



## Original Article

DOI: 10.36959/987/264

# Relation Between Repetitive Head Traumas and Academic Performance of Non-Concussed High School Athletes: A Comparison of High And Low Contact Sports

William T Tsushima<sup>1\*</sup>, Vincent G Tsushima<sup>2</sup>, and Nathan M Murata<sup>3</sup>

<sup>1</sup>Psychologist, Psychiatry and Psychology Department, Straub Medical Center, 888 South King Street, Honolulu, Hawaii 96813, USA

<sup>2</sup>Psychologist, Department of Psychology, Hawaii Pacific University, 500 Ala Moana Boulevard, Honolulu, Hawaii 96813, USA

<sup>3</sup>Kinesiologist, College of Education, University of Hawaii, 1337 Lower Campus Road, Honolulu, Hawaii 96822, USA



## Abstract

**Objectives:** To assess the relation of repeated subconcussive head traumas and the academic performance and neuropsychological functioning of non-concussed high school athletes participating in high and low levels of contact sports.

**Design:** Cross-sectional study.

**Setting:** High school sports

**Patients or Other Participants:** A total of 641 non-concussed high school athletes, consisting of 464 males and 177 females participating in a variety of sports.

**Intervention:** The independent variables are the two levels of contact sport groups were identified, High and Low Contact groups, who were assumed to sustain varied degrees of repetitive subclinical head traumas, based on epidemiological concussion data.

**Main Outcome Measures:** The independent variables were the High and Low Contact Groups. The dependent variables were (1) baseline test results of the Immediate Post-Concussion Assessment and Cognitive (ImPACT) and (2) grade point averages (GPA) across four quarters of the school year.

**Results:** High Contact athletes obtained lower GPAs and had significantly poorer scores in ImPACT Visual Motor Speed and Reaction Time than the Low Contact athletes.

**Conclusions:** The findings, with medium effect sizes, suggested that repetitive subconcussive head traumas are associated with significant lowering of school grades and neuropsychological functioning in high school athletes. The clinical relevance of this association is not known and the findings of this study should be cautiously interpreted.

## Keywords

Repetitive head trauma, Grade point averages, Neuropsychological, High school

## Introduction

While considerable research activity has focused on the neuropsychological consequences of sports-related concussions (SRC), growing attention has been recently given to the impact of repetitive head traumas that may result in clinically undiagnosed concussions, or sub concussions [1]. Although subconcussive events are less severe than a diagnosable concussive episode, they occur much more frequently. These repetitive sub clinical head blows are

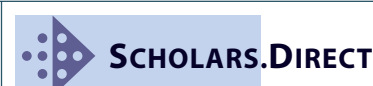
**\*Corresponding author:** William T Tsushima, Ph D, Straub Medical Center, 888 South King Street, Honolulu, Hawaii, 96813, USA

**Accepted:** January 14, 2022

**Published online:** January 17, 2022

**Citation:** Tsushima WT, Tsushima VG, Murata NM (2021) Relation Between Repetitive Head Traumas and Academic Performance of Non-Concussed High School Athletes: A Comparison of High And Low Contact Sports. Arch Sports Med 5(1):270-274

**Copyright:** © 2022 Tsushima WT. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.



generally ignored and untreated, and can result in a high number of these insults over the course of a season [2,3].

A comprehensive overview of the literature on repetitive head injuries primarily of football players consisted of biophysics studies that utilized helmet accelerometers, neuropsychological testing, neuroradiological results, as well as autopsy and laboratory data [1]. According to the authors, the evidence suggests that ongoing sub clinical impacts can result in significant neuroanatomical and physiological alterations that may result in mild cognitive impairment and post-concussive syndrome. A subsequent review of studies on the sub concussive impacts on youth and high school football players, revealed additional indication of neuroimaging changes, including diffusion tensor imaging and diffusion kurtosis imaging, that occur over a single football season in the absence of a clinically diagnosed SRC [2]. On the other hand, studies also employing biomechanical metrics found no short-term neurologic or neuropsychological impairment associated with cumulative head impacts and higher impact intensity among youth and collegiate football players [4,5].

Without the benefit of a direct metric for subthreshold head trauma, such as the helmet accelerometer, studies of repetitive head impact have relied on indirect methods based on the assumption that more frequent head blows occur in sports that report a higher frequency of concussion. Current research on the neurocognitive functioning of athletes exposed to varying degrees of head blows in different sports have yielded inconsistent results. Several investigations of cumulative minor head trauma found that non-concussed athletes in contact sports (e.g., football, hockey, soccer, lacrosse) exhibit more neurocognitive deficits than non-concussed athletes in non-contact sports (e.g., basketball, baseball, paddling, cricket) [6,7,8]. In contrast, results from a comparison of contact and non-contact sports indicated no differences in the athletes' neuropsychological test performances [9]. The conflicting findings of the above studies of repetitive head injuries may be attributed to methodological factors, such as employing different age groups, test instruments, and sports [10,11].

Head trauma can result in youngsters experiencing cognitive difficulties, such as concentration and memory, that may impact school performance [12]. The effects of SRCs on school functioning have been cited in various reports but investigation into the relation between sub concussive blows and academic performance has not, to our knowledge, been conducted [13,14]. In view of the lack of research regarding repeated sub concussive head trauma with youth and high school populations, [2] the present study was designed to fill the gap, with an examination of the school grades and neuropsychological test results of non-concussed high school athletes across a school year after participation in varied sports, comparing players in high and low levels of contact sports.

## Methods

### Measures

Grade point averages (GPA), as a measure of school performance, were employed to assess the effects of

repetitive head trauma on the academic functioning of high school athletes with no reported history of SRC. GPA is well known as a useful indicator of classroom performance, [15,16] but GPA is rarely utilized in sport neuropsychological research [17].

In addition to GPA, the study employed the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), [18] which is a web-based computerized neuropsychological test battery widely used for the assessment of SRCs in high school, collegiate, and professional athletes [19]. ImPACT takes about 30 minutes to complete and yields four Composite scores, including Verbal Memory, Visual Memory, Visual Motor Speed, and Reaction Time. In addition, ImPACT provides a Total Symptom score based on the Post-Concussion Symptom Scale that consists of 22 commonly reported symptoms (e.g., headache, dizziness) rated on a 7-point Likert scale. The ImPACT examination also includes self-reported demographic and health information, such as age, sex, sport played, and history of prior SRC. A growing body of research has established ImPACT's usefulness in the neuropsychological assessment of SRC in high school and collegiate athletes, but critics have also noted issues with its reliability and validity [19,20,21]. A more complete description of ImPACT can be found elsewhere [18].

### Participants

The participants for this study consisted of multi-ethnic English-speaking students from 65 high schools in Hawaii. The schools belonged to a single state educational department, employing a unified grading system and ImPACT testing program. The participants included 641 non-concussed high school athletes (464 males, 177 females) with valid baseline ImPACT test results. Excluded from this research were 160 athletes who reported a prior SRC, and 56 athletes who sustained a concussion during the school year.

The study, utilizing a differential prevalence design, was based on the assumption that more subconcussive trauma occur in sports in which more SRCs are reported. Thus, the investigation relied upon recently published data of SRC risk in a large sample of high school athletes [22] to operationally define two levels of contact sport groups: High and Low Contact groups. The High Contact group consisted of 453 athletes (412 males, 41 females) who participated in sports with the highest risk for an SRC: football ( $n = 330$ ) and wrestling/martial arts ( $n = 123$ ). The Low Contact group consisted of 188 athletes (52 males, 136 females) who participated in sports with the lowest risk for an SRC: volleyball ( $n = 138$ ) and baseball ( $n = 50$ ).

### Procedure

The GPAs of the High Contact and Low Contact groups were obtained from official school records for each of the four quarters of the school year. Online ImPACT baseline testing was administered in the Fall prior to the athlete's season in small group settings of 20 or fewer by certified athletic trainers who conducted the standard administration of the examination.

**Table 1:** Post-hoc tests of between-subjects effects revealed significant difference in GPAs for each of the four quarters, with the Low Contact group obtaining higher GPAs than the High Contact.

First Quarter	Second Quarter	Third Quarter	Fourth Quarter
F = 30.48	F = 39.87	F = 47.39	F = 28.11
p < .001	p = < .001	p = < .001	p = < .001
partial $\eta^2$ = .05	partial $\eta^2$ = .06	partial $\eta^2$ = .07	partial $\eta^2$ = .04

The effect sizes of the between-subjects effects, represented by partial  $\eta^2$ s, were medium. (Small partial  $\eta^2$  = 0.01; medium = 0.09, large = 0.25.).

Approval for the use of the research data was granted by the State of Hawaii Department of Education. ImPACT data were provided by the Hawaii Concussion Awareness and Management Program. The archival study was evaluated by the Hawaii Pacific Health Research Institute and was determined to be exempt from Institutional Review Board review.

## Statistical analyses

A *t*-test was employed to compare ages between the two Contact groups. The dependent variables were the GPA, the four baseline ImPACT Composite scores (Verbal Memory, Visual Memory, Visual Motor Speed, and Reaction Time), and the Total Symptom score of the participants. We conducted a (1) *t*-test to compare the ages and  $\chi^2$  test to compare sex ratios of the two Contact groups; (2) MANOVA of the GPAs of the two Contact groups across four quarters; and (3) MANOVA of the ImPACT scores of the two Contact groups. For the comparisons of GPAs across four quarters, an a priori statistical significance level was set with Bonferroni correction at  $.05/4 = p < 0.01$ . For the multiple comparisons of the five ImPACT scores, the statistical significance level was set at  $.05/5 = p < 0.01$ .

## Results

The mean ages of the two groups were as follows: High Contact group 15.20 years ( $SD = 1.22$ ), and Low Contact group 14.88 years ( $SD = 1.22$ ). The age difference between the two groups was small but statistically significant,  $t = 3.01$ ,  $df = 639$ ,  $p = .003$ . The male:female ratios of the two groups were High Contact 412:41 (90.94%:9.05%) and Low Contact 52:136 (27.66%:72.34%). The sex ratio difference between the two groups was significant,  $\chi^2(1) = 266.25$ ,  $p < 0.01$ . MANOVA, using Pillai's trace, indicated significant between-group difference in GPAs for the four school quarters,  $V = 0.73$ ,  $F = 12.09$ ,  $p < 0.01$ .

A factorial MANOVA, using Pillai's trace, analyzing the GPAs across the four quarters of the school year revealed significant within-group GPA difference,  $V = 137$ ,  $F(3,619) = 32.71$ ,  $p < 0.01$ , with a significant interaction effect between groups,  $F(3,619) = 4.77$ ,  $p = 0.03$ . Post-hoc tests of within-subjects effects indicated a significant linear decline in GPA across time for both Contact groups, with lower grades as the school year progressed. The first quarter GPAs were significantly higher than the fourth quarter GPAs,  $F = 38.39$ ,  $p < 0.01$ , while comparisons of the other school quarters were not significant. The effect size, partial  $\eta^2 = 0.6$ , was medium. As noted, the factorial MANOVA also showed an interaction between the two groups across the four quarters with the Low Contact group demonstrating a continuous decrease in

GPAs from the first quarter through the fourth quarter, while the High Contact group showed a continuous decrease from the first quarter through the third quarter; however, their fourth quarter GPAs were higher than the third quarter GPAs.

MANOVA, using Pillai's trace, indicated significant between-group difference in baseline ImPACT scores,  $V = 0.30$ ,  $F(5, 635) = 3.97$ ,  $p < 0.01$ . Post hoc tests of between-subjects effects indicated that the High Contact group had significantly poorer scores in Visual Motor Speed ( $F = 10.06$ ,  $p = 0.02$ , partial  $\eta^2 = 0.1$ ) and Reaction Time ( $F = 12.33$ ,  $p < 0.01$ , partial  $\eta^2 = 0.1$ ). Both effect sizes were small.

## Discussion

The present study adds to the research that suggests that repetitive subclinical head trauma is associated with significant neurocognitive deficits, including school performance, among young athletes in high contact sports, such as football, compared to those in low contact sports, such as baseball [6,7,8]. Compared to the Low Contact athletes, the High Contact athletes were found to have lower GPAs across all four quarters of the school year, and had poorer baseline scores in Visual Motor Speed and Reaction Time, with medium effect sizes. The significantly lower GPAs and poorer ImPACT scores among the High Contact athletes were statistically significant, but the cognitive differences between the two contact groups are of unknown clinical relevance, with findings that should be cautiously interpreted. While associations between frequent sub concussive hits in high contact sports with school and neurocognitive performances were found, it should be emphasized here that the study did not demonstrate a causal relationship between subclinical head traumas and neuropsychological functioning.

Managing the subconcussive episodes of high school athletes can be challenging as players would not easily recognize the mild aftereffects of repeated subconcussive trauma. Just as high school and collegiate athletes tend to underreport concussions [23,24,25], athletes may even more likely ignore subconcussive head trauma, accepting marginal symptoms, like dizziness or headache, as a normal part of participating in contact sports. The present findings suggest the need for more awareness and education of the cumulative effects of repetitive sub clinical impacts for players, coaches, team physicians, parents, and school personnel. School administrators, league officials, health care providers, and legislators should support initiatives to tighten rules that would reduce serious head collisions in games, limit contact in practice sessions, and promote improved equipment to protect young athletes [26,27].

The significance of the sex ratio difference between the two Contact groups is unclear. While some studies have

shown that adolescent female athletes exhibit more post-concussion neuropsychological decline, such as reaction time, memory, visual motor speed, and executive functions [28,29,30,31], other reports have found no significant sex differences in cognitive functioning and recovery after an SRC [32,33,34,35]. A systematic analysis of the findings of the World Health Organization Collaborating Centre Task Force on mild traumatic brain injury and the International Collaboration on Traumatic Brain Injury Prognosis concluded that sex is not a well-studied variable in recovery after mild traumatic brain injury, and only small sex differences were found in some studies [36]. Empirical reports comparing females and males responses to repetitive head impacts are, to our knowledge, non-existent. Having more males in the High Contact group and more females in the Low Contact group resulted in a critical confound that cannot be ignored. Sex differences in response to repeated non-concussive head trauma deserve further attention.

The difference in the ages of the High and Low Contact groups was statistically significant, with the High Contact athletes being slightly older than the Low Contact group. A meta-analysis of research into the acute neuropsychological impact of sports-related concussion found that younger athletes sustained more deficits in neuropsychological functioning compared to older athletes [34]. The degree to which age factors could influence GPA and ImPACT scores deserves further analyses.

## Limitations

Recent studies of repetitive subclinical head impacts in football have been advanced by the use of helmet-based telemetry systems, such as the Head Impact Telemetry System (HITS), that directly measure the intensity and frequency of head trauma [37]. In contrast, we were unable to quantify head impacts and had to rely on an indirect method of defining the two levels of contact groups based on prior research of concussion risks in sports [22]. The differential prevalence design of this study was an imperfect methodology because impact frequencies in different sports were assumed, based on prior epidemiological SRC research, compromising the validity of the contact group assignments. The present approach was, at best, a modest preliminary effort in assessing the effect of frequent sub concussive impacts on school performance.

There are varied factors that can affect GPA and ImPACT scores, such as socioeconomic status, concussion history, and physical symptoms [12,14,38]. These variables were not controlled in this archival study; thus, the possible influence of these factors on the results is unknown. Demographic factors deserve further attention in future investigations of repetitive head trauma.

The binary classifications in this study of High and Low Contact sports could be misleading. In high school, some athletes play more than one sport varying in level of physical contact. In this archival study we were unable to identify if any of the athletes played in more than one sport. Those who played in more than one sport could have increased their exposure to head trauma. A baseball player may have

played other sports, but for the purpose of this study he was classified only as a baseball, or Low Contact, player.

The GPA is a global measure of a student-athlete's school performance. A prior study found no overall academic differences between contact and no contact athletes, but differences were seen in social studies [39]. More could be learned about the effects of repetitive head trauma on academic functioning by examining specific subjects, such as mathematics and reading, or by obtaining school achievement test scores.

## Conclusion/Summary

Athletes in High Contact sports obtained lower GPAs and significantly poorer scores in ImPACT Visual Motor Speed and Reaction Time than the Low Contact athletes. The findings suggested that repetitive sub concussive head traumas are associated with lowering of school performance and neuropsychological functioning in high school athletes. The clinical relevance of this association is unclear and the findings of this study should be cautiously interpreted.

## References

1. Bailes J E, Petraglia A L, Omalu B I, et al. (2013) Role of subconcussion in repetitive traumatic brain injury: A Review. *J Neurosurg* 119: 1235-1245.
2. Davenport E M, Urban J E, Mokhtari F, et al. (2016) Subconcussive impacts and imaging findings over a season of contact sports. *Concussion* 1: CNC 19.
3. Talavage T M, Nauman E A, Breedlove E L, et al. (2014) Functionally-detected cognitive impairment in high school football players without clinically-diagnosed concussion. *J Neurotrauma* 31: 327-338.
4. Gysland S M, Mihalik J P, Register-Mihalik J K, et al. (2012) The relationship between subconcussive impacts and concussion history on clinical measures of neurologic function in collegiate football players. *Ann Biomed Eng* 40: 14-22.
5. Rose S C, Yeates K O, Fuerst D R, et al. (2018) Head impact burden and change in neurocognitive function during a season of youth football. *J Head Trauma Rehabil* 34: 87-95.
6. McAllister T W, Flashman L A, Maerlender A, et al. (2012) Cognitive effects of one season of head impacts in a cohort of collegiate contact sport athletes. *Neurology* 78: 1777-1784.
7. Koerte I K, Nichols E, Tripodis Y, et al. (2017) Impaired cognitive performance in youth athletes exposed to repetitive head impacts. *J Neurotrauma* 34: 2389-2395.
8. Tsushima W T, Ahn H J, Siu A M, et al. (2019) Effects of repetitive subconcussive head trauma on the neuropsychological test performance of high school athletes: A comparison of high, moderate, and low contact sports. *Appl Neuropsychol Child* 8: 223-230.
9. Stephens R, Rutherford A, Potter D, et al. (2010) Neuropsychological consequence of soccer play in adolescent U K school team soccer players. *J Neuropsychiatry Clin Neurosci* 22: 295-303.
10. Mainwaring L, Pennock K M F, Mylabathula S, et al. (2018) Subconcussive head impacts in sport: A systematic review of the evidence. *Int J Psychophysiol* 132: 39-54.



11. Schneider D K, Galloway R, Bazarian J J, et al. (2019) Diffusion tensor imaging in athletes sustaining repetitive head impacts: A systematic review of prospective studies. *J Neurotrauma* 36: 2831-2849.
12. Halstead M E, McAvoy K, Devore C D, et al. (2013) Returning to learning following a concussion. *Pediatrics* 132: 948-957.
13. Moser R S, Schatz P, Jordan B D (2005) Prolonged effects of concussion in high school athletes. *Neurosurgery* 57: 300-306.
14. Ransom D M, Vaughan C G, Pratson L, et al. (2015) Academic effects of concussion in children and adolescents. *Pediatrics* 135: 1043-1050.
15. Al-Hatami A (2014) Short- and long-term validity of high GPA for admission to colleges outside the United States. *J Coll Stud Ret* 16: 277-291.
16. Bacon D R, Bean B (2006) GPA in research studies: An invaluable but neglected opportunity. *J Mark Educ* 28: 35-42.
17. Rozbacher A, Selci E, Leiter J, et al. (2017) The effect of concussion or mild traumatic brain injury on school grades, national examination scores, and school attendance: A systematic review. *J Neurotrauma* 34: 2195-2203.
18. ImPACT Applications, Inc. (2016) Administration and Interpretation Manual.
19. Alsalaheen B, Stockdale K, Pechumer D, et al. (2016) Validity of the Immediate Post Concussion Assessment and Cognitive Testing (ImPACT). *Sports Med* 46: 1487-1501.
20. Mayers L B, Redick T S (2012) Clinical utility of ImPACT assessment for post concussion return-to-play counseling: Psychometrics issues. *J Clin Exper Neuropsych* 34: 235-242.
21. Schatz P, Kontos A, Elbin R J (2012) Response to Mayers and Redick: "Clinical utility of ImPACT assessment for post concussion return-to-play counseling: Psychometric issues." *J Clin Exp Neuropsychol* 34: 428-434.
22. Tsushima W T, Siu A M, Ahn H J, et al. (2019) Incidence and risk of concussion in youth athletes: Comparisons of age, sex, concussion history, sport, and football Position. *Arch Clin Neuropsychol* 34: 60-69.
23. Baugh C M, Kiernan P T, Kroshus E, et al. (2015) Frequency of head impact related outcomes by position in NCAA I collegiate football players. *J Neurotrauma* 32: 314-326.
24. McCrea M, Hammeke T, Olsen G, et al. (2004) Unreported concussion in high school football players: Implications for prevention. *Clin J Sport Med* 14: 13-17.
25. Williamson I J S, Goodman D (2006) Converging evidence for the under-reporting of concussions in youth ice hockey. *Br J Sport Med* 40: 128-132.
26. Cobb B R, Urban J E, Davenport E M, et al. (2013) Head impact exposure in youth football: Elementary school ages 9-12 years and the effect of practice structure. *Ann Biomed Eng* 41: 2463-2473.
27. Kerr Z Y, Simon J E, Grooms D R, et al. (2016) Epidemiology of football injuries in the National Collegiate Athletic Association, 2004-2005 to 2008-2009. *Orthop J Sports Med* 4: 2325967116664500.
28. Broshek D K, Kaushik T, Freeman J R, et al. (2005) Sex differences in outcome following sports-related concussion. *J Neurosurg* 102: 856-863.
29. Dougan B K, Horswill M S, Geffen G M (2014) Athletes' age, sex, and years of education moderate the acute neuropsychological impact of sports-related concussion: A meta-analysis. *J Int Neuropsychol Soc* 20: 64-80.
30. Russell K, Hutchison M G, Selci E, et al. (2016) Academic outcomes in high-school students after a concussion: A retrospective population-based analysis. *PLoS ONE* 11: e0165116.
31. Sicard V, Moore R D, Ellemberg D (2018) Long-term cognitive outcomes in male and female athletes following sport-related concussions. *Int J Psychophysiol* 132: 3-8.
32. Baker J G, Leddy J J, Darling S R, et al. (2016) Gender differences in recovery from sports-related concussion in adolescents. *Clin Pediatr* 55: 771-775.
33. Brooks B L, Silverberg N, Maxwell B, et al. (2018) Investigating effects of sex differences and prior concussions on symptom reporting and cognition among adolescent soccer players. *Am J Sports Med* 46: 961-968.
34. Henry L C, Elbin R J, Collins M W, et al. (2016) Examining recovery trajectories after sport-related concussion with a multimodal clinical assessment approach. *Neurosurgery* 78: 232-241.
35. Zuckerman S L, Apple R P, Odom M J, et al. (2014) Effect of sex on symptoms and return to baseline in sport-related concussion. *J Neurosurg Pediatr* 13: 72-81.
36. Cancelliere C, Donovan J, Cassidy J D (2016) Is sex an indicator of prognosis after mild traumatic brain injury?: A systematic analysis of the findings of the world health organization collaborating centre task force on mild traumatic brain injury and the international collaboration on mild traumatic brain injury prognosis. *Arch Phys Med Rehabil* 97: S5-S18.
37. Broglio S P, Eckner J T, Martini D, et al. (2011) Cumulative head impact burden in high school football. *J Neurotrauma* 28: 2069-2078.
38. Houck Z M, Asken B M, Bauer R M, et al. (2020) Academic aptitude mediates the relationship between socioeconomic status and race in predicting ImPACT scores in college athletes. *Clin Neuropsychol* 34: 561-579.
39. Sandel N K, Schatz P, Goldberg K B, et al. (2017) Sex-based differences in cognitive deficits and symptom reporting among acutely concussed adolescent lacrosse and soccer players. *Am J Sports Med* 45: 937-944.

**DOI: 10.36959/987/264**