**SUPPLEMENTARY MATERIAL**

**Assessment Details**

**Immediate Post-Concussion Assessment and Cognitive Test (ImPACT)**

 The ImPACT battery is a computerized neurocognitive assessment that tests 6 cognitive domains(1). Upon completion of the battery, there are 5 composite scores computed. These scores are combinations of tests for verbal and visual memory, reaction time, visual motor processing speed, and impulse control(2). Additionally, the Post-Concussion Symptom Scale (PCSS) is also included. The PCSS is a 21-item symptom checklist that asks the participant to grade each symptom on a scale of 0 (not experiencing symptom) to 6 (severely experiencing symptom)(3). The ImPACT battery was used in 13 out of 28 studies and covered 1,527 participants (1,107 males, 342 females, and 78 unspecified).

 ImPACT is considered reliable, sensitive, and valid with normative data for ages 12-59(4, 5). The test requires a computer and, preferably a quiet, dimly lit room. Although there are normative data for the test, it is recommended to perform baseline testing prior to participation in the season.

**Sport Concussion Assessment Tool (SCAT)**

 The SCAT is a multifaceted paper test that was developed as part of the Second International Conference on Concussion in Sport(6). Currently, the most updated version of the SCAT is the fifth edition(7). The SCAT-5 includes an immediate or on-field evaluation determining signs and symptoms including: observable signs, Maddocks Score(8), the Glascow Coma Scale for assessment of level of conciousness(9), and a cervical spine evaluation. There is also an off-the-field evaluation, including patient demographics, a 22-item symptom checklist, cognitive screening (immediate memory, orientation, and concentration task). There is a basic neurological screening and balance examination utilizing a Modified Balance Error Scoring System(10) followed by a follow-up delayed recall memory test.

 The SCAT-5 is freely available and may be considered more convenient than computerized neurocognitive assessments for “on the field” assessments or immediate assessments. Although the current version of the SCAT (version 5) does not have normative data available yet, previous versions do provide normative data for comparison. However, some of the normative data for components of the previous versions have been found to be less reliable (11). Specifically, the Modified Balance Error Scoring System (mBESS), a component of the SCAT, total score shows poor inter-rater and intra-rater reliability (12). The SCAT-5 may be used for participants ages 12 and older, with the Child SCAT-5 covering ages 5 to 12. The SCAT was included in 8 of the 28 studies and employed 933 participants (629 males, 117 females, and 187 unspecified).

**King-Devick Test (K-D Test)**

 The K-D Test(13) includes measurements of language, attention, eye-movements, and reading performance during a directional number reading task. This oculomotor test is able to detect and identify injuries in players that do not report any obvious signs or symptoms of a concussion(14). Participants are instructed to read increasingly difficult numbers in a directional sequence and the administrator notes any verbal or saccadic issues that the participant experiences.

 The K-D Test is a simple-to-use sideline assessment that preliminary data shows high test-retest reliability with clinicians and parents(15). The K-D Test was included in 5 of the 28 studies and employed 400 participants (174 males, 20 females, and 206 unspecified).

**Digit Symbol Substitution Test (DSST)**

 The DSST is a portion of the Wechsler-Bellevue Intelligence Scale(16). This test allocates specific symbols to certain numbers and requires the participant to recall which symbol corresponds to the given number. Normative data for ages 24-81 is available for several alternate forms of the DSST(17).

 The DSST is a paper test that requires minimal equipment, utilizing only a score sheet, stopwatch, and pencil, but must be purchased. The administrator instructs the participant according to the guidelines, and records the amount of time taken to complete the task sheet. The participant is then given a score based on the number of correctly and incorrectly coded symbols. The DSST was included in 4 of the 28 studies and included 293 male participants.

**Trail Making Test Part B (TMT-B)**

 TMT-B is an evaluation of a participants executive, speed, and visual function(18). This test requires individuals to draw lines connecting alternating letters and numbers in sequential form (i.e. A-1-B-2). This is a more difficult task than part A, which includes only numbers. Studies show a statistically significant decrease in performance (increase in time to complete the task) and increase in task difficulty of those with concussions(19).

 The TMT-B has normative data for individuals 18-89 years(18). This assessment is free to use and requires only a pencil, paper, and stopwatch. Scoring is determined by the amount of time taken to correctly connect all letters and numbers. Participants completing the trail in 75 seconds or less are considered average and greater than 273 seconds is scored as deficient. This leaves a large margin without differentiating performance. The TMT-B was included in 4 of the 28 studies and included 293 male participants.

**CogState (CogSport)**

 The CogState assessment is used more frequently outside the United States. This assessment was developed to be used in conjunction with other concussion-related assessments(20). CogState measures aspects of psychomotor function, decision making, working memory, and learning, all with speed and accuracy sub score. Some studies show that this test is reliable for multiple sessions(21) while others find that there is a practice effect after the second assessment(22). The CogState was included in 3 of the 28 studies and included 155 male participants.

**Additional Assessments**

NHL Battery, Automated Neuropsychological Assessment Metrics (ANAM), Sensory Organization Test (SOT), Rivermead Post-Concussion Symptoms Questionnaire (RPQ), Headminder

**References**

1. Belanger HG, Vanderploeg RD. The neuropsychological impact of sports-related concussion: a meta-analysis. J Int Neuropsychol Soc. 2005;11(4):345-57. PubMed PMID: 16209414.

2. Schatz P, Pardini JE, Lovell MR, Collins MW, Podell K. Sensitivity and specificity of the ImPACT Test Battery for concussion in athletes. Arch Clin Neuropsychol. 2006;21(1):91-9. doi: 10.1016/j.acn.2005.08.001. PubMed PMID: 16143492.

3. Lovell MR, Collins MW. Neuropsychological assessment of the college football player. J Head Trauma Rehabil. 1998;13(2):9-26. Epub 1998/05/09. PubMed PMID: 9575253.

4. Iverson GL, Lovell MR, Collins MW. Validity of ImPACT for measuring processing speed following sports-related concussion. J Clin Exp Neuropsychol. 2005;27(6):683-9. doi: 10.1080/13803390490918435. PubMed PMID: 17540149.

5. Merritt VC, Bradson ML, Meyer JE, Arnett PA. Evaluating the test-retest reliability of symptom indices associated with the ImPACT post-concussion symptom scale (PCSS). J Clin Exp Neuropsychol. 2017:1-12. Epub 2017/07/22. doi: 10.1080/13803395.2017.1353590. PubMed PMID: 28728465.

6. McCrory P, Johnston K, Meeuwisse W, Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. Br J Sports Med. 2005;39(4):196-204. doi: 10.1136/bjsm.2005.018614. PubMed PMID: 15793085; PubMed Central PMCID: PMCPMC1725173.

7. McCrory P, Meeuwisse W, Dvorak J, Aubry M, Bailes J, Broglio S, et al. Consensus statement on concussion in sport-the 5th international conference on concussion in sport held in Berlin, October 2016. Br J Sports Med. 2017;51(11):838-47. doi: 10.1136/bjsports-2017-097699. PubMed PMID: 28446457.

8. Maddocks DL, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. Clin J Sport Med. 1995;5(1):32-5. PubMed PMID: 7614078.

9. Jennett B, Bond M. Assessment of outcome after severe brain damage: a practical scale. The Lancet. 1975;305(7905):480-4.

10. Guskiewicz KM. Assessment of postural stability following sport-related concussion. Curr Sports Med Rep. 2003;2(1):24-30. PubMed PMID: 12831673.

11. Jinguji TM, Bompadre V, Harmon KG, Satchell EK, Gilbert K, Wild J, et al. Sport Concussion Assessment Tool-2: baseline values for high school athletes. Br J Sports Med. 2012;46(5):365-70. doi: 10.1136/bjsports-2011-090526. PubMed PMID: 22228554.

12. Finnoff JT, Peterson VJ, Hollman JH, Smith J. Intrarater and interrater reliability of the Balance Error Scoring System (BESS). PM R. 2009;1(1):50-4. doi: 10.1016/j.pmrj.2008.06.002. PubMed PMID: 19627872.

13. Galetta KM, Barrett J, Allen M, Madda F, Delicata D, Tennant AT, et al. The King-Devick test as a determinant of head trauma and concussion in boxers and MMA fighters. Neurology. 2011;76(17):1456-62. doi: 10.1212/WNL.0b013e31821184c9. PubMed PMID: 21288984; PubMed Central PMCID: PMCPMC3087467.

14. King D, Brughelli M, Hume P, Gissane C. Concussions in amateur rugby union identified with the use of a rapid visual screening tool. Journal of the Neurological Sciences. 2013;326(1):59-63. doi: <http://dx.doi.org/10.1016/j.jns.2013.01.012>.

15. Leong DF, Balcer LJ, Galetta SL, Liu Z, Master CL. The King-Devick test as a concussion screening tool administered by sports parents. J Sports Med Phys Fitness. 2014;54(1):70-7. PubMed PMID: 24445547.

16. Wechsler D. The measurement of adult intelligence. Baltimore, MD, US: Williams & Wilkins Co; 1939. ix, 226-ix, p.

17. van der Elst W, van Boxtel MP, van Breukelen GJ, Jolles J. The Letter Digit Substitution Test: normative data for 1,858 healthy participants aged 24-81 from the Maastricht Aging Study (MAAS): influence of age, education, and sex. J Clin Exp Neuropsychol. 2006;28(6):998-1009. doi: 10.1080/13803390591004428. PubMed PMID: 16822738.

18. Tombaugh TN. Trail Making Test A and B: normative data stratified by age and education. Arch Clin Neuropsychol. 2004;19(2):203-14. doi: 10.1016/S0887-6177(03)00039-8. PubMed PMID: 15010086.

19. Moser RS, Schatz P, Jordan BD. Prolonged effects of concussion in high school athletes. Neurosurgery. 2005;57(2):300-6; discussion -6. Epub 2005/08/12. PubMed PMID: 16094159.

20. Collie A, Maruff P, Makdissi M, McCrory P, McStephen M, Darby D. CogSport: reliability and correlation with conventional cognitive tests used in postconcussion medical evaluations. Clin J Sport Med. 2003;13(1):28-32. PubMed PMID: 12544161.

21. Makdissi M, Collie A, Maruff P, Darby DG, Bush A, McCrory P, et al. Computerised cognitive assessment of concussed Australian Rules footballers. Br J Sports Med. 2001;35(5):354-60. PubMed PMID: 11579074; PubMed Central PMCID: PMCPMC1724390.

22. Christy JB, Steed L. Commentary on "The effect of suit wear during an intensive therapy program in children with cerebral palsy". Pediatr Phys Ther. 2011;23(2):143. doi: 10.1097/PEP.0b013e318219352d. PubMed PMID: 21552074.