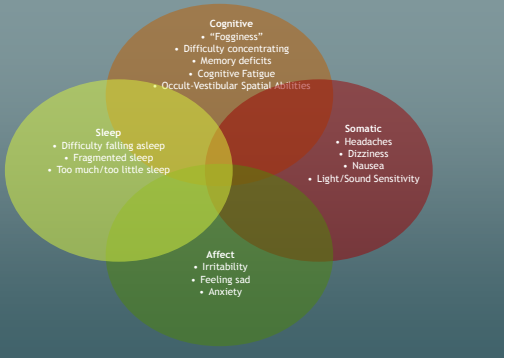
CONCUSSION UPDATE 2017

Shannon Woods MD
Medical Director CoxHealth Sports Medicine
Team Physician Evangel University
Team Physician Drury University



Covassin, MA, McCrea M, Meinerz, RW, et al. Cumulative effects associated with recurrent concussion in collegiate football players: the NCAA concussion study

CONCUSSION HISTORY

- Further definition is needed of Phenotypic clusters to help define further research:
  - Headache
  - Vestibular
  - Psychological
  - Physiologic
  - Neurocognitive
- "Key objective of the clinical assessment should therefore be to identify specific pathologies that may be contributing to the persistence of symptoms."
- Identifying primary and secondary causes of persistent concussion symptoms.

Makdissi, M., et al. Approach to Investigation and Treatment of Persistent Symptoms Following Sports Related Concussion: A Systematic Review. Br J Sports Med. 2017; 0: 1-12

CONCUSSION HISTORY

- Symptoms-Self reported symptoms in a verbal history are often underreported.
- 22 Item Likert scale
  - 7 point scale (0-6)
    - 0-No symptoms
    - 6-Bad symptoms
  - "Evolutionary process"-The Post-Concussion Symptom Scale (PCSS) and Graded Symptom Checklist (GSC)
  - Sensitivity 64%–89%; Specificity 91%– 100%

Zuckerman SLM, et al. Br J Sports Med 2013;47:289–293. doi:10.1136/bjsports-2013-092225

Kelly, J.P., et al. Summary of Evidence-Based Guidelines: Update, Evaluation and Management of Concussion in Sports: Report of the Guideline Development Subcommittee of the

22 ITEM LIKERT SCALE

Headache	4
Nausea	5
Vomiting	0
Balance Problems	1
Dizziness	6
Fatigue	4
Trouble falling asleep	5
Sleeping more than usual	0
Sleeping less than usual	0
Drowsiness	2
Sensitivity to light	2
Sensitivity to noise	3
Irritability	0
Sadness	0
Nervousness	0
Feeling more emotional	0
Numbness or tingling	6
Feeling slowed down	5
Feeling mentally foggy	4
Difficulty concentrating	4
Difficulty remembering	1
Visual problems	3
Total Symptom Score	55

SCAT 3

- Symptom Likert Scale
- Orientation
- Immediate memory
- Delayed memory
- Concentration
- Balance
- Neck Examination
- Coordination

SCAT 3

- Performed on the sideline:
  - Sensitivity-94%; Specificity of 76%
    - SCAT 2
  - When compared to baseline testing in the preseason
- In a study of youth ice hockey players:
  - Average total score of 86.9 out of 100 points
- Until now no data on long term use?

McCrea, M. Standardized Mental Status Assessment of Sport Concussion. Clin J Sport Med. 11; 176-181. 2001.
Giza, C., et al. Evidence Based Approach to Revising the Scat 2: Introducing the Scat 3. Br J Sports Med. 47; 259-263. 2013.
Echemendia, R., et al. Advances in Neuropsychological Assessment of Sports-Related Concussion. Br J Sports Med. 47; 294-298. 2013.

SCAT 3

- Maddocks Score

TABLE 3. *Orientation items (number correct)*

Item	Concussed	Nonconcussed	χ^2	p
1. Name?	27	28	0.00*	1.00
2. Date of birth?	27	28	0.00*	1.00
3. Age?	25	28	1.41*	.24
4. Year?	24	28	2.42*	.12
5. Month?	22	26	1.31*	.25
6. Day?	23	28	3.51*	.06
7. Date?	12	19	3.54	.06
8. Time?	24	28	2.42*	.12

n = 28 for each group.
* Yates correction.

TABLE 4. *Recent memory items (number correct)*

Item	Concussed	Nonconcussed	χ^2	p
9. Ground?	19	28	8.47*	<.004
10. Quarter?	8	28	31.11	<.001
11. Far quarter?	7	24	20.88	<.001
12. Last goal?	13	25	11.79	<.001
13. Played?	9	28	28.76	<.001
14. Won?	13	28	20.49	<.001

n = 28 for each group.
* Yates correction.

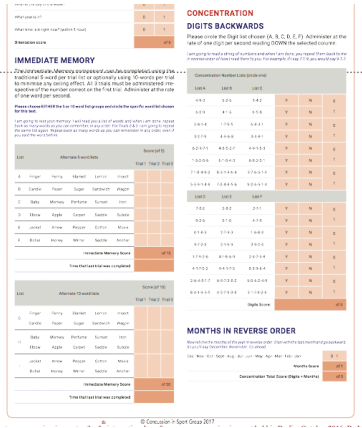
Maddocks, D., et al. The assessment of orientation following concussion in athletes. Am J Sports Med 1995; 23: 3

SCAT 3

- SAC-Sideline assessment of Concussion
  - Foundation of the SCAT 3 cognitive testing.
  - One point deficit from athletes baseline SAC score
    - Sensitivity-80-94%; Specificity-76-91%
  - "Brief cognitive screening tests such as the SAC and SCAT2 are not substitutes for more comprehensive neuropsycho- logical assessment."

McCrea, M. Standardized Mental Status Assessment of Sport Concussion. Clinical Journal of Sport Medicine. 2001; 11:176-181
Echemendia, R., et al. Advances in Neuropsychological Assessment of Sports-Related Concussion. Br J Sports Med 2013;47:294–298
Giza C., et al. Evidence Based Approach to Revising the Scat 2: Introducing the Scat 3. Br J Sports Med. 47; 259-263. 2013

SCAT 5



SCAT 3

- BESS-Balance Error Scoring System
  - Sensitivity-34-64%; Specificity-91%
  - Low Bess scoring is associated with increased risk of Post-Concussion Syndrome.
- Other Balance tests:Sensory Organization Test
  - Force plates
  - Sensitivity-48-61%; Specificity-85-90%

SCAT 3-NEW

- Baseline testing:N=2018
  - Symptom severity score: 5.33+/-6.81(Score of 0= no concussion sxs)
  - SAC 27.08+/-1.9(higher score, better performance)
  - BESS 3.12+/- 2.5 errors(lower score, better performance)
- Symptom severity score and BESS testing was significantly diminished up to 8d out after injury.
- SAC was significantly diminished at 24 h only.
- Performance is affected by being male, LD, ADHD, age, psychological illness.
- Baseline testing did not show statistical support.
- Symptom severity score was the most sensitive test.
  - BESS and SAC did not perform as well, though other studies have shown better results.

SCAT 3-NEW

TABLE 2
Descriptive Statistics and Concussed Versus Control Group Differences for SCAT3 Components[a]

	Concussed (n = 168)	Control (n =164)	*t* Value	*P* Value	*d* Value
Symptom severity					
Baseline	6.53 ± 10.19	5.90 ± 7.49	0.62	.566	0.07
24 hours	24.91 ± 18.25	4.50 ± 5.06	13.80	**<.001**	**1.52**
Day 8	7.44 ± 14.32	3.21 ± 5.14	3.52	**.003**	**0.39**
Day 15	3.16 ± 6.95	2.46 ± 4.22	1.07	.458	0.12
Day 45	1.87 ± 4.18	2.97 ± 5.38	−1.86	.162	−0.23
SAC					
Baseline	26.84 ± 2.09	27.06 ± 1.81	−0.97	.458	−0.11
24 hours	25.54 ± 2.68	26.38 ± 1.90	−3.27	**.005**	**−0.36**
Day 8	27.14 ± 1.99	27.38 ± 1.67	−1.15	.458	−0.13
Day 15	26.74 ± 1.99	26.85 ± 1.91	−0.95	.458	−0.11
Day 45	26.96 ± 1.95	27.03 ± 1.80	−0.33	.746	−0.04
mBESS					
Baseline	3.37 ± 2.34	3.06 ± 2.68	1.45	.329	0.12
24 hours	4.16 ± 2.96	2.90 ± 2.54	4.54	**<.001**	**0.46**
Day 8	3.34 ± 2.74	2.50 ± 2.33	2.96	**.011**	**0.33**
Day 15	2.76 ± 2.35	2.55 ± 2.41	0.75	.535	0.09
Day 45	3.10 ± 2.55	2.73 ± 2.82	0.70	.540	0.14
ImPACT					
Baseline	12.94 ± 4.52	12.70 ± 5.26	1.09	.458	0.17
24 hours	13.85 ± 5.45	11.28 ± 4.55	4.08	**.004**	**0.51**
Day 8	11.98 ± 5.02	10.39 ± 4.42	2.01	**.011**	**0.34**
Day 15	10.78 ± 4.67	10.37 ± 4.83	0.78	.535	0.09
Day 45	11.04 ± 4.63	10.62 ± 5.15	1.10	.458	0.09

[a]Values are reported as mean ± SD unless otherwise indicated. Bolded values indicate statistically significant difference between groups after adjusting for multiple comparisons ($P < .05$). n values range from 131 to 166 for the concussed group and 127 to 164 for the control group. fBESS, Full Balance Error Scoring System (tiles and foam surface trials); mBESS, modified Balance Error Scoring System; SAC, Standardized Assessment of Concussion; SCAT3, Sport Concussion Assessment Tool–3.

Chin E, et al. Reliability and Validity of the SCAT 3 in High School and Collegiate Athletes. AJSM. 44:91-2376-2385.

NEUROPSYCHOLOGICAL TESTING

- ImPact
  - There are five ImPACT Test domains
    - Composite 1: Verbal Memory Composite
      - This score is comprised of the average of the following scores:
        - Total memory percent correct
        - Symbol match (total correct hidden symbols)
        - Three letters (total percent of total letters correct)
      - A higher score indicates better performance on the Verbal Memory Composite.
    - Composite 2: Visual Memory Composite
      - This score is comprised of the average of the following score
        - Design memory (total percent correct score)
        - X's and O's (total correct memory score)
      - A higher score indicates better performance on the Visual Memory Composite.
    - Composite 3: Processing Speed Composite
      - This score is comprised of the average of the following scores:
        - X's and O's (total correct (interference))
        - Three-letters (average counted correctly)
      - A higher score indicates better performance on the Processing Speed Composite.

https://www.impactnet.com/products/TheImPACTTest-2

NEUROPSYCHOLOGICAL TESTING

- Composite 4: Reaction Time Composite
  - This score is comprised of the average of the following scores:
    - X's and O's (average correct RT (interference))
    - Symbol match (average correct RT/3)
    - Color match (average correct RT)
  - A lower score indicates better performance on the Reaction Time Composite.
- Composite 5: Impulse Control Composite
  - This score is comprised of the average of the following scores:
    - X's and O's (total incorrect (interference))
    - Color match (total commissions)
  - A lower score indicates better performance on the Impulse Control composite.

https://www.impactnet.com/products/TheImPACTTest-2

NEUROPSYCHOLOGICAL TESTING

Exam Type	Post-Injury 1	Post-Injury 3			
Date Tested	04/20/2015	05/26/2015			
Last Concussion	04/02/2015				
Exam Language	English	English			
Test Version	2.1	2.1			

Composite Scores Percentile scores if available are listed in small type.

Memory composite (verbal)	79 25%	93 71%			
Memory composite (visual)	57 14%	73 48%			
Visual motor speed composite	35.65 28%	43.28 67%			
Reaction time composite	0.72 5%	0.53 69%			
Impulse control composite	1	3			
Total Symptom Score	14	0			

Cognitive Efficiency Index: 0.28 0.5

The Cognitive efficiency Index measures the interaction between accuracy (percentage correct) and speed (reaction time) in seconds on the Symbol Match test. This score was not developed to make return to play decisions but can be helpful in determining the extent to which the athlete tried to work very fast on symbol match (decreasing accuracy) or attempted to improve their accuracy by taking a more deliberate and slow approach (jeopardizing speed). The range of scores is from approximately zero to approximately .70 with a mean of .34. A higher score indicates that the athlete did well in both the speed and memory domains on the symbol match test. A low score (below .20) means that they performed poorly on both the speed and accuracy component. If this score is a negative number, the test taker performed very poorly on the reaction time component.

Hours slept last night	6.5	8.5			
Medication	*				

https://www.impacttest.com/products/?The-ImPACT-Test-2

NEUROPSYCHOLOGICAL TESTING

- Automatically computer scored
- Extensive normative data available from age 11-60 yrs
- Sensitivity-82%; Specificity-90%
  - Reaction time alone has had specificities as high as 97%.
- Has been studied up to 14d out from injury.

Schatz P, Pardini J, Lovell MR, Collins MW. *Archives of Clinical Neuropsychology*. 2005;21;91-99

NEUROPSYCHOLOGICAL TESTING

- "There is no scientific evidence that traditional testing, computerized testing or a hybrid approach is superior; each approach has its strengths and limitations."
- Paper and pencil tests administered by Neuropsychologists.
  - Sensitivity-71-88%
- Athletes that undergo NP testing take longer to RTP.
- If an athlete is asymptomatic, but still is not back to baseline of NP testing are they at risk for injury?
  - Underreporting symptoms?
  - Second impact syndrome has never been reported in asymptomatic individuals.

Giza, CC. et al. Summary of Evidence Based Guidelines Update: Evaluation and Management of Concussion in Sports: Report of the Guideline development Subcommittee of the American Academy of Neurology. Neurology. 20
Shriek, I. et al. Neuropsychological Testing and Concussions: A Reasoned Approach. Clin J Sport Med Volume 22, Number 3, May 2012.
Echemendia, R., et al. Advances in Neuropsychological Assessment if Sports Related Concussion. Br J Sports Med 2013;47:294-298.

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM

- >50% of brain circuits are involved in vision!
- Vestibular system
  - 2 subsystems;
  - Some overlap of circuitry
  - Vestibulo-spinal
    - Postural control
    - BESS testing to look for dysfunction
  - Vestibulo-occular system
    - Visual stability with head movements
    - What tests?

Mucha, Anne, et al. A Brief Vestibular/Ocular Motor Screening (VOMS) Assessment to Evaluate Concussions: Preliminary Findings. Am J Sports Med. 2014 October ; 42(10): 2479–2486.

Ventura, R. et al. The Concussion Toolbox: The Role of Vision in the Assessment of Concussion. Semin Neurol 2015;35:599–606.

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM

- UPMC VOMS testing
  - Pursuit
  - Horizontal and vertical saccades
  - Convergence-eye crossing distance
    - NL <5cm
  - Horizontal and vertical ocular reflex-Dolls eyes test
  - Visual motion sensitivity
  - 9% of non-concussed controls with symptoms

Mucha, Anne, et al. A Brief Vestibular/Ocular Motor Screening (VOMS) Assessment to Evaluate Concussions: Preliminary Findings. Am J Sports Med.

2014 October ; 42(10): 2479–2486.

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM

VOMS Assessment Domain Scores: Individual Item Associations With the Likelihood of Concussions[a]

VOMS Domain	β	Wald χ^2	*P* Value	Odds Ratio	$R^{2\,b}$
Smooth pursuit	.83	7.89	<.01	2.29	0.28
Horizontal saccade	1.01	10.31	<.01	2.75	0.34
Vertical saccade	.98	8.96	<.01	2.65	0.31
Convergence	.78	7.98	<.01	2.18	0.30
Horizontal vestibular ocular reflex	1.36	16.97	<.001	3.89	0.53
Visual motion sensitivity	1.21	10.35	<.01	3.37	0.40
Near point of convergence distance, cm	.19	13.33	<.001	1.21	0.23

[a] Logistic regression (maximum likelihood estimation), adjusted for ln(age). VOMS, Vestibular/Ocular Motor Screening.

[b] Nagelkerke R^2.

AUC Analysis, Cutoff Score, and LR of Positive Results for VOMS Domain Scores[a]

VOMS Domain	AUC	*P* Value	Cutoff Score for Positive Test Result (≥)	LR for Positive Test Result
Smooth pursuit	0.64	<.01	2	23.9
Horizontal saccade	0.68	<.001	2	28.9
Vertical saccade	0.65	<.01	2	23.9
Convergence	0.64	<.01	2	26.4
Horizontal vestibular ocular reflex	0.78	<.001	2	42.8
Visual motion sensitivity	0.73	<.001	2	32.7
Near point of convergence distance, cm	0.73	<.001	5	5.8

[a] AUC, area under the curve; LR, likelihood ratio; VOMS, Vestibular/Ocular Motor Screening.

Mucha, Anne, et al. A Brief Vestibular/Ocular Motor Screening (VOMS) Assessment to Evaluate Concussions: Preliminary Findings. Am J Sports Med.

2014 October ; 42(10): 2479–2486.

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM

Figure 1. Smooth pursuits.

Figure 2. Horizontal saccades.

Figure 3. Vertical saccades.

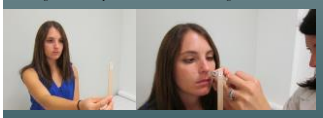


Figure 4. Convergence

Mucha, Anne, et al. A Brief Vestibular/Ocular Motor Screening (VOMS) Assessment to Evaluate Concussions: Preliminary Findings. Am J Sports Med. 42nd Volume , 42(10), 2479–2486

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM

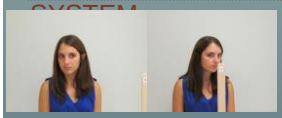


Figure 5. Horizontal VOR.

Figure 7. VMS.

Mucha, Anne, et al. A Brief Vestibular/Ocular Motor Screening (VOMS) Assessment to Evaluate Concussions: Preliminary Findings. Am J Sports Med. 42nd Volume , 42(10), 2479–2486

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM-NEW

- Acute concussion has been shown to demonstrate abnormal occulomotor testing.
  - fMRI demonstrated increased areas of recruitment and activation.
- Subacute testing of 7 young adults 30d post injury (reported no symptoms, physician determined they were not concussed):
  - Horizontal video goggle saccades and pursuits were delayed in reaction time.
  - Improved compared to acute phase injury.
  - fMRI showed increased brain recruitment patterns, though improved compared to acute phase.
    - This has been shown to still be present at 6m post injury.

Johnson, B., et al. Follow-up Evaluation of the Oculomotor Performance With fMRI in The Subacute Phase of Concussion. Neurology 2015; 85:1363-1370

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM-NEW

- Adolescents tested <1 wk post concussion.
  - Sxs rated on 10pt Likert scale sxs after each VOMS test completed.
  - ImPACT testing revealed statistical significance for prolonged recovery of 30-90d.
    - For Visual Motor Speed (score change -9.1)greatest predictor. (OR 0.86 [0.79-0.94] p0.001)
    - and Reaction Time (score change 0.13s) (OR 3.73 [1.09-4.76] p0.029).
      - Reaction time greatest predictor of all fields tested.

Galetsky, A., et al. Using Acute Performance on a Comprehensive Neurocognitive, vestibular and Oculomotor Assessment Battery to Predict Recovery Duration After Sport-Related Concussions. AJSM. 48:8. 1937-1946.

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM-NEW

TABLE 2
Results of Univariate Multinomial Regression for Neurocognitive Scores as Predictive of Postconcussion Recovery of 15-29 and 30-90 Days Relative to <14 Days[a]

Recovery, d	Neurocognitive Predictor	β	SE	*P* Value	Odds Ratio	95% CI
30-90	Verbal memory	−.055	0.022	.013	0.95	0.91-0.99
	Visual memory	−.099	0.028	.001	0.91	0.86-0.97
	Visual motor speed	−.147	0.046	.001	0.86	0.79-0.94
	Reaction time[b]	1.317	0.418	.002	3.73	1.64-8.47
15-29	Verbal memory	−.017	0.021	.40	0.98	0.94-1.02
	Visual memory	−.032	0.024	.17	0.97	0.92-1.01
	Visual motor speed	−.09	0.037	.015	0.91	0.85-0.98
	Reaction time[b]	.823	0.376	.029	2.28	1.09-4.76

[a]Multivariate model includes visual memory and visual motor speed (chi-square = 22.68, $df = 4$, $P < .001$, pseudo-$r^2 = 0.32$).
[b]Standardized as *Z* score to distribution, with mean = 0, SD = 1.

Galetsky, A., et al. Using Acute Performance on a Comprehensive Neurocognitive, vestibular and Oculomotor Assessment Battery to Predict Recovery Duration After Sport-Related Concussions. AJSM. 48:8. 1937-1946.

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM-NEW

- Adolescents tested <1 wk post concussion.
  - Sxs rated on 10pt Likert scale sxs after each VOMS test completed.
  - VOMS
    - Positive VOMS testing showed predictability of 30-90d recovery in all subcategories.
      - Smooth pursuit (OR 1.5 [1.19-1.90] p<0.001).
      - Horizontal saccade (OR 1.5 [1.19-1.88] p0.001).
      - Vertical saccade (OR 1.43 [1.16-1.75] p0.001).
      - These are the 3 I find to be the most reliable in my practice.

Galetsky, A., et al. Using Acute Performance on a Comprehensive Neurocognitive, vestibular and Oculomotor Assessment Battery to Predict Recovery Duration After Sport-Related Concussions. AJSM. 48:8. 1937-1946.

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM-NEW

TABLE 3
Results of Multinomial Regression for VOMS Scores as Predictive of Postconcussion Recovery of 15-29 and 30-90 Days Relative to ≤14 Days[a]

Recovery, d	VOMS Predictor	β	SE	*P* Value	Odds Ratio	95% CI
30-90	Smooth pursuit	.405	0.565	<.001	1.50	1.19-1.90
	Horizontal saccade	.404	0.117	.001	1.50	1.19-1.88
	Vertical saccade	.356	0.105	.001	1.43	1.16-1.75
	Convergence distance	.192	0.088	.029	0.12	1.02-1.44
	Horizontal VOR	.271	0.086	.002	1.31	1.11-1.55
	Vertical VOR	.253	0.079	.001	1.29	1.10-1.51
	VMS	.210	0.063	.001	1.23	1.09-1.40
15-29	Smooth pursuit	.225	0.107	.036	1.25	1.02-1.55
	Horizontal saccade	.267	0.108	.013	1.31	1.06-1.62
	Vertical saccade	.203	0.095	.035	1.22	1.01-1.47
	Convergence distance	.016	0.090	.86	1.02	0.85-1.21
	Horizontal VOR	.142	0.082	.08	1.15	0.98-1.35
	Vertical VOR	.131	0.075	.08	1.14	0.98-1.32
	VMS	.102	0.058	.08	1.11	0.99-1.24

[a]Multivariate model includes vertical saccade (chi-square = 17.53, $df = 2$, $P < .001$, pseudo-$r^2 = 0.29$). VMS, visual motion sensitivity; VOMS, Vestibular/Ocular Motor Screening; VOR, vestibular ocular reflex.

Galetinis, A., et al. Using Acute Performance on a Comprehensive Neurocognitive, vestibular and Oculomotor Assessment Battery to Predict Recovery Duration After Sport-Related Concussions. AJSM. 46:8. 1997-2006

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM-NEW

- Case control study N=270.
  - Measured Near point convergence
    - Point at which double vision occurs or exophoria
      - Point at which eye deviates outward to midline.
      - >6cm abnormal, from bridge of nose.
      - NL in adolescents <6cm.
    - Those with increased convergence were more likely to take longer to recover from concussion.
      - OR 12.3 [6.6-23.0] p<0.001.

DePrey, K., et al. Convergence Insufficiency Identifies Athletes at Risk of Prolonged Recovery From Sport-Related Concussion. AJSM. 20 (10): 1-6

VOMS: VESTIBULO-OCCULAR MOTOR SYSTEM-NEW

- Sensitivity 84.2%
- Specificity 70.0%
- PPV 62.5%
- NPV 88.1%

TABLE 2
Outcome Measures[a]

	Normal NPC (n = 134)	CI (n = 136)	*P* Value
Recovery, d, mean ± SD	19.2 ± 14.7	51.8 ± 59.9	<.001
NPC at initial office visit, cm, mean ± SD	4.1 ± 1.3	12.3 ± 4.7	<.001
Prolonged recovery (>28 days), n (%)	16 (11.9)	85 (62.5)	<.001

[a]CI, convergence insufficiency; NPC, near point of convergence.

DePrey, K., et al. Convergence Insufficiency Identifies Athletes at Risk of Prolonged Recovery From Sport-Related Concussion. AJSM. 20 (10): 1-6

KING-DEVIK TEST

- K-D test is performed by:
  - Rapidly reading numbers with variable spacing on three test cards.
  - It is scored by adding the total time required in seconds.
- The test usually takes 1 to 2 minutes.
- Rapid number naming requires saccades, attention, and language, as well as other areas involved in reading.
- K-D thereby evaluates functioning of the brainstem, cerebellum, and cerebral cortex.

http://kingdevicktest.com

Ventura, R. et al. The Concussion Toolbox: The Role of Vision in the Assessment of Concussion. Semin Neurol 2015;35:599–606.

KING-DEVIK TEST

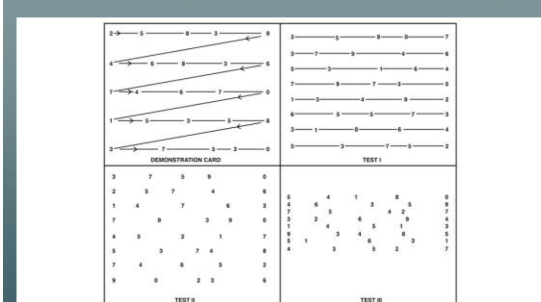
- Baseline test time
- Timed after concussion
  - If slower, may have a concussion
  - If faster, that's the new baseline and may not have a concussion.
- NL-Around 50sec to complete in College age.
- Average increase of 5-7sec above baseline after concussed.
- Sensitivity as high as 86%; Specificity as high as 90%
  - I could only find this information from a study funded by KD, not in a reputable journal.

http://kingdevicktest.com

Galletta, K. The King-Devick test of rapid number naming for concussion detection: meta- analysis and systematic review of the literature. futuremedicine.com.Concussion (2016) 1(2), CNC8

Ventura, R. et al. The Concussion Toolbox: The Role of Vision in the Assessment of Concussion. Semin Neurol 2015;35:599–606.

KING-DEVIK TEST



BUFFALO PROTOCOL

- Used in athletes with >6weeks of symptoms
- Balke protocol
  - 3.3mph@ 0% grade warmup—>Increase 2% grade at min 2—>1% grade increase thereafter.
- If symptoms of concussion occur before Max_{HR} then the athlete is not ready to go back.
- No Sensitivity/Specificity date
- Inter-rater and intra-rater reliability in 90%'s.

Leddy, J., et al. Reliability of a Graded Exercise Test for Assessing Recovery From Concussion Clin J Sport Med Volume 21, Number 2, March 2011

2017 CONSENSUS UPDATE

- Rest:
  - Currently insufficient evidence to prescribe complete rest after 48h of injury.
  - Encouraged to stay below symptom threshold.
    - Retrospective study of >3000 kids reporting to ER and retrospective analysis 28d later.
      - Question posed was: < or > 7d at which activity was started.
    - RR reduction of up to 0.77 with light activity to full exercise after concussion v. absolute rest CI(0.63-0.86).
      - Walking, swimming, cycling.
      - Running, skating.
      - Passing drills.
      - Full contact drills.
    - Encouraging NL cerebral blood flow is proposed mechanism.

McCrory, P., et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. Br J Sport Med. 2017.; 0. 1-10.

Grool, A., et al. Association Between Early Participation in Physical Activity Following Acute Concussion and Persistent Postconcussive Symptoms in Children and Adolescents. JA

2017 CONSENSUS UPDATE

- Helmet and video impact sensors/analysis:
  - While this is quite cool in theory, currently we do not know how to use the data.
  - No data for non-contact sports limits usefulness.
  - May not reflect brain forces, as sensors are on helmet and skin?

McCrory, P., et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. Br J Sport Med. 2017.; 0. 1-10.

2017 CONSENSUS UPDATE

- SCAT 5
  - Replaces older SCAT3 testing.
  - Baseline testing *MAY* be useful.
  - Should be used on sideline as a screening tool.
  - Effective for the first 5d following concussion
    - Usefulness wanes after 5d.
    - System checklist is useful beyond 5d.

2017 CONSENSUS UPDATE

- Return To Learning:

Table 2 Graduated return-to-school strategy

Stage	Aim	Activity	Goal of each step
1	Daily activities at home that do not give the child symptoms	Typical activities of the child during the day as long as they do not increase symptoms (eg, reading, texting, screen time). Start with 5–15 min at a time and gradually build up.	Gradual return to typical activities
2	School activities	Homework, reading or other cognitive activities outside of the classroom	Increase tolerance to cognitive work
3	Return to school part-time	Gradual introduction of schoolwork. May need to start with a partial school day or with increased breaks during the day	Increase academic activities
4	Return to school full time	Gradually progress school activities until a full day can be tolerated	Return to full academic activities and catch up on missed work

2017 CONSENSUS UPDATE

- "It is recommended that all athletes should have a clinical neurological assessment (including evaluation of mental status/ cognition, oculomotor function, gross sensorimotor, coordination, gait, vestibular function and balance) as part of their overall management."
  - "This will normally be performed by the treating physician, often in conjunction with computerized NP screening tools."
  - Should not be used as sole determinant of concussion.

2017 CONSENSUS UPDATE

- Rehabilitation:
  - First time listed in a consensus statement.
  - A variety of rehabilitation treatments may be required for symptoms lasting greater the 10-14d.
  - Data supports:
    - Psychological
    - Cervical
    - Vestibular rehabilitation
  - May be of benefit, in controlled programs:
    - Sub-threshold Exercise
    - Cognitive rehab

McCrory, P. et al. Consensus statement on concussion in sport –the 5th international conference on concussion in sport held in Berlin, October 2016. Br J Sport Med. 2017; 0: 1-10

2017 CONSENSUS UPDATE

- The 85% better in 1 wk research may be tainted by people returning back to play while symptomatic. Especially pre-2005 research.
  - I find this to be true in my clinic and do not believe this statistic is accurate.
- Further definition of Post concussion syndrome needed
  - >10-14d in adults
  - >4 weeks in children
- Prevention:
  - Helmets in snowboarding/skiing have been shown to reduce overall head injuries.
  - Limiting body checking in ice hockey has been shown to reduce concussion risk in those under age 13yo.
  - Increased red card rule enforcement in soccer has been shown to reduce risk in pro soccer.
  - No evidence that limiting contact in football, fair play rules in hockey, tackle training in football or rugby reduces concussion, but may limit head contact.
  - May be underpowered studies"

McCrory, P. et al. Consensus statement on concussion in sport –the 5th international conference on concussion in sport held in Berlin, October 2016. Br J Sport Med. 2017; 0: 1-10

SCAT5

1

IMMEDIATE OR ON-FIELD ASSESSMENT

All athletes should be assessed for all athletes who are suspected of having a concussion prior to proceeding to the on-field assessment and ideally should be done on-field after the first aid / emergency care priorities are completed.

If any of the "Red Flags" or observable signs are noted after a direct or indirect blow to the head, the athlete should be immediately and safely removed from participation and evaluated by a physician or licensed healthcare professional.

Consideration of transportation to a medical facility should be at the discretion of the physician or licensed healthcare professional.

The GCS is important as a standard measure for all patients and can be done serially if necessary. In the event of deterioration in conscious state, the Maddocks questions and cervical spine exam are critical steps of the immediate assessment, however, these do not need to be done serially.

STEP 1: RED FLAGS

RED FLAGS:

- **Neck pain or tenderness**
- **Double vision**
- **Weakness or tingling/ burning in arms or legs**
- **Severe or increasing headache**
- **Seizure or convulsion**
- **Loss of consciousness**
- **Deteriorating conscious state**
- **Vomiting**
- **Increasingly restless, agitated or combative**

STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

	Y	N
Lying motionless on the playing surface		
Balance / gait difficulties / motor incoordination: stumbling, slow / laboured movements		
Disorientation or confusion, or an inability to respond appropriately to questions		
Blank or vacant look		
Facial injury after head trauma		

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

STEP 4: EXAMINATION

GLASGOW COMA SCALE (GCS)[3]

Time of assessment			
Date of assessment			
Best eye response (E)			
No eye opening	1	1	1
Eye opening in response to pain	2	2	2
Eye opening to speech	3	3	3
Eyes opening spontaneously	4	4	4
Best verbal response (V)			
No verbal response	1	1	1
Incomprehensible sounds	2	2	2
Inappropriate words	3	3	3
Confused	4	4	4
Oriented	5	5	5
Best motor response (M)			
No motor response	1	1	1
Extension to pain	2	2	2
Abnormal flexion to pain	3	3	3
Flexion / Withdrawal to pain	4	4	4
Localises to pain	5	5	5
Obeys commands	6	6	6
Glasgow Coma score (E + V + M)			

CERVICAL SPINE ASSESSMENT

	Y	N
Does the athlete report that their neck is pain free at rest?		

SCAT

STEP 1: RED FLAGS

RED FLAGS:

- Neck pain or tenderness
- Double vision
- Weakness or tingling/ burning in arms or legs
- Severe or increasing headache
- Seizure or convulsion
- Loss of consciousness
- Deteriorating conscious state
- Vomiting
- Increasingly restless, agitated or combative

STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

Lying motionless on the playing surface	Y	N
Balance / gait difficulties / motor incoordination: stumbling, slow / laboured movements	Y	N
Disorientation or confusion, or an inability to respond appropriately to questions	Y	N
Blank or vacant look	Y	N
Facial injury after head trauma	Y	N

STEP 3: MEMORY ASSESSMENT MADDOCKS QUESTIONS[2]

"I am going to ask you a few questions, please listen carefully and give your best effort. First, tell me what happened?"

Mark Y for correct answer / N for incorrect

What venue are we at today?	Y	N
Which half is it now?	Y	N
Who scored last in this match?	Y	N
What team did you play last week / game?	Y	N
Did your team win the last game?	Y	N

Note: Appropriate sport-specific questions may be substituted.

No eye opening	1	1	1
Eye opening in response to pain	2	2	2
Eye opening to speech	3	3	3
Eyes opening spontaneously	4	4	4
Best verbal response (V)			
No verbal response	1	1	1
Incomprehensible sounds	2	2	2
Inappropriate words	3	3	3
Confused	4	4	4
Oriented	5	5	5
Best motor response (M)			
No motor response	1	1	1
Extension to pain	2	2	2
Abnormal flexion to pain	3	3	3
Flexion / Withdrawal to pain	4	4	4
Localizes to pain	5	5	5
Obeys commands	6	6	6
Glasgow Coma score (E + V + M)			

CERVICAL SPINE ASSESSMENT

Does the athlete report that their neck is pain free at rest?	Y	N
If there is NO neck pain at rest, does the athlete have a full range of ACTIVE pain free movement?	Y	N
Is the limb strength and sensation normal?	Y	N

In a patient who is not lucid or fully conscious, a cervical spine injury should be assumed until proven otherwise.

SCAT 5

OFFICE OR OFF-FIELD ASSESSMENT

Please note that the neurocognitive assessment should be done in a distraction-free environment with the athlete in a resting state.

STEP 1: ATHLETE BACKGROUND

Sport / team / school: ____

Date / time of injury: ____

Years of education completed: ____

Age: ____

Gender: M / F / Other

Dominant hand: left / neither / right

How many diagnosed concussions has the athlete had in the past?: ____

When was the most recent concussion?: ____

How long was the recovery (time to being cleared to play) from the most recent concussion?: ____ (days)

Has the athlete ever been:

Hospitalized for a head injury?	Yes	No
Diagnosed / treated for headache disorder or migraines?	Yes	No
Diagnosed with a learning disability / dyslexia?	Yes	No
Diagnosed with ADD / ADHD?	Yes	No
Diagnosed with depression, anxiety or other psychiatric disorder?	Yes	No

Current medications? If yes, please list:

Name: ____
DOB: ____
Address: ____
ID number: ____
Examiner: ____
Date: ____

2

STEP 2: SYMPTOM EVALUATION

The athlete should be given the symptom form and asked to read this instruction paragraph out loud then complete the symptom scale. For the baseline assessment, the athlete should rate his/her symptoms based on how he/she typically feels and for the post injury assessment the athlete should rate their symptoms at this point in time.

Please Check: ☐ Baseline ☐ Post-Injury

Please hand the form to the athlete

	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
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
Trouble falling asleep (if applicable)	0	1	2	3	4	5	6

Total number of symptoms:	of 22
Symptom severity score:	of 132
Do your symptoms get worse with physical activity?	Y N
Do your symptoms get worse with mental activity?	Y N
If 100% is feeling perfectly normal, what percent of normal do you feel?	

SCAT 5

3

STEP 3: COGNITIVE SCREENING

Standardised Assessment of Concussion (SAC)[4]

ORIENTATION

What month is it?	0	1
What is the date today?	0	1
What is the day of the week?	0	1
What year is it?	0	1
What time is it right now? (within 1 hour)	0	1
Orientation score		of 5

IMMEDIATE MEMORY

The Immediate Memory component can be completed using the traditional 5-word per trial list or optionally using 10-words per trial to minimise any ceiling effect. All 3 trials must be administered irrespective of the number correct on the first trial. Administer at the rate of one word per second.

Please choose EITHER the 5 or 10 word list groups and circle the specific word list chosen for this test.

I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order. For Trials 2 & 3: I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before.

List	Alternate 5 word lists					Score (of 5) Trial 1	Trial 2	Trial 3
A	Finger	Penny	Blanket	Lemon	Insect			
B	Candle	Paper	Sugar	Sandwich	Wagon			
C	Baby	Monkey	Perfume	Sunset	Iron			
D	Elbow	Apple	Carpet	Saddle	Bubble			
E	Jacket	Arrow	Pepper	Cotton	Movie			
F	Dollar	Honey	Mirror	Saddle	Anchor			
					Immediate Memory Score			of 15

Name: ____
DOB: ____
Address: ____
ID number: ____
Examiner: ____
Date: ____

CONCENTRATION

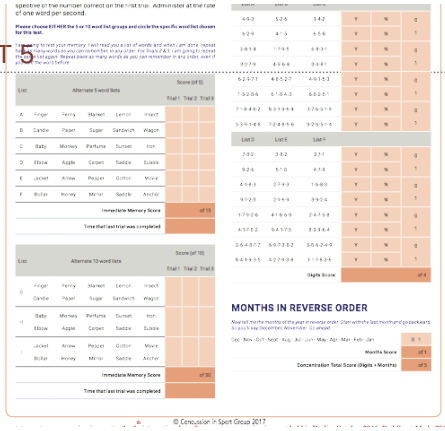
DIGITS BACKWARDS

Please circle the Digit list chosen (A, B, C, D, E, F). Administer at the rate of one digit per second reading DOWN the selected column.

I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7.

Concentration Number Lists (circle one)					
List A	List B	List C			
4-9-3	5-2-6	1-4-2	Y	N	0
6-2-9	4-1-5	6-5-8	Y	N	1
3-8-1-4	1-7-9-5	6-8-3-1	Y	N	0
3-2-7-9	4-9-6-8	3-4-8-1	Y	N	1
6-2-9-7-1	4-8-5-2-7	4-9-1-5-3	Y	N	0
1-5-2-8-6	6-1-8-4-3	6-8-2-5-1	Y	N	1
7-1-8-4-6-2	8-3-1-9-6-4	3-7-6-5-1-9	Y	N	0
5-3-9-1-4-8	7-2-4-8-5-6	9-2-6-5-1-4	Y	N	1
List D	List E	List F			
7-8-2	3-8-2	2-7-1	Y	N	0
9-2-6	5-1-8	4-7-9	Y	N	1
4-1-8-3	2-7-9-3	1-6-8-3	Y	N	0
9-7-2-3	2-1-6-9	3-9-2-4	Y	N	1

SCAT 5



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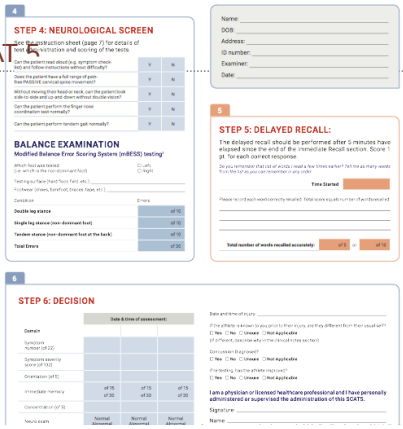
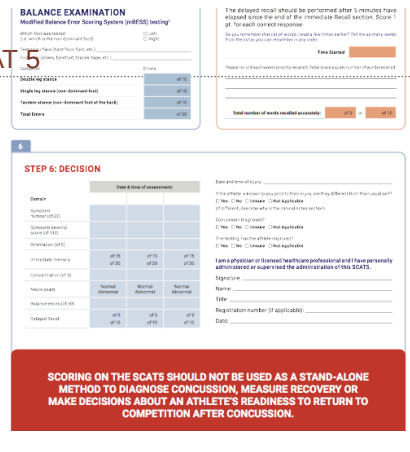
SCAT 5



SCAT 5



SCORING ON THE SCAT5 SHOULD NOT BE USED AS A STAND-ALONE METHOD TO DIAGNOSE CONCUSSION, MEASURE RECOVERY OR MAKE DECISIONS ABOUT AN ATHLETE'S READINESS TO RETURN TO COMPETITION AFTER CONCUSSION.

2017 CONSENSUS UPDATE

- Biomarkers, genetic testing and research based neuroimaging remain important research tools.
  - Not currently ready for clinical use.
    - Tau linked to axonal damage in traumatic brain injury.
    - Tau higher in all athletes, regardless of trauma.
    - Tau may be higher in those with longer concussions.

McCrory, P., et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. Br J Sport Med. 2017 ; 0. 1-10

LONG TERM SEQUELAE

- Case descriptions of boxers with deficits in cognitive abilities date back to 1920's.
- NFL-CTE
  - Some retired athletes have Tau deposition in cortical brain matter.
- Survey of >3700 retired college contact sport participants aged 40-70.
  - No hx of concussion
  - suspected "sub-threshold blows"
  - No difference in mental illness, sleep disorders, perceived cognitive decline.
  - Was greater alcohol use.

Manley, GT., et al A systematic Review of Potential Long Term Effects of Sports-Related Concussion. Br J Sports Med. 2017; 0: 1-10.

LONG TERM SEQUELAE

- Neuroimaging:
  - 14 studies using Diffusion Tensor Imaging, PET, Magnetic Resonance Spectroscopy
  - Diffusion Tensor Imaging (DTI) is an MRI-based neuroimaging technique which makes it possible to estimate the location, orientation, and anisotropy of the brain's white matter tracts.
  - Magnetic Resonance spectroscopy is a noninvasive diagnostic test for measuring biochemical changes in the brain. It compares the chemical composition of normal brain tissue with abnormal tumor tissue.

Manley, GT., et al A systematic Review of Potential Long Term Effects of Sports-Related Concussion. Br J Sports Med. 2017; 0: 1-10.

LONG TERM SEQUELAE

- Neuroimaging:
  - 14 studies using Diffusion Tensor Imaging, PET, Magnetic Resonance Spectroscopy
  - All reported long term changes in brains of Football and soccer athletes.
  - Subject to significant bias with study design.
- MRI study of 72 former NFL athletes with a history of >1 concussion showed structural differences that were associated with deficits in memory, word pronunciation test.
- DTI study of 37 soccer athletes showed no change in structure or testing performance in amateur soccer athletes. Unless, significant heading of ball (>885/y).

Manley, GT., et al.A systematic Review of Potential Long Term Effects of Sports Related Concussion. Br J Sports Med. 2017; 0: 1-10.

LONG TERM SEQUELAE

- Neuroimaging:
  - MRS study of 11 pro soccer athletes found chemical differences in brains, but no cognitive changes.
  - PET study of 5 NFL athletes with mood/cognitive problems showed increased Tau and Amyloid activity compared to controls.

Manley, GT., et al.A systematic Review of Potential Long Term Effects of Sports Related Concussion. Br J Sports Med. 2017; 0: 1-10.

LONG TERM SEQUELAE

- Neurocognitive and mental health:
  - Survey of >2500 NFL athletes, 758 older than 50:
    - 1.3% Doctor diagnosed dementia
    - 2.9% reported doctor diagnosed cognitive impairment
  - If wives completed survey:
    - 12-35% reported cognitive impairments in spouses.
  - Death certificate study of 334 NFL athletes
    - All cause mortality lower than general population.
    - Suicide and mental illness listed less than general population.
    - Nervous system disorders higher, but not statistical significant.

Manley, GT., et al.A systematic Review of Potential Long Term Effects of Sports Related Concussion. Br J Sports Med. 2017; 0: 1-10.

LONG TERM SEQUELAE

- Neurocognitive and mental health:
  - Autopsy studies:
    - 85 control matched athletes
    - 80% had tau deposition compared to 0% of controls.
- Conclusions on long term sequelae:
  - Some professional contact sports athletes are at increased risk of
    - Cognitive deficits
    - Metal health illness
    - No increased risk of suicide
  - There is a link to repeat concussions: most pronounced in NFL athletes, boxers with a greater number of bouts and soccer athletes who head the ball a lot.
  - No association with high School athletes.
- Study of long term sequelae are of limited quality and subject to significant bias.

Stanley, GT., et al.A systematic Review of Potential Long Term Effects of Sports Related Concussion. Br J Sports Med. 2017; 0: 1-16.