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Computerized neuropsychological test performance of youth football players at different positions: A comparison of high and low contact players

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Abstract

The aim of this study was to examine the effects of head impact frequency on the neuropsychological test results of football players who participate in different positions on the team. Based on the biomechanical measures of head impact frequency reported in high school football, a High Contact group ($n = 480$) consisting of offensive and defensive linemen was compared with a Low Contact group ($n = 640$) comprised of receivers and defensive backs. The results revealed that the High Contact group obtained poorer performances on the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) on three Composite scores (Verbal Memory, Visual Motor Speed, Impulse Control) and the Total Symptom score compared to the Low Contact group. The present study is the first, to date, to report differences in the neuropsychological test performances of athletes who participate in high and low contact football positions. The findings raise tentative concerns that youth football players exposed to repetitive head trauma, including subconcussive impacts, may be at risk for lowered neuropsychological functioning and increased symptoms.

Keywords

Contact frequency; football; neuropsychological; positions

Introduction

Sports-related concussions have become a magnet for increasing scrutiny by clinicians, researchers, and popular media alike, largely due to the highly publicized cases of concussion damage in National Football League players (Fainaru-Wada & Fainaru, 2013). In recent years, the widespread participation in high school and collegiate sports has also attracted attention due to higher concussion rates in sport, with a significant increase from 23% to 57% from 2005 through 2012 (Rosenthal, Foraker, Collins, & Comstock, 2014). Some authorities contend that the reported increase in concussion rates is due to efforts in concussion education and awareness, resulting in improved identification and reporting of concussion (Kerr et al., 2015; Lincoln et al., 2011). At the same time, others opine that concussion incidences are underestimated because young athletes have insufficient knowledge of concussion symptoms (Cournoyer, 2014) and also resist reporting head injury in order to continue to play (Daneshvar, Nowinski, McKee, & Cantu, 2011; Williamson & Goodman, 2006). While the frequency of concussion varies from sport to sport, football consistently commands one of the highest rates of concussion at high school and collegiate levels compared to other sport activities (Jinguji, Krabak, & Satchell, 2011; Marar, McIlvain, Fields, & Comstock, 2012; Noble & Hesdorffer, 2013).

Within football, the rate of concussive injuries appears to vary depending on which position the athlete plays. An 8-year (1975–1982) investigation of 49 college teams found that the highest frequency of game-related concussions on defense were reported by defensive backs, while among the offensive players, running backs reported the most game-related concussions (Buckley, 1988). A study of concussions in college football players by Collins et al. (2005) indicated that quarterbacks and tight ends reported the highest rates of prior concussion. A review of 16 years of National Collegiate Athletic Association (NCAA) injury surveillance data for football found that (a) offensive players received more concussions than defensive players; and (b) quarterbacks and running backs had the highest number of concussions, while offensive and defensive linemen had the lowest number of concussions (Dick et al., 2007). Among high school football players, linebackers sustain the highest proportion of concussion injuries among the defensive players, while running backs have the highest proportion of concussions of players in offensive positions (Gessel, Fields, Collins, Dick, & Comstock, 2007; Powell & Barber-Foss, 1999). The concussion rates in high school and college football suggest, in general, that offensive skill players (running backs and quarterbacks) and linebackers may experience more concussions than players in other positions.

Recent biomechanical technology has been employed to quantify the magnitude and frequency of head impacts sustained by football players in different positions. Researchers at the University of Oklahoma used the Head Impact Telemetry (HIT) System placed in the helmets of 40 college football players and 16 high school football players to measure all head impacts from practices and games during the 2005 football season (Schnebel, Gwin, Anderson, & Gatlin, 2007). In addition to noting that college players sustained highlevel impacts more frequently than high school players, the investigators found that skill position players (quarterbacks, running backs, wide receivers, cornerbacks, and safeties) in high school and college received a greater percentage of high level impacts (60–98 g) than

linemen. In contrast, linemen sustained the highest number of impacts, but most were of relatively low magnitude (20–30 g). A similar HIT approach to analyze head impacts incurred by high school football players found that offensive skill players (quarterback, receiver, tight end, running back, fullback) sustained the greatest magnitude of linear acceleration after an impact (Broglio et al., 2009). Defensive and offensive linemen, in contrast, sustained the lowest magnitude impacts but had the most impacts during games and practices. A four-year investigation, using the HIT system of helmet-mounted accelerometers with high school football players, found that linemen sustained the highest number of impacts (>15 g) per season, while the lowest number of impacts were attained by receivers, corner backs and safeties (Broglio et al., 2011).

With accelerometers embedded in the helmets of college football players, Mihalik, Bell, Marshall, and Guskiewicz (2007) reported that offensive linemen had the highest frequency of recorded impacts, while offensive backs sustained the highest magnitude impacts. Crisco et al. (2010) also used HIT instrumentation with college football players in one season and found that linemen and linebackers had a greater number of impacts per practice and game than players at other positions. Crisco et al. (2012) later reported that running backs consistently sustained the greatest impact magnitudes of head trauma. Similarly, Funk, Rowson, Daniel, and Duma (2012) examined the HIT data of college football players over a 4-year period and reported that linemen sustained the highest number of head impacts, while skill position players had a higher number of more severe head impacts (>100 g). In summarizing the research utilizing HIT with high school and collegiate football players, it appears that offensive skill players are likely to sustain more severe head impacts, while linemen have the highest number of head impacts in football.

Comparing the outcomes of head impact across different football positions in college, Baugh et al. (2015) found no differences between position groups in the number of diagnosed concussions, but reported that offensive linemen had higher amounts of undiagnosed concussions and subconcussive head impacts than other position players. Moreover, the authors stated that offensive linemen, who experience frequent but low magnitude head impacts, develop more post-impact symptoms than other position players.

The high frequency of subconcussive head impacts in football has been noted in past reviews to have serious cumulative effects, with functional deficits measured by neuropsychological, and corroborated by functional MRI and diffusion tensor imaging results (Bailes, Petraglia, Omalu, Nauman, & Talavage, 2013; Stern et al., 2011). Together these reviews suggest that head impact frequency encountered in football in youths may result in neurological consequences, including deleterious effects on neuropsychological functioning.

The research literature that have compared the head trauma frequencies of football players in varied positions is increasing but thus far there are no known studies examining the neuropsychological test data of youth football athletes playing in different team positions. The primary aim of this research was to examine the effects of head trauma frequency by comparing the baseline neuropsychological test scores of youth football players in different positions on the team, with a focus on the test results of players in high and low contact football positions.

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

This study utilized the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery, which has been employed in several studies of concussions among high school athletes (Lovell, 2006). ImPACT is a web-based computerized neuropsychological test battery developed for the assessment of sports-related concussion in youth, collegiate, and professional athletes. The test, which takes about 30 minutes to complete, is administered at grades 9 and 11 at all schools, but is also provided at all others who were not previously tested, such as transfers from out-of-state schools where ImPACT baseline testing was not performed. ImPACT was administered in groups of about 20 prior to the season, monitored by certified athletic trainers educated in the standardized administration of the examination. A more complete description of ImPACT can be found elsewhere (Lovell, 2012). ImPACT produces five neurocognitive composite scores, including Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control. The testing also yields a Total Symptom score, based on the ImPACT Post-Concussion Symptom Scale that consists of 22 commonly reported symptoms (e.g., headache, dizziness). The test provides self-reported demographic and health information, such as age, sex, years of education, native language, sport played, prior concussion, and history of learning disability, attention deficit disorder, psychiatric illness, or seizures.

Procedure

The present study, utilizing a differential prevalence design, operationally defined a High and a Low Contact group according to the frequency of head impacts reported at different positions in high school football (Broglio et al., 2009; Schnebel et al., 2007). Similar patterns of head impact frequency were noted by Crisco et al. (2010) and Funk et al. (2012) in their HIT evaluations of collegiate players in varied football positions. Baseline testing was conducted before season play, with the understanding that the athletes participated in football in the past and experienced varying degrees of contact and head trauma. The study assumed that the players in certain football positions, based on prior biomechanical research, were subjected to a greater number of head impacts and were, therefore, more likely to be affected in their neuropsychological test performances. This research design was similar to previous investigations of repetitive head impacts that compared athletes in contact sports, such as football and soccer, with athletes in non-contact sports, like track and tennis (McAllister et al., 2012; Stephens, Rutherford, Potter, & Fernie, 2010; Tsushima, Geling, Arnold, & Oshiro, 2016).

Participants

The pool of athletes was 4,952 males, ages 13 to 18 years, from 65 schools in Hawaii. Of these, 4,453 athletes met the following inclusionary criteria: native language of English and valid ImPACT baseline test results. Excluded from the study were 162 who indicated that English was not their native language, and 337 who had invalid profiles which were

automatically identified by the online ImPACT version that incorporates the following cut-off scores: Impulse Control Composite score ≥ 30 , X's and O's–Total Incorrect >30 , Word Memory–Learning Percent Correct <69 , Design Memory–Learning Percent Correct <50 , and Three Letters–Total Letters Correct <8 (Lovell, 2012). There were 2,173 athletes who participated in football. Football position data were missing for 423. Additionally, 630 football players were excluded who were not in the High Contact (offensive and defensive linemen) or Low Contact (receivers and defensive backs) groups. The High Contact group was comprised of 212 offensive linemen and 268 defensive linemen, who are known to have the highest frequency of head impacts, while the Low Contact group consisted of 347 receivers and 293 defensive backs, who have the lowest frequency of head impacts.

Data analysis

Descriptive statistics were summarized by means and standard deviations, along with medians and ranges for continuous variables (e.g., age and ImPACT scores). The data were summarized by frequencies and percentages for categorical variables (e.g., LD/ADHD and the number of concussions). The two contact groups were examined in terms of age, and history of prior concussions, learning disability (LD), and attention-deficit/ hyperactivity disorder (ADHD). Due to the non-normal distributions of the ages, assessed via the Shapiro-Wilk test and the Kolmogorov-Smirnov test, non-parametric statistics (i.e., Wilcoxon Rank Sum test, was used to compare age differences between the two contact groups). For the categorical variables, namely, history of prior concussions and LD/ADHD, chi-square tests were utilized for frequency comparison purposes. The two groups were also compared regarding six ImPACT scores (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, Impulse Control, and Total Symptom). Because of the nonnormal distribution of the ImPACT scores, the nonparametric Wilcoxon Rank Sum tests were employed as post-hoc analyses to determine which ImPACT score was significantly different. Effect size was calculated by the nonparametric Cliff's Delta. All data analyses were performed in SAS 9.3 (SAS Institute Inc., 2011). Statistical tests were two-tailed, with an *a priori* statistical significance set with Bonferroni correction at $p < .007$ for all analyses.

Results

The mean age of the High Contact Group was 14.92 ($SD = 1.17$) and the mean age of the Low Contact Groups was 14.92 ($SD = 1.18$), with no significant difference between the two groups ($\chi^2[1] = 0.003$, $p = 0.96$).

Of the High Contact players, 411 (85.6%) had no prior concussion, 49 (10.2%) had one concussion, 17 (3.5%) had two concussions, and 3 (0.6%) had three or more concussions. The Low Contact groups had 520 (81.3%) with no previous concussion, 89 (13.9%) with one concussion, 27 (4.2%) with two concussions, and 4 (0.6%) with three or more concussions. The differences in concussion history between the two groups were not significant ($\chi^2[3] = 4.00$, $p = 0.26$).

Among the High Contact Group, 30 (6.25%) had a history of LD or ADHD, while the Low Contact Group consisted of 33 (5.16%) who had a history of LD or ADHD. The difference in LD/ADHD between the two groups was not significant ($\chi^2[1] = 0.62$, $p = 0.43$).

MANOVA revealed significant differences on ImPACT scores between the two groups ($F=5.55$, $p<.0001$). The High Contact group obtained significantly poorer ImPACT Composite scores in Verbal Memory ($Z=-3.15$, $p=0.002$), Visual Motor Speed ($Z=-2.99$, $p=0.003$), Impulse Control ($Z=3.75$, $p=0.0002$), and Total Symptom ($Z=3.44$, $p=0.0006$). Effect sizes calculated by Cliff's Delta were very small but statistically significant with 95% *CI*. No significant differences were seen between the two groups in Visual Memory and Reaction Time. The results of the ImPACT scores of the High and Low Contact Groups appear in Table 1.

Discussion

The present study represents, to our knowledge, the first effort to evaluate the consequences of frequent head impacts on youth football players in different positions by examining the neuropsychological test scores of a large sample of athletes in different positions of the football team. The data analysis focused on two groups of football positions, based on the reported frequency of head impacts of high school players found at different positions (Broglia et al., 2009), with the assumption that lower test scores occur at positions where more impacts occur. The results revealed that the High Contact group of offensive and defensive linemen obtained poorer results on three ImPACT Composite scores (Verbal Memory, Visual Motor Speed, Impulse Control) and reported more symptoms than the Low Contact group comprised of receivers and defensive backs. The effect sizes were very small but statistically significant.

The present findings are consistent with prior research of collegiate football players that revealed an increase in neurological symptoms associated with head impact frequency (Baugh et al., 2015), but are at odds with a HIT study by Gysland et al. (2012) that found no relation between neuropsychological test results and the total number of head impacts of college football players over one season. However, Gysland and her associates employed a relatively small sample of 46 college football players, with an unreported number of players with prior concussion and did not include a comparison group—factors that reduced the significance of their findings.

While high magnitude collisions and concussions capture much of the attention of football fans and sports media, frequent lower intensity head trauma and subclinical concussions cannot be ignored or taken lightly. Researchers have noted that high school football players sustain a greater number of head impacts compared to other sports, like soccer and ice hockey (Broglia et al., 2011). In football, non-concussive hits can occur on nearly every play, especially for linemen who encounter constant helmet-to-helmet crashes (Talavage et al., 2013). A high school football player may experience over 2,000 subconcussive blows during the course of a single season (Broglia et al., 2011). The consequences of repetitive head blows in sports are not insignificant. Investigators have found that youth athletes in collision sports, like football, display poorer performances in neurocognitive tasks than noncontact athletes, such as in basketball, baseball, and track (McAllister et al., 2012; Tsushima et al., 2016). On the other hand, Stephens et al. (2010) found no differences in the neuropsychological test performances of adolescent soccer, rugby, and noncontact players (e.g., swimming, tennis, cricket). It should be noted, however, that Stephens et al. sought to

evaluate the neuropsychological effects of repetitive soccer heading, but compared soccer players with rugby and noncontact players, 60% of whom also played recreational soccer. In recent years the interest in repetitive head impacts in youths has grown, with concerns that cumulative head trauma, including subconcussive blows, can seriously affect brain functions (Bailes et al., 2013; Graham, Rivara, Ford, & Spicer, 2014; Stern et al., 2011).

Without quantifiable measures of head trauma as provided by the use of head impact telemetry, it is difficult to directly study repetitive head impacts and their potential effects. The present investigation provided an indirect option by comparing a group of athletes who are known to incur high frequencies of head impacts with athletes who reportedly have a low frequency of head impacts. The differential prevalence design of this study is indeed an imperfect approach to clinical research because impact frequency at different football positions is assumed, based on prior biomechanical studies, rather than controlled or measured directly. This assumption does not ensure that athletes in the High or Low Contact groups truly sustained a high or low frequency of head impacts, posing a significant threat to the validity of the group assignments. The present investigative method can be helpful in assessing the variable risk of repetitive head trauma in football players when there is no direct measuring of head trauma, and can be useful as a preliminary effort in understanding the effect of frequent subconcussive impacts in sports. Nevertheless, more sophisticated research on the effects of head impact frequency utilizing HIT methodology to assure accurate identification of High and Low Contact players, along with neuropsychological testing, could be even more informative.

The lower scores in neurocognitive functioning in certain football positions noted in this study, however subtle, is of concern, and suggests the need for more and improved concussion education regarding repetitive head impact for players, coaches, parents, and teachers. In addition, school administrators, league officials, health care providers and legislators should support efforts to limit contact in practices, tighten rules pertaining to head impacts, and increase awareness of repeated subconcussive head blows to ensure the safety of youth football players (Cobb et al., 2013; Kerr et al., 2016).

Limitations

The methodological flaws of this study should be recognized when interpreting these findings.

1. In youth football some athletes play more than one position. We were unable to identify if any of the players played in more than one position or how much time they may have played in different positions. An athlete who played in both offensive and defensive line positions could have increased his exposure to impacts, fatigue, and the risk for injury.
2. The neuropsychological test measures in this research represent only the handful of neurocognitive functions contained in the ImPACT battery, and do not represent the wide range of neuropsychological variables found in a comprehensive test battery. Further investigation employing a broader set of neurocognitive measures is warranted.

3. This retrospective study was not able to assess other variables that could affect neuropsychological functioning, such as school aptitude and test effort.
4. The two contact groups may have differed in levels of effort during testing, as studies have indicated that some athletes tend to “sandbag” their baseline test performances so as to make post-concussion return-to-play testing easier to pass (Schatz & Glatts, 2013).

Unfortunately, no effort tests were administered that could have assessed test motivation in the participants of this study.

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Table 1

ImPACT scores of high and low contact groups.

Variable	High Contact		Low Contact		Z score	p value	Cliff's delta [95% CI]
	(n = 480)	mean (SD)	(n = 640)	mean (SD)			
Verbal Memory Composite Score	80.97	(10.63)	82.95	(10.15)	-3.15	0.002*	-0.11 [-0.18, -0.04]
Visual Memory Composite Score	72.66	(13.58)	74.27	(12.97)	-1.91	0.057	-0.07 [-0.13, 0.002]
Visual Motor Composite Score	33.15	(6.75)	34.32	(6.57)	-2.99	0.003*	-0.10 [-0.17, -0.04]
Reaction Time Composite Score	0.65	(0.10)	0.64	(0.10)	1.43	0.16	0.05 [-0.02, 0.12]
Impulse Control Composite Score	8.18	(5.21)	7.11	(4.88)	3.75	0.0002*	0.13 [0.06, 0.20]
Total Symptom Score	7.00	(10.65)	5.04	(8.44)	3.44	0.0006*	0.12 [0.05, 0.18]