



Complete Concussion Management Inc. Baseline Testing Protocol & Supporting Evidence

Purpose:

Resolution of symptoms following concussion is known to be a very poor indicator of brain recovery. Concussion results in metabolic disturbance, changes in cerebral blood flow and perfusion, and a number of other pathophysiologic processes known as the *Neurometabolic Cascade* (1,2). Numerous studies show that prior to full metabolic recovery from a concussion, the brain is extremely vulnerable, where even smaller impacts can cause secondary concussion injuries and these injuries can result in severe brain injury with potentially permanent or fatal outcomes (3,4). These same studies demonstrate that if the individual is to fully recover, in a metabolic sense, from their concussion, then suffering a second concussion will cause little to no additive/cumulative effect. The most important aspect to the safe and proper management of concussions is therefore to ensure that full recovery of the brain has been achieved prior to allowing an athlete to return to a sporting/contact environment; a process which has been shown to take at least 3 to 4 weeks(5-7).

Relying on symptoms, or lack thereof, to make return-to-play decisions puts healthcare practitioners in an extremely precarious position, as we are fully aware that symptoms do not reflect true recovery of the brain following concussion. Self-reported symptoms at rest are even more unreliable as ongoing blood-flow and cognitive abnormalities may only come to light when challenged by intensive physical exertion tests (8-12).

Baseline testing involves testing high-risk athletes prior to starting their sporting season to assess numerous physical and cognitive systems that could potentially become affected by a concussion. Despite some critical views towards baseline testing, it has been strongly recommended by many supporting studies (see below). When properly used and interpreted, baseline testing adds useful information to the management of sport-related concussion by giving access to pre-injury physical and cognitive functioning (13). Having access to sound test results as compared to an individual's healthy state provides clinicians with a set of objective data that can be utilized to make better informed, and therefore safer, return-to-play decisions.

It should be noted that baseline testing should involve more than just computerized neurocognitive measures. These measures are insufficient as stand-alone entities displaying numerous reliability and validity issues (see below). Additionally, these tests don't measure important aspects of concussion injuries such as balance, visual tracking and processing speed, strength & physical performance measures, auditory memory & concentration. A good baseline assessment should involve all of these areas, **including** neurocognitive testing parameters.

This document covers all aspects of the Complete Concussion Management Inc. baseline testing protocol and provides evidence for each test included within our testing battery.

Overview of the CCMI baseline test protocol:

CCMI baseline testing takes roughly 30 minutes per individual and is **covered under secondary health insurance benefits** for either physiotherapy or chiropractic (depending on who administers the test). Full team testing can be completed within 1 to 2 hours and can be done either at a certified CCMI clinic location or off site at a team training/practice facility. All patient data is stored on an electronic health records system that is accessible by all 190+ clinic locations across Canada.

The CCMI baseline test protocol consists of the following test areas:

- Concussion history, medical history, learning disabilities, psychiatric history
- Symptom score
- Orientation
- Auditory Memory
- Concentration
- Visual tracking and processing speed
- Balance (sideline measure)
- Balance – using force-plates to measure postural sway
- Reaction Time
- Strength
- Delayed Recall
- ImPACT neurocognitive testing
 - Visual word & shape memory
 - Go/No-go tests
 - Reaction Time (with cognitive processing component)
 - Effort tests

****Note:** Re-testing prior to return to play also involves physical exertion testing immediately prior to conducting the baseline re-assessment. This method (testing in a physically exerted state), has been shown to be a more sensitive way of testing, revealing up to 28% more neurocognitive impairment than neurocognitive testing at rest (11,12).

Symptom Score

The Post-Concussion Symptom Score (PCSS) is the most widely used concussion symptom inventory worldwide. Adapted by the Concussion In Sport Group as part of the Sideline Concussion Assessment Tool (SCAT), the PCSS is a 22-item measure with each symptom scored on a 7-point likert scale (14). A study by McCrea et al., found that the PCSS demonstrated the most sensitive and specific measure for concussion at the time of injury (when compared to balance and a neurocognitive examination), however, fewer than 5% of athletes reported higher symptom scores than baseline at 7 days post injury(15). These findings have also been replicated in other studies(5). This indicates that the symptom score, while potentially the most useful parameter for making the initial diagnosis of concussion, does not coincide with the recovery of the brain following concussion (22 to 30 days in previous metabolic studies). Therefore, more objective testing parameters are required to inform safer return-to-play decision-making.

Standard Assessment of Concussion (SAC)

Also a component of the SCAT, the SAC is a verbal/auditory neurocognitive test, which consists of Orientation, Immediate Memory, Concentration, and Delayed Memory Recall Tests. The SAC has been validated in several studies for use in the assessment of sport-related concussion(16-18). Because the SAC does not yet have established normative data, this test must be administered at baseline to establish individualized scores(19). Barr & McCrea found that immediate SAC scores decrease in concussion patients by an average of 4 points from baseline. Using multiple regression the authors found that a 1-point decrease from baseline SAC carried a 94% sensitivity and 76% specificity for the diagnosis of concussion (20). Marindes et al., found that the SAC alone was only able to accurately diagnose concussion 52% of the time, however adding in balance assessments and the King-Devick test improved the diagnostic accuracy to 100% (21). This demonstrates that the strength of concussion assessment rests in having numerous testing parameters versus relying on one single test. This test has also been found to demonstrate objective impairment in individuals reporting a complete resolution of symptoms (15).

King-Devick Test

Originally developed for the assessment of dyslexia, the King-Devick (K-D) test has emerged as one of the most popular and useful sideline concussion tests. The K-D test is an easily administered and scored test for visual tracking and processing speed. Dhawan et al., found that following a concussion, there is an average drop from baseline score by 7.3 seconds. These deficits can also remain for some time beyond the symptomatic period (30 to 40 days post-injury), which makes the K-D test not only a good immediate sideline test, but also a good return-to-play assessment measure (22). Marindes et al., found that the K-D test alone was able to pick up 79% of concussion injuries and when combined with balance and SAC testing, 100% of concussions were accurately diagnosed(21), once again demonstrating the value of using a multifaceted approach to concussion assessment. In healthy individuals, scores tend to improve over time due to a known learning effect; however with concussion, scores significantly worsen compared to baseline making this a good test for distinguishing healthy vs. concussed individuals (23-25).

Balance Assessment

Complete Concussion Management Inc. performs a two-part balance assessment, which consists of the Balance Error Scoring system from the SCAT as well as a more objective measure of postural sway utilizing force-plate technology.

The BESS test has been studied extensively in the concussed population(17,26,27). Research in this area has found that the range of baseline scores in healthy individuals is quite wide and also age dependent, making the utilization of normative data virtually useless as a comparison(28,29). This test has been shown to be most useful for acute concussion as scores have been found to normalize within 3 days from injury(27,30). As such, the Complete Concussion Management program utilizes a secondary balance assessment examining centre of pressure measurements from force-plate technology that has been found to show deficits beyond

resolution of symptoms, SAC scores, BESS, and computerized neurocognitive test scores(31). Other studies have demonstrated more sophisticated measures of balance utilizing force-plate technology can show impairments for up to 30-days following injury(32), which correlates well with previously identified physiologic recovery following concussion.

Clinical Reaction Time

This test was developed and validated by Dr. James Eckner and Dr. Jeff Kutcher, of the University of Michigan. Dr. Jeff Kutcher is a neurologist at Michigan and the head concussion physician for the NHLPA. This test is easily administered in a seated position using the athlete's non-dominant hand to grasp a dropped measuring stick with a standardized weight and spacer. This test has been found to show immediate deficits following concussion when compared to baseline (33) and has been validated against both computerized neurocognitive measures (34,35) as well as a 'functional head protective response' (the ability for an athlete to react to and protect themselves from incoming objects aimed at their head) (36), making this a useful test when determining the safety of an athlete to return to the playing field. This test has also been found to have moderate test-retest reliability over 1 to 2 seasons in NCAA athletes (37). Complete Concussion Management Inc. performs this test on a yearly basis.

Motor Strength

Tests of motor strength are currently being studied at Holland-Bloorview kids rehabilitation hospital with preliminary findings demonstrating that non-dominant hand grip strength shows concussion deficits beyond symptomatic recovery in children between the ages of 5 and 18. Complete Concussion Management is looking to contribute to this research by testing both dominant and non-dominant grip strength in all baseline assessments performed.

ImPACT®

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT®) is a computer-based neurocognitive battery. This test, comprising of visual memory tasks for shapes and words, reaction time, and basic executive function tasks, takes roughly 30-minutes to complete and is the most studied computerized neurocognitive test on the market. ImPACT supplies tables of normative data for high school & college level athletes however it has not yet been validated in ages younger than 13 years old. As such, Complete Concussion Management only utilizes this test as a part of our comprehensive battery in athletes 13 years or older. A recent study found that comparison of concussed individuals to a pre-injury baseline test is superior to using age-adjusted normative data as normative comparisons identified fewer symptomatic, concussed athletes than baseline comparisons using reliable change indices (38).

ImPACT testing has come under scrutiny in recent years as many clinicians are using this test as the sole determination of both injury diagnosis and return-to-play decision-making. Numerous studies have found poor test-retest reliability (39,40) and low-to moderate effect sizes (41), which has lead researchers and experts to strongly oppose the use of ImPACT as a stand-alone measure for baseline and post-injury testing (14,42,43). These same statements suggest that when used as a part of a comprehensive concussion evaluation, these tests can be quite useful in the overall concussion evaluation. ImPACT testing has been shown to demonstrate ongoing impairment in 25% of individuals who have been cleared to return-to-play following sports physician clearance based on examination and passing of baseline SCAT parameters (44). ImPACT test is therefore a useful test to include as part of a comprehensive concussion testing battery both at baseline and post-injury, but should not be used in isolation.

Two recent studies have also found that high-intensity physical exertion, completed prior to test administration effects neurocognitive function (11,12). As such, the current recommendation is to perform ImPACT tests following intensive physical exertion when making return-to-play clearance decisions, as this may be a more sensitive measure of ongoing cognitive deficits. In lieu of these studies, Complete Concussion Management Inc. performs our entire testing battery following the completion of the Chicago Blackhawks physical exertion test prior to making return-to-play clearance decisions. Athletes must remain symptom free throughout the duration of the Chicago Blackhawks test as well as complete ALL physical and cognitive measures (including ImPACT if 13 years or older) to a level at or above their pre-season baseline test results immediately following the Blackhawks test. If no

baseline test is available, the clinician can compare results to age-adjusted normative data however this may result in less than optimal return-to-play decisions as norms are based on U.S. data and adjusted to U.S. grade point averages.

CCMI Baseline and Concussion Management Summary

Complete Concussion Management Inc. was developed from the necessity to provide high-risk athletes with evidence-based concussion management strategies. The baseline testing protocol outlined above was developed through years of research to establish the most comprehensive testing battery to assess both acute injuries and the readiness to return to high-risk sporting activities. The period of brain vulnerability prior to full recovery from concussion injuries has been shown to result in long lasting and potentially permanent or fatal outcomes should an individual suffer another concussion during this time. It has been well established through the literature that symptoms alone do not reflect true recovery of the brain, making it imperative that objective measures be incorporated into the decision making process. In addition to this, healthcare practitioners often face pressure from athletes and/or their parents to provide clearance because the symptoms have dissipated. Having rigorous objective testing parameters can relieve this pressure and provide the clinician with the needed evidence to hold an athlete back from an early return to competition.

As was demonstrated above, no single concussion test is adequate to be used in isolation for either diagnosis or return-to-play decision-making. The Complete Concussion Management protocol conducts the most extensive concussion baseline testing available. Clearance of any athlete is not granted until there is a complete return to baseline of ALL pre-season measures following the passing of all step-wise return-to-learn and return-to-play stages including a 2-step process of physical exertion testing.

References

1. Giza CC, Hovda DA. The New Neurometabolic Cascade of Concussion. *Neurosurgery*. 2014;75:S24–S33.
2. Signoretti S, Lazzarino G, Tavazzi B, Vagnozzi R. The Pathophysiology of Concussion. *PM&R*. 2011;3(10):S359–68.
3. Vagnozzi R, Tavazzi B, Signoretti S, Amorini AM, Belli A, Cimatti M, et al. Temporal window of metabolic brain vulnerability to concussions. *Neurosurgery*. 2007;61(2):379–89.
4. Vagnozzi R, Signoretti S, Tavazzi B, Cimatti M, Amorini AM, Donzelli S, et al. Hypothesis of the Postconcussive Vulnerable Brain: Experimental Evidence of Its Metabolic Occurrence. *Neurosurgery*. 2005;57(1):164–71.
5. Vagnozzi R, Signoretti S, Cristofori L, Alessandrini F, Floris R, Isgro E, et al. Assessment of metabolic brain damage and recovery following mild traumatic brain injury: a multicentre, proton magnetic resonance spectroscopic study in concussed patients. *Brain*. 2010;133(11):3232–42.
6. Vagnozzi RR, Signoretti SS, Tavazzi BB, Floris RR, Ludovici AA, Marziali SS, et al. Temporal window of metabolic brain vulnerability to concussion: a pilot 1H-magnetic resonance spectroscopic study in concussed athletes--part III. *Neurosurgery* 2008;62(6):1286–6.
7. Signoretti S, Vagnozzi R, Tavazzi B, Lazzarino G. Biochemical and neurochemical sequelae following mild traumatic brain injury- summary of experimental data and clinical implications. *Neurosurg Focus*. 2010;29(5):1–12.
8. Baker JG, Freitas MS, Leddy JJ, Kozlowski KF, Willer BS. Return to Full Functioning after Graded Exercise Assessment and Progressive Exercise Treatment of Postconcussion Syndrome. *Rehabilitation Research and Practice*. 2012;2012:1–7.
9. Leddy JJ, Baker JG, Kozlowski K, Bisson L, Willer B. Reliability of a graded exercise test for assessing recovery from concussion. *Clin J Sport Med*. 2011;21(2):89–94.
10. Len TK, Neary JP. Cerebrovascular pathophysiology following mild traumatic brain injury. *Clinical Physiology and Functional Imaging* 2011;31:85-93.
11. Whyte EF, Gibbons N, Kerr G, Moran KA. The Effect of a High Intensity, Intermittent Exercise Protocol on Neurocognitive Function in Healthy Adults: Implications for Return to Play Management Following Sport Related Concussion. *J Sport Rehabil*. 2014 (Epub ahead of print).
12. McGrath N, Dinn WM, Collins MW, Lovell MR, Elbin RJ, Kontos AP. Post-exertion neurocognitive test failure among student-athletes following concussion. *Brain Inj*. 2013;27(1):103–13.
13. Vartiainen MV, Holm A, Lukander J, Lukander K, Koskinen S, Bornstein R, et al. A novel approach to sports concussion assessment: Computerized multilimb reaction times and balance control testing. *J Clin Exp Neuropsychol*. 2015;1–15.
14. McCrory P, Meeuwisse WH, Aubry M, Cantu B, Dvorak J, Echemendia RJ, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Br J Sports Med*. 2013;47(5):250–8.
15. McCrea M, Barr WB, Guskiewicz K, Randolph C, Marshall SW, Cantu R, et al. Standard regression-based methods for measuring recovery after sport-related concussion. *J of Int Neuropsychol Soc* 2005;11:58–69.
16. Naunheim RS, Matero D, Fucetola R. Assessment of patients with mild concussion in the emergency department. *Journal of Head Trauma Rehabilitation*. 2008;23(2):116–22.
17. McCrea M, Guskiewicz KM, Marshall SW, Barr W, Randolph C, Cantu RC, et al. Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. *JAMA*. 2003 Nov 19;290(19):2556–63.
18. McCrea M. Standardized mental status testing on the sideline after sport-related concussion. *J Athl Train*. 2001.
19. Baird JT. An effective tool in establishing the diagnosis of sport-related concussion. *Journal of the American Academy of Physician* 2011.

20. Barr WB, McCrea M. Sensitivity and specificity of standardized neurocognitive testing immediately following sports concussion. *J Int Neuropsychol Soc.* 2001 Sep 1;7(6):693–702.
21. Marinides Z, Galetta KM, Andrews CN, Wilson JA, Herman DC, Robinson CD, et al. Vision testing is additive to the sideline assessment of sports-related concussion. *Neurology: Clinical Practice.* 2015 Feb 16;5(1):25–34.
22. Dhawan P, Starling A, Tapsell L, Adler J, Galetta S. King-Devick Test Identifies Symptomatic Concussion in Real-time and Asymptomatic Concussion Over Time. (S11. 003). *Neurology.* 2014.
23. Leong DF, Balcer LJ, Galetta SL, Evans G, Gimre M, Watt D. *Journal of Optometry.* 2015 (Epub ahead of print)
24. Galetta KM, Morganroth J, Moehringer N, Mueller B, Hasanaj L, Webb N, et al. Adding Vision to Concussion Testing. *Journal of Neuro-Ophthalmology.* 2015 (Epub ahead of print).
25. Galetta KM, Brandes LE, Maki K, Dziemianowicz MS, Laudano E, Allen M, et al. The King–Devick test and sports-related concussion: Study of a rapid visual screening tool in a collegiate cohort. *Journal of the Neurological Sciences.* 2011 Oct;309(1-2):34–9.
26. Riemann BL, Guskiewicz KM, Shields EW. Relationship Between Clinical and Forceplate Measures of Postural Stability. *J Sport Rehabil* 1999;8:71-82.
27. Riemann BL, Guskiewicz KM. Effects of mild head injury on postural stability as measured through clinical balance testing. *J Athl Train.* 2000 Jan 1;35(1):19–25.
28. Snyder AR, Bauer RM, Health IMPACTS for Florida Network. A Normative Study of the Sport Concussion Assessment Tool (SCAT2) in Children and Adolescents. *The Clinical Neuropsychologist.* 2014 (Epub ahead of print).
29. Jinguiji TM, Bompadre V, Harmon KG, Satchell EK, Gilbert K, Wild J, et al. Sport Concussion Assessment Tool - 2: Baseline Values for High School Athletes. *British Journal of Sports Medicine.* 2012 Mar 22;46(5):365–70.
30. Murray N, Salvatore A, Powell D, Reed-Jones R. Reliability and Validity Evidence of Multiple Balance Assessments in Athletes With a Concussion. *J Athl Train.* 2014;49(3):540-9.
31. Buckley T, Evans K, Munkasy B. Lingering Impairments in Postural Control Despite Clinical Concussion Recovery (S27. 001). *Neurology.* 2015.
32. Slobounov S, Slobounov E, Sebastianelli W, Cao C, Newell K. Differential rate of recovery in athletes after first and second concussion episodes. *Neurosurgery.* 2007;61(2):338–44.
33. Eckner JT, Kutcher JS, Broglio SP, Richardson JK. Effect of sport-related concussion on clinically measured simple reaction time. *Br J Sports Med.* 2014; 48(2):112-8.
34. Eckner JT, Kutcher JS, Richardson JK. Effect of Concussion on Clinically Measured Reaction Time in 9 NCAA Division I Collegiate Athletes: A Preliminary Study. *PM&R.* 2011;3(3):212–8.
35. Eckner JT, Kutcher JS, Richardson JK. Pilot evaluation of a novel clinical test of reaction time in National Collegiate Athletic Association Division I football players. *J Athl Train. National Athletic Trainers Association;* 2010;45(4):327.
36. Eckner JT, Lipps DB, Richardson JK, Ashton-Miller JA. Can a Clinical Test of Reaction Time Predict a Functional Head-Protective Response? *Medicine & Science in Sports & Exercise.* 2011;43(3):382–7.
37. Eckner JT, Kutcher JS, Richardson JK. Between-Seasons Test-Retest Reliability of Clinically Measured Reaction Time in National Collegiate Athletic Association Division I Athletes. *J Athl Train. National Athletic Trainers' Association;* 2011;46(4):409–14.
38. Schatz P, Robertshaw S. Comparing Post-Concussive Neurocognitive Test Data to Normative Data Presents Risks for Under-Classifying “Above Average” Athletes. *Archives of Clinical Neuropsychology.* 2014 Oct 15;29(7):625–32.
39. Broglio SP, Ferrara MS, Macciocchi SN, Baumgartner TA, Elliott R. Test-retest reliability of computerized concussion assessment programs. *J Athl Train.* 2007 Oct;42(4):509–14.
40. Resch J, Driscoll A, McCaffrey N, Brown C, Ferrara MS, Macciocchi S, et al. ImPact Test-Retest Reliability: Reliably Unreliable? *J Athl Train.* 2013 Jul;48(4):506–11.
41. Kontos AP, Braithwaite R, Dakan S, Elbin RJ. Computerized Neurocognitive Testing within 1 Week of Sport-Related Concussion: Meta-analytic Review and Analysis of Moderating Factors. *J Int Neuropsychol Soc.* 2014 Feb 13;20(03):324–32.
42. Harmon KG, Drezner JA, Gammons M, Guskiewicz KM, Halstead M, Herring SA, et al. American Medical Society for Sports Medicine position statement: concussion in sport. *British Journal of Sports Medicine.* 2012 Dec 13;47(1):15–26.
43. Mayers LB, Redick TS. Clinical utility of ImPACT assessment for postconcussion return-to-play counseling: Psychometric issues. *Journal of Clinical and Experimental Neuropsychology.* 2012 Mar;34(3):235–42.
44. Taylor K, Brooks B, Schneider K, Blake T, McKay C, Meeuwisse W, et al. Neurocognitive performance at return to play in elite youth hockey players with sport-related concussion. *Br J Sports Med.* 2014;48(7):664–4.