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Test-Retest Reliability of Impact Based on External Factors

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TEST-RETEST RELIABILITY OF ImPACT BASED ON EXTERNAL FACTORS

BY

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To the Dean of the School of Human Performance and Leisure Sciences:

I am submitting herewith a thesis written by Nicole K. Carbone entitled "Test-Retest Reliability of ImPACT based on External Factors." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Athletic Training.

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Dr. Kathy Ludwig, Thesis Committee Chair

We, members of the thesis committee,
have examined this thesis
and recommend its acceptance:

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Accepted:

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Chair, Department of Sport and Exercise Sciences

Accepted:

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Dean, School of Human Performance and
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Abstract:

The purpose of this study was to examine the effect of external factors of anxiety; alcohol, caffeine, and sleep on the test- retest reliability of the ImPACT computerized concussion management software. Twenty-five Division II athletes took a pre and post test computer software test (ImPACT) and additional questionnaires, (STAI to measure anxiety, and the demographic survey). Any participants with a concussion within the last year were excluded from testing. The participants were instructed to fill out a short questionnaire about their daily living activities. After the questionnaire was complete, the ImPACT test was administered. After the participant completed the ImPACT test, they were given another short questionnaire about state anxiety (STAI). The procedure was then repeated again seven to fourteen days after the first test. Using a Pearson correlation, the overall reliability correlations were poor. The only significant correlation was in the Reaction Time composite (r = .611, p <.05). When sleep, anxiety, and caffeine were used as covariates, reliability improved only slightly with none becoming significant. Also a moderate non-significant correlation (r = .418 p > .05) was found in the visual motor speed composite without covariates. However it appears that verbal memory, visual memory, and impulse control reliability, when sleep, anxiety, and caffeine are used as covariates improve slightly.

Using anxiety, sleep, and caffeine consumption as covariates did not significantly change the test retest reliability. Though the reliability was poor overall, more research is needed in this area because these covariates have been shown to have an effect on reaction time, impulse control, and memory, which could end up hindering the results and causing further injury when a concussion is sustained. Athletic Trainers should

emphasize the importance of the test to try to ensure the athletes are giving their best effort. They should also consider performing more than one baseline test to improve the reliability of ImPACT.

Key Words: Concussion, Evaluation, Return to play, Balance Error Score System, Symptoms check list SPSS, Standardized Assessment of Concussion

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CHAPTER ONE

Introduction

The study of concussions and there effects has always been an important topic. However during the past seven years more attention has been given to head injuries, "a surplus of three hundred articles have been published since 1991".[1] In the past, concussions have been known to players, coaches, and parents as "getting your bell rung" or a "ding", but that isn't the case at all. [1,2] The past seven years have been important when considering head injuries and how to treat them. The added attention given to concussions has raised many questions such as; how many concussions have athletes sustained throughout their careers? How can a person tell when an athlete sustains a concussion? How does the appropriate professional treat a concussion?[3]

The increased attention on concussions has spurred the use of computerized testing batteries within the athletic training field.[4] The computer based technology for concussions are only useful if the organization is able to purchase them and understand how to use them. With the advancement in technology it would be easy to rely on this technology only. However, if the researcher is to be very thorough and make effective use of this technology he/she needs to investigate and evaluate other factors that may affect the reliability of the neurocognitive outcomes. Practioner should be able to compare a baseline reading of the composite scores of ImPACT to the post concussion scores. The baseline scores are measured during the preseason period to get accurate baseline readings before the season starts, and a concussion has occurred.[4] After a concussion is sustained during play, the athlete is then retested on ImPACT and the scores are compared to the baseline.

ImPACT is a computer based test used to recognize a difference in the athletes' post-concussion scores from baseline composite scores to determine if a concussion has occurred and help in the determination of when an athlete can safely return to play. ImPACT measures the player's symptoms, is computer administered, has easy access, and can be administered via laptop. [10] The results can help assist athletic trainers and physicians make return to play decisions, provide baseline information, and the results of the test can be sent via email to any number of doctors in order to make an informed decision on returning the athlete to play. The test measures memory, attention, processing speed and reaction time. To test these composites the neurophysiological tests can be broken up into six different modules. Module one, is word discrimination which is used to evaluate attentional processes and verbal recognition memory. Module two, is the design memory, which is used to evaluate attentional processes and visual recognition memory. Module three, is the X's and O's test, which is used to test visual working memory, visual processing speed, and visual memory. Module four, is the symbol matching test. This test in used to measure visual processing speed, learning, and memory. Module five, the color matching test, measures choice reaction time, impulse control, and response inhibition. Finally, module six is the three letters test. After the test is completed the participant is asked if they had any problems with the mouse, or computer.[10] The complete test takes about twenty minutes and can be administered in large groups or on an individual basis.[11] In order to avoid the practice affect when the athlete is retested the computer program will automatically generate random test on its own.[10]

By knowing the athlete, practitioners should be able to understand that certain external factors such lack of sleep, alcohol consumption, caffeine consumption may affect the test-retest reliability of ImPACT and other neurocognitive tests. This information becomes essential when assessing an athlete, particularly when a decision is being made concerning the athlete's status such as whether or not an athlete can return to play. It is important to understand how to read the results and develop an accurate interpretation of these results. It is essential to assess whether or not the results of the retest are a true indication when making the status of the athlete eligible and ready to return to play.

Recognition and treatment of a concussion are very important to help prevent future concussions. In order to identify a concussion the professional has to know the signs and symptoms that occur when one is sustained. Some of these signs and symptoms that could be recognized by the medical professional could be "fluctuating levels of consciousness, balance problems, and memory and concentration difficulties".[6] There are also self-reported symptoms such as "dizziness, nausea, headache, and ringing in the ears".[3] With this case, it only shows the importance of having a baseline test to compare the results to if an athlete, did in fact, sustain a concussion. If the athletic trainer is unsure if an athlete has sustained a concussion, the reliability of the test and the retest results become even more essential, as that may be deciding factor for the athlete to return to play.

Statement of the problem

Most current guidelines for evaluating a concussion only use loss of consciousness and amnesia as signs for grading a concussion, but it is important to look

at the clinical picture as well.[7] According to Notebaert and Guskiewicz, athletic trainers use the Standard Assessment of Concussion (SAC), a symptoms check list, the balance error scoring system (BESS), and neurocognitive computerized test battery to assess concussions.[5] The problem with using computerized testing batteries is that the baseline tests are being used to help grade a concussion and return athletes to play but reliability of the baseline tests have not been definitively established.

The purpose statement

The purpose statement of this study is to determine if external factors such as sleep, stress, anxiety, alcohol consumption, and caffeine consumption, have an effect on the reliability of the ImPACT computerized testing results. The research has shown that computerized testing is in the preliminary stages and the reliability based on external factors has not been tested.

Hypotheses

Within the limitations of this study the following research hypotheses will be tested:

1. Higher anxiety scores will be correlated with lower composite scores.
2. Alcohol will be associated in lower reaction time domain of ImPACT.
3. Caffeine consumption will be associated in lower composite scores of ImPACT.
4. The amount of sleep the athlete gets the night prior to testing will be positively associated with composite scores of ImPACT.

Significance of Study

Previous research has not investigated whether external factors such as alcohol consumption, caffeine consumption, amount of sleep, stress level/anxiety level may affect the reliability of the test-retest reliability. This study will educate athletic training professionals on the importance of concussions and the fact that external factors may change the results of ImPACT.

Definitions

- Concussion: "immediate and transient impairment of neural functions, such as alteration of consciousness, disturbance of vision and equilibrium due to brain stem involvement.[2]
- Evaluation: a diagnosis or diagnostic study of a physical or mental condition.[5]
- ImPact: a computerized testing battery that measures the cognitive functioning[6]
- Return to play: The guidelines used to determine if an athlete can return to sports participation. [1]
- Balance Error Score System- (BESS) is a system used to evaluate an athlete's balance after sustaining a possible concussion.[5]
- Symptoms check list- a list of symptoms an athlete may have when he/she sustains a concussion.[5]

- Standardized Assessment of Concussion- an assessment tool used immediately after an athlete sustains a concussion to determine if an athlete can return to play based on their results compared to their baseline.
- SPSS- a computerized statistical program

Assumptions

Within the study there is the assumption that the participants will answer all questions asked truthfully and put forth their best effort. All participants in the study will have the basic computer skills needed to complete the computerized testing.

Limitations

The amount of time allotted between test and retest (14 days) will be a concern as that timeframe may be too short-term for significant results to be noted. It is difficult to control aspects of the participant's lives that are separate from the study.

Delimitations

The researcher has chosen to conduct the study at the Barry University. The study will use 25 Barry University athletes, who have had no head injuries within the past year.

Chapter 2
Literature Review

The purpose of this study is to determine if external factors such as sleep, stress, anxiety, alcohol consumption, and caffeine consumption have an effect on the test--retest reliability of the ImPACT computerized testing results. The subtopics of the chapter include a definition of concussion, the signs and symptoms one may experience when a concussion occurs, an overview of computerized testing batteries, and external factors that may affect the reliability of ImPACT.

Definition of Concussion

According to most researchers a concussion can be defined as "trauma-induced alteration in mental status that may or may not involve loss of consciousness".[4,6,7] As an athletic trainer, certain questions would likely be standard when using this working definition. Examples of some of the questions could be, "Did you black out? Are you dizzy? Do you feel nauseous?" All of these are asked in order to assess the severity of the concussion. An alternate definition of a concussion is an "immediate and transient impairment of neural functions, such as alteration of consciousness, disturbance of vision and equilibrium due to brain stem involvement."[2] Using this working definition, the athletic trainer would still ask all the questions above but according to the definition visual impairment has become an important focus. When a concussion occurs in the athletic world it is important for the athletic trainer to recognize and assess the severity of a concussion. Each definition has an important place in that assessment. Selecting the appropriate definition may be dependent upon the individual athletic trainer, the particular situation, and who will be utilizing the information obtained.

Proper management is needed to ensure successful recovery and prevent a second impact which might be fatal to an athlete. Second impact syndrome is a rare but fatal event that occurs after a concussion or massive brain swelling. An athlete usually sustains a concussion and doesn't give the brain time to heal and the swelling to subside, then sustains a second blow to the head.[1] A less severe consequence of returning an athlete too soon after sustaining a concussion is post-concussion syndrome. This syndrome is defined by persistent headaches, dizziness, and irritability which could lead to depression. These symptoms can last longer than six weeks after the initial concussion.[1] When diagnosing a concussion it should not be strictly determined by loss of consciousness. Some current guidelines strictly use loss of consciousness and retrograde or anterograde amnesia to grade a concussion. While guidelines account for the clinical picture, the interpretation from clinician to clinician shows significant variability.[1]

Theye and Mueller's review revealed that there is a serious lack of knowledge by parents, coaches, and athletes. Another problem is the lack of recognition that a concussion has occurred.[1] The lack of knowledge is due to the lack of education. The phrase "he had his bell rung" or "he suffered a ding" are very typical responses from the media, parents and coaches. Quite the contrary, suffering even a mild brain injury is still a concussion and may require medical attention. If attention is not given it may lead to a second impact syndrome, or post-concussion syndrome. In addition to these physical complications additional difficulties in the cognitive and personal realm may also occur. It has been shown that concussions can interfere with "both academic performance and social interactions."[1]

With the advances in research, Theye and Mueller suggest that recognition and proper treatment when a concussion occurs is the most important objective for the athletic trainer and the athlete. In order to accomplish this, clinicians, need to do a better job educating our athletes, coaches and parents. As a clinicians need to handle every case individually and realize there is "no one formula that can handle an injury this complex and multifaceted issues"[1]

Signs and Symptoms

Signs and symptoms of a concussion are different for every athlete. When a concussion has occurred in a sporting event, the athlete may experience any number of the following symptoms: headache, nausea, vomiting, balance problems, memory problems, dizziness, fatigue, sleeping problems, drowsiness, sensitivity to light and sound, and blurred vision.[6] It is very important to assess every possible avenue and explain to the athlete the importance of telling the truth about what and how they feel and the possible consequences of returning too soon to athletic competition.[6] When assessing an athlete there are tools that are used in the athletic training field which include; the Standardized Assessment of Concussion test (SAC), the symptoms check list, the Balance Error Scoring Test (BESS), and computer based testing batteries which include ImPACT.[2,5,7] The SAC test is a neurocognitive assessment tool that can be used on and off the field to help assess the severity of the concussion. This test is used to assess "orientation, immediate memory recall, concentration, and delayed recall".[8] The BESS test is used as a coordination test. The subject is assessed in three different positions two different times. The three positions consist of double leg, single leg, and tandem stance

and each position is assessed on a hard surface and then on a foam surface with the eyes closed. The subjects are asked to stand with their hands on their hips and hold their balance. If balance is lost the score is reduced, using the final results of the test helps the athletic trainer return the athlete to play. [8] Finally ImPACT is a computer based testing program that is used to assess reaction time, verbal memory, visual memory, visual motor speed, reaction time, and impulse control. One way to determine if an athletes' concussion has gotten worse could include change in any number of the following symptoms: the headache can get worse, a seizure can occur, there can be focal neurological signs, when the athlete falls asleep and cannot be awakened, the athlete appears to be drowsy, the athlete is repeatedly vomiting, experiences slurred speech, he/she appear to not know where he/she is, the athlete appears confused and or when talking to the athlete he/she become irritable, if the athlete has any numbness or tingling in their arms or legs, and if the athlete is experiencing neck pain that has intensified.[9]

After a concussion has been assessed it is most important to monitor the athlete for any changes in symptoms.[2] When the athlete's symptoms start to subside, the athlete grows anxious to return to activity. According to researchers and the National Athletic Training Association, the main thread between all seventeen different guidelines to return an athlete to play is that the athlete must be symptom free.[4,7] The discrepancy lies in how long the athlete must be symptom free before returning to play and what type of testing is used when returning the athlete to competition. For example, Cantu's guidelines dictate that a grade three concussion warrants the athlete to go one full year until returning to play. [8] While the Colorado guidelines say that play should be terminated and can resume in three months.[8] According to Oliaro, Anderson, and Hooker the athletic trainer should

"review each case on an individual basis to determine if the athlete can return safely to sport."[2] Since each athletic trainer may have a wide variety of assessment tools a new tool that can be utilized by the athletic trainer to assess concussion is to use software named ImPACT.

ImPACT

ImPACT is a computer based test used to recognize a difference in the athletes' post-concussion scores from baseline composite scores to determine if a concussion has occurred and help in the determination of when an athlete can safely return to play. ImPACT measures the player's symptoms, is computer administered, has easy access, and can be administered via laptop. [10] The results can help assist athletic trainers and physicians make return to play decisions, provide baseline information, and the results of the test can be sent via email to any number of doctors.

The test measures specifically, memory, attention, processing speed and reaction time. To test these composites the neurophysiological tests can be broken up into six different modules. In the beginning of the test the participant is asked to fill out a short medical history. This health history questionnaire included the athletes height, weight, age, years playing a specific sport, gender, whether the athlete is right handed or left handed, and previous concussion history. The athlete is then asked if they have any symptoms and to grade the level of those symptoms on a scale of one, being minor, and six, being severe. After the medical history is completed the athlete will then continue into the neurophysiological exam. The exam consists of six different modules.[10] Module one, is word discrimination which is used to evaluate attentional processes and verbal

recognition memory. The test is composed of twelve words that are presented and athletes have to recall those twelve words from a list of twenty four. After about twenty minutes the words are shown to the athlete again to test the memory recall of the participant. Module two, is design memory, which is used to evaluate attentional processes and visual recognition memory. This test shows twelve designs and then those designs are displayed in a list of twenty four. The participant is then asked to recall the designs that were just presented. Module three, is the X's and O's test, which is used to test visual working memory, visual processing speed, and visual memory. In this test, the participant must click the left mouse button when a blue square appears on the screen and the right mouse button when a red circle appears on the screen. Module four, is the symbol matching test. This test in used to measure visual processing speed, learning, and memory. In this test, nine symbols appear with corresponding numbers, when the symbol appears on the screen the player has to recall what number went with what symbol. Module five, the color matching test, measures choice reaction time, impulse control, and response inhibition. This test uses the words blue, green, and red. When those words correlate with their color the participants must click in the box as fast as possible. For example when the word green appears on the screen and is written in green you must click in the box. Finally, module six is the three letters test. This test measures working memory and visual-motor response speed. In this test, three letters will appear and participants will be told to remember them. Then twenty-five numbers appear in a five by five grid. The participants must click them as quickly as possible. After clicking the numbers, the participant will be asked to type in those three letters from recall. Five trials will be completed to satisfy the requirements of this test. In order to avoid the practice

affect the computer program generates random test on its own and the administrator has no control.

After the test is completed the participant is asked if they had any problems with the mouse, or computer.[10] The complete test takes about twenty minutes and can be administered in large groups or on an individual basis.[11]

Since athletes tend to minimize their symptoms in order to return faster to the game, and every athlete has their own reasons why they do not tell the truth, new technology such as ImPACT takes much of the subjectivity out of returning the athlete to play. [12] If the baseline scores are taken in the beginning of the season, the athlete can be tested after they sustain a head injury following the guidelines suggested by ImPACT. If the baseline scores and the new test scores show a discrepancy, then certified athletic trainers would not return the athlete to play. [12] In a study conducted by Broglio, Macciocchi, and Ferrara, the ImPACT test was administered to 21 NCAA division I athletes. [13] After the ImPACT test was administered they gave the athletes' a symptoms check list that was similar to the symptoms list contained within ImPACT. The results of the study revealed that athletes' who sustained a concussion had results that had not returned to baseline, but when administered a symptoms check they appeared to be symptom free. Thus, a symptoms checklist alone may be misleading. The researchers stated that it is important to look at the whole picture, the clinical assessment, the baseline scores, the retest, the symptoms check list, and the experience of the athletic trainer and physician to determine the proper care for athletes. [13] The athlete's safety is the number one concern of the athletic trainer and the team physician so the "golden standard for concussion assessment is the clinical examination." [13]

Another study conducted by Schatz et al looked at the sensitivity and specificity of ImPACT in athletes with concussions.[14] One hundred and thirty eight high school athletes were recruited for the study and seventy- two had sustained a concussion within seventy two hours of testing, and the other sixty-six were concussion free. They found a significant multivariate effect of concussion on test performance. [14] An ANOVA test was also conducted and "showed all six measures contributed to the between group differences." Finally a discriminate function analyses was done to measure the capability of the five composite scores to predict whether or not an athlete had suffered a concussion. The discriminate function test revealed that visual memory, impulse control, and processing speed composites correctly classified 85.5% of the cases. This measure shows that ImPACT is sensitive and specific, and can be used as a useful tool for the practioner when assessing a concussion, and returning an athlete safely back to play. [14]

Another study that was conducted by Iverson, Lovell, and Collins measured attention and processing speed. [15] In this study, the ImPACT composite scores were validated by comparing the results to the Symbol Digit Modalities Test (SMDT). The subjects in this test were seventy- two amateur athletes, who had sustained a concussion and were seen within twenty one days. The hypothesis of this study was that the SMDT would have a high correlation with ImPACT processing speed, reaction time, and memory. The results "showed that SMDT had a significant high correlation with processing speed and the reaction time composite and lower correlations for memory composites and total symptoms scores, though still significant." [15] This study helped to validate the ImPACT software. The overall outcome of this test showed that ImPACT is very sensitive to the initial effects of a concussion in amateur athletes. This study helps

with the validation because it has helped to clarify what the body goes through when a concussion occurs. It is said "that cerebral concussion triggers a multilayered neurometabolic cascade of physiological changes at the cellular level." [15]

Test -- Retest

Broglio *et al* conducted a study to measure the test--retest reliability of the computer based assessment tools; ImPACT, the Concussion Sentinel, and the Concussion Resolution Index.[16] Each participant was given a baseline examination. After 45 to 50 days the test was administered again and the results were tabulated. [16] The authors concluded that the reliability of scores was significant but more research should be done on the psychometric properties. The results for ImPACT, the Concussion Sentinel, and the Concussion Resolution Index using an interclass correlation (ICC) from baseline to forty-five days ranged from .15 to .39, for ImPACT, compared to .23 to .65 on the Concussion Sentinel and .15 to .66 on the Concussion Resolution Index. From day forty-five to fifty reliability ICC of ImPACT, ranged from .39 to .61, the Concussion Sentinel .39 to .66, and .03 to .66 on the Concussion Resolution Index. [16] Though the scores are similar and each test has it strengths, it is important to understand that all three tests were found reliable in the test—retest. The authors also pointed out that low reliability scores could be due to sleep deprivation or stimulant use, daily life stressors, and excessive intense physical activity. More research needs to be completed on these factors. It is still essential for more testing be done and that evaluators should use more than one method when assessing if an athlete is ready to return an athlete to play. [16]

When using a computer based testing tool such as ImPACT, it is important to know whether an athlete has been drinking within the last twenty four hours, sleeping well at night, or, drinking caffeine. Everything that an athlete does outside of the knowledge of the athletic trainer or team physician can slow down the healing process and affect other aspects of the healing process.

External Factors

External factors, not measured by ImPACT, may affect the scores on the individual test and thus threaten the test-retest reliability. One external factor that may affect the test/retest reliability of ImPACT is anxiety and stress. Anxiety can be defined as "a negative emotional state characterized by nervousness, worry, and apprehension and associated with activation or arousal of the body." [17] Anxiety can also trigger stress. The body goes through four stages of stress response. Stage one is environmental demands, which are mental or psychological stresses that are put on the body. Stage two, perception of demands, is the individuals' perception of how much stress or demand there is in a particular situation. The third stage is stress response, which can be broken down into the arousal of the body, state anxiety, muscle tension, and an attention change. The final stage is the behavioral consequence, which is what the athlete does to accommodate the stress and the outcome.[17] When administering the ImPACT test it may be important note whether the athlete is under undue stress or anxiety.

Anxiety can be divided further into state or trait anxiety. State anxiety can be defined as a "conscious control that can disrupt the automatic processing of well-learned motor tasks and lead to impaired performance." [18] In a study conducted by Hardy and

Mullen a learning paradigm test was used to test the hypothesis of conscious processing. [18] Conscious processing is a stage of conception of learning, or the stages of learning. Learning was defined as an ordered process in which "the performer begins with overtly controlled processes that gradually undergo structural constrictions into the smooth unconscious, and covertly controlled processes of the expert." [18] In the current study Hardy and Muller observed 12 female trampolinists and anxiety was measured with the State-Anxiety Inventory. [18] The participants were told to perform their competitive routine in competition while being videotaped and then asked to perform the same routine again five minutes later outside of competition. This same procedure was done again a week later. The results on the state anxiety inventory showed an increase from a 22, for the non competition routine, to a 36.5, before the competitive competition. Upon examination of the video the hypothesis was supported, that under increased stress the performance had more mistakes and problems as compared to the non-competition performance. It appears that performers did not consciously control their moves in the low anxiety non competitive performance." [18]

Another anxiety study conducted by Sansgiry and Sail, examined the effect of course load on students' anxiety levels. [19] The main purpose of the study was to relate course load and student's time management and anxiety levels. This particular study examined test anxiety which is defined as "the reaction to stimuli that are associated with an individual's experience of testing or evaluating situations."[19] Anxiety was described by using two different topics: cognition and emotion, which can have a negative effect on testing outcomes. The outcome showed that a students' course load can increase ones anxiety level.[19] Sansgiry and Sail discussed the negative effects that anxiety has on

performance, breaking performance into two models. The first model is the interference model which describes those students who are anxious and easily distracted.[19] The second group is the learning-deficit model which are those students who get anxious due to poor test preparation. With the results of study the majority of the sample of 198, exhibited moderate test anxiety, and moderate test anxiety can cause physiological distress.[19] Anxiety can affect reaction time due to distraction and missing a response that relies on quickness, which when compared to ImPACT will decrease the reaction time composite. According to the interference model if one is easily distracted he/she may miss a word/symbol/ or shape that is presented for memory recall, which may affect visual composite and memory visual and verbal composites.

Based on these studies, high anxiety levels might affect the reaction time composite, impulse control, visual memory, verbal memory, and visual motor speed composites of ImPACT. With ImPACT if you look away from the screen and are distracted you could miss points by not responding fast enough. During levels of high anxiety performance is decreased, reaction time, visual motor speed and impulse control may increase, and visual memory and verbal memory may decrease.

Caffeine and alcohol are other factors that may have an effect on the test retest reliability of ImPACT. Hindmarch, Kerr, and Sherwood found that "Alcohol has a disruptive effect on psychological aspects of behavior and performance."[20] They also assert that a low does to a medium sized dose of alcohol can have a depressant effect on the central nervous system, psychomotor functions and cognitive abilities. In their study, four different doses of alcohol were given to participants and the effects of those doses on

the standardized test battery were examined. The subjects of this study were nine males and nine females who have similar drinking history. The eighteen subjects were then divided into a placebo group and a group who were given alcohol. The calculated doses of alcohol were .25, .50, .75 and 1.0 gram per kg of bodyweight for the males and 92% of their body weight for the females. The practioner measured scores on the following tests: choice reaction time, compensatory tracking task, critical flicker fusion, and short term memory. In general, as alcohol consumption increased, performance decreased. According to the results "reaction time task, recognition reaction time is affected much more by alcohol even at low doses than the motor components" [20] At the two higher doses the ability to perform a complex tracking task was shown to be impaired. Also memory recall time was increased, which is due to the fact the "memory is sensitive to the effects of alcohol." [20] Overall, alcohol impairs cognitive and psychomotor function.[20]

Martin looked specifically at alcohol use in female division I basketball, softball, and volleyball players.[21] The study involved 371 participants, who were interviewed and given a questionnaire. The results showed that 80% of the participants consumed alcohol, and that most females' athletes, 72.6% consumed alcohol before the age of 18. The average number of alcoholic drinks consumed in one drinking episode was four which in this study for females was known as binge drinking.[21] The results finally concluded that alcohol consumption can impair their athletic performance. Alcohol consumption within twenty four hours before the ImPACT test may decrease the reaction time composite.

Azcona, Barbanoj, and Jane, looked at the central effect of alcohol by assigning eight males to a control group and an experimental group.[22] The groups then were given a beverage, either a caffeinated or alcoholic, followed up with three different tests; a psychomotor performance test, which was measured by the Critical flicker test; a simple reaction test; and a tapping test. There was a neurophysiological measurement and a clinical evaluation of the participants.[22] Of all the variables, the simple reaction time was increased with alcohol and decreased with caffeine. The results also showed that when caffeine and alcohol are taken together this is no significant difference in the performance. Alcohol consumption close to the legal limit showed depressant effects on the Central Nervous System, the cognitive and psychomotor function.[22]

This study indicates that any alcohol consumption may affect the reliability of ImPACT if alcohol is consumed within twenty four hours of the baseline reading or the retest. Most studies measured the effect of alcohol within twelve to twenty four hours after consumption. In order to test the effect of alcohol on the ImPACT composite scores, a rough estimate of alcohol impairment at the time of the test will be used. This estimate will be determined by the number of drinks within twenty-four hours of the test, the body weight, and a .015% rate of alcohol metabolism.

Another factor that may impact the test-retest reliability is caffeine. A continuation of the Azcona, Barbanoj, and Jane study found that when caffeine is consumed it will act as a stimulant, which can increase one's cognitive or psychomotor function.[22] In another study, Lieberman et al took 68 male NAVY seals trainees, one week of NAVY "Hell Week" and told them they were not permitted any caffeine or

nicotine.[23] Throughout Hell Week sleep deprivation, high anxiety, and high stress levels occur because SEALS have to be able to think and operate at a high levels of cognitive performance. When Hell Week started different increments of caffeine were given to the SEALS. Caffeine significantly helped SEALS' deteriorating cognitive performance during hell week. Caffeine helped stop the performance deterioration. Lieberman et al looked at the effect caffeine, sleep loss, and stress had on cognitive performance.[23] Caffeine is found in many beverages and foods that are widely consumed. It is important to understand that caffeine has a positive effect on cognitive performance.[23] This is key to show that changes in reaction time can significantly change the composite scores of ImPACT. The stimulation of caffeine will increase ones reaction to stimuli, which may affect the score for the module four symbol matching test. This test is done for time and you have to match the number to the symbol it corresponds with, this test in used to measure visual processing speed, learning, and memory. Module five, the color matching test, is also done for time and visual processing, when the word and color match as fast as possible the participant must click the mouse, if caffeine is consumed that reaction may be faster.

The final external factor that may alter the test retest reliability of ImPACT is sleep. The performance on ImPACT may be affected by the amount the athlete sleeps the night prior to the test. Lack of sleep has been shown to effect athletic performance, performing in a play, or even driving a car.[24] A normal night of sleeping consists of seven to eight hours of sleep.[24] According to Smith, REM sleep is the most important and restorative sleep. If the sleep cycle is interrupted then so can learning.[24] An article by Gottselig et al looked at random number generation during stages of sleep deprivation.[25]

According to the study "people who are sleep deprived exhibit cognitive deficit." The participants were 23 male students aging from 20-30 years old in good health and without neurological or psychiatric diseases. The subjects were given the random number generation test fourteen times at three hour intervals during a forty hour period of sleep deprivation. Data was collected in the SAS statistic program using a mixed model ANOVAS. The results determined that under sleep deprivation fewer number generations were created by the participants.[25]

Pilcher and Huffcut looked at the effects sleep deprivation on performance in a meta- analysis.[26] They concluded that sleep deprivation decrease both reaction time and cognitive distortion. The results also concluded that the type of sleep deprivation can affect cognitive function. The moderate level of sleep deprivation had the most effect on the overall performance. This meta-analysis concluded that "sleep deprivation has a significant effect on human performance."[26]

Lack of sleep can affect all five composite scores of ImPACT. The reaction time composite and the visual motor speed and impulse composite may decrease due to the lack of focus and fatigue. The memory composites, verbal and visual, may be affected because memory recall is decreased due to fatigue.

Summary

When a concussion occurs on the field it is important to recognize it has occurred. Even more importantly, there is a need to provide the best available treatment to assure the safety of the athlete and to educate the population of the importance of concussion

treatment. A concussion can be defined as a "trauma-induced alteration in mental status that may or may not involve loss of consciousness".[2,4,6,7] The signs and symptoms of concussions signs can vary by individual but it is important to monitor all signs and symptoms for severity. If a concussion goes unmonitored a more dangerous consequence could face the athlete, either second impact syndrome, or post-concussion syndrome. The introduction of ImPACT, a computer based testing program, helps clinicians to determine when to safely return an athlete to play after a concussion.

External factors may affect the results of ImPACT tests. Anxiety may affect the reaction time composite, visual motor speed, impulse composite, verbal memory, and visual memory composites. Anxiety has been shown to decrease performance. [17] Alcohol and caffeine consumption within twenty four hours of testing may have an effect on the reaction time composite. Alcohol may decrease the composite score while caffeine may increase the composite score. [20] Finally sleeps may affect reaction time composite, visual motor speed, impulse composite, verbal memory, and visual memory composites. Sleep deprivation may decrease all the composites due to lack of focus and fatigue. [26] This study will examine a group of athletes and whether their performance on a test/ retest of ImPACT is affected by external factors.

Chapter 3

Methods

The purpose of this study is to determine if external factors such as sleep, stress, anxiety, alcohol consumption, and caffeine consumption, have an effect on the reliability of the ImPACT computerized testing results. The research has shown that computerized testing is in the preliminary stages and the reliability based on external factors has not been tested.

Participants:

The participants in this study will be current Barry University athletes, both male and female, and aged eighteen and above. Participants with previous concussions within one year will be eliminated from the study.

Instrumentation/ Equipment:

A computerized software program, ImPACT will be used to assess the baseline scores and the post-test scores. ImPACT is used for concussion management and return to play criteria for athletes who sustain a concussion during competition. ImPACT was developed by sports concussion researchers Lovell, Collins, Maroon, from the University of Pittsburgh Medical Center (UPMC) Sports Medicine Concussion Program. ImPACT's. ImPACT is made up of four main sections, section one is a subject profile and a health history questionnaire, section two is a current signs and symptoms section, all symptoms that are answered "yes" are followed up by a severity rating on a seven point Lickert

scale. The third section is neuropsychological test, within this section there are six module sections:

Module one is the word discrimination which is used to evaluate attentional processes and verbal recognition memory, the test is composed of twelve words are presented and had to recall those twelve words from a list of twenty four, after about twenty minutes the words are then showed again to test the memory recall of the participant.

Module two is design memory, which is used to evaluate attentional processes, and visual recognition memory, this test shows twelve designs and then those designs are showed in a list of twenty four, the participant is then asked to recall the designs that were just presented.

Module three is the X's and O's test, which is used to test visual working memory, visual processing speed, and the visual memory paradigm. In this test the participant must click the left mouse button when a blue square appears on the screen and the right mouse button when a red circle appears on the screen.

Module four is the symbol matching test. This test in used to measure visual processing speed, learning and memory. In this test nine symbols appear with corresponding numbers, when the symbol appears on the screen you have to recall what number went with symbol.

Module five, the color matching test, measures choice reaction time, impulse control, and response inhibition. This test uses the words blue, green, and red when those words correlate with their color the participants must click in the box as fast as possible.

For example when the word green appears on the screen and is written in green you must click in the box.

Module six is the three letters test. This test measures working memory and visual-motor response speed. In this test a twenty-five numbers appear in a five by five grid and in a decreasing order the participants must click them as quickly as possible. With that three letters will appear to remember and after clicking the numbers the participant will be asked to type in those three letters from recall, five trials will be done of this test. Finally, the fourth section is after the test is completed the administrative password is entered and the participant is asked if they had any problems with the mouse, or computer. The test will be administered twice throughout the study. [10]

A short questionnaire will be administered asking for information about the participant's daily activities, how many hours they slept, had they consumed alcohol the day prior to testing, and if they consumed caffeine the day prior to testing, refer to the appendix for a full copy.

After the computerized portion of the testing, the participant will be given a short five minute questionnaire on state anxiety. The self- evaluation state anxiety questionnaire was developed by Spielberger, Gorsuch, and Lushene. [27] The test is called the STAI. This questionnaire helps to determine how the athlete feels at the time of testing. The STAI is an instrument for measuring style anxiety in adults. Specifically this tool helps to evaluate how respondents felt at a particular time in the recent past and how they anticipate they will feel either in a specific situation.

Procedure:

The participants will be directed to come to the Barry University Campus during their assigned time during the day of testing. The test and surveys will take about thirty to forty minutes to complete. The participants will be instructed to fill out a short questionnaire about their daily living activities, refer to the appendix for a full copy of the survey. After the questionnaire is complete, the participant will be brought into the athletic training lab or a faculty member's office where the ImPACT test will be administered. The neuropsychological test is made up of six module sections. Module one is the word discrimination, module two is design memory, module three is the X's and O's test, module four is the symbol matching test, module five the color matching test, and module six is the three letters test.[10] The test takes about twenty minutes to complete. After the participant completes the test, they will be given another short questionnaire about state anxiety, refer to the appendix for a full copy of the survey. The procedure will then be repeated again seven to fourteen days after the first test. According to Broglio et al concluded that the best results on retesting of a concussion occurred between days seven and ten. This conclusion was due to the classification of a concussion, a simple concussion that did not have loss of consciousness showed symptoms starting to clear between day seven and ten. While a complex concussion, showed a fluctuation in results therefore symptoms were alleviated at a longer rate.[13] The testing will be in a controlled environment and participants will be retested around the same time of day to mimic the same atmosphere and state as the first test; unless there is an extreme circumstance, inclement weather, or illness.

Design and Analysis:

This study will examine the effects of anxiety, sleep, alcohol and caffeine on the test—retest reliability of ImPACT. Specifically, the standard error of difference will be examined with and without the external factors used as covariates in specific ImPACT scores. Standard error of difference will be measured as follows:

$$S_{diff}\sqrt{SEM^2_1 + SEM^2_2}$$

Where $SEM_1 = SD1\sqrt{1-r_{12}}$ and $SEM_2 = SD2\sqrt{1-r_{12}}$ and r_{12} is the test—retest coefficients and SD is the standard deviation of the individual tests.

Chapter 4

Results

The purpose of this study was to determine if external factors such as sleep, stress, anxiety, alcohol consumption, and caffeine consumption have an effect on the test--retest reliability of the ImPACT computerized testing results.

Demographics

Thirteen males and seven females whose average age was 20.05 years old participated in the study. All demographics are found in Table 1. Table 2 contains the results of the pre and post tests and the measures of the covariates. The outliers were excluded case wise from the individual variables.

Participant Demographics

	Gender	Age	Sport	Position	Previous Concussions	Class
Subject 1	Male	21	Baseball	Pitcher	0	Senior
Subject 2	Male	18	Baseball	3rd Base	0	Sophomore
Subject 3	Male	23	Baseball	Pitcher	0	Senior
Subject 4	Male	23	Baseball	Pitcher	0	Senior
Subject 5	Male	19	Basketball	Center	0	Junior
Subject 6	Female	19	Soccer	Defender	0	Freshman
Subject 7	Female	21	Softball	1st Base	0	Senior
Subject 8	Male	18	Baseball	Shortstop	0	Freshman
Subject 9	Female	19	Softball	1st Base	0	Freshman
Subject 10	Female	18	Softball	Outfielder	2	Freshman
Subject 11	Female	18	Soccer	Midfielder	0	Freshman
Subject 12	Female	21	Rower		0	Senior
Subject 13	Male	21	Soccer	Keeper	0	Senior
Subject 14	Male	21	Baseball	Right Field	0	Junior
Subject 15	Male	21	Baseball	1st Base	0	Senior
Subject 16	Female	19	Softball	Pitcher	0	Freshman
Subject 17	Male	19	Baseball	3rd Base	0	Freshman

Subject 18	Male	21	Baseball	Pitcher	0	Junior
Subject 19	Male	23	Baseball	2nd Base	0	Senior
Subject 20	Male	18	Baseball	Pitcher	0	Freshman

Table 1

Means and Standard Deviations for Pre and Post Test Results

	Mean test 1	Std. Deviation	Mean test 2	Std. Deviation	N
Verbal Memory	83.80	9.04	88.45	8.12	20
Visual Memory	76.82	8.11	82.59	8.41	17
Visual Motor Speed	40.55	5.77	43.75	5.41	19
Reaction Time	0.50	0.06	0.51	0.05	20
Impulse Control	7.8	3.08	4.81	2.11	16
Anxiety	66.40	16.16	70.25	19.91	20
Hours Slept	7.38	1.35	7.28	1.95	20
Caffeine	0.80	0.95	1.15	1.66	20

Table 2

Hypotheses

The hypotheses tested in this study are the following: When anxiety, sleep, and caffeine differences are used as covariates, test-retest reliability of the composite scores of ImPACT will improve. Specifically, higher anxiety scores will be correlated with lower composite scores. Alcohol will be associated in lower reaction time domain of ImPACT. Caffeine consumption will be associated in lower composite scores of ImPACT. The amount of sleep the athlete gets the night prior to testing will be positively associated with composite scores of ImPACT. The means and standard deviations of the ImPACT test results and the test-retest correlations before and after inclusion of covariates are found in Table 3 and 4. No participants had alcohol in their systems when tests were completed. Therefore alcohol consumption was not included in the analysis.

Means, Standard Deviation Correlations without Covariates

	Test 1		Test 2		Coefficient of Reliability
	mean	SD1	mean	SD1	r
Verbal Memory	83.80	9.04	88.45	8.12	0.073
Visual Memory	76.82	8.11	82.59	8.41	0.067
Visual Motor Speed	40.55	5.77	43.75	5.41	0.418
Reaction Time	0.50	0.06	0.51	0.05	0.611*
Impulse Control	7.81	3.08	4.81	2.11	0.066

Table 2. * Significant correlation at p<.05

Means, Standard Deviation Correlations with Covariates

	Test 1		Test 2		Coefficient of Reliability
	mean	SD2	mean	SD2	r
Verbal Memory	83.57	9.18	88.93	8.89	0.077
Visual Memory	78.71	6.80	82.86	8.95	-0.015
Visual Motor Speed	38.89	4.90	43.43	5.58	0.205
Reaction Time	0.51	0.05	0.52	0.05	0.414
Impulse Control	8.21	3.07	4.93	1.90	0.083

Table 3

The pretest results showed that visual memory was significantly correlated to caffeine consumption (r=4.85, p<.05), the mean and standard deviation for caffeine were M=.80 and the SD= .951; and the mean and standard deviation for visual memory were M=76.82 and the SD= 8.11. The post-test results showed visual memory was significantly related to number of hours slept (r=-.597, p<.05), the means and standard deviations for visual memory were M=82.59 and SD= 8.412 and the means and standard deviations for hours slept were M=7.275 and SD=1.95.

Overall reliability of the correlations was poor. The only significant pre post-test correlation was in the Reaction Time composite (r = .611, p <.05). When sleep, anxiety, and caffeine were used as covariates, reliability improved only slightly with none becoming significant. Also a moderate non-significant correlation (r = .418 p > .05) was found in the visual motor speed composite without covariates. However it appears that verbal memory, visual memory, and impulse control reliability, when sleep, anxiety, and caffeine are used as covariates, improve slightly. When the partial correlations were conducted all the composites got slightly better, except for visual motor speed and the reaction time composite (see Tables 3 & 4).

Chapter 5

Discussion

The purpose of this study was to determine if external factors such as sleep, stress, anxiety, alcohol consumption, and caffeine consumption have an effect on the test--retest reliability of the ImPACT computerized testing results.

The hypotheses tested in this study were the following: When anxiety, sleep, and caffeine differences were used as covariates, test-retest reliability of the composite scores of ImPACT will improve. Overall, reliability correlations were poor. The only significant correlation was in the Reaction Time composite (r = .611, p <.05). When sleep, anxiety, and caffeine were used as covariates, reliability improved only slightly with none becoming significant. Also a moderate non-significant correlation (r = .418 p > .05) was found in the visual motor speed composite without covariates. The pretest results showed that visual memory was significantly correlated to caffeine consumption (r=4.85, p<.05), the means and standard deviations for caffeine were M=.80 and the SD= .951; and the mean and standard deviation for visual memory were M=76.82 and the SD= 8.11. The post test results showed visual memory was significantly related to number of hours slept (r=-.597, p<.05), the means and standard deviations for visual memory were M=82.59 and SD= 8.412 and the means and standard deviations for hours slept were M=7.275 and SD=1.95.

Overall reliability of the ImPACT tests in this study was poor (see Tables 3 & 4). One reason for the poor reliability could be due to the fact that the ImPACT tests are not

reliable for the sample studied. However, several studies have found good reliability in similar sport samples. In the study conducted by Broglio *et al* the test--retest reliability of the computer based assessment tools (ImPACT, the Concussion Sentinel, and the Concussion Resolution Index) good reliability scores were found.[16] Though the scores are similar and each test has it strengths, it is important to understand that all three tests were found reliable in the test-retest aspect. Also, another study conducted by Schatz et al looked at the sensitivity and specificity of ImPACT in athletes with concussions.[14] The researchers found a significant multivariate effect of concussion on test performance. [14] The discriminate function test revealed that visual memory, impulse control, and processing speed composites correctly classified 85.5% of the cases, [$x^2(4)=74.4$, $p=.0001$]. This measure shows that ImPACT is sensitive and specific, and can be used as a useful tool for the practioner when assessing a concussion, and returning an athlete safely back to play. [14] Another reason for the poor reliability in the present study could have involved a lack of space allotted for the use of the mouse, which could have skewed the overall composite results therefore skewing the results of the test-retest reliability.

Another reason for the poor reliability is that there may have been a testing effect. Most subjects verbally reported that the second time they took the test it was easier, they knew what was coming. Schatz et al looked at the sensitivity and specificity on ImPACT, there results concluded that ImPACT was sensitive and specific enough but some subjects reported on the retest they knew what to expect and the test was easier to complete.[14] For example, in the current study, one subject reported that after reading the instructions of the color match test, the test still caught him off guard. When compared to the second test, the subject stated that he knew what was expected of him. Thus, a lack

of understanding or reading of the directions of the test may have had an effect on the results. With a drastic change in results between the verbal memory and visual memory composites, which can be seen in Table 4, one may conclude that the subjects may not have read the directions thoroughly enough before continuing with the test. Some participants told the test administrator anecdotally that they should have read the directions better.

Another factor could have been the testing environment. According to the ImPACT users manual it is important to try and recreate the same atmosphere for the re-test to assure the best results.[10] Although every effort was made to keep the environment consistent between tests, three subjects said that the mouse space provided in the testing area was too small and could have slowed down their testing, and changed their results. Another subject said that the computer screen was too bright and started to hurt her eyes during test. Thus, the lighting in the testing area could have been too low which could have had affect on her ability to do the test therefore changing her results.

The final reason, which may be the most relevant, was that this test was done for a thesis and not diagnostically. Therefore participants may have lacked the motivation to perform at their best. Several subjects asked the researcher whether their results would impede their ability to participate. A few related that they would have tried harder if they knew the test would count for something. It is critical to emphasize the importance of the test and the end results for which the test is used.

When the covariates (anxiety, sleep, and caffeine) were added in the data set no significant correlations were found between the pre and post test. The lack of any change

in reliability could have been due to the lack of sensitivity in the measures used for the covariates. For example, the State-Trait Anxiety Inventory may not have been able to pick up subtle differences in anxiety level. Also, the participants may not have given accurate information on their caffeine consumption, alcohol consumption, anxiety level, or the amount of hours they slept the night prior to test. The results of the covariates were based on the truthfulness and accuracy of the participants' answers. The information was to be kept confidential, but the in-season athletes seemed worried about their coaches getting access to their test results, which could have therefore skewed the answers given during testing.

With regards to the hypothesis that higher anxiety scores will be correlated with lower composite scores, results showed no correlation with any of the composite scores. The level of anxiety in the pre and post test was 66.40 (16.16) and 70.25 and (19.91) respectively. The anxiety level increased but not significantly. The testing week for the post test exam was one week before final exams. The added anxiety of exams could explain this increase.

Alcohol was not used as a variable in the study because, based on self-reports, no athletes had alcohol in their system at the time of testing. It is possible that the participants were not truthful due to their athletic standing.. The in-season participants were approaching their post season play, so they may not have been as truthful in the study for fear of coaches gaining access to the results. The truthfulness of the athlete on the amount of alcohol consumed the night prior to the testing may have had an influence on the composite scores. When explaining the test to the athlete it is critical to

emphasize the importance of telling the truth and the possible consequences or outcomes that could come from not disclosing all the proper information, which is for their benefit.

The hypothesis that higher caffeine consumption would be associated with lower composite scores of ImPACT was not supported. Though not significant, caffeine consumption was moderately correlated with the Visual Memory composite in the pre-test but not in the post test, refer to Tables 3 & 4. This result may be due to the large differences in the pre and post test Visual Memory means (see Tables 3 and 4). Also, these results may be due to a lack of motivation from the participants. As has been stated above, participants were aware that these results would not decide whether or not they would return to play.

The hypothesis that the amount of sleep the athlete gets the night prior to testing would be positively associated with composite scores of ImPACT was only supported for the visual memory composite in the post-test but not in the pre-test. Again, these results may be due to the overall lack of motivation from the participants. Another reason could be that there was not enough discrimination in the measure for sleep. Most of the participants were within one hour of sleep from pretest to post test. For example one subject jumped from seven hours to five hours from the pretest to the post test and her composite scores in visual memory drastically changed. Perhaps a measure of the pattern of sleep prior to testing, perhaps over several days, would be a more sensitive and valid measure of the effect of sleep on the composite scores of ImPACT.

Clinical Implications

The lack of reliability in the ImPACT test scores in this study has several clinical implications. As an athletic trainer, it is important that we not use this tool as a lone measure when a concussion occurs. It should be used in conjunction with other available measures such as the Standardized Assessment of Concussion test (SAC), the symptoms check list, the Balance Error Scoring Test (BESS).[2,5,7] ImPACT as a tool helps to put a value on certain symptoms. When an athlete has symptoms like a headache or dizziness, they can put a specific value which can help to rate the severity. Another positive aspect of using ImPACT is that the results can be immediately sent to a neurologist for review. It is also easy to administer, but it is important that the test administrator, though not an expert, read through the user's manual. It is important for the Athletic Trainer to know what procedures to follow in order to take the next step.

When administering the test it is also important that the directions are explained and emphasized enough to the individuals taking the test. The user's manual says that the test is proctored but if the proctor does not know the software then they will not be able to help. In the current study it seemed as though the directions were either too long, or too confusing to the participants. It is the job of the Athletic Trainer to find a way of expressing the significance of the test, but to know what the does and how to explain it to the participant. The emphasis needs to be on the understanding that the test results may be used when a concussion occurs along with other tools in order to return the athlete to activity. It is also important to know your athletes. By knowing your athletes, you may be able to discern whether that person is trying their very best. Finding ways in order to motivate athletes to do their very best is a daunting task and one that the Athletic Trainer needs to think about.

Comment [L1]: Huh?

External factors in this study were very hard to control for. For example when measuring caffeine consumption one may want to limit or have a set number of caffeinated drinks consumed before testing and then have a control group that received no caffeine. Though no significance was found in this study, Lieberman et al studied 68 male NAVY seals trainees who were not permitted any caffeine or nicotine.[23] Throughout Hell Week sleep deprivation, high anxiety, and high stress levels were tracked. When Hell Week started specific increments of caffeine were given to the SEALS. Caffeine significantly helped SEALS' deteriorating cognitive performance.[23] Caffeine is found in many beverages and foods that are widely consumed. Caffeine was proven to have a positive effect on cognitive performance.[23]

Another external factor was alcohol consumption, which was not controlled in the study. A major ongoing issue is that alcohol consumption is not truthfully communicated by athletes. Though no significance was found in the study, alcohol has been shown to have an effect on motor and cognitive function. [20,21,22] One way to get a true reading would be to do a breathalyzer test prior to testing. Hindmarch, Kerr, and Sherwood found that "Alcohol has a disruptive effect on psychological aspects of behavior and performance."[20] They also assert that a low does to a medium sized dose of alcohol can have a depressant effect on the central nervous system, psychomotor functions and cognitive abilities. They report that "reaction time task, recognition reaction time is affected much more by alcohol even at low doses than the motor components" [20] At the two higher doses the ability to perform a complex tracking task was shown to be impaired. Also memory recall time was increased, which is due to the fact the "memory is sensitive to the effects of alcohol." [20]

The results of the current study point to the importance of getting baseline measures during off-season or pre-season. When the post test was done in this study, several subjects were in the final stages of their seasons and were one week away from final exams which could have hindered the reliability. With that knowledge about the athlete and time of year, an additional baseline test may be needed in order to obtain the best possible results. When using the ImPACT software it is important not only to administer the test but to look at when the baseline test was given, because the results may not have been accurate enough and another baseline test may be needed.

When thinking about purchasing this software, it may not be cost efficient for your athletic training program. You as the Athletic Trainer may want to purchase the software but need to ask yourself a few questions. Do you have a neurologist to send the results to for interpretation? Do you have the computer access and the time to administer this to every athlete? Will you follow through with the retest? You as the Athletic Trainer may want to consider doing a cost benefit analysis before purchasing the software.

Recommendations for future research

Recommendations for future research would include taking caffeine, alcohol consumption, sleep, and anxiety into consideration when administering this test. Though the results of this study did not show to be significant, other studies by Hardy and Mullen have shown that anxiety has an effect on cognitive tasks. [18] Also, Hindmarch, Kerr, and Sherwood found that "Alcohol has a disruptive effect on psychological aspects of behavior and performance."[20] Finally, Pilcher and Huffcut, concluded that sleep

deprivation decreases both reaction time and cognitive distortion.[26] With this knowledge base it can be concluded that these factors along with a concussion may have an effect on the results of the composite scores of ImPACT.

Another recommendation for the future would be to use the same protocol and do another test and see if the test retest reliability is better between test two and test three. Along with testing the reliability it may be beneficial to look for certain trends. From week one to week two a participant may drink less than between week two and week three. When looking at trends you will learn more about the participant, one person may drink caffeine on a normal basis as opposed to another who gets profound effects from drinking caffeinated drinks. Also someone may perceive their anxiety level as higher than someone who is at the same level. The information needs to be gathered on a more individual basis in order to get the most beneficial results.

Another recommendation may be taking medications into more consideration. Though the test asks what medications each athlete is taking, these are not factored into computing the composite scores unless examined by a neurologist.

Conclusions

Based on the results of the study, test retest reliability of composite scores of ImPACT in Division II collegiate athletes was poor. Using anxiety, sleep, and caffeine consumption as covariates did not significantly change the test retest reliability. Though the reliability was poor overall, more research is needed in this area because these covariates have been shown to have an effect on reaction time, impulse control, and

memory, which could end up hindering the results and causing further injury when a concussion is sustained.

Athletic Trainers should emphasize the importance of the test to try to ensure the athletes are giving their best effort. They should also consider performing more than one baseline test to improve the reliability of ImPACT. Athletic Trainers should also conduct a cost-benefits analysis in order to see if it is beneficial to invest in the software.

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APPENDICES

Appendix A

Informed Consent

Barry University
Informed Consent Form

Your participation in a research project is requested. The title of the study is The Test Re-test reliability of ImPACT based on External Factors. The research is being conducted by Nicole Carbone, a student in the Human Performance and Leisure Sciences department at Barry University, and is seeking information that will be useful in the field of Athletic Training. The aims of the research are to determine if external factors such as sleep, anxiety, alcohol consumption, and caffeine consumption, have an effect on the reliability of the ImPACT test. ImPACT is a computerized test that requires participants to answer questions designed to measure memory, processing speed, and reaction time. In accordance with these aims, the following procedures will be used: We anticipate the number of participants to be 25.

If you decide to participate in this research, you will be asked to do the following: Participate in two separate sessions lasting forty minutes each which does not include time to the laboratory.

Upon entering the Athletic Training lab, participants will be asked to read and sign the informed consent form. Then they will be given the opportunity to ask any questions they may have.

The participants will be instructed to fill out a short questionnaire about their activities over the last 24 hours. After the questionnaire is complete, the participant will be brought into the athletic training lab or a faculty member's office where the ImPACT test will be administered. ImPACT is a computerized test that requires participants to answer questions designed to measure memory, processing speed, and reaction time. Following the ImPACT test participants will be asked to fill out the STAI questionnaire about anxiety. After the questionnaire is complete the participant will be free to leave and return seven to fourteen days to complete the same procedure.

Your consent to be a research participant is strictly voluntary and should you decline to participate or should you choose to drop out at any time during the study, there will be no adverse effects on your athletic participation at Barry University.

The risks of involvement in this study are minimal and include potential discomfort with disclosure of alcohol consumption. The following procedures will be used to minimize these risks: This risk will be minimized by reminding the participant that all information gathered will be kept confidential and used only for research purposes. There are no direct benefits to the participant, although this study will help benefit the Athletic Training field by further expanding the knowledge of computerized testing batteries, and using those results to return an athlete to play.

As a research participant, information you provide will be held in confidence to the extent permitted by law. Any published results of the research will refer to group averages only and no names will be used in the study. Data will be kept in a locked file in the researcher's office. Your signed consent form will be kept separate from the data. All data will be destroyed after 5 years.

If you have any questions or concerns regarding the study or your participation in the

study, you may contact me, Nicole Carbone at (315) 794-2617, or my supervisor Dr. Kathy Ludwig at (305) 899-4077, or the Institutional Review Board point of contact, Barbara Cook, at (305) 899-3020. If you are satisfied with the information provided and are willing to participate in this research, please signify your consent by signing this consent form.

Voluntary Consent

I acknowledge that I have been informed of the nature and purposes of this experiment by Nicole Carbone and that I have read and understand the information presented above, and that I have received a copy of this form for my records. I give my voluntary consent to participate in this experiment.

_____ _____

Signature of Participant *Date*

_____ _____ _____ _____

Researcher *Date* *Witness* *Date*

(Witness signature is required only if research involves pregnant women, children, other vulnerable populations, or if more than minimal risk is present.)

Appendix B
Human Subjects Form

Barry University

Research with Human Subjects Protocol Form

PROJECT INFORMATION

1. **Title of Project**
   Test-retest Reliability of ImPACT based on external factors

2. **Principal Investigator**

Nicole Carbone
School of Human Performance and Leisure Sciences -- SES
315-794-2617
Nicole.Carbone@mymail.barry.edu

3. **Faculty Sponsor** (If Applicable)

Name: Dr. Kathy Ludwig
School – Department: HPLS- SES
Mailing Address: 11300 NE 2nd Ave. Miami Shores, FL 33161
Telephone Number: 305-899-4077
E-Mail Address: kludwig@mail.barry.edu

Faculty Sponsor Signature:_____ Date: _____

4. **Funding Agency or Research Sponsor**
   None

5. **Proposed Project Dates**
   Start April 6th, 2009
   End April 6th, 2010

A. Project activity STATUS is: (Check one of the following three as appropriate.)

__ X _ NEW PROJECT
____ PERIODIC REVIEW ON CONTINUING PROJECT
__ _ PROCEDURAL REVISION TO PREVIOUSLY APPROVED PROJECT

B. This project involves the use of an **INVESTIGATIONAL NEW DRUG (IND) OR AN APPROVED DRUG FOR AN UNAPPROVED USE** in or on human subjects.
___ YES __**X**_ NO
Drug name, IND number and company:
_____

C. This project involves the use of an **INVESTIGATIONAL MEDICAL DEVICE (IMD)** or an **APPROVED MEDICAL DEVICE FOR AN UNAPPROVED USE.**
___ YES __**X**__ NO

D. This project involves the use of **RADIATION** or **RADIOISOTOPES** in or on human subjects.
___ YES __**X**__ NO

E. This project involves the use of Barry University students as subjects.
__**X**__ YES ___ NO
___ MINORS

F. **HUMAN SUBJECTS** from the following population(s) would be involved in this study:

___ Minors (under age 18)
___ Abortuses
___ Prisoners
___ Mentally Disabled
___ Other institutionalized persons (specify)
___ Other (specify)
___ Fetuses
___ Pregnant Women
___ Mentally Retarded

_____

G. Total Number of Subjects to be Studied: ___25_____

Description of Project

1. **Abstract** (200 words or less)

The purpose of this study is to determine if external factors such as sleep, anxiety, alcohol consumption, and caffeine consumption, have an affect on the reliability of the ImPACT computerized testing results. ImPACT is a computerized test that requires participants to answer questions designed to measure memory, processing speed, and reaction time. The research has shown that computerized testing is in the preliminary stages and the reliability based on external factors has not been tested.

The participants in this study will be current athletes at a Division II school, aged eighteen and above. Participants with previous concussions within one year will be eliminated from the study.

Investigators will administer the ImPACT test and follow up with the STAI test to measure anxiety, and questionnaire to measure external factors. Participants' reaction time, visual motor speed, impulse control, verbal memory, and visual memory will be measured. A questionnaire on activates of daily living, sleep habits, alcohol consumption, and caffeine consumption will be administered. One week to fourteen days later the same protocol will be repeated.

2. Recruitment Procedures

Participants will be asked to volunteer for the investigation based on a flyer that will be hung up around the athletic areas at Barry University. They will be informed of the purpose and methods of the investigation and the need for volunteers to participate.

3. Methods

The participants will be directed to come to the Barry University Campus during their assigned time during the day of testing. The total time commitment for the subjects involved in the investigation will be two separate sessions lasting forty minutes each which does not include time to the laboratory. The ImPACT test takes a total of about 20 minutes.

Upon entering the Athletic Training lab, participants will be asked to read and sign the informed consent form. Then they will be given the opportunity to ask any questions they may have.

The participants will be instructed to fill out a short questionnaire about their activities over the last 24 hours. After the questionnaire is complete, the participant will be brought into the athletic training lab or a faculty member's office where the ImPACT test will be administered. ImPACT is a computerized test that requires participants to answer questions designed to measure memory, processing speed, and reaction time. The neuropsychological test is made up of six modules:

Module 1 (Word Discrimination): This module evaluates attentional processes/verbal recognition memory and utilizes a word discrimination paradigm. Twelve target words are presented for 750 milliseconds on the computer screen. This word list is presented twice to facilitate learning of the list. At the end of the second presentation of the list, the subject is tested for recall via the presentation of the 24-word list that is comprised of 12 target words and 12 non-target words that have been chosen from the same semantic category as the target word. For example, the word "ice" is a target word, while the word "snow" represents the non-target word. The subject responds by mouse-clicking the "yes" or "no" buttons on the screen. Individual scores are provided both for correct "yes" and "no" responses. In addition, a total percent correct score is provided. There are five different forms of the word list. Delay Condition: Following the administration of all other test modules (approximately 20 minutes), the subject is again tested for recall via the same method described above. The same scores that are described above are provided for the delay condition.

Module 2 (Design Memory): This module evaluates attentional processes and visual recognition memory and utilizes a design discrimination paradigm. Twelve target designs are presented for 750 milliseconds on the computer screen. This sequence is presented twice to facilitate learning. At the end of the second presentation of the list, the subject is tested for recognition via the presentation of 24-designs comprised of 12 target designs and 12 non-target designs (target designs that

have been rotated in space). Similar to the word recognition task, the subject responds by mouse-clicking the "yes" or "no" buttons on the screen. Individual scores are provided both for correct "yes" and "no" responses. In addition, a total percent correct score is provided. There are five different forms of this task. Delay Condition: Following the administration of all other test modules (approximately 20 minutes), the subject is again tested for recall via the same method described above. The same scores that are described above are provided for the delay condition.

Module 3 (X's and O's): This module measures visual working memory as well as visual processing speed and consists of a visual memory paradigm with a distractor task. The subject is allowed to practice the distractor task prior to presentation of the memory task. The distractor is a choice reaction time test during which the subject is asked to click the left mouse button if a blue square is presented and the right mouse button if a red circle is presented. Once the subject has completed this task, the memory task is presented. For each of the trials of the memory task, a screen is displayed for 1.5 second that has a computer generated random assortment of X's and O's. For each of the trials, three of the X's or O's are illuminated in **YELLOW** on the screen. The subject is asked to remember the location of the illuminated objects. The X's and O's that are illuminated are randomized by the computer for each trail and for each administration of the test. Immediately after the presentation of the 3 X's or O's, the distractor task re-appears on the screen. Following the distractor task, the memory screen (X's and O's) re-appears and the subject is asked to click on the previously illuminated X's and O's. Scores are provided for correct identification of the X's and O's (memory), reaction time for the distractor task, and number of errors on the distractor task. For each administration of ImPACT, the subject completes 4 trials.

Module 4 (Symbol Matching): This module evaluates visual processing speed, learning and memory. Initially, the subject is presented with a screen that displays 9 common symbols (triangle, square, arrow, etc). Directly under each symbol is a number button from 1 to 9. Below this grid, a symbol is presented. The subject is required to click the matching number as quickly as possible and to remember the symbol/number pairings. Correct performance is reinforced through the illumination of a correctly clicked number in **GREEN**. Incorrect performance illuminates the number button in **RED**. Following the completion of 27 trials, the symbols disappear from the top grid. The symbols again appear below the grid and the subject is asked to recall the correct symbol/number pairing by clicking the appropriate number button. This module provides an average reaction time score and a score for the memory condition.

Module 5 (Color Match): This module represents a choice reaction time task and also measures impulse control /response inhibition. First, the subject is required to respond by clicking a read, blue or green button as they are presented on the screen. This procedure is completed to assure that subsequent trials would not be affected by color blindness. Next, a word is displayed on the screen in the same colored ink as the word (e.g. **RED**), or in a different colored ink (**GREEN** or **BLUE**). The subject is instructed to click in the box as quickly as possible only if the word is presented in

the matching ink. In addition to providing a reaction time score, this task also provides an error score.

Module 6 (Three letters): This module measures working memory and visual-motor response speed. First, the subject is allowed to practice a distractor task, which consists of 25 numbered buttons (5 x 5 grid). The subject is instructed to click as quickly as possible on the numbered buttons in backward order starting with "25." Once the subject has completed this initial practice task, he/she is presented with three consonant letters that are displayed on the screen. Immediately following display of the three letters, the numbered grid re-appears and the subject is instructed to click the numbered buttons in backward order as quickly as possible. After a period of 18 seconds, the numbered grid disappears and the subject is asked to recall the three letters by typing them from the keyboard. Both the number placement on the grid and letters displayed are randomized for each trial. This module yields a memory score (total number of correctly identified letters) and a score for the average number of correctly clicked numbers per trial from the distractor test. Five trials of this task are presented for each administration of the test.

The total time for completing the ImPACT© tests is 20 minutes.

Upon completion of these tests, participants will be asked to fill out the STAI questionnaire (state anxiety measure). Upon completion of the STAI questionnaire the participants will be free to leave and asked to return for a repeat test seven to fourteen days later.

4. Alternative Procedures

The only alternative procedure is not to participate. Participants may withdraw at any time during testing.

5. Benefits

There are no direct benefits to the participant, although this study will help benefit the Athletic Training field by further expanding the knowledge of computerized testing batteries, and using those results to return an athlete to play.

6. Risks

1. There may be a risk of discomfort to the athletes who admit to alcohol consumption.

This risk will be minimized by reminding the participant that all information gathered will be kept confidential and used only for research purposes.

7. Anonymity/Confidentiality

Participants will be identified by participant number on all forms and data. No names will be kept on the questionnaires or data. The principle investigator will have the only key matching participants' names and participant number. Information on alcohol use will be used only as a

covariate and will not be disclosed to anyone outside the research team. Consent forms and other identifiers will be kept separate from the data in order to provide confidentiality.

Data will be stored for 5 years. Data will be stored in a locked file cabinet in the principal investigator's office. Only the principal will have a key to the filing cabinet. At the end of the time period, files will be shredded.

8. **Consent**

(A copy of the consent form should be offered to each subject.) If this is an anonymous study, attach a cover letter in place of a consent form.

I certify that the protocol and method of obtaining informed consent as approved by the Institutional Review Board (IRB) will be followed during the period covered by this research project. Any future changes will be submitted to IRB review and approval prior to implementation. I will prepare a summary of the project results annually, to include identification of adverse effects occurring to human subjects in this study.

_____ _____

Principal Investigator *Date*

***Reminder*: Be sure to submit fourteen (14) copies of this form with your application.**

Appendix C

ImPACT Symptoms Check List

Signs and Symptoms that often develop early after injury

- Headache
- Nausea with or without vomiting
- Confusion or disorientation to time, place
- Retrograde amnesia (loss of memory for events preceding injury)
- Posttraumatic amnesia (difficulty with formation of new memory)
- Feeling mentally slowed down
- Feeling mentally "foggy" or "groggy"
- Dizziness
- Disruption of balance
- Light sensitivity (photosensitivity)
- Sensitivity to noise (phonosenstivity)
- Visual blurriness or fuzziness
- Short-term memory difficulties
- Concentration problems
- Motor clumsiness (stumbling, slowed movement)

Appendix D

STAI FORM X-1

STAI FORM X-2

SELF-EVALUATION QUESTIONNAIRE

Developed by C. D. Spielberger, R. L. Gorsuch and R. Lushene

STAI FORM X-1

NAME _____ DATE _____

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate how you *feel* right now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	①	②	③	④
2. I feel secure	①	②	③	④
3. I am tense	①	②	③	④
4. I am regretful	①	②	③	④
5. I feel at ease	①	②	③	④
6. I feel upset	①	②	③	④
7. I am presently worrying over possible misfortunes	①	②	③	④
8. I feel rested	①	②	③	④
9. I feel anxious	①	②	③	④
10. I feel comfortable	①	②	③	④
11. I feel self-confident	①	②	③	④
12. I feel nervous	①	②	③	④
13. I am jittery	①	②	③	④
14. I feel "high strung"	①	②	③	④
15. I am relaxed	①	②	③	④
16. I feel content	①	②	③	④
17. I am worried	①	②	③	④
18. I feel over-excited and "rattled"	①	②	③	④
19. I feel joyful	①	②	③	④
20. I feel pleasant	①	②	③	④

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SELF-EVALUATION QUESTIONNAIRE

STAI FORM X-2

NAME _____ DATE _____

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate how you *generally* feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	①	②	③	④
22. I tire quickly	①	②	③	④
23. I feel like crying	①	②	③	④
24. I wish I could be as happy as others seem to be	①	②	③	④
25. I am losing out on things because I can't make up my mind soon enough	①	②	③	④
26. I feel rested	①	②	③	④
27. I am "calm; cool, and collected"	①	②	③	④
28. I feel that difficulties are piling up so that I cannot overcome them	①	②	③	④
29. I worry too much over something that really doesn't matter	①	②	③	④
30. I am happy	①	②	③	④
31. I am inclined to take things hard	①	②	③	④
32. I lack self-confidence	①	②	③	④
33. I feel secure	①	②	③	④
34. I try to avoid facing a crisis or difficulty	①	②	③	④
35. I feel blue	①	②	③	④
36. I am content	①	②	③	④
37. Some unimportant thought runs through my mind and bothers me	①	②	③	④
38. I take disappointments so keenly that I can't put them out of my mind	①	②	③	④
39. I am a steady person	①	②	③	④
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	①	②	③	④

Appendix D

Demographic Questionnaire

Demographic Survey

ID number:_____ Gender:_____

1. Are you a nervous test taker?

2. Number of hours slept last night?

3. Average number of hours per night within the last week?

4. Do you consume alcohol? If so how many drinks in the last 24 hours? Time of last drink?

5. Do you consume caffeine? If so how many cups/drinks within the past 24 hours?

6. Do you feel anxious?

7. Rate your stress level on a scale of 1-10?

8. Have you had any documented concussions? How many?

Appendix E

Journal Manuscript

Journal Manuscript

Journal Manuscript

Test Retest Reliability of ImPact Based on External Factors

Nicole Carbone and Kathy Ludwig

Barry University, Miami Shores, FL, USA

Abstract:

The purpose of this study was to examine the effect of external factors of anxiety; alcohol, caffeine, and sleep on the test- retest reliability of the ImPACT computerized concussion management software. Twenty-five Division II athletes took a pre and post test computer software test (ImPACT) and additional questionnaires, (STAI to measure anxiety, and the demographic survey). Any participants with a concussion within the last year were excluded from testing. The participants were instructed to fill out a short questionnaire about their daily living activities. After the questionnaire was complete, the ImPACT test was administered. After the participant completed the ImPACT test, they were given another short questionnaire about state anxiety (STAI). The procedure was then repeated again seven to fourteen days after the first test. Using a Pearson correlation, the overall reliability correlations were poor. The only significant correlation was in the Reaction Time composite (r = .611, p <.05). When sleep, anxiety, and caffeine were used as covariates, reliability improved only slightly with none becoming significant. Also a moderate non-significant correlation (r = .418 p > .05) was found in the visual motor speed composite without covariates. However it appears that reliability of verbal memory, visual memory, and impulse control, when sleep, anxiety, and caffeine are used as covariates, improve slightly.

Using anxiety, sleep, and caffeine consumption as covariates did not significantly change the test retest reliability. Though the reliability was poor overall, more research is needed in this area because these covariates have been shown to have an effect on reaction time, impulse control, and memory, which could end up hindering the results and

causing further injury when a concussion is sustained. Athletic Trainers should emphasize the importance of the test to try to ensure the athletes are giving their best effort. They should also consider performing more than one baseline test to improve the reliability of ImPACT.

Key Words: Concussion, Evaluation, Return to play, Balance Error Score System, Symptoms check list SPSS, Standardized Assessment of Concussion

Introduction:

The study of concussions and their impact has always been an important topic. However during the past seven years more attention has been given to head injuries, "a surplus of three hundred articles have been published since 1991".[1]

Randolph's research as well as the research others have conducted and the increased attention on concussions have jump started the use of computerized testing batteries within the athletic training field.[4] When assessing a concussion, certain questions have been asked about which guidelines should be used to return an athlete to play and how a person grades a concussion. Currently there are seventeen different published guidelines to assess a concussion.[1] These guidelines appear to be redesigned and improved as a result of technological advances. New software has been invented that help Athletic Trainers better understand how to treat an athlete after he/she sustains a concussion.[5] The computer based programs for concussions are only useful if the organization is able to purchase them and understand how to use them. There are some basic guidelines that should be followed to evaluate a concussion at all levels of sports.[2] With the advancement in technology it would be easy to rely on this technology only. However, if the researcher is to be very complete and make effective use of this technology he/she needs to investigate and evaluate other factors that may affect the reliability on the neurocognitive outcomes. Practitioners should be aware that certain external factors such lack of sleep, alcohol consumption, caffeine consumption may affect the test retest reliability of ImPact and other neurocognitive tests. This information becomes essential when assessing an athlete, particularly when a decision is being made concerning the athlete's status such as the decision concerning whether or not an athlete

can return to play. It is important to understand how to read the results and develop an accurate interpretation of these results. It is essential to assess whether or not the results of the retest are a true indication when making the status of the athlete eligible and ready to return to play.

Recognition and treatment of a concussion are very important to help prevent future concussions. In order to identify a concussion the professional has to know the signs and symptoms that occur when one is sustained. Therefore, the purpose of this preliminary study was to determine if external factors such as alcohol, caffeine, stress level, anxiety level, and sleep, will affect the reliability of the composite scores of ImPact.

Methods:

Twenty-five Barry University athletes whose ages ranged from 18-25 years were recruited to participate in this study. The participants were required to be active Barry University athletes, and have no reported concussions within the last year, if a concussion was reported they were excluded from the study. The participants were directed to come in during their slotted time during the day of testing. The test and questionnaires took about thirty to forty minutes to complete. The participants were instructed to fill out a short questionnaire about their daily living activities. After the questionnaire was completed, the participant was brought into the biomechanics lab or a faculty member's office where the ImPACT test was administered. The test took about twenty minutes to complete. After the participant completed the test, they were given another short questionnaire about competitive state anxiety (STAI). The procedure was then repeated again seven to ten days after the first test. The test procedure was completed the same

way and the time the participant took the exam was duplicated as close as possible based on the participant's schedule. The testing was in a controlled environment and participants were given their retest around the same time of day to mimic the same atmosphere and state as the first test; unless there was an extreme circumstance, inclement weather, or illness.

Data Analysis:

This study examined the effects of anxiety, sleep, alcohol and caffeine on the test—retest reliability of ImPACT. The reliability was measured with and without covariates. The hypotheses tested in this study were the following: When anxiety, sleep, and caffeine differences were used as covariates, test-retest reliability of the composite scores of ImPACT, as measured with Pearson correlations, will improve. Specifically, higher anxiety scores will be correlated with lower composite scores. Alcohol will be associated in lower reaction time domain of ImPACT. Caffeine consumption will be associated in lower composite scores of ImPACT. The amount of sleep the athlete gets the night prior to testing will be positively associated with composite scores of ImPACT. Also, the standard error of difference will be examined with and without the external factors used as covariates in specific ImPACT scores. Standard error of difference will be measured as follows:

$$S_{diff}\sqrt{SEM^2_1 + SEM^2_2}$$

Where $SEM_1 = SD1\sqrt{1-r_{12}}$ and $SEM_2 = SD2\sqrt{1-r_{12}}$ and r_{12} is the test—retest coefficients and SD is the standard deviation of the individual tests.

Results:

There were a total of twenty participants in the study: Thirteen males and seven females whose average age was 20.05 (SD) years old. All demographics are found in Table 1. The outliers were excluded case wise from the individual variables.

Participant Demographics

	Gender	Age	Sport	Position	Previous Concussions	Class
Subject 1	Male	21	Baseball	Pitcher	0	Senior
Subject 2	Male	18	Baseball	3rd Base	0	Sophomore
Subject 3	Male	23	Baseball	Pitcher	0	Senior
Subject 4	Male	23	Baseball	Pitcher	0	Senior
Subject 5	Male	19	Basketball	Center	0	Junior
Subject 6	Female	19	Soccer	Defender	0	Freshman
Subject 7	Female	21	Softball	1st Base	0	Senior
Subject 8	Male	18	Baseball	Shortstop	0	Freshman
Subject 9	Female	19	Softball	1st Base	0	Freshman
Subject 10	Female	18	Softball	Outfielder	2	Freshman
Subject 11	Female	18	Soccer	Midfielder	0	Freshman
Subject 12	Female	21	Rower		0	Senior
Subject 13	Male	21	Soccer	Keeper	0	Senior
Subject 14	Male	21	Baseball	Right Field	0	Junior
Subject 15	Male	21	Baseball	1st Base	0	Senior
Subject 16	Female	19	Softball	Pitcher	0	Freshman
Subject 17	Male	19	Baseball	3rd Base	0	Freshman
Subject 18	Male	21	Baseball	Pitcher	0	Junior
Subject 19	Male	23	Baseball	2nd Base	0	Senior
Subject 20	Male	18	Baseball	Pitcher	0	Freshman

Table 1

Hypotheses

The means and standard deviations of the ImPACT test results and the test-retest correlations before and after inclusion of covariates are found in Table 2 and 3. No participants had alcohol in their systems when tests were completed. Therefore alcohol consumption was not included in the analysis. The measures of anxiety, sleep, and caffeine consumption are found in Table 4.

Means, Standard Deviation Correlations without Covariates

	Test 1		Test 2		Coefficient of Reliability
	mean	SD1	mean	SD1	r
Verbal Memory	83.80	9.041	88.45	8.121	0.073
Visual Memory	76.82	8.110	82.59	8.412	0.067
Visual Motor Speed	40.5468	5.77363	43.7526	5.406	0.418
Reaction Time	0.504	0.05977	0.51	0.053	0.611*
Impulse Control	7.813	3.0815	4.81	2.105	0.066

Table 2. * significant and p<.05

Means, Standard Deviation Correlations with Covariates

	Test 1		Test 2		Coefficient of Reliability
	mean	SD2	mean	SD2	r
Verbal Memory	83.57	9.17953	88.9286	8.88789	0.077
Visual Memory	78.71	6.79851	82.8571	8.95164	-0.015
Visual Motor Speed	38.89	4.90066	43.4271	5.57801	0.205
Reaction Time	.51	.05010	.5229	.05455	0.414
Impulse Control	8.21	3.06791	4.9286	1.89997	0.083

Table 3

Means and Standard Deviations for Pre and Post Test Results

	Mean test 1	Std. Deviation	Mean test 2	Std. Deviation	N
Verbal Memory	83.80	9.041	88.45	8.121	20
Visual Memory	76.82	8.110	82.59	8.412	17
Visual Motor Speed	40.5468	5.77363	43.7526	5.40646	19
Reaction Time	.5040	.05977	.5100	.05262	20
Impulse Control	7.813	3.0815	4.81	2.105	16
Anxiety	66.40	16.158	70.25	19.905	20
Hours Slept	7.375	1.3463	7.275	1.9499	20
Caffeine	.80	.951	1.15	1.663	20

Table 4

Overall reliability correlations were poor. The only significant correlation was in the Reaction Time composite without covariates (r = .611, p <.05). When sleep, anxiety, and caffeine were used as covariates, reliability improved only slightly with none becoming significant. Also a moderate non-significant correlation (r = .418 p > .05) was found in the visual motor speed composite without covariates. However it appears that the reliability of verbal memory, visual memory, and impulse control improved slightly when sleep, anxiety, and caffeine are used as covariates. When the partial correlations were conducted all the composite scores got slightly better, except for visual motor speed and the reaction time composite (see Tables 2 & 3). Due to the lack of overall reliability the standard error of difference could not be measured.

In other results, the pretest results showed that visual memory was significantly correlated to caffeine consumption (r=4.85, p<.05), the means and standard deviations for caffeine were M=.80 and the SD= .951; and the mean and standard deviation for visual memory were M=76.82 and the SD= 8.11. The post test results showed visual memory was significantly related to number of hours slept (r=-.597, p<.05), the means and

standard deviations for visual memory were M=82.59 and SD= 8.412 and the means and standard deviations for hours slept were M=7.275 and SD=1.95.

Discussion:

The purpose of this study was to determine if external factors such as sleep, stress, anxiety, alcohol consumption, and caffeine consumption have an effect on the test--retest reliability of the ImPACT computerized testing results.

The hypotheses tested in this study were the following: When anxiety, sleep, and caffeine differences were used as covariates, test-retest reliability of the composite scores of ImPACT will improve. Overall, reliability correlations were poor. The only significant correlation was in the Reaction Time composite (r = .611, p <.05). When sleep, anxiety, and caffeine were used as covariates, reliability improved only slightly with none becoming significant. Also a moderate non-significant correlation (r = .418 p > .05) was found in the visual motor speed composite without covariates. The pretest results showed that visual memory was significantly correlated to caffeine consumption (r=4.85, p<.05), the means and standard deviations for caffeine were M=.80 and the SD= .951; and the mean and standard deviation for visual memory were M=76.82 and the SD= 8.11. The post test results showed visual memory was significantly related to number of hours slept (r=-.597, p<.05), the means and standard deviations for visual memory were M=82.59 and SD= 8.412 and the means and standard deviations for hours slept were M=7.275 and SD=1.95.

Overall reliability of the ImPACT tests in this study was poor (see Tables 2 & 3). One reason for the poor reliability could be due to the fact that the ImPACT tests are not

reliable for the sample studied. However, several studies have found good reliability in similar sport samples. In the study conducted by Broglio *et al* the test--retest reliability of the computer based assessment tools (ImPACT, the Concussion Sentinel, and the Concussion Resolution Index) good reliability scores were found.[16] Though the scores are similar and each test has it strengths, it is important to understand that all three tests were found reliable in the test—retest aspect. Also, another study conducted by Schatz et al looked at the sensitivity and specificity of ImPACT in athletes with concussions.[14] The researchers found a significant multivariate effect of concussion on test performance. [14] The discriminate function test revealed that visual memory, impulse control, and processing speed composites correctly classified 85.5% of the cases, [$x^2(4)=74.4$, $p=.0001$]. This measure shows that ImPACT is sensitive and specific, and can be used as a useful tool for the practioner when assessing a concussion, and returning an athlete safely back to play. [14] Another reason for the poor reliability in the present study could have involved a lack of space allotted for the use of the mouse, which could have skewed the overall reaction time composite results therefore skewing the results of the test-retest reliability.

Another reason for the poor reliability is that there may have been a testing effect. Most subjects verbally reported that the second time they took the test it was easier, they knew what was coming. Schatz et al looked at the sensitivity and specificity on ImPACT, there results conducted that ImPACT was sensitive and specific enough but some subjects reported on the retest they knew what to expect and the test was easier to complete.[14] For example, in the current study, one subject reported that after reading the instructions of the color match test, the test still caught him off guard. When compared to

the second test, the subject stated that he knew what was expected of him. Thus, a lack of understanding or reading of the directions of the test may have had an effect on the results. With a drastic change in results between the verbal memory and visual memory composites, which can be seen in table 4, one may conclude that the subjects may not have read the directions thoroughly enough before continuing with the test. Some participants told the test administrator anecdotally that they should have read the directions better.

Another factor could have been the testing environment. According to the ImPACT users manual it is important to try and recreate the same atmosphere for the re-test to assure the best results.[10] Although every effort was made to keep the environment consistent between tests, three subjects said that the mouse space provided in the testing area was too small and could have slowed down their testing, and changed their results. Another subject said that the computer screen was too bright and started to hurt her eyes during test. Thus, the lighting in the testing area could have been too low which could have had affect on her ability to do the test therefore changing her results.

The final reason, which may be the most relevant, was that this test was done for a thesis and not diagnostically. Therefore participants may have lacked the motivation to perform at their best. Several subjects asked the researcher whether their results would impede their ability to participate. A few related that they would have tried harder if they knew the test would count for something. It is critical to emphasize the importance of the test and the end results for which the test is used.

When the covariates (anxiety, sleep, and caffeine) were added in the data set no significant correlations were found between the pre and post test. The lack of any change in reliability could have been due to the lack of sensitivity in the measures used for the covariates. For example, the STAI may not have been able to pick up subtle differences in anxiety level. Also, the participants may not have given accurate information on their caffeine consumption, alcohol consumption, anxiety level, or the amount of hours they slept the night prior to test. The results of the covariates were based on the truthfulness and accuracy of the participants' answers. The information was to be kept confidential, but the in-season athletes seemed worried about their coaches getting access to their test results, which could therefore skew the answers given during testing.

With regards to the hypothesis that higher anxiety scores will be correlated with lower composite scores, results showed no correlation with any of the composite scores. The level of anxiety in the pre and post test was 66.40 (16.16) and 70.25 and (19.91) respectively. The anxiety level increased but not significantly. The testing week for the post test exam was one week before final exams. The added anxiety of exams could explain this increase.

Alcohol was not used as a variable in the study because, based on self-reports, no athletes had alcohol in their system at the time of testing. It is possible that the participants were not truthful due to their athletic standing as collegiate athletes. The in-season participants were approaching their post season play, so they may not have been as truthful in the study for fear of coaches gaining access to the results. The truthfulness of the athlete on the amount of alcohol consumed the night prior to the testing may have

had an influence on the composite scores. When explaining the test to the athlete it is critical to emphasize the importance of telling the truth and the possible consequences or outcomes that could come from not disclosing all the proper information, which is for their benefit.

The hypothesis that higher caffeine consumption would be associated with lower composite scores of ImPACT was not supported. Though not significant, caffeine consumption was moderately correlated with the Visual Memory composite in the pre-test but not in the post test, refer to tables 2 & 3. This result may be due to the large differences in the pre and post test Visual Memory means (see Tables 2 and 3). Also, these results may be due to a lack of motivation from the participants. As has been stated above, participants were aware that these results would not decide whether or not they would return to play.

The hypothesis that the amount of sleep the athlete gets the night prior to testing would be positively associated with composite scores of ImPACT was only supported for the visual memory composite in the post-test but not in the pre-test. Again, these results may be due to the overall lack of motivation from the participants. Another reason could be that there was not enough discrimination in the measure for sleep. Most of the participants were within one hour of sleep from pretest to post test. For example one subject jumped from seven hours to five hours from the pretest to the post test and her composite scores in visual memory drastically changed. Perhaps a measure of the pattern of sleep prior to testing, perhaps over several days, would be a more sensitive and valid measure of the effect of sleep on the composite scores of ImPACT.

Clinical Implications

The lack of reliability in the ImPACT test scores in this study has several clinical implications. As an athletic trainer, it is important that we not use this tool as a lone measure when a concussion occurs. It should be used in conjunction with other available measures such as the Standardized Assessment of Concussion test (SAC), the symptoms check list, the Balance Error Scoring Test (BESS).[2,5,7] It is also important that the directions are explained and emphasized enough to the individuals taking the test. The athletes need to understand that the test results may be used when a concussion occurs along with other tools in order to return them to activity. When administering the test it is important to know your athletes. By knowing your athletes, you may be able to know if that person is trying their very best.

The results of this study point to the importance of getting baseline measures during off-season or pre-season. When the post test was done in this study, several subjects were in the final stages of their seasons and were one week away from final exams which could have hindered the reliability. With that knowledge about the athlete and time of year, an additional baseline test may be needed in order to obtain the best possible results.

Recommendations for future research

Recommendations for future research would include taking caffeine, alcohol consumption, sleep, and anxiety into consideration when administering this test. Though the results of this study did not show to be significant, other studies by Hardy and Mullen

have shown that anxiety has an effect on cognitive tasks.[18] Also, Hindmarch, Kerr, and Sherwood found that "Alcohol has a disruptive effect on psychological aspects of behavior and performance."[20] Finally, Pilcher and Huffcut, concluded that sleep deprivation decreases both reaction time and cognitive distortion.[26] With this knowledge base it can be concluded that these factors along with a concussion may have an effect on the results of the composite scores of ImPACT.

Another recommendation may be taking medications into more consideration. Though the test asks what medications each athlete is taking, these are not factored into computing the composite scores.

Conclusions

Based on the results of the study, test retest reliability of composite scores of ImPACT in Division II collegiate athletes was poor. Using anxiety, sleep, and caffeine consumption as covariates did not significantly change the test retest reliability. Though the reliability was poor overall, more research is needed in this area because these covariates have been shown to have an effect on reaction time, impulse control, and memory, which could end up hindering the results and causing further injury when a concussion is sustained.

Athletic trainers should emphasize the importance of the test to try to ensure the athletes are giving their best effort. They should also consider performing more than one baseline test to improve the reliability of ImPACT.