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Annotated Bibliography

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Introduction

Over the last several years, the topic of concussions in athletics has permeated the lay media to the point that it is now a part of the popular video game, John Madden NFL 2012 (Schwartz, 2011). The recent highlighting of this type of injury was triggered by, and has resulted in a plethora of new research. Since 2000 there has been more peer reviewed research in this area than had been cumulatively done before (Cantu, 2006). One specific area benefiting from this new infusion of research is youth athletics. Studies show adolescent athletes recover more slowly from concussions than their collegiate counterparts (Field, Collins, Lovell, & Maroon, 2003), and deficits can be noted via electroencephalogram (EEG) up to one year post injury (Boutin, Lassonde, Robert, Vanassing, & Ellemberg, 2008). Another area of recent focus is non-somatic post-concussion symptomology. Research shows that attention and executive function may be impaired up to one year post injury (Catale, Marique, Closset, & Meulemans, 2009), and more importantly that non-somatic symptomology may be present even in the absence of a clinically diagnosed concussion (Talavage et al., 2010). It has become painfully obvious through these new research undertakings that our understanding of the damage done to the developing brain by repetitive impacts, and the associated post-concussion symptoms, is far from sufficient.

Problem Statement

The purpose of this research report is to critically assess current research that addresses mild traumatic brain injury (MTBi) and related non-somatic post-concussion symptoms (PCS) in children and adolescents.

The baseline concussion testing model has developed into the preferred method for diagnosing concussions in athletics (Brooks, 2007; Guskiewicz et al., 2004). This retrospective study was designed in an effort to formulate a greater understanding of what these neurocognitive baseline tests actually measure. Data was collected on forty-seven college football players from a review of medical charts. These athletes all completed baseline testing and a self-administered personality measure prior to competition. Through analysis, it was determined that there was a significant relationship between psychological distress and baseline testing performance. This discovery confirms previous data that shows there is significant overlap between depression and post-concussion symptoms (Garden et al., 2010). The author proposes that this can be a meaningful way to recognize athletes that have psychological stress.

What was not covered was the fact that the psychological stress associated with an athlete being injured (Mainwaring, Hutchison, Bisschop, Comper, & Richards, 2010) could potentially confound the results of post injury neuropsychological testing. Dr. Bailey is an assistant professor at Case Western University, an institution that has a history of supporting pediatric concussion research (Yeates & Taylor, 2005; Taylor et al., 2010).

The lead researcher for this study is a professor at the University of Liége in Liége, Belgium. A search of the PsychINFO database reveals one other published work from Dr. Catale (Catale, & Meulemans, 2009). Twenty-one individuals, with a mean age of 8.3, were recruited from two institutions where they had sought medical attention for mTBI. Several measures covering behavior, intellectual function, and attention were administered one year after injury to the injured subjects and a control group. Results showed that subjects with a history of mTBI performed poorly on evaluation of selective attention when compared with a control group; however, there was no difference intellectual performance. Intellectual functionality of the two groups being similar validates the control group appropriateness. This reinforces previous research that established attention issues in a youth athlete with mTBI a year after injury (Boutin et al., 2008). Attention may become another potential diagnostic tool, or warning flag, for youth with a history of mTBI.


Established research demonstrates a significant overlap between post-concussive symptoms and other psychological disorders (Bailey, Samples, Broshek, Freeman, & Barth, 2010; Hajek et
al, 2010; Preece & Geffen, 2007). Subjects of this study were comprised of healthy individuals with no history of head injury or other neurological issues. Sixty-five percent of the subjects were between the ages of 19 and 29 years. Subjects were given both a PCS and Depression inventory, both of which, by nature, rely heavily on somatic symptoms. Results of the study, which strongly correlates depression and PCS, reinforce that clinicians should be wary of relying on PCS symptom inventories in diagnosing PCS, especially when a history of depression is known or suspected. These results add to the mounting data pointing to the fact that there is not yet a PCS measuring instrument that is sensitive to PCS exclusively. The authors of this study have two published works, both of them from 2010, in the PsychINFO database. Sullivan and Garden, who are associated with Queensland University of Technology in Brisbane Australia, currently have a study published in the most recent issue of *The Journal of Head Trauma Rehabilitation* (Sullivan & Garden, 2011) that is not yet available through the PsychINFO or MEDLINE databases.


One of the major discoveries brought about by recent research is that somatic post-concussive symptoms resolve before cognitive symptoms (Heitger et al., 2009; Talavage et al., 2010; Taylor et al., 2010). This study compared the symptoms of post-traumatic stress disorder (PTSD) in
children with orthopedic injuries (OI) against children with mTBI. The results of the study were contrary to the hypothesis presented by the researchers. PTSD symptoms in the OI group were significantly higher at the one year mark than PTSD symptoms in the mTBI group. Despite those findings researchers concluded that acute PCS can account for reported symptoms of PTSD; however the opposite cannot be supported. They based this finding on the fact that subjects in the OI group reported symptoms of PCS at all three post injury assessment points. Participants of this study were children between the ages of 8 and 15, and met predetermined, injury specific, criteria for inclusion in the study. Several of the researchers on this investigation have a long standing history of research into pediatric head injuries (Levi, Drotar, Yeates, & Taylor, 1999). Despite that failure of this study to support the main hypothesis it remains a significant investigation due to the fact that it was methodologically sound, and therefore, allowed the researchers to draw reliable conclusions.


New means of detecting impairment from mTBI have become evident as the research into mTBI has increased. Dr. Marcus Heitger, from the University of Otago in New Zealand, began studying saccadic eye movements and how they relate to mild closed head injuries (mCHI) nearly a decade ago (Heitger, Anderson, & Jones, 2002). To clarify, it is commonly accepted that the terms mTBI and mCHI are interchangeable in the literature (Kirkwood, Yeates, Taylor,
Randolph, McCrea, & Anderson, 2008). The current study compares thirty-six subjects with a history of a mCHI and post-concussion syndrome with a similarly numbered group with a history of mCHI and no post-concussion syndrome. The study found that functional eye movements are significantly correlated to post-concussion syndrome, and more importantly point to deficits that cannot be diagnosed by current methodology. Because it is known that symptoms of depression and post-concussion syndrome overlap (Garden & Sullivan, 2010), it is of great importance to find a way to clinically assess PCS that is more sensitive than current measures. The ability to reliably assess these deficits becomes more important as time increases from the initial injury due to the fact that self-reported symptoms may resolve more quickly than clinically detected changes (Talavage et al., 2010).


This prospective cohort study is the first investigation into the value of a mandatory waiting period after cessation of symptoms from concussion before returning to play. The cohort for this study was based on three parallel, multi-organizational investigations into athletic concussions, including the National Collegiate Athletic Association concussion study (McCrea, Guskiewicz, Marshall, Barr, Randolph, Cantu, & ... Kelly, 2003). Results of this study were significant because they concluded that there is no long term difference on neuropsychological
testing between those that had a mandatory symptom free waiting period (SFWP) and those that did not. Other researchers have pointed to this result as an argument against neuropsychological baseline testing (Randolph, 2011). There was also no statistical difference on the rates of re-injury between athletes in the two groups. However, the authors point out that the majority of those in the SFWP group that were reinjured, returned to activity inside of ten days. Dr. McCrea’s work on sports concussion vaulted him to the forefront of research on traumatic brain injury (TBI). He contributes greatly to the government’s research into soldiers with TBI (McCrea, Pliskin, Barth, Cox, Fink, French, & ... Yoash-Gantz, 2008). This study, when compared with the study from Talavage et al. (2010), shows that the current assessment tools for tracking long term impairment from mTBI may be insufficient.


Postconcussive symptoms are associated with compensatory cortical recruitment during a working memory task. *Neurosurgery, 67*(4), 1020-1027. doi: 10.1227/NEU.0b013e3181ee33e2

This study uses a subset of subjects from a larger study (Lovell et al., 2007). The investigators were a combination of orthopedists and psychiatrists, and unlike the study by Talavage et al. (2010), did not have a researcher with an extensive functional MRI (fMRI) research background. Concussed individuals, with a mean age of 16.3 years, were administered the Post-Concussion Symptom Scale. Each subject was then given two cognitive tasks to do while an fMRI was done. Results showed that more athletes reporting more PCS did no worse than those with less self-
reported symptoms. Of interest was the fact that the athletes reporting more symptoms had to recruit more cognitive regions of the brain to match there less injured counterparts. More symptomatic subjects were able to do as well as the less symptomatic which causes a quandary in regards to clinical use of neurocognitive testing. Furthermore, when we draw conclusions from this study and the Talavage et al. (2010) study, we see that fMRI may be the only clinically appropriate way to grade severity of mTBI in pediatric subjects.


Neurocognitive testing investigations show that impairment from mTBI can outlast somatic symptoms (Broglio, Macciocchi, & Ferrara, 2007). Subjects for this study were recruited from an emergency department in Brisbane Australia. Candidates were either seen for mTBI or orthopedic injury. Each group was administered two depression and anxiety stress scales, and three neuropsychological tests. Results revealed that depression did not have a positive correlation with poor neuropsychological testing, as had been hypothesized. Patients diagnosed with mTBI did do significantly worse on verbal memory and information processing speed. Considering there is a quarter century of research with similar findings (Drew, Templer, Schuyler, Newell, & Cannon, 1986), this was an expected result. Methodology for the study was not vigorous for inclusion into the depressed group. Self-reported diagnosis of depression was all that was required to be included in the depression group, and is conceded as a week point.
by the authors. Despite this weakness, this study further highlights the need for a comprehensive screening process when evaluating patients with mTBI and post-concussion symptoms. Ms. Preece is listed as a graduate student, and Dr. Geffen is Emeritus Professor at the University of Queensland, School of Psychology website.


The lead author, Thomas Talavage, is the founding Co-Director of the Purdue MRI Facility, and has an extensive background in MRI research (Talavage, 2011). *The Journal of Neurotrauma* accepted this study in late 2010. Mild TBI is a national health concern, according to the authors, and this study aims to expose undiagnosed mTBI in previously undiagnosed athletes. Subjects of this study consisted of varsity and junior varsity football players from one high school. Three evaluative tools were used; they were the HIT™ system, ImPACT™ software, and functional MRI. Results of the study showed measurable brain changes in athletes that had no clinical signs of concussion. When asked about the implication of this study on the clinical usefulness of the ImPACT software Dr. Leverenz stated; “ImPACT, at least, gives us a hint of something happening but there is no direct/significant correlation between ImPACT scores and what we see with the fMRI.” (L. Leverenz, personal communication, April 12, 2011). No researchers
Children and adolescent brains that have been concussed are severely impacted when compared to their non-injured peers, even up to ten years post injury (Horneman & Emanuelson, 2009). The results reveal a new, previously unrealized, population of injured children.


This is one of many studies recently published by researchers at Case Western University on the subject of pediatric concussions. The data from participants in this investigation was the same as in another recently published study on PTSD and PCS in pediatric mTBI (Hajek et al., 2010), and were part of a larger study (Yeates & Taylor, 2005). Patients from two emergency departments became recruited subjects, and were categorized into either the orthopedic injury (OI) group or mTBI group. Results from the study reinforced that PCS may be evident in both groups in the acute stages of injury, but that parent reporting of PCS in the mTBI group did not peak until the 3 month follow-up. Accounting for the fact that there can be a baseline reporting of PCS (Garden, & Sullivan, 2010), this study confirmed that there are most likely neurological and psychological components of PCS. When combining the long term somatic symptomology of this study, with the understanding that cognitive symptoms outlast somatic symptoms
(Boutin, 2008; Heitger, 2009), we see that these PCS deficits may not be as transient as once thought (McCrean et al., 2005).

Clinical Implications

Though our understanding of the impact of mTBI on young developing brains increased greatly over the last decade, we have a long way to go. Popular belief remains that the majority of these injuries cause only transient impairment that resolves quickly. With each new study that popular understanding is challenged. Fortunately the media has taken an interest in this new information and is being proactive about educating the public. On April 12, 2011 The Public Broadcasting Service aired an episode of Frontline, a public affairs program, which highlighted the dangers associated with mTBI in high school football (Dretzin, R., 2011). This is just one example of the many ways the public is being educated about the dangers of cerebral concussion.

It is easy to fall into a complacent position as a practitioner and rely on somatic symptomology to drive decision processes. However, since the brains of children are at risk there needs to be extreme rigor and discipline applied in making these assessments. The knowledge base of the effects of mTBI is expanding rapidly and as such these conclusions must be grounded in sound research. Considering the possible negative outcomes clinicians must be diligent in the vital task of protecting these most valuable resources. Educating clinicians, parents, and children about mTBI, including the associated short and long term non-somatic post-concussion symptoms, should be a top priority for us all.
Conclusion

Concussions are a part of sport, and will continue to be a part in the future. Clinicians, parents, and athletes need to have an understanding of the long term effects of this injury. Fortunately there is a lot of research focusing on this area right now. This new research gives us a better view of how to diagnoses and treat this common injury. Athletes that present with altered neurologic function should be considered concussed (McCrory et al., 2005). If the clinician is unsure if the athlete is having altered neurologic function, use of neurologic baseline testing can be a practical tool. However, complete reliance on neurocognitive testing should be avoided and should only be a single part of an overall diagnostic protocol. Considering the overlap of depressive symptoms and post-concussion symptoms, it would be prudent for the clinician to complete a rudimentary psychological history to properly interpret the neurocognitive testing results. Furthermore, when an athlete reports somatic symptoms (headache, dizziness, fatigue) for more than three days a full neurologic evaluation is warranted. Normal neuroimaging results are to be expected (McCrory et al., 2005); however, fMRI may be useful in determining the severity of the injury (Pardini, J., Pardini, D., Becker, Dunfee, Eddy, Lovell, & Welling, 2010). Resolution of the injury should not be considered complete until the athlete is asymptomatic somatically and cognitively, and depending on the severity of the injury this may take more than a year. Of paramount importance for the clinician of young athletes is the understanding that this population heals more slowly than their elder counterparts (Field et al., 2003). While researching, the results must be weighed with an understanding of the age of subjects in
the study. Again, current guidelines are based on neuropsychological testing results (Kirkwood et al., 2008), and do not account for more recent study results that point to compensatory activities in the brain that may mask injury on these types of testing.

Further Research

Based on this review of current literature it is evident that more research in the area of the cognitive effects of mTBI is warranted. This research should continue to be focused on understanding the long term effects of mTBI on brain function, and more specifically how that impact affects the developing brain. Dr. Talavage is continuing his study of brain changes discovered by fMRI (Dretzin, R., 2011). A longer term longitudinal study would be the most effective way to continue to study the epidemiology of this type of injury. Obviously there are many obstacles, financial and otherwise, to completing such a study. Given the number of children, not just athletes, that are seen in emergency departments for mTBI every year it is an investment worth making.
References List


http://cobweb.ecn.purdue.edu/~tmt/TTalavageCV.pdf

