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Baseline Concussion Testing: The Effects of Learning Disabilities and Sleep

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Introduction

Mild traumatic brain injury (mTBI), or concussion, has been a controversial discussion topic in the media and among the members of the National Athletic Trainer's Association (NATA), as well as in the athletics community as a whole, for the past several years. The National Athletic Trainer's Association defines concussion as a "trauma-induced alteration in mental status that may or may not involve loss of consciousness" (Broglio, Cantu, Gioia, Guskiewicz, Kutcher, Palm, & Valovich McLeod, 2014). The onset of a concussion can be acute, involving a mechanism of a blow to the skull or spinal column transmitting an injurious force to the brain (Starkey, Brown, & Ryan, 2010, p. 889). Chief complaints and symptoms include but are not limited to somatic symptoms, neurocognitive symptoms, emotional symptoms, behavior changes, sleep disturbances, and balance problems (Starkey, et al., 2010, p. 877). The severity and longevity of some of these symptoms can be devastating to the injured athlete, especially if the athlete is returned to play prior to complete healing from concussion as this may exacerbate unresolved symptoms (Starkey, et al., 2010, p. 893). Second impact syndrome is a consequence that can occur if an athlete returns to participation too soon after suffering from a concussion, which is sustaining a second concussion while the individual is still symptomatic from the first (Starkey, et al., 2010, p. 893). This type of re-injury can result in death (Starkey, et al., 2010, p. 894). In order to prevent premature return to participation it is preferred that all athletes undergo neurocognitive testing to determine the baseline functionality of the brain. It is recommended that athletes at high risk for concussion, including those athletes participating in collision and contact sports, undergo baseline concussion testing prior to participation in sport (Broglio, et al., 2014.

There are many tools and methods to assess and assist in the diagnosis of neurological deficits. A common form of neurocognitive testing is a computerized assessment tool that generates composite scores for several cognitive categories (Schatz & Sandel, 2012). Immediate Post-Concussion Assessment and Cognitive Testing, ImPACT, is a widely used, computer-based system that is divided into three basic sections with the primary purpose of assessing neurocognitive function (Schatz & Sandel, 2012). The first section is a questionnaire asking the patient's personal and athletic characteristics, demographics, and health history, including that of the diagnosis of a learning disability and the number of hours of sleep the night prior to the test (Schatz & Sandel, 2012). Section two consists of a self-reported symptom scale in which the patient is instructed to rate a series of concussion symptoms from 0 (not present) to 6 (severe) based on how they are feeling at that given time and over the previous 24 hours (Schatz & Sandel, 2012). The third and final section goes into the assessment of neurocognitive function and is divided into 6 modules (Schatz & Sandel, 2012). The results from the modules provide scores in verbal memory, visual memory, visual motor, reaction time, impulse control, and overall symptom scores (Schatz & Sandel, 2012).

ImPACT computerized testing has been shown to be sensitive, specific, valid, and reliable for assessing neurocognitive function (Cole, Arrieux, Schwab, Ivins, Qashu, & Lewis, 2013; Nakayama, Covassin, Schatz, Nogle, & Kovan, 2014; Resch, Driscoll, McCaffrey, Brown, Ferrara, Macciocchi, & Baumgartner, 2013; Schatz, & Sandel, 2012). In comparison with other neurocognitive assessment tools, ImPACT has the highest test-retest reliability, falling in the high reliability category (0.80-0.89; Cole, et al., 2013). Intraclass correlation coefficients show that all of the composite scores exceed the test-retest threshold values for reliability (Nakayama, et al., 2014). Other studies show that some of the category composite scores prove to be more reliable than others, with visual motor speed and reaction time demonstrating more reliability than verbal and visual memory (Resch, et al., 2013). The longevity of the ImPACT test has also proven to be reliable. In a study performed over a 2-year timeline, the test results showed a minimal number of athletes with significant change on composite scores of their baseline tests (Schatz, 2009); meaning that baseline tends to remain stable for up to a two year period. In another study performed by Schatz and colleagues (2012), the sensitivity and specificity values of the ImPACT test were calculated to be 91.4% and 69.1%, respectively. However, there have been questions as to what factors affect the baseline results and if these factors create significant changes in the composite scores of the test.

Recent research has examined factors that alter or significantly change baseline composite scores for athletes. In one such study, athletes with learning disability and/or ADHD were compared with athletes with no learning disabilities or ADHD (Elbin, Kontos, Kegel, Johnson, Burkhart, & Schatz, 2013). The results of this study showed that athletes with learning disability and/or ADHD were more likely to report higher symptom scores and were also more likely to perform significantly lower on all ImPACT composite scores than athletes with no disability (Elbin, et al., 2013). In another study examining the number of hours of sleep the athlete received the night prior to taking the test, athletes performed worse with less hours of sleep. The results revealed that athletes receiving less than 7 hours of sleep the night before performing baseline ImPACT testing performed significantly worse on reaction time, verbal memory, and visual memory scores than those athletes who received more than 7 hours of sleep prior (McClure, Zuckerman, Kutscher, Gregory, & Solomon, 2013). Another similar study also demonstrated that athletes with fewer hours of sleep reported more symptoms on baseline testing (McClure, et al., 2013; Mihalik, Lengas, Register-Mihalik, Oyama, Begalle, & Guskiewicz, 2013). This study also examined the effects of sleep quality on baseline testing, but found no significant results to demonstrate that sleep quality interfered with testing results (Mihalik, et al., 2013).

It is important for baseline testing to be as accurate as possible because these scores are used to compare with the athlete's scores post-concussion to determine when they are ready to return to participation. There is research out about both of these two factors affecting baseline concussion testing, but no research that examines the two in conjunction. Previous research has examined college and high school athletes; this study will only examine college athletes. Based on the findings of other authors, however, the main purpose of this study is to address these topics, to note any similarities or differences. Do athletes with learning disabilities score differently on the ImPACT concussion test at baseline? Does the amount of sleep received by athletes prior to baseline testing also affect their ImPACT scores? Are the two factors inter-related in anyway, and which scores are most affected?

Methods

The data analyzed for this study was collected using the ImPACT battery, collected from testing completed at a National Collegiate Athletic Association (NCAA) Division II university. Collection took place as a part of athletes' pre-participation physical examination during their first year at the university. Some male football players were re-baselined after two years. One researcher directed all the observed testing.

Collection years ranged from 2009 to 2014. Participants included males and females from various sports including football, diving, baseball, softball, basketball, women's lacrosse, women's soccer, women's volleyball, golf, swimming, tennis, and track and field/cross country. Data was categorized based on presence of a learning disability. Learning disability was defined using the self-report data collected from each participant during the beginning questionnaire of the ImPACT test. Athletes that reported having a learning disorder or specifically having ADD/ADHD were categorized as part of the LD group (LD=1) and athletes who did not report a learning disorder or ADD/ADHD were categorized in the no LD group (LD=0). Data was categorized again, separately, based on the number of hours of sleep received by each athlete the night prior to testing. Participants were subdivided into three categories – low ($\leq$6 hours), medium (6.5-7.5 hours) and high ($\geq$8 hours). Participants that had invalid baseline scores were excluded from the data for the purposes of this study.

Results

Data was collected from 705 athletes. Participant numbers for learning disorder (LD) and sleep can be found in the Table 1.

Table 1: Participant Numbers

	High Hours	**Medium Hours**	**Low Hours**	**Total**
No LD	188	161	310	659
LD	8	14	24	46
Total	196	175	334	705

Table 1 shows the number of participants for each category as well as for the combination of categories and gives the total number of 705 participants.

The means for each composite score – verbal memory, visual memory, visual motor, reaction time, impulse control, and total symptom score – were found for each category of subjects (Table 2).

Table 2: Means and Standard Deviations

	Total Symptoms (# symptoms)	**Impulse Control** (# incorrect)	**Reaction Time** (seconds)	**Visual Motor** (# correct)	**Visual Memory** (% correct)	**Verbal Memory** (% correct)
No LD	6.04 ± 8.07	5.25 ± 3.92	0.59 ± 0.03	41.73 ± 6.14	77.84 ± 12.20	86.67 ± 9.45
LD	7.96 ± 10.51	6.13 ± 4.03	0.62 ± 0.09	38.21 ± 5.66	71.70 ± 11.64	84.09 ± 9.64
4High Hours	4.55 ± 6.20	5.02 ± 3.58	0.58 ± 0.07	42.07 ± 5.94	78.03 ± 12.12	86.71 ± 9.71
Medium Hours	5.04 ± 6.66	5.43 ± 4.20	0.59 ± 0.09	41.38 ± 6.26	77.24 ± 12.46	86.97 ± 8.86
Low Hours	10.12 ± 11.26	5.39 ± 3.77	0.60 ± 0.08	41.11 ± 6.24	77.16 ± 12.02	85.38 ± 10.28
Total	6.17 ± 8.26	5.31 ± 3.93	0.59 ± 0.08	41.50 ± 6.17	77.44 ± 12.25	86.50 ± 9.48

Table 2 shows the mean and standard deviation for each subject group in each of the 6 composite score categories, as well as the mean and standard deviation overall for all the subjects in each of the 6 categories.

A Chi-Squared test showed that the variables of learning disability and the amount of sleep are not related – they are independent from each other (p=0.249). Upon further correlation evaluations, however, it was noted that multiple of the composite scores were related, varying within the different independent variables of sleep and LD. In the low sleep category verbal memory is related to both visual memory and visual motor; visual memory is related to both visual motor and impulse control; and visual motor is related to reaction time (Table 3). In the medium sleep category verbal memory is related to visual memory, visual motor and impulse control; visual memory is related to visual motor and reaction time; and visual motor is related to reaction time and impulse control (Table 4). In the high sleep category verbal memory is related to visual memory, visual motor, reaction time and impulse control; visual memory is related to visual motor and reaction time; and visual motor is related to reaction time (Table 5). In the non-LD category verbal memory is related to visual memory, visual motor, reaction time, impulse control and symptom score; visual memory is related to visual motor, reaction time and impulse control; and visual motor is related to reaction time and impulse control (Table 6). In the LD category verbal memory is related to visual memory, visual motor and reaction time; visual motor is related to reaction time and symptom score; and reaction time is related to symptom score (Table 7).

Table 3: Low Hours Group Composite Correlations

	Verbal Memory	Visual Memory	Visual Motor	Reaction Time	Impulse Control	Total Symptoms
Verbal Memory		0.000	0.000	0.482	0.162	0.441
Visual Memory	0.000		0.000	0.155	0.000	0.218
Visual Motor	0.000	0.000		0.000	0.067	0.868
Reaction Time	0.482	0.155	0.000		0.076	0.675
Impulse Control	0.162	0.000	0.067	0.076		0.108
Total Symptoms	0.441	0.218	0.868	0.675	0.108	

Table 3 shows the correlations, as p-values, for each of the 6 composites in the low hours of sleep group. The ones highlighted are significantly related.

Table 4: Medium Hours Group Composite Correlations

	Verbal Memory	Visual Memory	Visual Motor	Reaction Time	Impulse Control	Total Symptoms
Verbal Memory		0.000	0.000	0.107	0.037	0.287
Visual Memory	0.000		0.000	0.001	0.057	0.465
Visual Motor	0.000	0.000		0.000	0.001	0.937
Reaction Time	0.107	0.001	0.000		0.579	0.457
Impulse Control	0.037	0.057	0.001	0.579		0.867
Total Symptoms	0.287	0.465	0.937	0.457	0.867	

Table 4 shows the correlations, as p-values, for each of the 6 composites in the medium hours of sleep group. The ones highlighted are significantly related.

Table 5: High Hours Group Composite Correlations

	Verbal Memory	Visual Memory	Visual Motor	Reaction Time	Impulse Control	Total Symptoms
Verbal Memory		0.000	0.000	0.000	0.003	0.063
Visual Memory	0.000		0.000	0.000	0.114	0.083
Visual Motor	0.000	0.000		0.000	0.171	0.971
Reaction Time	0.000	0.000	0.000		0.389	0.882
Impulse Control	0.003	0.114	0.171	0.389		0.985
Total Symptoms	0.063	0.083	0.971	0.882	0.985	

Table 5 shows the correlations, as p-values, for each of the 6 composites in the high hours of sleep group. The ones highlighted are significantly related.

Table 6: No LD Group Composite Correlations

	Verbal Memory	Visual Memory	Visual Motor	Reaction Time	Impulse Control	Total Symptoms
Verbal Memory		0.000	0.000	0.015	0.002	0.005
Visual Memory	0.000		0.000	0.000	0.000	0.060
Visual Motor	0.000	0.000		0.000	0.000	0.374
Reaction Time	0.015	0.000	0.000		0.094	0.660
Impulse Control	0.002	0.000	0.000	0.094		0.199
Total Symptoms	0.005	0.060	0.374	0.660	0.199	

Table 6 shows the correlations, as p-values, for each of the 6 composites in the no LD group. The ones highlighted are significantly related.

Table 7: LD Group Composite Correlations

	Verbal Memory	Visual Memory	Visual Motor	Reaction Time	Impulse Control	Total Symptoms
Verbal Memory		0.003	0.011	0.006	0.060	0.229
Visual Memory	0.003		0.764	0.072	0.846	0.817
Visual Motor	0.011	0.764		0.001	0.604	0.005
Reaction Time	0.006	0.072	0.001		0.748	0.024
Impulse Control	0.060	0.846	0.604	0.748		0.954
Total Symptoms	0.229	0.817	0.005	0.024	0.954	

Table 7 shows the correlations, as p-values, for each of the 6 composites in the LD group. The ones highlighted are significantly related.

Univariate analysis of variance was conducted for each ImPACT composite score with Bonferroni corrections for multiple comparisons. Tests of between-subjects effects showed varying results for each composite score. The new significance level was found using the original significance level of p=0.05 and then factoring in the 6 different composites. So the new significance level is p=0.0083.

$$p = 0.05/6 = 0.0083$$

Analysis for Verbal Memory and Impulse Control revealed significant differences only when examining a combination of the learning disorder variable along with the amount of sleep the athlete received the night prior. Verbal Memory (p=0.001) showed significant differences for athletes that have a learning disorder that got a high amount of sleep when compared to any athlete without a learning disorder, regardless of the amount of sleep, and when compared to other athletes with a learning disorder that got low sleep (Figure 1). Impulse Control (p=0.004) showed significant differences, similarly, for athletes that have a learning disorder that got a lot of sleep when compared to any athlete that does not have a learning disorder, regardless of the amount of sleep. Alternatively, Impulse Control showed significant differences between athletes with a learning disorder who got a lot of sleep and athletes with a learning disorder that got a medium amount of sleep, but not with athletes that have a learning disorder that got little sleep (Figure 2).

Figure 1: Verbal Memory Confidence Intervals for LD * Hours of Sleep

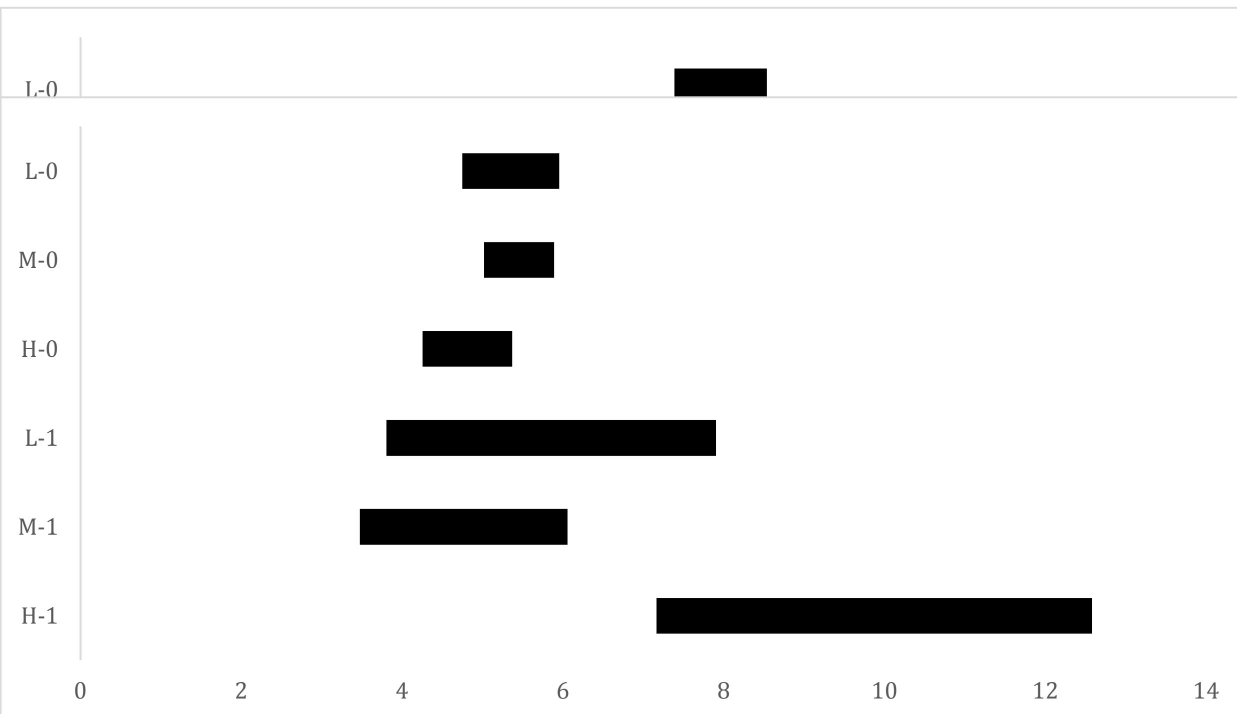

Figure 2: Impulse Control Confidence Intervals for LD * Hours of Sleep

Figure 1 shows the confidence interval bars for all combinations of LD * hours of sleep in the verbal memory composite. Where the lower bounds and upper bounds do not overlap is a significant finding.

Figure 2 shows the confidence interval bars for all combinations of LD * hours of sleep in the impulse control composite. Where the lower bounds and upper bounds do not overlap is a significant finding.

Significant differences were noted only amongst the learning disorder variable for the composite scores of Visual Memory (p=0.001), Visual Motor (p=0.001), and Reaction Time (*p*=0.003). Visual Memory, Visual Motor and Reaction Time analysis all revealed that athletes with a learning disorder performed worse than athletes without a learning disorder, regardless of the amount of sleep that they received the night prior to baseline testing.

Total Symptom Score analysis was the only test to reveal effects solely by the amount of sleep that the athlete received the night prior to taking the baseline test (*p*=0.000). Data showed that athletes that received low sleep reported more symptoms than athletes that got medium amounts of sleep, but not more than athletes that got high sleep. Also notable, Levene's Test of Equality of Error Variance showed data for this composite score to be significantly skewed (*p*=0.000).

Discussion

The primary objectives for this study were to determine if having a learning disability affects an athlete's baseline ImPACT composite scores, as well as if the number of hours of sleep the athlete received the night prior to taking the test affects their score as well. It was determined that the two are not interrelated. So the results for each independent variable can be looked at individually, but it is also important to look at them together as well. Verbal memory and impulse control scores were both affected by learning disorder in combination with the number of hours of sleep the athlete received the night prior. However, not all category combinations were affected significantly. Verbal memory score was affected for athletes that have a LD and get more sleep. These athletes scored notably lower than athletes that do not have a LD and those that do have a LD, but got low sleep. Impulse control scores were affected for athletes that have a LD and got more sleep as well. These athletes scored notably worse than athletes that do not have a LD and athletes that have a LD and get medium amounts of sleep.

Examining Visual Memory, Visual Motor and Reaction Time, it was noted that only the variable of learning disability affected the scores. Sleep was not a factor affecting any of these three composites. The similarities among these results can be partially explained by the fact that when looking at the composites for the variable LD, visual memory is correlated with visual motor, which is correlated with reaction time. Since all three of these variables are correlated, it is reasonable for them to all be affected by the same factor. Learning disability was the only factor that affected the cognitive performance for these three composites.

Total Symptom Score was the only composite affected solely by the amount of sleep that athletes received the night prior to taking the baseline test. It is important to note with this that total symptom score is the only composite not correlated with any other composite scores for any of the different sleep levels, and this makes sense since the total symptom score is not a cognitive function like the rest of the composites so it is affected differently. When looking at each of the different sleep levels to see where the significant difference falls, it is noted that the difference falls only between those athletes that got a little amount of sleep and those athletes that got a medium amount of sleep. The athletes that got medium amounts of sleep tended to report the fewest symptoms and athletes that got little sleep reported the most symptoms. Athletes that got high amounts of sleep reported a number of symptoms somewhere in between those athletes in the low and medium categories. Those that got little amounts of sleep were affected greatly because their brain was not well rested. These results are similar to the findings in an article by Lo and colleagues, in which they found that sleep loss primarily effects physical emotions rather than affecting cognitive memory and functioning (2012). And those that got high amounts of sleep were affected differently. Each person’s body works differently and has a separate amount of sleep that they need to receive each night in order to function at their highest level. Too much sleep can be just as negatively effective as too little sleep, which is why the athletes that received high amounts of sleep fell somewhere in between the other two categories. It is important for these athletes to know what their specific body needs in order to function at its highest level. And if they have not received the adequate amount of sleep they need then their symptom scores should not be considered a valid baseline. In order for the baseline symptom scores to be considered valid, the athlete should have received at least a minimum of 6.5 hours of sleep the night prior to taking the baseline test.

In conclusion, it is very important for athletic trainers to recognize when athletes have not had sufficient amounts of sleep, especially it they have a learning disability as well. Athletes with learning disabilities tend to perform worse on cognitive memory tasks than athletes without learning disabilities. Also, if those athletes with learning disabilities do not get adequate amounts of sleep they perform significantly worse on certain cognitive memory tasks. Sleep deprivation can also alter the amount of symptoms that athletes report at their baseline concussion test. The accuracy of these baseline tests are important for the proper return to play of athletes post-concussion. If returned to play before adequately ready to return, it could be detrimental to the athletes health.

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