionally, while ocular motor deficits may be a contributor to the delay of completion in concussed patients, it is unknown whether attentional and/or cognitive deficits interact with ocular motor deficits during K-D performance.

Pillar # 2 Vestibular/Ocular System

- Vestibular focus tasked (tends to get better on it's own)
- Ambulation with HHT, VHT, DHT
  - Varying/ Progressive speeds.
- Jumping Jacks
- Stair work
- Sport specific tasks

(putting it all together)

  - Throw/ Catch, Pass/trap, Dribble

Pillar # 3 Cervical/Spinal

- **Whiplash/ Cervical strain**
- Indications
  - Aberrant cervical movement with oculomotor, or cervical screen
  - Constant Headaches
  - ***Reproducible*** Cervicogenic Headaches
  - Significant changes in balance with static head positions
  - Postural abnormalities or weakness
  - Abnormal Saccadic accuracy
  - If cervical issue is present, this pillar is often addressed first prior to others.
  - Rarer in diagnosis

C-Spine or Concussion?

Symptoms	Concussion	Cervical injury
Headache	X	X
Dizziness	X	X
Irritability	X	X
Sleep disturbances	X	X
Blurred vision	X	X
Neck stiffness	X	X
Balance disturbances	X	X
Depression	X	
Cognitive deficits	X	X
Memory deficits	X	
Attention deficits	X	X
Decreased cervical range of motion		X
Decreased isometric neck strength	X	X

Pillar # 4 Behavioral/ Cognitive

- NEW idea
  - Flight or flight response to injury
  - Stress/Anxiety/Panic loop
  - Parental or Social cause
- Sports Confidence/Mental Health
- Primary Symptoms
  - Severe symptoms that do not vary
  - Convergence spasm
  - Unable to elicit predictable symptoms within the other pillars.
  - Unable to induce symptoms with correlated tasks within other pillars.

Pillar # 4 Behavioral/ Cognitive

- Clinical pearls
  - Physiologic quieting
    - Low stimulation environment
    - Deep pressure
  - Meditation
  - Manual Therapy
- Refer
  - May require assistance from Behavioral Psychology and/or Sports Psychology.
  - Sports Confidence

PILLAR POINTS

WHEN IN DOUBT REFER OUT!!!

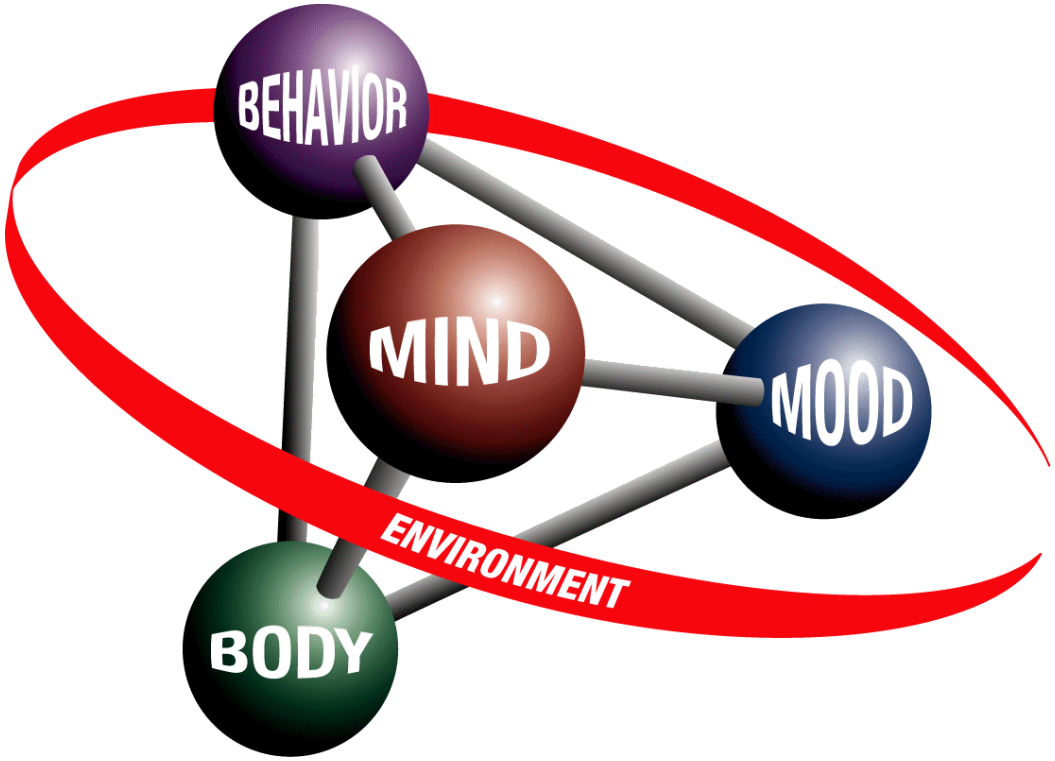
- Neuropsychologist
- Cardiovascular- Pediatric Cardiologist
- Ocular/Motor- Neuro-opthamologist
- Cervical- Ortho (Spine)
- Behavioral/Cognitive- Cognitive therapist and/or Mental Health provider

*** Patient must pass all pillars prior to progressing to full contact practice and game play

Have strong cross referral partnerships!

Return to Learn before Return to Play

- Academic restrictions
- Graded activities
  - Ie. VOR > 30 reps = 5 minutes of reading.
- Cognitive Duel tasking
  - DURING ALL (PCS Rehab) tasks.
- Cognitive Therapy
  - If symptoms do not resolve within > 2 months PT
  - Or if stimulation/concentration is primary limiting factor.



RTL Before RTP- how do we gradually re-introduce?

****Parent and child/athlete **accountability**- Must have for effectiveness.

Name: _____

Matthew J. Morahan, III
Health Assessment Center for Athletes
RWJBarnabas Health

Today's Date: _____

Patient Instructions: This daily symptom log is a tool that can be used to track your symptoms throughout recovery. Please identify (using the key below) & rate any symptom you have during your class (1-2: Mild, 3-4: Moderate, 5-6: Severe). Also include what activity (ie: reading, algebra, computer) that you were doing and how long it lasted

	EXAMPLE Class: Math Duration: 45 minutes	1st Period Class: _____ Duration:____	2nd Period Class: _____ Duration:____	3rd Period Class: _____ Duration:____	4th Period Class: _____ Duration:____	5th Period Class: _____ Duration:____	6th Period Class: _____ Duration:____	7th Period Class: _____ Duration:____	8th Period Class: _____ Duration:____
Cognitive work during class/ activity that caused symptoms	Smart Board use MacBook Use								
List Symptoms (using below abbreviations) during class & Rate (1-6)	H- 5 N-3 SL- 2								
How long did the symptom(s) last?	H- 2 hours N-30 minutes SL- 2 hours								
What did you do to reduce the symptom?	Left class 20 minutes early and rested at nurses office.								

Symptoms of a concussion:

Physical	**Cognitive**	**Emotional**	**Sleep**
(H)Headache, (N)Nausea, (V)Vomiting, (B)Balance Problems, (D) Dizziness, (VP)Visual Problems, (F)Fatigue, (SL)Sensitivity to light & (SN)Noise, (NT)Numbness/Tingling	(MF)Mentally Foggy,(SD)Slowed Down, (DC)Difficulty Concentrating, (DR)Difficulty Remembering	(I)Irritability, (S) Sadness, (NE)Nervousness, (E) Emotional (More than usual)	(DR) Drowsiness, (SLU)Sleeping Less Than Usual, (SMU)Sleeping More Than Usual, (TFA)Trouble Falling Asleep

Matthew J. Morahan, III
Health Assessment Center for Athletes
RWJBarnabas Health

Name: _____ DOB: _____

Active Recovery Plan

Exercise Log: This daily at home exercise log is a tool that can help fast track your recovery for Return to Play (RTP). Please identify which cardiovascular activity (Walking, Treadmill, Stationary Bike) you participated in below each day. Please rate any symptoms you may have during your workout (1-2: Mild, 3-4: Moderate, 5-6: Severe) based on symptom key at the bottom of this page. **STOP ANYTIME YOUR SYMPTOMS CHANGE OR INCREASE**.

Activity: _____	**Borg Rating of Perceived Exertion**
Duration: _____	6 No exertion at all 7 8 Extremely light 9 Very Light 10
Times a day: _____	11 Light 12 13 Somewhat hard 14
Additional comments: _____	15 Hard (heavy) 16 17 Very Hard 18
	19 Extremely hard 20 Maximal exertion

1 Workout	DAY 1 Date: _____	DAY 2 Date: _____	DAY 3 Date: _____	DAY 4 Date: _____	DAY 5 Date: _____	DAY 6 Date: _____	DAY 7 Date: _____
Activity							
Duration/Time							
RPE							
Symptoms							
2 Workout	**DAY 1** Date: _____	**DAY 2** Date: _____	**DAY 3** Date: _____	**DAY 4** Date: _____	**DAY 5** Date: _____	**DAY 6** Date: _____	**DAY 7** Date: _____
Activity							
Duration/Time							
RPE							
Symptoms							

Physical	Cognitive	Emotional	Sleep
(H)Headache, (N)Nausea, (V)Vomiting, (B)Balance Problems, (D) Dizziness, (VP)Visual Problems, (F)Fatigue, (SL)Sensitivity to light & (SN)Noise, (NT)Numbness/Tingling	(MF)Mentally Foggy,(SD)Slowed Down, (DC)Difficulty Concentrating, (DR)Difficulty Remembering	(I)Irritability, (S) Sadness, (NE)Nervousness, (E) Emotional (More than usual)	(DR) Drowsiness, (SLU)Sleeping Less Than Usual, (SMU)Sleeping More Than Usual, (TFA)Trouble Falling Asleep

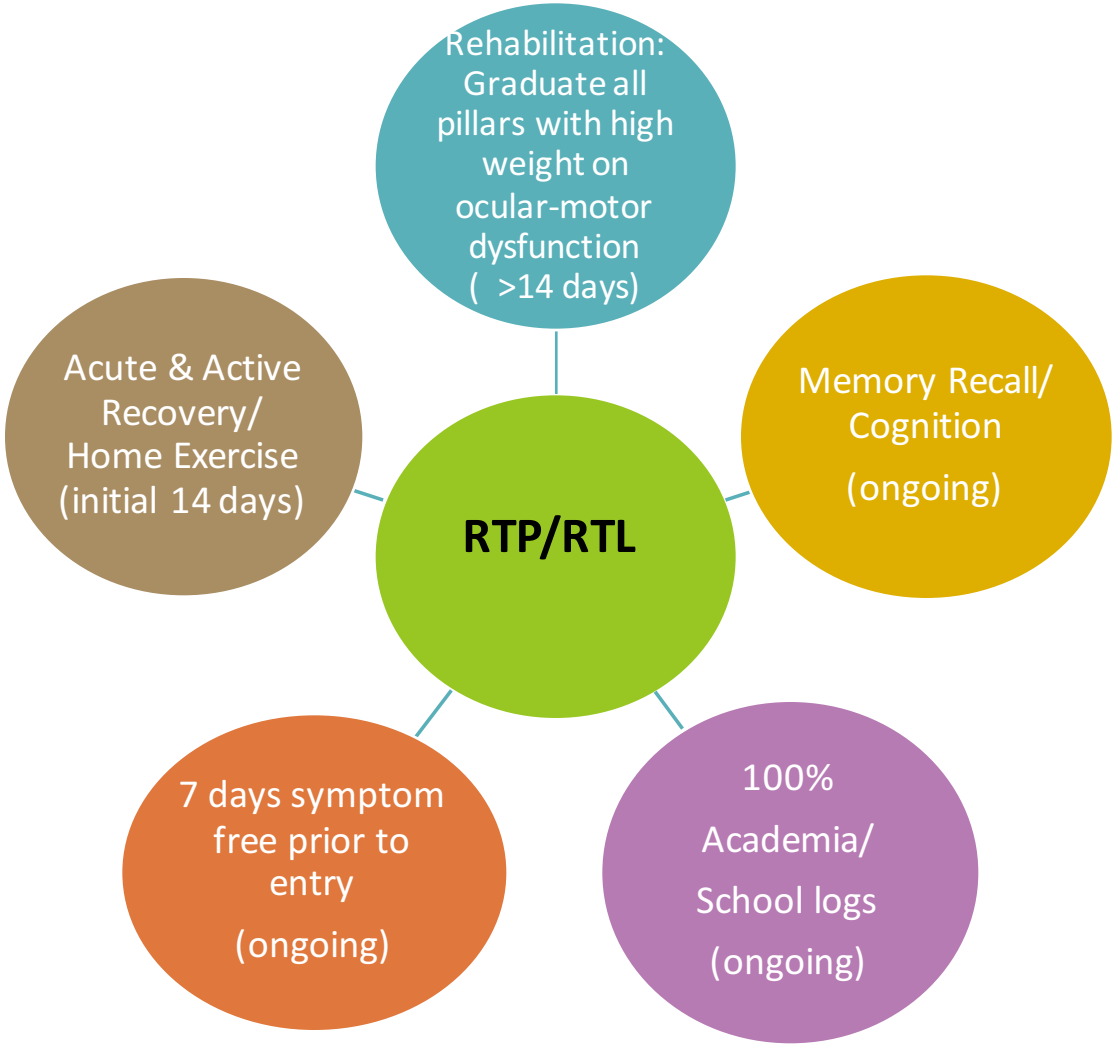
****IF ATHLETE BEGINS TO VOMIT OR REPORTS AN INCREASED HEADACHE OR SYMPTOMS CONTINUE TO WORSEN, OR IF YOU HAVE ANY URGENT CONCERNS ABOUT THE ATHLETE'S CONDITION PLEASE REPORT TO THE CLOSEST EMERGENCY ROOM AND ALSO CALL THE MJM CENTER at 973-322-7913****

Athlete Signature: _____

Parent Signature: _____ Date : _____

Barnabas Health Ambulatory Care Center | RWJBarnabas HEALTH

A Comprehensive Concussion Continuum of Care



Developing a Track Based Approach in Recovery

Slow Track---------→

Symptom Criteria: High Symptom Score, Constant Headache; Highly weighted assessments with highest weight on ocular motor dysfunction and cardiovascular intolerance.

Academia: Modify < 50% cognitive work load based on symptomatology with school based tasks.

Activity: Establish heart based parameters from initial treadmill testing.

Modified Track --------→

Symptom Criteria: Overall symptom score <6;No Constant Headache;Highly weighted assessments with highest weight on ocular motor dysfunction and cardiovascular intolerance.

Academia: Achieve 50%-70% of normal cognitive workload based on symptomatology with school based tasks.

Activity: Establish heart based parameters from initial treadmill testing.

Fast Track --------→

Symptom Criteria: Symptoms resolve completely within 48 hours of initial reporting. Symptoms cannot be induced with visual, ocular, cognitive, or through physically induced parameters.

Academia: Lift all school restrictions.

Activity: Establish heart based parameters from initial treadmill testing.

Other considerations-------→ Ergonomics/seat in the classroom (lateral/front view); Cervical injury vs. concussive based injury, lack of baseline criteria, Age of development.

Suspected or Subjective?

Suspected Concussion--------→

When do we put an athlete into concussion protocol? Considerations?

Considerations

- Age of brain development, sport, concussion history, length of symptoms.
- Sub-concussive blows

Optimal Outcomes

Early Diagnosis---------→Early Intervention----------→

Prescribed Active Recovery----------→Prescribed Pillar driven rehabilitation

Case Study Review

Scenario 1– Slow Track ----------→ Fast Track

Initial Visit

15 year old male, 1 diagnosed concussion.

No history of ADHD or Migraines

Initial eval- 48 hours after initial incident (Soccer)

Symptom score on initial MD visit – 42

KD time 47.5

Positive VOMS and KD (Dizziness/Headache/KD errors induced)

Stable Treadmill Test (No Change)

Follow up visit

100% compliance with academic restriction/ active recovery programming in initial week.

KD time- 41/ VOMS- Negative; Symptoms reduced to a score of 0

Total days from initial evaluation to full symptom resolve- 7 days

Case Study Review

Scenario 2– Slow Track ----------→ Fast Track

Initial Visit

14 year old female, 1 diagnosed concussion.

No history of ADHD or Migraines

Initial eval- 72 hours after initial incident (Volleyball)

Symptom score on initial MD visit – 38

KD time 75.5

Positive VOMS and KD (Dizziness/Headache/KD errors induced)

Positive TM test (Dizziness)

Follow up visit

100% compliance with academic restriction/ active recovery programming in initial week.

KD time- 53/ VOMS- Negative; Symptoms reduced to a score of 0

Total days from initial evaluation to full symptom resolve- 2 days

A Case Review

On average Acute Concussion and PCS patients with severe symptoms had a faster percentage of symptom resolve (by 5 or more days), Improved KD test time by 10 or more seconds, and negative VOMS results with 100% compliance rates for active recovery and academic restrictions compared to those that did not become active in the first week or follow academic restrictions.

- Early Intervention for all acute brain injury leads to earlier and better outcomes.
- Delay in referral to a specialist can delay symptom resolve
- Early activity in non-contact setting is essential with defined parameters.
- Make activity simple with specific parameters in prescription that co-incide with functional level on the treadmill testing.
- Prescribe effective parameters for school based on cognitive and dual tasking capability indicated from evaluation and testing. Avoid big picture definitions, be specific in your guide.
- Hold parent and athlete/child accountable for compliance to your protocols to ensure clinical effectiveness.
- Hold progression where necessary to ensure good clinical outcomes and possible effectiveness with reducing re-injury.

A Brief Pediatric insight

What we're finding out?

- Return to play programming for pediatrics is a safer approach to brain healing and safe play.
- Ocular motor dysfunction is prevalent in brain injury of all ages.
- The pace and complexity of the tasks for pediatrics is still being perfected, however, very similar responses to healing through eye movement and activity occur in a pediatric and adolescent brain in terms of response. It is the pace at which we set the tasks for recovery that has strong variability.
- More research in this area is essential in order to develop a true parameter for pediatric intervention however progressive return to play and return to learn should be explored in acute concussion recovery within existing protocols.

Return to Play – What's your RTP POC

- Stage 1
  - X 7days no symptoms, 100% academia (48 hours full school and cognitive tasks within the asymptomatic week)
- Stage 2 (Recovery Zone)
  - TM test ≤ 70% HR, basic balance, oculomotor, sport movements
- Stage 3 (Aerobic Zone)
  - 80% HRR, sport movements, cone drills, cognitive duel tasking
- Stage 4 (Anaerobic Zone)
  - 90% + HRR, max effort, all sport specific tasks/High Intensity.
- Stage 5
  - Return to supervised sports
- Stage 6
  - Return to competition

Consider Antidepressant therapy, multiple concussion history. VOMS?

***Vitals are a MUST!

Return to Play

- Basic Format (50 – 60 min)
  - Always take a resting and 2 minute recovery HR and BP
  - 15-20 minutes cardiovascular exercise.
    - Treadmill Modified Balke protocol
    - Attain desired HR (if possible) or Max RPE
  - Cone drills → Make sport specific if possible
    - Circular
    - Linear
    - Side shuffle
    - Diagonal

Thank you!

Matthew J. Morahan, III
Health Assessment Center for Athletes
RWJBarnabas Health

973-322-7913

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