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Baseline Concussion Testing: A Comparison between Collision, Contact, and Non-Contact Sports

Christopher Benedict
Grand Valley State University

Tonya M. Parker
Grand Valley State University

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Introduction

The incidence, management, and recovery from a mild traumatic brain injury (MTBI) are topics that have seen an explosion of attention from both the layperson and medical professionals in recent years. This increase in attention has led to an increase in understanding of concussions by the public, as well as an increase in fear of the potential repercussions of such an injury. A concussion is “a brain injury defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces” (McCrory et al., 2013). The symptoms of a concussion vary widely between injuries and individuals, and can include somatic symptoms (headache), neurocognitive symptoms (feeling in a fog, slowed reaction times), balance problems, emotional symptoms (depression), behavioral changes (irritability), and sleep disturbances. The majority of concussions will resolve within 7-10 days, although the recovery time may extend much further in some cases (McCrory et al., 2013).

The widespread worry about concussions is not unfounded. MTBI’s have been found to be one of the most commonly occurring injuries in sports, with an estimated 300,000 sport-related brain injuries annually in the United States, and an estimated 136,000 occurring annually in high school sports (Meehan, d’Hemecourt, & Comstock, 2010; Gessel, Fields, Collins, Dick, & Comstock, 2007; Marar et al., 2012). The aforementioned symptoms of concussion can cause a loss of the ability to perform activities of daily living, as well as a severe negative impact on the injured athlete’s academic, social, and athletic life. Also, while the recovery period for most acute concussions is relatively brief, an athlete that sustains one concussion is 3-5 times more likely to suffer a subsequent concussion (Guskiewicz et al., 2004).

A very real and very scary consequence that has recently been brought into the forefront of public attention is the possible long term effect of sub-concussive head impacts – impacts sustained during the course of playing collision and contact sports that is below the level that might cause an acute injury. An athlete can suffer thousands of these head traumas during their career. An average college football player was found to be subjected to 420 head impacts during a single season (Crisco et al., 2011). Similarly, a collegiate soccer player was found to average about 8 headers per game (Rutherford, Stephens, Potter, & Fernie, 2005). Over the course of a 20-25 game season, this amounts to up to 200 headers, not including practices. If it is found that these cause neurological deficits, it could change the culture of sports forever.

There are many different tools and methods that are used to assess neurological deficits and assist in the diagnosis of a concussion. One widely used clinical neuropsychological tool is the Immediate Post-Concussion Assessment and Cognitive Testing test, or the ImPACT test. ImPACT is a computer based system that tests neurocognitive function, and is divided into three sections. The first section is a questionnaire that asks about different characteristics of the athlete, such as concussion history, demographics, history of learning disabilities, etc. The second section consists of a self-assessment of concussion symptoms on a scale of 0 (not present) to 6 (severe). The final section assesses neurocognitive function, and is divided into 6 modules. These modules ask the athlete to perform different tasks that test memory, attention, reaction time, processing speed, learning, and visual motor response. It is important to note that this does not test for intelligence or achievement (ImPACT Applications, Inc., 2014).

Baseline testing is a critical component of ImPACT testing. A baseline test is performed prior to the competitive season when the athlete is asymptomatic. These scores are then used as a reference during the recovery period when an athlete suffers a concussion during the competitive season. If the post-injury test results show significant deficits, then it is recommended that the athlete be withheld from competition. Therefore, baseline testing is critical to for proper management of a concussion when using ImPACT.

ImPACT has been shown to be sensitive, specific, valid, and reliable for assessing neurocognitive function (Schatz, Pardini, Lovell, Collins, & Podell, 2006; Maerlender et al., 2013; Register-Mihalik et al., 2012). Its sensitivity in diagnosing concussion was found to be 81.9% and its specificity was found to be 89.4% (Schatz et al, 2006). Reliability for ImPACT has shown to be adequate up to two years following the baseline test (Register-Mihalik et al., 2012). The test has been proven to be valid as well, providing an invalid test on 4.1%-6.3% of tests (Schatz, Moser, Solomon, Ott, & Karpf, 2012; Maerlander et al., 2013). Many factors have been thought to influence ImPACT scores, including concussion history, age, gender, and sport played. While it was once believed that concussion history played a major role in neuropsychological testing scores, recent research has questioned this conclusion. McCrory (2011) states that based on the current research, history of concussion does lead to a decrease in neurocognitive function. However, others have found that concussion history does not play a role in decreased neurocognitive scores (Shuttleworth-Edwards, Smith, & Radloff, 2008; Broglio, Ferrara, Piland, & Anderson, 2006).These authors explain that any long term effects may be too slight to be detected by these tests. Another possible explanation for these results is that athletes who suffered long term effects from their concussions were removed from competition. Therefore, without the data from these athletes, the data is skewed to show higher neurocognitive function. They acknowledge the possibility of long term effects on the individual level, and state that these athletes with long term effects may have been removed from competition due to the effects, leading to these conclusions.

Age also seems to have an impact on neurocognitive ability, as high school juniors and seniors have a higher neurocognitive test scores than freshman, particularly regarding information processing, attention, and motor dexterity (Hunt & Ferrara, 2009).This could be due to the cognitive growth of the prefrontal cortex, the portion of the brain which has been linked to executive function and is one of the most slowly developing areasof the brain (Hunt & Ferrara, 2009). Finally, gender may play a role in neurocognitive function. Prior research has shown that women perform better on neurocognitive tests than men (McCleod, Bay, Lam, & Chhabra, 2012), but tend to take more time to recover from injury (Covassin, Elbin, Harris, Parker,& Kontos, 2012).

Previous research has provided decidedly mixed conclusions regarding this extent of the damage caused from subconcussive blows. Neurocognitive function was compared between university level rugby players and swimmers/cricket players in a study published by Shuttleworth-Edwards et al. (2008). They used common tests, such as memory and attention tests (including ImPACT), to assess neurocognitive function between the two groups. They found that the rugby players had decreased scores in the majority of categories, and even those that failed to reach statistical significance were trending towards rugby players being worse than the controls (Shuttleworth-Edwards et al., 2008). Based on this data, they concluded that the repetitive head microtraumas were negatively impacting neurocognitive function.

Another study published by Parker, Osternig, Donkelaar, and Chou (2008) compared balance control of both athletes and non-athletes with and without a concussion. Surprisingly, they found that regardless of their concussion status, athletes showed significantly impaired balance control as compared to non-athletes. In other words, non-concussed athletes had worse balance control than concussed non-athletes. In a comparison within the athlete subgroup, it was found that athletes who were subjected to fewer high-velocity head impacts, such as football wide receivers, had better balance control as compared to athletes with a higher frequency of lower-velocity impacts, such as football linemen. Based on these results, the authors concluded that the sub-concussive head impacts the athletes were subjected to may have caused them to exhibit poorer balance control, and that these sub-concussive impacts may be more harmful than acute concussions.

Another study authored by Mulligan, Boland, and Payette (2012) reached a similar conclusion. They assessed the neurocognitive and physical performance of uninjured NCAA Division I football players using the ImPACT testing software, the Postconcussion Symptom Scoring Scale, and the Balance Error Scoring System (BESS), comparing preseason and postseason scores. They found that 32 of 45 tested athletes (71.1%) demonstrated a decrease in at least one ImPACT results category, with 19 of those exhibiting changes in 2 or more categories. The authors suggested the possibility of cumulative effects of sub-concussive blows to the head as being an explanation of these results.

However, a study conducted by Miller, Adamson, Pink, and Sweet (2007) had a similar method but found the opposite results. They compared preseason, midseason, and postseason neurocognitive scores of college football players using various neurocognitive testing programs including ImPACT, and found little to no changes in scores in any domain of the tests.

Therefore, they concluded that the repetitive head contact did not have a negative impact throughout the season. This is in stark contrast to the majority of the literature that is presented. The authors discuss the idea that the athletes may have practice effect with the tests, meaning that their scores improve simply because they have taken the test before. This could mask any possible deficits throughout the season. In addition, the cumulative effects of sub-concussive blows may not be seen immediately following the season, but later on in the athlete's life.

The sport of soccer is of particular interest due to the use of the head to strike the ball during play. Multiple studies have examined if heading the ball has any long term effects on the function of the brain. One report that attempted to answer this question assessed neuropsychological impairment using planning and memory tests in amateur soccer players as compared to swimmers (Matser, Kessels, Lezak, Jordan, & Troost, 1999). They found impaired performance on the planning test in 39% of soccer players, compared to 13% of swimmers. The memory tests showed impairment in 27% of soccer players, compared to 7% of swimmers. Similarly, Zhang, Red, Lin, Patel, and Sereno (2013) assessed reaction time among high school female soccer players and non-soccer players. Once again, soccer players showed a slower reaction time as compared to controls, particularly with voluntary responses. One last study by Rutherford et al. (2004) exhibits similar results. They compared university soccer players, rugby players, and non-contact athletes using various neuropsychological tests, while keeping track of possible extraneous variables including concussion history and alcohol consumed. They found that despite the higher incidence of acute brain injury in rugby players, soccer players performed more poorly on the neuropsychological tests. Each of these three studies support the conclusion that heading the ball in soccer may have long term negative effects on neurocognitive function.

The goal of this project will be to identify deficits in baseline neuropsychological performance in athletes of contact/collision sports including football and soccer, which are subject to repetitive subconcussive head traumas, as compared to athletes of non-contact sports such as tennis, track, cross country, and swimming. To our knowledge, no currently available studies have been performed evaluating these differences, and thus this project will be an important addition to the currently available literature. If, after controlling for confounding variables such as gender and concussion history, athletes in collision sports score lower than athletes in non-collision sports, it would suggest that the repetitive sub-concussive head impacts are having a negative effect on the brain. This information would increase our understanding of the long-term risks involved in sport, and enable us to further warn the public of these risks.

Methods

All data collected for this study was generated from the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery. ImPACT is a computer based system that tests neurocognitive function, and is divided into three sections. The first section is a questionnaire that asks about different characteristics of the athlete, such as concussion history, demographics, history of learning disabilities, etc. The second section consists of a self-assessment of concussion symptoms present over the previous 24 hours graded on a scale of 0 (not present) to 6 (severe). The final section assesses neurocognitive function, and is divided into 6 modules. These modules ask the athlete to perform different tasks that test memory, attention, reaction time, processing speed, learning, and visual motor response. It is important to note that this does not test for intelligence or achievement. Data examined for this study are: Verbal Memory, Visual Memory, Visual Motor composite, Reaction Time, Impulse Control, and Total Symptom Score.

All data utilized in this study were culled from baseline testing completed at a National Collegiate Athletic Association Division II university as a part of a pre-participation physical exam. This baseline testing was administered to all student athletes during their first year of competition at the university. Testing was administered in groups by sport, and was supervised by one researcher who monitored for potential distractions.

Records were collected from the years 2009-2013. These records include both male and female athletes from many different sports. These sports were divided into separate categories based on the amount of contact present in the game: collision sports, contact sports, and non-contact sports. The first category is collision sports, which are defined as a sport in which athletes purposely hit or collide with each other or inanimate objects with measurable force (Rice, 2008). Collision sports that are included in this study are men’s and women’s diving and football. Contact sports are defined as a sport in which athletes routinely make contact with each other, but with less force involved. Contact sports included in this study are baseball, men’s and women’s basketball, women’s lacrosse, women’s soccer, softball, and women’s volleyball. Non-contact sports are defined as a sport that requires no contact, including men’s and women’s golf, men’s and women’s swimming, men’s and women’s tennis, men’s and women’s track and field, and men’s and women’s cross country.

Table 1: Included Sports and Their Classifications

Collision	**Contact**	**Non-Contact**
Men's Football	Men's Baseball	Men's Golf
Men's Diving	Men's Basketball	Women's Golf
Women's Diving	Women's Basketball	Men's Swimming
	Women's Lacrosse	Women's Swimming

	Women's Soccer	Men's Tennis
	Women's Softball	Women's Tennis
	Women's Volleyball	Men's Track and Field
		Women's Track and Field
		Men's Cross Country
		Women's Cross Country

Results

Overall, baseline data was collected from 650 total athletes, and data can be found in Table 2.

Table 2: Participant Numbers

	Collision	**Contact**	**Non-Contact**	Total
Males	173	69	119	361
Females	10	150	129	289
Total	183	219	248	

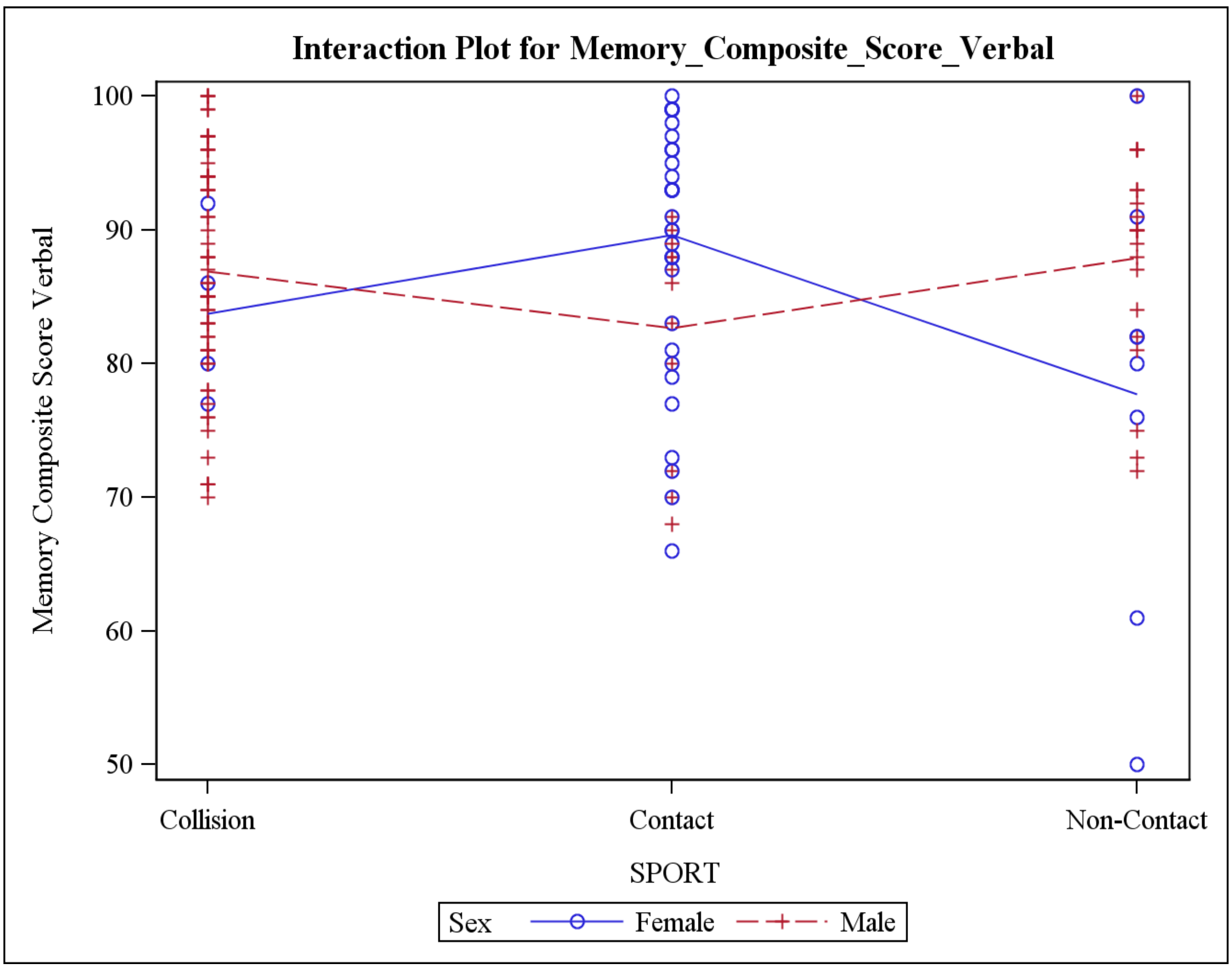
The means of each variable, Verbal Memory, Visual Memory, and Visual Motor composite, Reaction Time, Impulse Control, and Total Symptom Score, were found for Collision, Contact, and Non-Contact sports, as well as between sexes (Table 3). Each of the means was compared for significance in two separate groups: those with no concussion history and those with more than one previous concussion.

Table 3: Means by Sport Category

	Non-Contact		Contact		Collision	
Number of Concussions	Zero	1+	Zero	1+	Zero	1+
Verbal Memory	86.15 (9.36)	85.00 (11.43)	86.04 (10.23)	87.92 (9.37)	85.06 (10.12)	86.70 (8.34)
Visual Memory	76.58 (12.92)	76.75 (13.13)	78.35 (12.33)	77.08 (11.42)	77.22 (11.98)	76.94 (12.00)
Visual Motor Composite	41.25 (6.14)	40.85 (6.73)	42.19 (6.19)	41.93 (7.30)	39.64 (6.30)	41.51 (5.55)
Reaction Time	0.60 (0.08)	0.56 (0.06)	0.58 (0.07)	0.59 (0.09)	0.60 (0.11)	0.57 (0.08)

Impulse Control	5.42 (3.98)	4.89 (2.95)	4.71 (3.27)	5.49 (3.92)	5.28 (3.89)	6.11 (5.11)
Symptom Score	6.47 (7.88)	7.36 (7.81)	6.27 (8.15)	7.65 (12.67)	6.13 (8.17)	5.76 (7.70)

The Verbal Memory showed an interaction effect (*p*=0.0021) for sport and sex in those patients with a concussion history that was not present in the athletes with no concussion history. Upon post-hoc analysis, it was found that the Contact females and Non-Contact males scored significantly higher that the collision athletes and the contact males and non-contact females (Graph 1).



The analysis for the Visual Motor Composite Score revealed a significant difference between the sexes in those athletes with no concussion history, with females scoring higher on this portion of the test across all sports (p=0.0431). However, this significance disappears completely in those athletes with a concussion history (p=0.8176).

No significant differences were found regarding the Visual Memory Composite Score or the Reaction Time Composite Rcore category. No significant results were found in the Impulse Control Composite Score.

The Total Symptom Score was found to have a significant main effect for sex in athletes with no concussion history, with females exhibiting more symptoms than males (p=0.0111). Similar to the Visual Motor Composite Score, this significance disappears when evaluating athletes with a concussion history (p=0.0596). No correlation between sports was found for this variable.

Discussion

The primary objective of this study was to identify any potential neuropsychological deficits that existed between athletes of collision, contact, and non-contact sports on baseline examination. Our data revealed that regardless of concussion history, there were few significant differences in neurocognitive scores between athletes of collision, contact, and non-contact sports. This result is surprising given the results of prior studies with similar objectives. A study performed by Parker et al. (2008) found that athletes exhibited poorer overall balance control than non-athletes, particularly those subjected to repetitive low-velocity head impacts. Similarly, a study published by Shuttleworth-Edwards, Smith, and Radloff (2008) found decreased neurocognitive scores across the board in rugby players as compared to swimmers and cricket players. On the other hand, the results of our study more closely line up with those published by Miller et al. (2007). He found no decrease in neurocognitive scores in football players between the beginning and the end of the competitive season, suggesting that there is no significant damage resulting from the sub-concussive blows seen in collision sports.

There are a few possible explanations for the lack of differences between sports, aside from suggesting that there are no consequences from the head microtraumas. One possible explanation is that the changes may be too slight to be detected by the ImPACT software. Therefore, deficits may be associated with the sub-concussive impacts, but those deficits will not appear in our results.

Another objective of our study was to identify differences in neurocognitive scores between males and females, as well as between athletes with and without a history of concussion. Our data found that females with no concussion history scored significantly higher in Visual Motor Score, as well as reporting a significantly higher Total Symptom Score as compared to males. Female scores also trended higher in Verbal Memory Score, although these results were short of significant. This is consistent with what prior research has shown regarding a difference in neuropsychological and subjective symptom baseline data between sexes. In a study published by Ryan, Atkinson, and Dunham (2004), females scored significantly higher than males in baseline testing, particularly regarding perceptual-motor tasks and verbal fluency tasks. In addition, research has shown that females report a higher number of subjective concussion symptoms, particularly at baseline (Covassin, Schatz, & Swanik, 2007; Shehata et al. 2009).

Surprisingly, this significant difference disappears in both Visual Motor Score and Total Symptom Score when evaluating athletes with a history of one or more concussions. This change has not been reported in the current literature. A few possible reasons exist to explain the similar scores being reported by men and women. It is possible that a concussion may cause a longer lasting deficit in females than it does in males. It has already been reported in previous literature that females have a longer recovery period from concussion than that from males (Covassin et al., 2012). Therefore, there may be an effect of concussion that lasts longer than anticipated. This lengthened effect may cause a "regression to the mean," where males and females show closer to the same scores following a concussion throughout the length of the concussion.

Our data also revealed a significant interaction effect for sport category and sex in athletes with a concussion history in Verbal Memory, but this interaction effect is not present in athletes with no history of concussion. Individuals in collision sports and non-contact male sports scored significantly lower than contact sport females. However, women in contact sports scored significantly higher than their male counterparts playing contact sports and their female counterparts in non-contact sports. These rather mixed findings do not offer a clear interpretation.

As with all studies, there were various limitations to our results. Our first and most notable limitation was the small sample size that we had for women's collision sports. Only ten female collision sport athletes were included in our study, due to data only being available for diving. A significantly higher number of athletes were in each other data group, which causes a high degree of variability and uncertainty in the data that is derived from this group. Future studies on this topic should include a greater variety of collision sports, possibly including men’s/women’s rugby or ice hockey. This would provide greater consistency between the genders in the data.

Another possible limitation to our study was the inclusion of women’s soccer as a contact sport. As previously mentioned, soccer is a sport of particular interest in this topic due to the repeated sub-concussive head impacts resulting from heading the ball. There was a bit of debate on whether to include women’s soccer as a collision or contact sport for this reason, but it was decided to classify it as a contact sport. However, this decision may have had an impact on our results. Previous research has identified soccer athletes as prone to long term neurocognitive deficits (Matser et al., 1999; Zhang et al., 2013; Rutherford et al., 2004). If these same deficits are consistent with the soccer athletes from our study, then it is possible our classifications of sports were too generalized and masked differences when deficits may actually be present. While this may be true, the authors believe the correct classification choice for soccer was made.

One final limitation to our study is the use of pre-existing data rather than collecting the data prospectively. While a single researcher administered the examinations, there could be a lack of consistency between the ImPACT testing sessions. Despite the fact that ImPACT has been shown to be sensitive, specific, valid, and reliable for assessing neurocognitive function (Maerlender et al., 2013; Schatz et al., 2006; Register-Mihalik, 2012), there are various factors that are known to influence the results. For example, it is well known that ImPACT testing must be performed in a quiet room free of distractions. If different groups of testing were subjected to a different test-taking environment, it could cause a change in the scores. For example, if the golf team taking the test experienced a distraction that the football team did not, it could artificially lower scores. Another possible factor is the psychological state of the individual being tested. In particular, the amount of sleep gotten the night before as well as the emotional state of the individual may impact ImPACT scores. These variables were not controlled for, and therefore may have influenced the results.

One potential takeaway from this study is the need for a second baseline test following a concussion. With the change in scores between athletes with and without a concussion history (noted with the lack of significance between males and females in athletes with a history of one or more concussions), it may be necessary to re-assess the athlete in order to provide a proper baseline. Without a second baseline test, the results may be skewed, leading to an inappropriate return-to-play decision following a concussion.

The few significant differences in baseline data between collision, contact, and non-contact sports may provide some indication that collision sports do not cause long term neurocognitive deficits. However, this study is not sufficient to rule out the possibility of these potential deficits. Clinicians should note the higher scores seen by females in Visual Motor Score and Total Symptom Score, suggesting that females may have specific differences that should be examined on re-baseline testing and confirming results of previous studies that at baseline, and that females report more subjective concussion symptoms. The loss of significance in these scores in athletes with a history of one or more concussion suggests a difference in the reaction to and recovery period from concussions between males and females, and should be taken into account in the process of returning an athlete to play following a concussion.

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