Mild Traumatic Brain Injuries: Reliability of Concussion Testing and Effects of Multiple Concussions in Athletes

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An estimated 3.8 million concussions happen every year in youth, adolescent, collegiate and professional athletes.[1] In recent years, concussions have come into the spotlight due to local and national stories about athletes collapsing after sustaining a second concussion while still suffering from a previous one and other athletes committing suicide, which seem to be linked to concussions. Concussion testing throughout the country has become a regular procedure and baseline testing is becoming more popular in high school settings. For collegiate athletics, NCAA policy requires a pre-participation assessment for all athletes that include: A brain injury/concussion history, symptom evaluation, cognitive assessment, and balance evaluation.[2]

Concussion Occurrence and Symptoms

According to the Center for Disease Control between 1.6-3.8 million sports and recreational concussions occur each year.[3] Most symptoms resolve after a few weeks, but some can be more serious persisting for months or years.[4] Most concussions occur in contact sports, such as football and hockey and account of 8.9% of high school athletic injuries and 5.8% of collegiate athletic injuries.[4]

There are many consensus-based definitions of a concussion. A generally agreed upon, evidence-based definition is “a change in brain function, following a force to the head, which may be accompanied by temporary loss of consciousness, but is identified in awake individuals with measures of neurologic and cognitive

dysfunction". [2] Most concussions do not involve a loss of concussion, but still cause neurological and cognitive disruption.

There are many symptoms that can be associated with a concussion. These can include, physical, cognitive, emotional problems and sleep disturbances. [5]

Physical symptoms can include:

- Headache
- Nausea and vomiting
- Balance problems
- Dizziness
- Visual problems
- Fatigue
- Sensitivity to light and noise
- Numbness/tingling [5]

Cognitive Symptoms include:

- Difficulty remembering
- Concentration problems
- Feeling mentally foggy
- Forget recent information
- Answers questions slowly [5]

Emotional Symptoms include:

- Irritability
- Sadness
- Nervousness
- Changes in emotions
- Depressive Symptoms [5]

Sleep disturbances can include drowsiness, changes in sleep patterns, trouble falling asleep or staying asleep. [5]

It is possible for athletes to develop depression after a concussion. Depression immediately following a concussion can be due to a number of reasons. The biggest predictor of depression after a concussion is depressive symptoms at

baseline testing.[6] Lingzhen Yang found that collegiate athletes that showed depression symptoms at baseline were 4.59 times more likely to experience depressive symptoms after a concussion.[6] Depression symptoms can occur in athletes because athletes identify strongly with their sports, so removal from competition and being temporarily isolated from the social environment of their sport can cause short-term depressive symptoms. Another reason depression symptoms are thought to occur is due to temporary neural disruption. [6]

Concussion Testing

There are many different ways to test for concussions both baseline and post concussion testing. Baseline testing is useful because it allows for a comparison between pre and post concussion scores and helps health professionals assess whether an athlete can return to play or not. Kansas State University requires baseline cognitive and postural-stability testing prior to any activity. [7] There are four tests that Kansas State University uses for baseline testing; SAC, BESS, ImPACT and a SCAT 2 form.

The first tool is a modified version of the Sports Concussion Assessment Tool (SCAT 2). The full SCAT 2 includes a symptom evaluation, a cognitive and physical examination and balance examination. There is also a sideline test for immediate post concussion. Kansas State uses the symptoms evaluation form of the SCAT and uses other forms to test balance, memory and reactions. [7] The SAC is included in the full SCAT 2, but is given separately at Kansas State. The symptom evaluation of the

SCAT 2 is self reported by athletes. At baseline, athletes typically rate their symptoms at a zero, and these symptoms normally increased post-concussion.

The second test used is the Standardized Assessment of Concussions (SAC). The SAC screens for concussions by testing both immediate and delayed memory in athletes. There are four sections to this test that include orientation, immediate memory, neurological screening, concentration and delayed memory recall. [8]

The Balance Error Scoring System (BESS) is used to test athletes' balance on both a stable surface and an unstable surface, such as a foam pad. [7] The goal of the unstable surface is to create a larger challenge for the athlete, requiring the brain to adapt to the surface in order to balance. [9] Three different stances are tested for 30 seconds each: a double leg stance, single leg stance (standing on non-dominant leg) and a tandem stance (non-dominant foot behind dominant foot). [7] Athletes are scored based on the amount of errors they make in the 30 seconds, which means the higher the score, the more errors made. With each stance, the athlete is required to stand with their eyes closed and hands on the iliac crest. [7] Each time an athlete does one of the following, it counts as one error: hands are lifted off the iliac crest, opening the eyes, step, stumble or fall, moving hip into >30 degrees abduction (single leg stance), lifting forefoot or heel, or remaining out of the testing position for more than 5 seconds. [7]

The final tool used at Kansas State for concussion testing is the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT). ImPACT is a newer, computerized test that objectively evaluates athletes for a concussion based on verbal and visual memory, processing speed and reaction time. [10] ImPACT testing is

not currently mandated for concussion testing by the NCAA, but the National Athletic Trainers' Association (NATA) recommends using ImPACT testing or similar tests along with other concussion diagnostic tools. [11]

SCAT 2 Reliability

Symptoms are a major part of diagnosis for any injury or disease, including concussions. Monitoring symptoms is a vital step in concussion management and historically are the primary grounds on which a concussion is diagnosed. [12] Nearly 80% of athletic trainers use symptom evaluation in a return to play (RTP) evaluation and 15% of those ATs indicate symptoms as their primary method for RTP decisions. [12] The SCAT 2 is a widely used assessment tool that has been shown to have both face and content validity. [12,13] This test measures symptoms commonly associated with concussions such as, headaches, nausea or vomiting, confusion, difficulty concentrating and more for a total of 18 symptoms for baseline testing and an additional six symptoms for post-concussion assessment. [7] A physician or certified athletic trainer (ATC) will administer the SCAT 2 at both baseline and post-concussion. At the time of testing the athletes are given the instructions to report symptoms, as they are that day. [14] The test will be given every day or frequently after concussions until symptoms are resolved and the athlete is cleared for RTP.

In a review of a very similar tool, the Post-Concussion Scale (PCS), which is also a tool in which athletes' self-report symptoms found high internal consistency reliability, ranging from .88 to .94. [14] This was measured in both male and female

athletes in high school and college. This study found that symptom severity reported increased with increasing severity of concussion. [14] The symptoms that were reported more frequently than others included headaches, fatigue, feeling slowed down, drowsiness, difficulty concentrating, feeling mentally foggy and dizziness; these symptoms were reported in 60-79% of the sample. The least frequently reported symptoms were nervousness, feeling more emotional, sadness, numbness and tingling and vomiting; these were reported in less than 25% of patients. [14] All of the symptoms reported on the PCS are also on the SCAT 2. High reliability and validity of the PCS can show similar results for the SCAT 2.

The problem with the reliability of the SCAT 2 is not in the test itself, but in the reliability of athletes' self-reporting symptoms. The SCAT 2 has been criticized as a concussion assessment tool because it relies on the athlete to report the symptoms they are experiencing. This can become an issue when the athlete is under the stress to return to competition by coaches, parents or teammates or the other psychological implications of a concussion causes the athlete to want to return before they should.

It is estimated that over 50% of concussions go unreported in high school athletes. [15] In a survey answered by 167 high school athletes, only 40% of concussion events reported to a supervising adult (coach, athletic trainer or parent). Common reasons for not reporting these concussion symptoms were they did not believe the injuries were serious enough to report, they did not want to leave the game, and they did not want to let teammates down. [15] Another study of 20 Washington State High Schools found that 40% of concussed athletes did not report

their concussions to coaches or athletic trainers. [16] Both of these studies found that increased knowledge of concussion symptoms and the dangers of playing with a concussion did not increase the likelihood of athletes reporting concussion events or symptoms to a coach or athletic trainer. [15,16]

Attitudes toward concussions did affect athletes' likelihood of reporting symptoms. Attitude was measured by using 14 7-point Likert-scale questions addressing overall attitude toward concussions; a higher score indicated a more favorable attitude toward concussions. [15] It was reported that the more favorable attitude towards concussions, the more likely an athlete was to report symptoms. [15]

Although the SCAT 2 and similar assessment tools have a high content reliability and validity, it is highly dependent on an athlete's honesty in reporting symptoms. Even with increasing education for athletes about concussion symptoms and the dangers of playing with a concussion, overall athletes continue to under report concussion events and symptoms. The SCAT 2 is useful assessment tool, but should be used along with other tools and not be the only measure used to assess an athlete's return after a concussion. It is important to continue to increase the education about concussions for athletes in hopes to increase the reporting of concussions. [15,16]

SAC Reliability

The SAC was developed in order to give clinicians an objective and standardized way of testing for a concussion on the sideline of a competition or

practice.[17] It has been widely used for testing since the mid 1990's and the NATA continues to recommend the implementation of the SAC in the most recent position statement released.[11] The SAC was designed in accordance with literature that demonstrates the functions most sensitive to concussions, including immediate and delayed memory, concentration and orientation.[18]

Michael McCrea, Director of Brain Injury Research at the Medical College of Wisconsin, has conducted multiple studies to test the reliability of the SAC when used immediately after injury on the sideline. These studies looked at both high school and collegiate football players. All subjects underwent baseline testing before the start of their respective season.[17,18] There were no significant difference between high school and college athletes for baseline scores in either study. These two studies were conducted four years apart (1995-96, 1998-99 seasons) and both looked at the scores of concussed athletes immediately after injury and 48 hours after injury. Both found that athlete who had suffered a concussion and significantly lower scores immediately after injury when compared to their baseline. Injured athletes' SAC scores had returned to near baseline scores 48 hours after injury.[17,18]

One concern that some clinicians have about the SAC is that testing on the field, scores may be lowered from fatigue. In a study to test the sensitivity and reliability of the SAC, William Barr and Michael McCrea administered the SAC to uninjured athletes on the sideline, during a practice and found that score did not significantly vary from their baseline scores.[19] Both high school and college athletes were retested 60 and 120 days after baseline testing, these predicted approximately the middle of the season and end of the season. Upon retesting at 120 days, college

athletes' test scores seemed to improve, demonstrating that college athletes showed more of a learning effect. After data analysis, it was indicated that there was a moderate score for test-retest reliability (r=0.55), which is statistically significant, but not clinically significant. [19] It was seen that injured athletes had an average of a four-point decrease in scores immediately after injury. Analysis determined that an increase or decrease of three points is statistically significant [19], showing that the SAC is a reliable tool for assessing concussions when administered immediately after injury.

The SAC has also been compared with the King-Devick (K-D) test, which tests rapid eye movement. Both have been proposed for sideline concussion testing. This study was conducted on professional hockey players. Subjects were tested pre-season for baseline scores and injured athletes were tested again immediately after injury. [13] It was found that for every increase of 2.2 seconds to complete the K-D test correlated with a 1-point reduction of overall SAC score; for every 1 point reduction on the immediate memory score correlated with a 7.3 second increase on the K-D test. [13] This study leads to further validity of the SAC because scores on both tests correlated when measured immediately after concussion.

Overall, the SAC is a valid and reliable measure to help assess concussion. It alone cannot diagnose a concussion, but it can help untrained coaches or clinicians assess an athlete for a concussion. Both the NCAA and NATA recommend the SAC for the assessment of concussions. [2,11] It is important that this test be administered immediately following injury or as soon as possible because multiple studies have

shown that injured athletes' scores return to baseline as quickly as 48 hours after the injury. [17,18]

BESS Reliability

Balance testing is often used with other tests for concussion baseline and diagnosis because postural stability can be impaired for up to three days following injury. [20] Gait stability can also be affected after a concussion. In a study by David Howell, it was shown that adolescence have more problems with gait stability while simultaneously performing cognitive tests for up to two months following a concussion. [21] This issue tends to decrease with age, but can still be a problem shortly after a concussion into adulthood. There was no relationship found between symptoms, performance on tests of cognitive function and postural stability [20] so BESS testing could be a valuable tool if used in conjunction with other tools.

Multiple studies have been conducted to test the reliability of BESS testing. In a two-study experiment by Tamerah Hunt, PhD, ATC, tested both a traditional BESS with all three stances on both a firm and foam surface and a modified BESS. The modified BESS tested only the single leg and tandem stance on a firm and foam surface and participants completely three trials of each stance. [22]

The first study showed insufficient intraclass reliability (r=0.60) of standard protocol. Intraclass reliability measures internal consistency or the extent that separate parts of the test measure the same thing. When the double leg stance was removed, reliability increased (r=0.71). [22] The second test had much higher

intraclass reliability (r=0.88) when the three trials of four stances were used.[22] These two studies show that slightly modifying the BESS can significantly improve reliability.

A study by Steven Broglio sought to test the test-retest reliability of the BESS. It is thought that multiple trials of this test my decrease the reliability because of improved balance controls from learning. In this study, participants (male and female) completed the BESS evaluation and returned after 50 days for a reevaluation.[23] Each participant completed five consecutive tests at both baseline and reevaluation. After analyzing data, it was found that the BESS had moderate test-retest reliability (r=0.64); clinically accepted reliability r>0.8.[23] Broglio and colleagues contributed the low reliability to learning effects after multiple exposures.

David Bell, PhD, ATC and colleagues performed a systematic review to test the reliability and validity of the BESS. When looking at reliability, criterion-related validity, construct validity, and construct validity, all appeared to show varied results between studies.[24]

Of the 9 studies that looked at reliability, intratester reliability ranged from 0.60 to 0.92 for the total BESS score and 0.5 to 0.98 for individual stances. Double leg stances on both a firm and foam surface had the highest amount of error. It is thought that this is due to the small amount of error associated with these stances.[24] Significant correlations were shown for criterion-related validity when compared to target sway. These correlations held true for 5 of the 6 stances, and double leg stance on a firm surface could not be measured because no errors were made.[24]

BESS scores varied with changing populations and conditions. For concussions, the BESS did not differentiate between athletes with concussions with or without headaches, but when measured by a instrumented balance testing device, athletes with headaches and worse balance than those without. [24] BESS tests can also be effected by fatigue, dehydration and neuromuscular training according to studies, which all may change between baseline and post-concussion tests.

According to this systematic review, the reliability of the BESS ranges from low to moderated to high. This wide range takes this test from both below and above the clinically approved cutoff. Criterion-related validity was dependent on the stance, with harder stances having higher validity. [24] Because the BESS does not differentiate between concussed athletes with or without headaches, it could be a valuable tool to help diagnose a concussion when athletes are not experiencing or not reporting headaches.

Overall, reliability for the BESS is highly variable between studies. Scores may improve for athletes between tests due to learning after being exposed to the test, but it can still be a useful tool when assessing concussions because postural stability is affected after a concussion. It is suggested that a difference in scores 4 points or greater is clinically significant to diagnose a concussion. [23] Clinicians should not solely rely on the BESS test for a concussion test because it can be affected by many different factors, but can be used in conjunction with others tests for a full assessment.

ImPACT Reliability

ImPACT requires a trained clinician to administer the test, and requires purchasing of the product unlike other assessment tools. [10] It takes approximately 25 minutes to complete the test and clinician must have access to a computer. [10] This is unlike other tools, taking much longer, but ImPACT results are more in depth than tools such as the SAC or PCS. [10] Collecting a baseline for each athlete using neurocognitive tests such as this, and then in the event of a concussion, the athlete should be retested and compared to baseline scores. [10]

ImPACT testing does have athletes report symptoms, but cognitive memory and reaction times are measured making the test objective. It has been indicated that self-reports of symptoms may not be indicative of resolution of a concussion [25], so researcher has sought to find if the ImPACT test is a reliable tool for diagnosing concussions.

One study by Philip Schatz looked to investigate the sensitivity and specificity of the ImPACT in high school and collegiate athletes. A total of 81 athletes 13-21 years old sustained a concussion and reported symptoms. An independent 81 athletes that completed a baseline ImPACT test were matched with the concussed athletes. [26] 37 athletes that did not report symptoms were also tested. All athletes were tested within 72 hours of sustaining a suspected concussion. [26] From this study, ImPACT correctly classified 80.2% of cases for the symptomatic concussed group and 69.1% of the non-concussed, control group. For reportedly asymptomatic

patients, ImPACT correctly identified 95.9% of the cases as concussed. After analyzing the 10 subscales of the ImPACT, it was found that scores showed a sensitivity of 91% and a specificity of 69%. [26] This research shows that ImPACT testing can be useful, especially when athletes are not reporting symptoms either by choice or they do not have symptoms. This study did not compare an athlete's personal baseline to their tests after a concussion, so sensitivity could be higher when comparing it to their personal baseline. For example, an athlete may test extremely high at baseline, so even concussed, the athletes scores may be high enough that the ImPACT would not normally read the scores of that athlete as concussed without a baseline score.

Grant Iverson also looked at interpreting overall scores of ImPACT. For athletes that were tested at baseline and with 72 hours after injury, a significant decline in verbal memory and visual memory, along with showing significantly slower processing speed and reaction time. [27] This study also concluded that athletes with a concussion are much more likely to have 2 or more declines than health athletes when retested. Statistically reliability declines that were measured in this study consisted of a decline in the following areas: verbal memory, 9 points, visual memory, 14 points, reaction time, 0.06 seconds, processing speed, 3 points, and post concussion scale, 10 points. [27]

This study along with a study by R.J. Elbin tested the test-retest reliability of ImPACT. When healthy subjects in Iverson's study, the average amount of time between tests was 5.8 days [27], while Elbin tested subjects 1 year apart. [28] Both tests found high test-retest reliability with processing speed being the most stable of the

five categories tested, r=0.86 [27] and r=0.85 [28], respectively. After 5 days, Iverson found the least reliable measure to be post-concussion scale (r=0.65) and immediately following was visual memory (r=0.67). [27] At one year, the least reliable measure appeared to be verbal memory (r=0.62). [28] Scores on ImPACT appear to be stable over 1 year and recent consensus and position statements suggest reestablishing baseline tests every 2 years to accommodate for athletes increasing neurocognitive development and learning, especially in high school athletes. [28]

Although ImPACT does show high sensitivity, validity and reliability, athletes may attempt to lower their baseline scores so they don't have to meet as high as scores when they are suffering a concussion. Although the ImPACT will test for invalidity, it may not catch every one. Athletic trainers or healthcare professionals administering the test should check for validity. In a survey of 399 athletic trainers, 94.7% of them reported to administering ImPACT, but only 51.9% of them examined the tests for validity. [29]

ImPACT can be a very valuable tool for concussion assessment. Although it takes more time to administer and can be costly, ImPACT can provide valuable information for clinicians and has high reliability and validity.

Concluding Comments on Testing

Overall, concussion testing is a complex process and should include a variety of tests in order to encompass all the different processes that concussions effect. All

of the tests used by Kansas State University use have shown to be reliable measures either how they are or with slight moderation.

It is important to not rely on symptoms alone to diagnose a concussion because symptoms may not be present or an athlete may lie about having symptoms in order to return to play faster. Both BESS and SAC can provide information immediately after injury, but scores may return to baseline within 48 hours after injury. ImPACT can be given further out from the concussion date, but it is recommended that it be given within 72 hours of injury. [27]

It is important to note that tests alone cannot diagnose a concussion, but it requires a trained clinician, such as an ATC or physician to diagnose a concussion. Because of the high risk an athlete takes when playing with a concussion, it is important for a clinician to take extreme caution when dealing with an athlete that is suspected to have a concussion.

Education

One of the most important factors when it comes to athletes and concussions is education. Educating athletes can play an important factor when it comes to athletes reporting a concussion. The NATA recommends that athletes, parents and coaches receive annual education about the signs and symptoms, prevention, management and dangers of playing with a concussion. [11] The NCAA requires that student-athletes be educated annually about the signs and symptoms of a concussion. [2]

Coach education is also important. NCAA coaches are required to sign a statement acknowledging that they understand concussion facts and that institution's concussion management plan. [2] Coach education can give the ATC another pair of eyes that can recognize an athlete with a possible concussion. If both coaches and athletes are educated about the signs and symptoms and dangers of playing with a concussion, then it decreases the likelihood of an athlete playing with a concussion.

Education about the dangers of playing with a concussion could have possibly saved numerous young athletes lives. This has lead to legislation across the United States about requiring education for athletes. One story that gained national attention occurred in 2010, in a town only 35 minutes from Kansas City.

A 17 year-old, high school football player collapsed on the sideline after complaining of a severe headache. This occurred in the second game back after being withheld from play for three weeks because of a diagnosed concussion. [30] The athlete complained of persistent headaches when his ATC sent him to his family physician to be evaluated for a concussion. It was there he went through multiple tests and underwent a CT scan, where the doctors found nothing out of the ordinary. A physician cleared him before he returned to play and had said he had no symptoms. [30]

In his returning game, it appeared he had been hit multiple times, but reported no symptoms to his ATC and told his parents that he felt great. The next game, the final game of his senior season, everything seemed normal until right before halftime, when his parents saw him on the sideline and thought he was acting

strange. By the time his parents got to the field, he had collapsed. He was airlifted to the University of Kansas Medical Center, but by 4 am, he was pronounced dead. [30]

The autopsy revealed that he had died from multiple hits to the head, which caused uncontrollable swelling and pressure, otherwise known as second impact syndrome. [30] His brain was donated to the Boston University Center brain bank, the leading center for studying sports related deaths. It was discovered upon examination that this athlete is one of the youngest known cases of chronic traumatic encephalopathy (CTE); a degenerative disease found in athletes who receive repeated concussions. [30] Later, it was also revealed that this athlete had reported he was still having headaches to close friends, but was not worried because all of his tests were normal.

There were many reasons that this gained national attention. At a time where the NFL is being sued over issues from concussions, new laws are being implemented in every state and more information is coming about concussions everyday, this story made this information very real for many people. Not only was this athlete so young, but he was also a straight-A student. He was smart, he and his parents had signs an acknowledgement or risk form and he still did not understand these risks that he took playing with a concussion. Education could have possibly prevented this, along with many other tragedies. This is the reason that education plays such a crucial role for concussion awareness.

<u>The Dangers of Concussions</u>

Playing with a concussion can have detrimental effects for an athlete as seen above. Multiple concussions can cause long-term effects for individuals such as impaired brain development, permanent brain damage, and even death. When an athlete is suffering a concussion and sustains another, even minor, blow to the head, in can cause further swelling and more bleeding in the brain, which can impair vital brain function. [31]

Second Impact Syndrome

One of the most devastating events that can happen to an athlete playing with a concussion is second impact syndrome (SIS). This occurs when an athlete sustains a second concussion while still suffering from a first. When an athlete is already suffering from a concussion, it does not take as high of force to sustain a second concussion. [32] This is a rare occurrence, but younger athletes seem to be more at risk, as most cases in the literature involve athletes under the age of 18. [32] This has also been seen in collegiate athletes as well.

The pathophysiology behind SIS is not well known, but it is believed that it is caused by a loss of autoregulation of the cerbrovasculature. [31] Under normal conditions, cerebral arteries relax and constrict uniformly to keep blood flow constant. It is known that brain surgery; trauma and even drugs can affect the pressure autoregulation. With increasing evidence that increasing severity of brain injury can induce this dysfunction, it is likely that the repeated trauma will do the same, causing increasing intracranial pressure from unregulated vasodilation. [31] The

severe increase in intracranial pressure causes herniation of the temporal lobes and the cerebellar tonsils through the foramen magnum and subsequent compression of the brain stem. [32] This compression of the brain stem causes respiratory failure and ultimately death. Brain stem failure is estimated to only take 2-5 minutes after second impact. [32] SIS does not always occur with hemorrhaging, but in a recent study by Robert Cantu, many cases have occurred with a small subdural hematoma.[32] SIS is a completely preventable scenario that stems from athletes knowing the dangers of playing with a concussion, especially while still experiencing symptoms. Young athletes are especially at risk, but it is important for any age athlete to understand these dangers.

Chronic Traumatic Encephalopathy

CTE is a degenerative brain disease that occurs from repetitive brain trauma.[33] This does not necessarily occur when an athlete plays with a concussion, but can occur if an athlete suffers from multiple concussions or even a number of subconcussive forces through out their life. Dr. Ann McKee, director of the brain bank has examined over 100 brains of former football players with a large majority of them playing in the NFL. McKee states that in many of these brains, there are tau deposits, which are a sign of brain degeneration in Alzheimer's patients and a sign of CTE. [34] CTE is thought to be linked to early onset of Alzheimer's in athletes that have had repetitive head injuries. McKee also suggests a link between CTE and depression in former NFL athletes. [34] This link could be very important because of

the several NFL athletes that have committed suicide in the last several years. Of the brains donated and studied, McKee suggests that of the 8 players that have committed suicide in the last 10 years, all showed signs of CTE. [34]

CTE has been recognized in professional boxers for a long time, due to repetitive subconcussive blows to the head. Symptoms of CTE progress much like Alzheimer's. First, patients will have deterioration in attention, concentration and memory. Often, they will also disorientation and confusion. Progressive deterioration causes lack of insight, poor judgment and dementia. Severe cases can be accompanied with slowing muscular movement, impeded speech, tremors and even deafness. [34] In the boxers looked at, time of their career ranged from 4-25 years and football players ranged from 14 to 23 years. [34] Death typically comes in middle age for CTE patients. CTE is starting to been seen in younger athletes as well, such as the 17-year-old athlete mentioned above and as well as in a 22-year-old collegiate football player who committee suicide in late 2014. [35]

CTE and concussions have shown a strong link to depression. Both Zachary Kerr and Nyaz Didehmani looked at depressive symptoms and concussions in retired NFL players in two separate studies. Didehmani looked at 42 subjects that were retired from the NFL, and these were matched for age, education and IQ. Of these subjects, retired NFL athletes that did not have a history of concussions reported depressive symptoms similar to the national average for males. Those subjects that have had a history of concussions reported higher scores on the BDI-II and on three Buckley factors: cognitive, affective and somatic. 12 subjects scored

high enough for a clinical diagnosis of mild to moderate depression and 3 others scored high enough to have mild depression.

Kerr looked a total of 1044 respondents to a general health survey that were former NFL players. Of the respondents, 106 reported being clinically depressed between baseline and follow up surveys. Kerr also found that the risk of reported clinical depression increased with increasing number of reported concussions from 0 having a 3% risk to 10+ having a 26.8% risk over 9 years between baseline test and follow up.[36] Both of these studies showed that retired NFL athletes with a history of concussions have a higher risk of having depression [3,36].

Between the studies done that have linked CTE to brain degeneration in many NFL athletes and boxers and studies that have shown that an increased number of reported concussions have higher reports of depression later in life. It is likely the CTE, concussions and depression are all linked. This shows that not only is playing with a concussion dangers, but also sustaining multiple concussions can cause problems later in life.

Concluding Comments

Concussions can have serious implications for athletes at any point in time in their life. Young athletes that think they will be okay plying with a concussion could suffer detrimental effects and athletes that sustain multiple concussions can suffer early brain degeneration and depression.

It is important to educate athletes on the recognition, management, prevention and dangers of playing with a concussion. Many concussions can be prevented by the athlete understanding proper tackling and avoiding head to head collisions. Athletes that understand how to recognize a concussion and understand the dangers of playing with one, reduce the risk of them participating with a concussion.

Reliable evaluation tools are also important in helping ATCs and physicians diagnose concussions. The SCAT 2, SAC, BESS and ImPACT are all reliable if implemented properly. Tests alone cannot diagnose a concussion, it is important for the AT and physician to work as a team to protect the athletes as much as possible.

Concussion testing needs to continually be evaluated as new research becomes available. Continued education is also important as coaches, parents and athletes should all be educated annually so they fully understand the serious effects concussions can have. Concussions are not fully preventable, but the risks can be greatly reduced through proper care and education.

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