CONCUSSION UPDATE 2017

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Cognitive
- Fogginess
- Difficulty concentrating
- Memory deficits
- Cognitive fatigue
- Occult vestibular/spatial sensation

Somatic
- Headaches
- Dizziness
- Nausea
- Light/sound sensitivity

Affect
- Irritability
- Feeling sad
- Anxiety

Sleep
- Difficulty falling asleep
- Fragmented sleep
- Too much/too little sleep

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.
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%


22 ITEM LIKERT SCALE

<table>
<thead>
<tr>
<th>Item</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>4</td>
</tr>
<tr>
<td>Blurred</td>
<td>0</td>
</tr>
<tr>
<td>Numbness</td>
<td>0</td>
</tr>
<tr>
<td>Balanced Postures</td>
<td>1</td>
</tr>
<tr>
<td>Tiredness</td>
<td>0</td>
</tr>
<tr>
<td>Feeling Dragging</td>
<td>0</td>
</tr>
<tr>
<td>Sleeping more than usual</td>
<td>0</td>
</tr>
<tr>
<td>Sleeping less than usual</td>
<td>0</td>
</tr>
<tr>
<td>Fatigue</td>
<td>2</td>
</tr>
<tr>
<td>Difficulty to bright</td>
<td>2</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty</td>
<td>0</td>
</tr>
<tr>
<td>Shortness</td>
<td>0</td>
</tr>
<tr>
<td>Headaches</td>
<td>0</td>
</tr>
<tr>
<td>Feeling more emotional</td>
<td>0</td>
</tr>
<tr>
<td>Feeling less emotional</td>
<td>0</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>5</td>
</tr>
<tr>
<td>Feeling extra tired</td>
<td>4</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty understanding</td>
<td>1</td>
</tr>
<tr>
<td>Visual problems</td>
<td>3</td>
</tr>
<tr>
<td>Total Symptom Score</td>
<td>16</td>
</tr>
</tbody>
</table>

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?


SCAT 3

➤ Maddocks Score

TABLE 1. Difference scores (number correct)

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct</th>
<th>Incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRT</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>DRT</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>CPT</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>DPT</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>CPT</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>FT</td>
<td>26</td>
<td>10</td>
</tr>
</tbody>
</table>

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.”


➤ 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%


➤ Baseline testing:N=2018
➤ Symptom severity score: 5.33+/−6.81(Score of 0= no concussion sx)
➤ 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

**Neuropsychological Testing**

- 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 scores:
    - 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.

- 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.
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


- “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 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.
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-ocular system
➤ Visual stability with head movements
➤ What tests?

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

Acute concussion has been shown to demonstrate abnormal oculomotor 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.
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] p<0.001)
➤ and Reaction Time (score change 0.13s) (OR 3.73 [1.09-4.76] p<0.029).
➤ Reaction time greatest predictor of all fields tested.


<table>
<thead>
<tr>
<th>Variable</th>
<th>Prediction Odds</th>
<th>p Value</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Memory</td>
<td>0.86</td>
<td>0.001</td>
<td>0.93</td>
<td>0.90-0.95</td>
</tr>
<tr>
<td>Visual Motor Speed</td>
<td>0.86</td>
<td>0.001</td>
<td>0.93</td>
<td>0.90-0.95</td>
</tr>
<tr>
<td>Vertical Saccade</td>
<td>0.86</td>
<td>0.001</td>
<td>0.93</td>
<td>0.90-0.95</td>
</tr>
<tr>
<td>Horizontal Saccade</td>
<td>0.86</td>
<td>0.001</td>
<td>0.93</td>
<td>0.90-0.95</td>
</tr>
<tr>
<td>Vertical Saccade</td>
<td>0.86</td>
<td>0.001</td>
<td>0.93</td>
<td>0.90-0.95</td>
</tr>
</tbody>
</table>
| These are the 3 I find to be the most reliable in my practice.

**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.

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

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**Table 2**

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>OR (95% CI)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory recovery</td>
<td>8.1 (6.6-23.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prognostic recovery</td>
<td>12.3 (6.6-23.0)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

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**Table 3**

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensory</th>
<th>Prognostic</th>
<th>Sensory vs Prognostic</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR</td>
<td>8.1</td>
<td>12.3</td>
<td>0.000</td>
</tr>
<tr>
<td>CI</td>
<td>(6.6-23.0)</td>
<td>(6.6-23.0)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
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


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


BUFFALO PROTOCOL

➤ Used in athletes with >6 weeks 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 MaxHR then the athlete
  is not ready to go back.
➤ No Sensitivity/Specificity date
➤ Inter-rater and intra-rater reliability in 90%’s.

2017 CONSENSUS UPDATE

➤ Test:
  ➤ 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
        vs. 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.

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?
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>
<thead>
<tr>
<th>Stage</th>
<th>Activity</th>
<th>Start</th>
<th>End of stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Light intensity: aerobic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Moderate intensity: aerobic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sports-specific exercises</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Contact in controlled settings</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Graduated return to sport stages


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

➤ 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.


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.


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.


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.

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 (>8 years).


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.


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.

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
    - Mental 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.