Comparison of Neuropsychological Test Scores of High School Athletes in High and Low Contact Sports: A Replication Study

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TABLE OF CONTENTS LISTING

The table of contents for the journal will list your paper exactly as it appears below:

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William T. Tsushima[a], Andrea M. Siu[b], Nozomi Yamashita[c], Ross S. Oshiro[d], and Nathan M. Murata[e]

[a]Psychiatry and Psychology Department, Straub Clinic and Hospital, Honolulu, Hawaii; [b]Research Institute, Hawaii Pacific Health, Honolulu, Hawaii; [c]Department of Neuroscience, Tulane University, Honolulu, Hawaii; [d]Queen's Center for Sports Medicine, POB III, Honolulu, Hawaii; [e]Department of Kinesiology and Rehabilitation Science, University of Hawaii at Manoa, Honolulu, Hawaii

ABSTRACT

This replication study re-examined the neuropsychological effects of participation in high and low contact youth sports. Modeled after a recently published investigation, two contact sport groups of participants ages 12 to 18 were formed based on the rate of concussion in their respective sport, with the assumption that more head impacts and neuropsychological effects occur in high contact sports that have a greater number of reported concussions as compared with low contact sports. The preseason baseline ImPACT neuropsychological test scores and symptom scores of non-concussed youth athletes in a High Contact Sport (football, $n = 139$) and a Low Contact Sport (basketball, baseball, soccer, wrestling, volleyball, paddling, and cheerleading, $n = 57$) were compared. The results revealed significantly poorer ImPACT test performances in Visual Motor Speed and Reaction Time among High Contact Sport athletes compared to Low Contact Sport athletes. No differences were found between the two groups in Verbal Memory, Visual Memory, and Total Symptom. These findings were identical to a recent study in which nonconcussed youth athletes in a high contact sport, that is, football, exhibited poorer neuropsychological test performance than their peers in low contact sports, that is, basketball, baseball, soccer, wrestling, and judo. This research replication verified the results of the prior study, and raises concerns that youth athletes exposed to repetitive head trauma may be at risk for lowered neuropsychological functioning, even without a reported concussive event.

KEYWORDS
Concussion; ImPACT; repetitive head trauma

Introduction

In the past decade, research and media coverage have increasingly focused on sports-related concussion, from youth recreation to college and professional sports. There is concern that the incidence of concussions is increasing in high school sports, as a recent epidemiologic study found that high school athlete concussion rates from 2005 through 2012 increased significantly from 23% to 51% over the 7-year period (Rosenthal, Foraker, Collins, & Comstock, 2014). While current interest in athletic concussion remains substantial, there is also growing interest in repeated nonconcussive head injuries resulting in symptoms and sequelae that do not fulfill the diagnostic criteria for concussion (Bailes, Petraglia, Omalu, Nauman, & Talavage, 2013; Graham, Rivara, Ford, & Spicer, 2014).

Although considerable literature on the consequences of concussion in football is available, a surprisingly minimal amount of information exists on the cumulative effects of repeated head blows in this high contact sport (Baugh et al., 2012; Gysland et al., 2012). High school football players sustain a markedly greater number of head impacts compared to other sports (e.g., soccer, ice hockey), raising concerns about the long-term effects of concussive and subconcussive head blows in football participation (Broglio et al., 2011). In football nonconcussive impacts can occur on nearly every play, particularly for linemen who encounter constant helmet-to-helmet contact (Gavett, Stern, & McKee, 2011; Talavage et al., 2013). Most head impacts in football are subconcussive in nature and do not result in a concussion (Crisco et al., 2012; Greenwald, Gwin, Chu, & Crisco, 2008). A high school football player may experience over 2,000 subconcussive impacts during the course of a single season (Broglio et al., 2011). In addition, functional magnetic resonance imaging and diffusion tensor imaging studies in high school athletes participating in football found cerebral alterations in the absence of concussion symptoms or clinically measurable cognitive impairment that were linked to subconcussive head blows (Bazarian, Zhu, Blyth, Borrino, & Zhong, 2012; Breedlove et al., 2012, Talavage et al., 2013). The findings of the latter

CONTACT William T. Tsushima wtsushima@straub.net Psychiatry and Psychology Department, Straub Clinic and Hospital, 888 South King Street, Honolulu, Hawaii 96813, USA.

studies suggest that high school football players may be at risk for neurologic injury from repeated low impact hits, perhaps due to their vulnerable stage of developmental maturation (Giza & Hovda, 2004). However, the small number of athletes examined in these various studies limits any conclusions regarding cumulative neuropathological effects in high school football players.

With the widespread popularity of sports among youths, many young athletes are exposed to repetitive head trauma and are at risk for brain injury in a variety of contact sports, including football, soccer, wrestling, ice hockey, boxing, and martial arts (Gavett et al., 2011; Rabadi & Jordan, 2001). Research on the effects of repetitive head impacts in different sports are few and have presented varied findings. For example, a study aimed at assessing the effects of cumulative nonconcussive hits in adolescent soccer players found no differences in the neuropsychological test performances of soccer, rugby, and noncontact sport players, for example, swimming, tennis, and cricket (Stephens, Rutherford, Potter, & Fernie, 2010). Based on a review of the sports concussion literature over 50 years, including boxing and football, McCrory (2011) asserted that only a fraction of athletes suffer cognitive and emotional impairment as a result of recurrent concussive or subconcussive head trauma.

In comparison, other studies revealed noteworthy sequelae of head trauma in contact sports. McAllister et al. (2012) examined the effects of repetitive head impacts over a single season and found that contact sport athletes (football, ice hockey) performed more poorly on one of seven neuropsychological measures than predicted postseason compared to noncontact athletes (track, crew, Nordic skiing). Furthermore, an evaluation of cerebral perfusion using single-photon emission computed tomography (SPECT) in 97 former professional football players found perfusion differences between the football cohort and a healthy control group, but noted no difference between football players with high versus no loss-of-consciousness (Amen et al., 2011). The latter findings led the authors to speculate that repetitive head impacts, rather than clinically diagnosed concussions, were responsible for the lack of SPECT and quantitative EEG differences between the high versus no loss-of-consciousness football groups.

A recent exploratory study designed to examine the neuropsychological effects of repetitive head blows in high school sports compared the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) neurocognitive test scores of nonconcussed athletes participating in a high contact sport (football, $n = 182$) with scores of low contact sport (soccer, basketball, baseball, wrestling, and judo, $n = 100$) (Tsushima, Geling, Arnold, & Oshiro, 2016). The high contact sport athletes had significantly poorer performances in Processing Speed and Reaction Time than the low contact sport athletes, raising concern that participation in high contact sports, even in the absence of a diagnosable concussion, could result in lowered neuropsychological functioning among high school athletes. The Tsushima et al. report provided relatively unique findings of the potential effects of repetitive subconcussive head trauma on high school athletes engaged in contact sport activities. These findings support the need for verification through replicated study (Krueger, 2001; Weiner, Schinka, & Velicer, 2003). To this end this research recreated the essential components of the Tsushima et al. investigation of repeated nonconcussive head blows with youth athletes. Research replication in psychology is relatively rare and is an important scientific process to assess whether prior statistically significant results reflect reliable findings or a false positive result (Klein et al., 2014; Maxwell, Lau, & Howard, 2015).

Materials and methods

This study was reviewed by the Hawaii Pacific Health Research Institute and was determined to be exempt from Institutional Review Board review.

Test instrument

To examine the effects of repeated head trauma on neurocognitive functioning and symptom reporting of youth athletes, this research utilized the ImPACT battery, which has been employed in many studies of high school athletes following a concussion (Lovell, 2006). ImPACT is a 20–30 minute computerized neuropsychological test instrument that evaluates verbal and visual memory, visual motor speed, reaction time, and impulse control, as well as postconcussion symptoms. ImPACT also provides self-reported demographic data, such as native language, past history of concussion and years of sport experience, obtained from the student completing the examination. In the past decade, a growing body of research has established ImPACT's usefulness in the neuropsychological assessment of concussion in high school and collegiate athletes (Lovell et al., 2003; Schatz, Pardini, Lovell, Collins, & Podell, 2006), although critics have also identified issues with its reliability and validity (Mayers & Redick, 2012; Randolph, McCrea, & Barr, 2005).

Version 2.1 of ImPACT yielded the five composite scores used for this study: Verbal Memory, Visual

Memory, Visual Motor Speed, Reaction Time, and Impulse Control. ImPACTalso provides a Total Symptom score based on the Post-Concussion Symptom Scale (PCSS) that consists of 22 commonly reported symptoms (e.g., headaches, dizziness) rated on a 7-point Likert scale.

Protocol

All athletes were administered the ImPACT test prior to the start of their sport. The baseline testing was conducted in groups of approximately 20 athletes, monitored by an athletic trainer who was trained in the standard administration of this computerized neuropsychological test battery. Although the baseline testing was conducted before season play, it was assumed that the athletes participated in their respective sports in the past, which involved varying degrees of contact and head trauma.

Participants

A pool of 247 middle and high school male athletes from ages 12–18 in a private middle and high school were administered ImPACT baseline testing. Of these 196 athletes met the following inclusion criteria: native language of English, no history of concussion, and valid ImPACT test results, for example, Impulse Control composite score <30 (Lovell, 2012). The participants in the study consisted of athletes who participated in football ($n = 139$), baseball ($n = 17$), basketball ($n = 15$), soccer ($n = 12$), wrestling ($n = 11$), paddling ($n = 1$), and cheerleading ($n = 1$). The subjects ($n = 196$) were then divided into two contact groups.

Procedure

This research design was similar to the Tsushima et al. (2016) study and previous investigations of repetitive head impacts that compared athletes in contact sports, such as football and soccer, with athletes in noncontact sports, such as track and tennis (McAllister et al., 2012; Stephens et al., 2010). The present study utilized a differential prevalence design and operationally defined a High and a Low Contact Sport group according to the frequency of concussions reported in different youth sports.

The High Contact Sport group, comprised of 139 football players, was formed based on recent epidemiologic studies (Lincoln et al., 2011; Marar, McIlvain, Fields, & Comstock, 2012; Noble & Hesdorffer, 2013; Rosenthal et al., 2014) as well as the review by the Institute of Medicine and National Research Council (Graham et al., 2014) that noted that football had the highest rate of concussion among high school athletes. The Low Contact Sport group ($n = 57$) of athletes from other sports (baseball, basketball, soccer, wrestling, paddling, and cheerleading) that had comparatively lower concussion rates. The baseline scores of the two contact groups were compared in terms of their four ImPACT Composite scores and Total Symptom score.

Data analysis

Descriptive statistics were calculated, and the two contact groups were compared in terms of age, education, years of sports experience, and five ImPACT scores (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Total Symptom), using *t*-tests. All variables were normally distributed and continuous. Statistical test results were reported with a priori statistical significance set at $p < 0.05$ for all analyses. Cohen's d values were computed as measures of effect size.

Based on the previous findings of Tsushima et al. (2016), the hypothesis was that the neuropsychological test performances of nonconcussed athletes in the High Contact Sport group would be lower than those participating in the Low Contact Sports. A rejection of the null hypothesis supports the reliability of the findings for the initial study.

Results

The mean age and education of the High and Low Contact Sport groups are presented in Table 1. The two sport contact groups differed in terms of age ($p = 0.02$), with the Low Contact Sport group being about a half-year older and having more sports experience ($p < 0.001$) than the High Contact Sport group. The two contact groups did not differ in years of education ($p = 0.46$).

The means and standard deviations of the four ImPACT composite scores and the Total Symptom score of the two contact groups are presented in Table 2. The High Contact Sport group had statistically significantly poorer scores than the Low Contact Sport group for Visual Motor Speed ($t = 9.29$, $df = 194$, $p < 0.002$) and Reaction Time ($t = 5.73$, $df = 194$, $p = 0.02$). The effect sizes, based on Cohen's d, were small. The *t*-tests revealed no statistically significant differences in Verbal Memory, Visual Memory, and Total Symptom scores between the two groups.

Discussion

Based on the assumption that head impacts occur more frequently in sports with a high concussion rate, this research replicated the recent study by Tsushima

Table 1. Age, education and years of experience of High and Low Contact Sport Groups.

	High contact sport group		Low contact sport group				
	n	Mean (SD)	*n*	Mean (SD)	*t* (df)	*p*	Cohen's *d*
Test age	139	15.04 (1.37)	57	15.53 (1.14)	−2.36 (194)	0.02	−0.37
Education (years)	136	9.27 (1.22)	57	9.42 (1.13)	−0.75 (191)	0.46	−0.12
Experience (years)	136	1.23 (1.46)	55	2.73 (2.93)	−4.71 (189)	<0.001*	−0.75[1]

*Statistically significant ($p < 0.05$).
[1]Medium effect size.

Table 2. ImPACT scores of high and low contact sport groups.

	High contact sport group ($n = 139$) Mean (SD)	Low Contact sport group ($n = 57$) Mean (SD)	*t* (df = 194)	*p*	Cohen's *d*
Verbal Memory	83.59 (9.81)	84.12 (9.38)	0.12	0.73	−0.06
Visual Memory	74.17 (12.08)	74.07 (14.68)	0.00	0.96	−0.01
Visual Motor Speed	35.43 (6.20)	38.58 (7.36)	9.29	0.002*	−0.48[2]
Reaction Time	0.61 (0.08)	0.58 (0.08)	5.73	0.02*	0.37[2]
Total Symptom	7.74 (11.74)	9.95 (14.34)	1.25	0.26	−0.18

*Statistically significant ($p < 0.05$).
[2]Small effect size.

et al. (2016) on the effect of repetitive head blows on the ImPACT neuropsychological test scores and symptom scores among youth athletes in a High Contact Sport (football) compared with Low Contact Sports (basketball, baseball, soccer, volleyball, wrestling, paddling, and cheerleading). As in the prior investigation on subconcussive head trauma, the High Contact Sport athletes had statistically significantly poorer scores than the Low Contact Sport athletes on Visual Motor Speed and Reaction Time, suggesting particular weaknesses in attention, concentration, and working memory. No significant differences were found between groups on Verbal Memory, Visual Memory, and Total Symptoms. Replicating similar findings despite employing a smaller sample (196 vs. 282) and different school settings (private vs. public schools) was noteworthy, albeit with smaller effect sizes. Research replication and statistically significant results reinforce the notion that the initial results represent stable neuropsychological findings rather than merely a chance phenomenon (Maxwell et al., 2015; Weiner et al., 2003).

Similar to the prior research by Tsushima et al. (2016), this study included only athletes with no reported history of concussion, which more clearly demonstrated the role of subclinical head trauma than previous efforts that found no effects of repeated head blows but included athletes with earlier concussions (Gysland et al., 2012; Miller, Adamson, Pink, & Sweet, 2007; Stephens et al., 2010). The present findings are consistent with those of Talavage et al. (2013), who found neurocognitive and neurophysiologic impairment in a small sample of high school football players who had received repetitive subconcussive blows to the head but had no clinically diagnosed concussion. Lower performances in certain areas of neurocognitive functioning among the football players compared to other high school sports may be related to the greater number of head impacts sustained by football players compared to other contact sports, for example, soccer and ice hockey (Broglio et al., 2011). Neuroradiological findings, laboratory evidence, and clinical examinations of head trauma have suggested the potential detrimental neurological impact of subconcussive level impacts in football (Bailes et al., 2013; Bazarian et al., 2012; Breedlove et al., 2012).

In this study, the impact of repetitive head blows was seen with football players, but these results may also be observed in other contact sports, like soccer. Amateur soccer players, who incur concussions as well as numerous subconcussive head blows, have exhibited impaired neuropsychological test performances compared with a control group of swimmers and track runners (Matser, Kessels, Lezak, Jordan, & Troost, 1999). Furthermore, an investigation using high-resolution diffusion tensor imaging found substantial differences between nonconcussed club soccer players and a comparison cohort of swimmers (Koerte, Ertl-Wagner, Reiser, Zafonte, & Shenton, 2012). The researchers found that widespread white matter diffusity in soccer players was commensurate with mild traumatic brain injury, perhaps due to frequent subconconcussive brain trauma. In contrast, Stephens et al. (2010) reported that neither soccer nor rugby players exhibited neuropsychological decrement compared with non-contact athletes (e.g., basketball, swimming, tennis, badminton). The growing body of evidence, overall, raises suspicion that the cumulative effect of repeated head blows in sports activity, such as football and soccer, can result in neurological changes (Spiotta, Shin, Bartsch, & Benzel, 2011).

Developmental factors need to be considered when evaluating the significance of this study. The underlying neurological causes of the present findings with high school players are not clear, but given their ongoing physical development, youth athletes may sustain more diffuse axonal injury from frequent nonconcussive blows and significant impact on their neurocognitive functioning (Bazarian et al., 2012; Giza & Hovda, 2004). Some authors suggest that the age at which the brain sustains repetitive head trauma can affect neuronal integrity that becomes clinically relevant later in life (Gavett et al., 2011; Spiotta et al., 2011; Stern et al., 2011), but this research does not shed light on whether cumulative head impacts in youth can result in long-term psychological deficits, such as chronic traumatic encephalopathy.

Other explanations for the present findings can be offered. The neuropsychological differences between the High and Low Contact Sport groups could be due to age factors (Hunt & Ferrara, 2009), as the Low Contact Sport group was found to be older than the High Contact Sport group, although the age difference was only a half-year. The two contact groups could have differed in terms of general intellectual skills, but data regarding the academic aptitude of the participants were not available.

Limitations

Presently there is no agreement as to the reliable identification and accurate quantification of repetitive incidents (Bailes et al., 2013; Spiotta et al., 2011). In this study, we sought to examine multiple head blows by relying on a proxy of known concussion rates. While concussions and head impact frequency may be related, these two variables are not necessarily interchangeable. For example, a wrestler may have a high number of head trauma but few diagnosable concussions, while a football quarterback may experience more intense concussive trauma but fewer head blows. Nonetheless, the differential prevalence design in this study and prior research (Matser et al., 1999; McAllister et al., 2012; Stephens et al., 2010; Tsushima et al., 2016) provided an indirect estimate of head impact frequency and could be a useful way to examine this relatively unexplored area of sports medicine. A promising method to assess head trauma frequency and intensity is the use of head impact telemetry placed in football helmets, which represents a more objective and precise measure of subconcussive trauma for the variable of central interest (Breedlove et al., 2012; Gysland et al., 2012).

Several other methodological flaws of this study should be acknowledged when evaluating these findings. (a) A notable limitation was the relatively small sample of athletes ($n = 57$) in the Low Contact Sport group. The number of athletes in a male-only private school, as well as the specific sports in this investigation, may not adequately represent the population of participants in low contact sports. (b) We relied on the self-report of concussion, an important exclusionary criterion. High school athletes have been found to underreport concussions, including football players (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004) and ice-hockey players (Williamson & Goodman, 2006). However, in this study 51 or 20.6% of the original pool of 247 athletes reported a prior concussion, which is a higher rate of reporting concussions than the 16.8% rate of concussions noted in a recent epidemiological report of high school sports (Meehan, d'Hemecourt, & Comstock, 2010), suggesting less guarded disclosure of concussions by this cohort. (c) The neuropsychological correlates in this research represent a handful of neurocognitive functions contained in a brief computerized neuropsychological test battery, and do not represent the wide array of neuropsychological variables found in a comprehensive test battery. Further work is needed to elucidate the varied neurocognitive sequelae of repeated head trauma. (d) Measures of test effort were not used to identify "sandbagging," or intentionally doing poorly on baseline testing in order to conceal post-concussive decrements (Schatz & Glatts, 2013). (e) Although participants in this study were classified in only one of the sports, youth athletes often participate in multiple sport activities. Thus, a basketball player could have played football earlier in the school year, but for the purpose of this research was considered only as a basketball player. (f) The inclusion of only male athletes in this study leaves unclear the generalizability of the results to female athletes, as it cannot be assumed that similar neuropsychological consequences for both genders occur following concussions or frequent head trauma.

This study was an effort to replicate directly the prior work that examined the effects of repetitive nonconcussive head trauma (Tsushima et al., 2016). The present research replication reinforced the original findings that high contact sports with multiple sublethal impacts are associated with neuropsychological decrements. Trauma to the adolescent head, even when obvious signs of concussion are not present, should be a serious matter to be managed conservatively. The understanding of the dynamics of repetitive head trauma is at a primitive level. For example, the magnitude or number of head blows that could affect brain structure or neurological functioning is unclear (Bailes et al., 2013). Thus, any conclusion about multiple nonconcussive head blows remains premature and should be considered tentative until further research into this relatively uncharted area of sports medicine is conducted. Physicians, athletic trainers, coaches, players, and parents would benefit from additional information about the impact of repeated head impacts for the care and safety of youth athletes.

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Q2 *Neurology*, *12*(3), 167–169.

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