Considerations for Neuropsychological Testing in the Adolescent Athlete: Implications for the Playing Field and Classroom

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“Concussion” is all over the news, and—yes—it has implications for combating chronic diseases such as obesity and diabetes. Many parents are pushing their children away from collision sports such as football, hockey, and lacrosse because they fear the risk of chronic neurodegenerative problems later in life. However, there is good logic in emphasizing the importance of physical activities such as collision type sports, during the developmental years. Physical educators, researchers, policy makers, and coaches must work together to encourage safe play and rules changes that can keep youth and adolescents active in sports that build character, discipline, and teach teamwork. Understanding the complexity of the highly adaptable adolescent brain both prior to and following sport-related concussion is critically important in accomplishing this goal.

Keywords: concussion, brain, development

The human brain is the most complex and intriguing organ in the human body, but as physical educators, injury prevention researchers, and human movement scientists we often overlook these intriguing complexities. Teenagers (or adolescents) think, behave, and motivate themselves in different ways than do adults. We need to consider these developmental differences in our study of teenagers. Understanding the way in which the brain works (or doesn’t work), especially during the adaptive period of adolescence, should be a goal of any parent, coach, or teacher of these wildly imaginative, challenging, and seemingly inconsistent creatures. I write this from the perspective of a parent of three boys (ages 16, 14, and 12) and a young girl (age 5)—yes she is the easiest to parent right now, and from the perspective of a neuroscientist studying the behavior of teenage athletes with sport-related concussion. On any given day, I play a guessing game—trying to creep inside their minds to stay just a half step ahead. It’s a game I lose more often than win.

Speaking of games, we live in a society where children and adolescents are encouraged more than ever to be physically active, and we may finally be seeing a leveling off and a subtle decline in the prevalence of childhood obesity and diabetes compared with the epidemic levels observed during the 1990s. Competitive sport is typically good in that it teaches children and adolescents about team building, responsibility, and discipline, but it can also lead to injury. The injury I am most passionate about figuring out is sport concussion, although it’s just as challenging as those teenagers to understand. I liken it to a snowflake, as there are no two alike. Our society has generally accepted the injury risks associated with sport and recreational play, but in recent years there are growing concerns being raised about the long term risks of ignoring concussions and continuing to play with a concussion. There is a developing body of literature, which calls into question the neurological consequences of repetitive concussions or brain injuries, not to mention subconcussive head impacts. Adolescents are typically big risk takers compared with children and adults, which already predisposes them to concussive injuries. A goal of my lecture during the 2012 National Academy of Kinesiology Annual Meeting was to get us thinking about the complexity of the adolescent brain, and to encourage us to consider the complexities involved with the adolescent brain both before and following a sport-related concussion. There are significant implications for injury prevention and management, and these likely extend beyond injuries to the brain.

The Adolescent Brain

The October 2011 issue of National Geographic offered an enlightening article, “Beautiful Brains Moody. Impulsive. Maddening. Why do TEENAGERS act the way they do?” by David Dobbs. He very eloquently, through a series of interviews with several developmental psychologists, illustrates how the adolescent brain undergoes a massive reorganization between age 12 and 25, and equates it to “a wiring upgrade.” I encouraged my colleagues to read this article in its entirety, but for now—here are a few take home points.
His synopsis of a large longitudinal National Institutes of Health neuroimaging study conducted on kids during the 1990s reveals that during adolescence, the brain’s axons become more myelinated causing transmission speeds to be increased by as much as 100 times. Dendrites are growing rapidly and synaptic pruning is taking place during this time, which causes thinning of the cortex in the adolescent brain while concurrently becoming more efficient. It is believed that the brain’s plasticity is at its greatest during this period, and is gradually becoming more sophisticated at information processing. Dobbs goes on to describe a slow wave of changes across the brain that begins posteriorly and progresses to anterior regions. So, the increased efficiency for basic behavioral functions (vision, movement, and fundamental processing) in adolescents occurs first in the occipital lobe, and the efficiencies for more complicated thinking regions in the frontal lobe occur last.

For kinesiologists, physical educators, and human movement scientists, there are implications of this developing brain. Consider that Beatriz Luna found that when compared with adults, teens make less use of brain regions important for monitoring performance, spotting errors, planning, and staying focused. (Luna, Garver, Urban, Lazar, & Sweeney, 2004; Luna, Padmanabhan, & O’Hearn, 2010). According to Abigail Baird (2009), teens behave with inconsistency because they are still learning to use their brain’s new networks.

This would suggest the need to develop unique strategies and incentives for teens to improve motor learning and ultimately performance. To simply demonstrate physically to a teenager their errors, poor decision making, or unsafe play, is often not sufficient. A better approach may be a multimodal strategy of allowing teens to visualize their own performance to compensate for these inefficiencies, or perhaps train the brain to work and respond more like an adult brain. An example is linking data from telemetered accelerometers or other kinematic tracking devices to video footage that can provide biofeedback to the young athlete. Showing the athlete a resultant reduction in the forces distributed to the head during tackling or blocking drills when the neck muscles are contracted and the head is rotated away from the opposing player’s head can be very meaningful in modifying future behavior and preventing a concussive injury.

Trying to modify behavior in teenagers who have a natural fascination for novelty and risk can be challenging. One would think that emphasizing the consequences of poor decision making and dangerous play might be sufficient, however again—teenagers think and behave differently. Dobbs goes on to illustrate the research findings by developmental psychologist Lawrence Steinberg who shows that although teens “may understand that risky behaviors such as smoking and unprotected sex carry consequences, they tend to give more weight to the pleasures than the costs.” The biggest risk-takers are between age 14–17yrs, according to Steinberg’s research (e.g., Steinberg 2004; 2008), and that on average, they weigh risk versus reward differently than both their younger and older counterparts (Figure 1).

![Figure 1](image)

**Figure 1** — As illustrated by Lawrence Steinberg, high risk preference increases gradually between age 10 and 17, and then drops off fairly dramatically over the next decade of life.
Managing Sport-Related Concussion in the Adolescent

Extrapolating the findings that teenagers represent our greatest risk takers, we can assume that they are more likely to take risks on the playing fields. And they do. Risk of catastrophic brain injury (although fortunately rare) is often the result of playing with symptoms from a previous concussion and sustaining another impact to the head while the brain is still recovering. The brain’s neural networks and vascular system is vulnerable following acute concussion, and if this additional stress to the system results in a loss of the brain’s ability to self-regulate the blood supply, then diffuse cerebral edema or swelling can occur and cause the brainstem to herniate. This rare condition, known as Second Impact Syndrome, is most common in contact sport athletes under the age of 18. It is very likely that adolescents are most vulnerable to this condition because of both physiological and behavioral reasons.

As previously described, the teenage brain has not yet physiologically reached full maturation and is in a period of rapid development (Anderson, Jacobs, & Anderson, 2008; Fischer & Rose, 1996; Luna et al., 2010). The continued development of the adolescent brain’s frontal region likely makes it more vulnerable to the effects of concussion (Luna et al., 2004) and challenged with tasks involving working memory and executive function (Baillargeon, Lassonde, Leclerc, & Ellemberg, 2012; Luna et al., 2010). Behaviorally, we know that the adolescent is willing to hide signs and symptoms of concussion, or at least not report them—allowing them to remain in the game. One study found that nearly 50% of high school football players did not report their concussions during the season, but admitted to them after the season (McCrea, Hammmeke, Olsen, & Guskiewicz, 2004). They reported three primary reasons for not wanting to report their injury when it occurred: 1) Not serious enough to report, 2) Did not want to be removed from play, and 3) Did not want to let coach/team down. This sounds like a combination of poor executive function and high risk taking, where the thrill outweighs the known risk. Since 2009, concussion laws aimed at education, no same-day return to play, and required return to play clearance by a trained health care provider, have been in place over 40 states. In time, it is hoped that these laws will help close the gap between the number of reported and unreported concussions. This will undoubtedly require a culture shift and some significant behavior modification on the part of the athletes, and support from parents, coaches, and educators.

It has been well established that the assessment and return to play decisions following concussion should involve a multifaceted approach (Guskiewicz et al., 2004; McCrory et al., 2009). Researchers have aimed to better understand the acute effects of concussion on clinical symptoms, cognitive deficits, and balance impairment, but for the aforementioned reasons it has been challenging in the adolescent athlete. We know the developmental factors are likely to affect working memory the most, followed by executive function (Lovell et al., 2003; Lovell, Collins, Iverson, Johnston, & Bradley, 2004; Sim, Terryberry-Spohr, & Wilson, 2008). Furthermore, full recovery from sport concussion in adolescent athletes will likely take longer than in adult athletes (Giedd 2008; Lovell et al., 2007; Moser, Schatz, & Jordan, 2005). There are, however, other factors that must be considered when evaluating the teenager with a concussion, such as knowing whether the athlete has a learning disability or attention deficit–hyperactivity disorder, each of which can affect the outcome of neurocognitive and balance testing. Or, simply knowing the motivation level of the athlete, which can be variable from day to day in many teenagers. Utilizing such tools to make decisions about limiting cognitive exertion and making academic accommodations can also be helpful. Interpretation is key here, and most often this should be done by a neuropsychologist or school psychologist.

Due to the developing brain, there may also be steeper learning and practice effects on both cognitive and balance tests during adolescence, further complicating the interpretation of results (Lovell & Fazio, 2008; Valovich McLeod, Barr, McCrea, & Guskiewicz, 2006). The continued motor development and ability to learn tasks in the young adolescent is good in most respects, but challenging in that we often do not know what’s “normal” for a given athlete as they are almost changing by the day. Learning effects can be influenced by both the nature of the balance task and the time intervals between the test sessions. Learning effects have been demonstrated in balance tasks utilizing static force platforms (Hamman, Longridge, Mekjavic, & Dickinson, 1995) and through more basic clinical balance assessments (Valovich, Perrin, & Gansneder, 2003). This research suggests that tasks requiring novel or unusual activities (moving surfaces or altered visual feedback) results in greater learning effects. Regardless of these challenges with inconsistencies on behavioral, cognitive, and motor performance—utilizing objective concussion management tools to assist the adolescent athlete in safely returning to the playing field and classroom is believed to be the best line of action.

Conclusions

In summary, understanding the adaptability of the adolescent brain should be a goal of any parent, coach, or teacher. Like most parents and educators, I have too often expected the brain of an adolescent (or the person housing that brain!) to function like that of an adult. Steinberg probably said it best in his 2011 National Geographic interview with Dobbs—“In scientific terms, teenagers can be a pain in the ass. But they are quite possibly the most fully, crucially adaptive human beings around” (pp. 55-56). As kinesiologists, we need to study and appreciate these differences and adaptabilities, and apply them to our work. Learning the best way to prevent and manage concussion in this uniquely challenging, yet intriguing population, has been very rewarding for me. We don’t
yet have all the answers, but we are capable of producing a more extensive body of knowledge to help modify behavior to prevent injury; and should injury occur, we are able to guide return to school and return to play decisions for the injured adolescent athlete. And we will.

References


