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The Effectiveness of a Dual Task Concussion Assessment for Identifying Impairments in Concussed Athletes

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THE EFFECTIVENESS OF A DUAL TASK CONCUSSION ASSESSMENT FOR IDENTIFYING IMPAIRMENTS IN CONCUSSED ATHLETES

by

KRISTIN BOCKELMAN

(Under the Direction of Thomas Buckley)

ABSTRACT

Context: Commonly used single task (ST) concussion assessments are unable to identify lingering impairments following a concussion. Current dual task (DT) assessments use cost prohibitive technological assessments not available to most clinicians, creating the need for a clinically applicable dual task assessment to identify impairments. **Objective:** To determine if a DT assessment consisting of the Standardized Assessment of Concussion (SAC) and with the Balance Error Scoring System (BESS) is able to identify impairments. **Design:** Prospective longitudinal. **Setting:** Research laboratory. **Participants:** Concussed student-athletes and matched health controls, 18 females, 10 males. Concussed group: age 19.00 ± 0.88 , height 174.53 ± 12.06 cm, and mass 75.28 ± 22.02 kg. Healthy group: age 19.36 ± 1.34 , height 171.45 ± 11.69 cm, mass 73.34 ± 22.7 kg. Participants were matched based upon gender, mass, and sport. **Interventions:** The DT assessment was administered on the day of recovery (REC), on the day of return to play (RTP), and 30 days post-concussion (D30). **Main Outcome Measures:** Scores of SAC and BESS as a dual task. **Results:** No significant interaction or main effect was found between session and group for BESS. No significant interaction between session and status was found for SAC. There was a significant main effect found for session for SAC. Simple contrasts revealed significant differences between recovery REC and D30, and between RTP and D30. The SAC D30 scores were significantly higher (better) than recovery and return to play day, regardless of group. No significant differences were found between concussed and healthy for SAC at REC, RTP, and D30. **Conclusions:** There were no differences between recently concussed and healthy participants when performing the BESS and SAC as a DT challenge. Interestingly, an improvement in cognitive performance was identified whereby all participants improved SAC performance with repeat administration. Conversely, no improvements were noted with repeat performance suggesting a posture first strategy was not being employed. Future research should utilize tasks that challenge both the cognitive and postural domains, but is also plausible and feasible for clinicians to utilize.

Key Words: Dual task, SAC, BESS, Concussion, Collegiate athlete

INDEX WORDS: Dual task, SAC, BESS, Concussion, Student athlete

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TABLE OF CONTENTS

LIST OF FIGURES	6
LIST OF TABLES.....	7
CHAPTER	
1 INTRODUCTION	8
2 METHODS	13
Participants	13
Instrumentation.....	14
Procedures	16
Data Analysis.....	17
Statistical Analysis	18
3 RESULTS	19
4 DISCUSSION.....	21
Conclusion.....	27
REFERENCES	28
APPENDICES	
A LIMITATIONS, DELIMITATIONS AND ASSUMPTIONS	32
B LITERATURE REVIEW.....	35
C FIGURES AND TABLES	60
D NIH, CITI AND IRB FORMS.....	71

LIST OF FIGURES

Figure 1: Informed Consent Page	63
Figure 2: Standardized Assessment of Concussion (SAC) Form A	65
Figure 3: Balance Error Scoring System (BESS) Score Sheet	66
Figure 4: Demonstration of the BESS	67
Figure 5: Health History and Demographics Questionnaire.....	68
Figure 6: Mean BESS Scores Across Testing Sessions.....	69
Figure 7: Mean SAC Scores Across Testing Sessions	70

LIST OF TABLES

Table 1: Demographics of Participants.....	61
Table 2: Testing Timeline.....	62

CHAPTER 1

INTRODUCTION

It is estimated that 1.6 to 3.8 million sports related concussions occur each year, with approximately half going unrecognized or unreported.^{1, 2} Concussions are known to cause deficits in cognition and balance, as well as increase in symptoms.³ A multifactorial concussion assessment, consisting of a symptom checklist, neuropsychological examination, cognitive testing, a postural control assessment, and clinical examination has been recommended for diagnosing acute concussion.⁴⁻⁶ The sensitivity for identifying acute concussion impairments is high at the initial assessment, but the assessment sensitivity as a whole and each single task's (ST) sensitivities decreases during recovery.^{7, 8} These tests were created to help evaluate an acute concussion, rather than track concussion recovery, and therefore is limited in the area of recovery.

Commonly used ST concussion assessments include the Balance Error Scoring System (BESS) and the Standardized Assessment of Concussion (SAC). BESS and SAC have been utilized to identify acute concussions, as their sensitivities are highest with administration within 24 hours post injury, and dropping significantly over the course of a week post injury.^{7, 9} The range of sensitivities across time are 0.34-0.07 for BESS and 0.02 to 0.80 for SAC.⁷ The specificity of the BESS ranges from 0.91-0.95⁷ and SAC from 0.91 to 0.98.⁷ The interrater reliability coefficients range for the BESS from 0.57-0.85, and the intrarater from 0.60-0.98.¹⁰⁻¹⁴ Despite low sensitivities, these tests are commonly used in the clinical setting.⁷

The BESS test was developed as a cost-effective assessment to evaluate postural stability following a concussion.¹⁵ The BESS test has been shown to have moderate to high correlations when compared to the Sensory Organization Test (SOT).¹⁰ When used to assess the recovery from concussion, subjects have been shown to display acute postural stability changes up to 3-5 days after injury, and display return to baseline values within 4 to 7 days following injury.^{3, 16, 17} The BESS test does display a practice effect when multiple trials of BESS are administered, which creates a limitation as the assessment is repeatedly administered until an athlete reaches their baseline score.¹⁴ This practice effect has been noted on administrations of the BESS on healthy individuals at 30 day and 90 day follow ups.^{9, 15, 18} However, if this practice effect is absent with repeated testing of concussed individuals, this should be considered when interpreting the scores.¹⁸

The SAC test is a valid, practical and effective assessment to assess cognitive functioning following a concussion.^{6, 19} When utilized to assess cognition after a concussion, the SAC has shown cognitive deficits in concussed individuals immediately after injury through post-injury day 2; mild deficits appear through day 5, and all resolve around day 7.³ The reliable change index for the SAC indicates that a change of 3 or more points is the most sensitive statistical index of change, however a decrease within the range of 1 to 3 points results would result in similar classification.¹⁹ A drop of one point may help to identify a concussed athlete, but it also provides an incorrect evaluation of potentially healthy ones, creating a false-positive result.¹⁹ Concussed athletes would not meet their baseline score and thus not be cleared, however healthy athletes could also be withheld from participation based on a one point decrease. In the clinical setting, a one

point decrease is considered failing, indicating the presence of a concussion.²⁰ Despite these limitations and practice effects, there is still an emphasis for an athlete to ‘meet baseline scores’ before returning to play. The test may then give a false-negative, as the scores are then a result of repeat administration rather than an improvement in the cognitive deficit. The SAC could potentially be utilized concurrently with another examination to improve the ability to differentiate a concussed and healthy individual as well as identify potential lingering cognitive deficits.

When healthy individuals complete a ST assessment, all of their attentional resources can be placed upon that task.²¹ A working memory task may cause concussed individuals to reallocate attention resources or employ compensatory mechanisms.^{21, 22} Current ST assessments may miss persistent deficits that last longer than 7-10 days.^{3, 23} If deficits are missed with ST assessments, premature return to play may be occurring, leading to repeat concussions occurring within the 10 day post injury window of vulnerability, in which 90% of repeat concussions occur.^{24, 25} One theory states, that with each subsequent blow to the head, the reserve capacity of the brain is decreased, thus limiting the rate and degree of recovery.²⁶ The athlete may be returning to play during a vulnerable state, and subsequent contact may lengthen their overall recovery. This could potentially lead to long term effects, such as second impact syndrome, permanent loss of neurocognitive functioning, increased sensitivity to the effects of normal aging, mild cognitive impairment, memory problems, Alzheimer’s disease, and depression.²⁶⁻²⁹ To help ensure that an athlete is fully recovered before a return to play decision is made, a more thorough and sensitive evaluation must be designed. One emerging area is DT assessment, combining two tasks required for athletic participation.³⁰

A DT paradigm is defined as completing a postural and cognitive task simultaneously with attention allocated to both tasks.³¹ DT may be more sensitive in identifying cognitive and physical impairments following a concussion when compared to a standard clinical ST assessment.^{32, 33} The ‘absolute DT deficit’ is the decrease in performance of a variable when the task is performed alone compared to when the task is performed simultaneously with another task.³¹ Past research has shown deficits a month post-concussion using a DT gait assessment.³⁴⁻³⁷ During DT assessment, symptomatic concussed individuals may be unable to reallocate the cognitive aspect of the DT assessment.²¹ During a DT, the individual must also allocate resources for both the cognitive and the postural tasks. Utilizing a DT assessment may allow a clinician to identify impairments that were not evident during a single task assessment.

Although DT is an emerging area of concussion research, there are few studies that attempt it, most noticeably with healthy subjects and/or real life scenarios.^{38, 39} Testing healthy individuals as controls is needed to ensure that the DT can be completed, and to have data for comparisons, yet these results are not directly applicable to concussed individuals. Concussed individuals display deficits when compared to healthy individuals, further strengthening the argument to continue to test concussed individuals with a DT assessment, however having a large number of concussed participants is not always clinically practical.^{33, 40}

There is a need for a DT assessment to be applicable to the athletic setting and available for clinicians use without substantial cost or training. Using gait as the motor function to assess postural deficits is applicable to the athletic setting as it is a dynamic task, but it may not be feasible for all clinicians to analyze gait patterns. Another

alternative research assessment, the SOT, is costly and it is not commonly used by practicing athletic trainers.⁴¹ The BESS examination is a popular postural stability assessment, already being used by athletic trainers. By taking two commonly used assessments, the BESS and SAC, a DT assessment may be created using tests that athletic trainers already are familiar with and have implemented in their own settings. The equipment that it uses is not expensive, the test can be administered in a short amount of time, and it requires only a comparison of scores to an already established ST baseline value.

Concussion evaluations are highly sensitive for acutely identifying concussions, but the evaluation is limited in identifying concussion recovery.⁷ Emerging evidence suggests that a DT assessment may be an improved methodology to identify potential lingering deficits post-concussion. By combining two commonly used assessments, SAC and BESS, a feasible DT evaluation is created. Therefore, the purpose of this study was to determine if a DT paradigm was able to identify cognitive and physical impairments in concussed athletes on their recovery day, return to play day, and at a 30 day follow up. We hypothesize that there will be a significant difference between groups at recovery day, return to play day, and a 30 day follow up. We also expect that concussed participants will display a significant difference between the recovery day, return to play, and 30 day follow up DT assessments within the group.

CHAPTER 2

METHODS

Participants

There were 28 participants recruited for this study. (Appendix C, Table 1) The inclusion criteria for the concussed group was that they were between the ages of 18-24 years, current collegiate athletes, identified as having a concussion by an athletic trainer, diagnosed by a physician, and were following the institution specific return to play concussion protocol. The exclusion criteria for concussion group participation will be to not have sustained and/or been diagnosed with a concussion in the last 6 months (excluding current concussion), and no known neurologic, vestibular, or visual deficits or taking medication which affects either cognitive or balance performance.^{38, 42} The control group was between the ages of 18-24 years of age, and had baseline ST SAC and BESS data available at the institution. Control participants were excluded if they report having a concussion in the last 6 months, or have sustained or been treated for a lower leg injury in the last 6 months.^{33, 43} Control participants were also current intercollegiate athletes and were matched to the injured participants based on gender, mass and sport.⁴⁴ All participants provided written informed consent (Appendix C, Figure 1) as approved by the Institutional Review Board after being provided with written and verbal instruction of the purpose and procedures of the study.

Instrumentation

The instrumentation for this study will involve the SAC and BESS.^{6, 10, 45} Other instruments include a standard physician's scale (Weight Beam Eye-Level Physician's Scale, Detecto Scale Company, Webb City, MO, USA) Airex Pad (Airex balance pad, Alcan Airex, Switzerland), standard stopwatch and two video cameras (Canon, Vixia HF M31, Canon Inc, Tokyo, Japan).

The SAC (Appendix C, Figure 2) is a mental status exam, developed to provide athletic trainers with a standardized evaluation for assessing athletes who may have sustained a concussion.¹⁹ It includes assessments for orientation, immediate memory, concentration, and delayed recall.^{46, 47} The orientation section has 5 questions, with a point scored for each question answered correctly, with a total of 5 points possible. Immediate memory is a list of 5 words that are repeated 3 times; requiring the athlete to repeat each list immediately after the administrator reads it. A point is given for each of the words when it is remembered correctly, with a total of 15 points possible. The concentration section requires the participant to recite a string of numbers in reverse order, with a total of 4 strings with 3, 4, 5, and 6 numbers, and a point given for each accurately recited list. There are 2 number string options in each section, such that if the participant repeats the first string incorrectly, they are given a second attempt with the next string. The concentration section also requires the athlete to recite all 12 months in reverse order. One point is given for each correct response, with a total of 5 points possible for this section. The last section is delayed recall, and requires the participant to recite the 5 words that were repeated earlier in "immediate memory" section. The athlete is given a point for each correctly remembered word. The entire SAC takes <5 minutes

and is worth a total of 30 points, with a higher score indicating better cognitive performance. There are three different forms of the SAC (A,B,C) and these have been found to be equivalent for clinical use.⁴⁷ The SAC has been shown to be a reliable and valid measure for evaluating the neurocognitive deficits of an acute concussion.^{19, 20, 48}

The BESS (Appendix C, Figure 3) is a clinical balance test, designed to measure balance performance after a concussion.¹⁰ It is administered with the participant balancing upon a firm surface and a medium density foam pad.³⁹ The BESS involves 3 different stances, performed on 2 surfaces, firm and foam (Appendix C, Figure 4).¹⁸ For the BESS examination the participant's dominant leg is the one the participant would kick a ball with. The first stance on each surface is double leg, with the heel and toes touching, hands on the iliac crest and eyes closed. The second stance is balancing single leg on the nondominant leg, with the opposite leg flexed at the hip at 30 degrees, and the knee flexed 45 degrees next to it.⁴⁹ The third stance is tandem, with the nondominant foot in the back, with the toes of the nondominant foot touching the heel of the dominant foot. The tests are then repeated on the foam pad. Each stance is administered for 20 seconds. During each 20-second stance, the clinician scoring the errors the participant commits. Errors include 1) lifting the hands off the iliac crest, 2) opening the eyes, 3) step, stumble or fall, 4) moving the hip into greater than 30° abduction, 5) lifting the forefoot or heel, and 6) remaining out of the test position for longer than 5 seconds.¹⁰ Multiple simultaneous errors are counted as 1 error, and the maximum amount of errors that can be committed in one stance is 10.⁴⁹ The errors are then counted for each stance, and totaled to create an overall score. A higher score indicates a worse performance on the assessment.

Procedures

Each participant completed a health history and demographics questionnaire to ensure inclusion criteria were met (Appendix C, Figure 5). Each of the DT trials was videotaped with cameras placed 5 m. away, in the frontal and sagittal planes. The participants' mass was measured utilizing the physician scale.

The concussed participants completed the return to play concussion protocol per institution protocol. This included testing the ST assessments of SAC and BESS within 24 hours of the initial injury, and after the athlete reported being asymptomatic if baseline scores were not achieved. Once asymptomatic, the athlete was retested each subsequent day until baseline scores were met. Once baseline scores were met for both of the ST assessments, the athlete was tested with the DT assessment within 24 hours of passing both tests, administered the DT again on return to play day and on the 30 day post injury follow up. Within the time between the first administration of the dual task and the second, the athlete will complete a 7 day progressive return to activity protocol as directed by the institution. Matched controls followed up on the same testing timeline as the concussed participant, with a recovery day DT administration, a follow up for return to play and a 30 day follow up.

To complete the DT assessment, the BESS and SAC were combined. The participant was required to keep their hands on their hips during each of the stances, as well as keep their eyes closed consistent with BESS. The orientation questions of SAC was administered during the double leg firm BESS, immediate memory trial 1 during single leg firm, immediate memory trials 2-3 during tandem firm, concentration 1-3

during double leg foam, concentration 4-5 during single leg foam, and delayed recall during tandem foam.

If the participant was unable to complete the SAC questions during the allotted 20 seconds, the participant continued to answer the SAC questions and continue to balance, but BESS errors will not be counted past the 20-second mark. If the participant answers all questions quickly, the participant continued with the BESS examination until the 20 seconds ended.

Data Analysis

This was a prospective longitudinal study. The descriptive variables of this study include mass, gender, and history of concussion. The independent variables involved include were the concussion status of the participant (concussed or healthy control), as well as the test session (recovery day, return to play day, or 30 day follow up). The dependent variables of the study included BESS total scores and SAC total scores.

For the BESS exam, scores from each of the 6 stances were combined to obtain a total score, with a maximum of 60 points possible. Higher scores indicated a decrease in postural stability. Scoring for the SAC consisted of points awarded for correct answers, with a maximal possible score of 30. Lower scores indicated a decrease in cognitive function.

Statistical Analysis

Two 2x3 repeated measure ANOVAs were performed to assess the DT SAC and BESS scores across time for each group at recovery day, return to play day, and 30 day follow up, as well as between groups at each testing session. The alpha level was set at 0.05. Video scoring versus live score of the assessments, and video scoring versus repeated video scoring was compared with intraclass coefficient to ensure reliability from video to live scoring and within video scoring. All data will be analyzed using SPSS.

CHAPTER 3

RESULTS

For the reliability between video to live scoring, the ICC value was 0.81 for BESS and 0.96 for SAC. For the reliability between intrarater video scoring, the ICC value was 0.91 for BESS and 0.99 for SAC. For the reliability between the interrater video scoring, the ICC value was 0.93 for BESS and 1.00 for SAC.

The LOC rate was 0%, the PTA rate was 21.4% (3/14) and 5 participants reported history of concussion. 4 healthy participants reported history of concussion. There were no significant differences between any of the demographic variables for the participants, or for the timelines between groups. (Appendix C, Table 2).

Regarding the BESS test across the DT testing sessions, no significant interaction between session and group was found (Wilk's $\lambda = .89$, $F(2, 25) = 1.51$, $p = .24$, $\eta^2 = .11$). There no significant main effect for session, ($F(2, 52) = 1.36$, $p = .27$, $\eta^2 = .05$). There is no significant effect for group, ($F(1, 26) = .03$, $p = .88$, $\eta^2 = .001$). No significant differences were found between concussed and healthy for BESS at REC (13.29 ± 6.90 , and 12.57 ± 7.09), RTP (14.00 ± 6.94 and 15.57 ± 6.85) D30 (14.14 ± 9.83 and 14.50 ± 7.73). (Appendix C, Figure 6).

Regarding the SAC test across the three DT testing sessions, no significant interaction between session and status was found, (Wilk's $\lambda = .82$, $F(2, 25) = 2.78$, $p = .08$, $\eta^2 = .18$). After adjusting for sphericity using the Huynh-Feldt calculation, there was a significant main effect found for session, ($F(1.74, 45.26) = 4.18$, $p = .03$, $\eta^2 = .14$). Simple contrasts revealed significant differences between recovery day and day 30, ($F(1,$

26) = 7.52, $p = .01$, $\eta^2 = .22$). Simple contrasts revealed significant differences between return to play day and day 30, ($F(1,26) = 4.55$, $p = .04$, $\eta^2 = .15$). The SAC day 30 scores were significantly higher than recovery and return to play day, regardless of group. No significant differences were found between concussed and healthy for SAC at REC (26.00±2.54, and 26.07±2.27), RTP (25.86±2.41 and 27.36±1.28) D30 (27.21±1.48 and 27.29±1.14). (Appendix A, Figure 7).

CHAPTER 4

DISCUSSION

ST assessments are commonly used to assess and track concussion recovery, and the DT assessments that are being developed utilize equipment not readily available to all clinicians. Therefore, the purpose of this study was to determine if a clinically plausible DT assessment could identify cognitive and physical impairments on three separate testing sessions (Recovery day, Return to play day, 30 day follow up) following a concussion. The main finding was the lack of group differences during the DT assessment at all three of the testing sessions. This suggests that concussion status did not affect how the participant performed on the DT assessment. A secondary finding was the significant improvement of scores for both group's combined SAC test scores across the three testing sessions, suggesting that even with in a DT assessment, the SAC practice effect persists.

The primary finding of this study was the lack of group differences during the DT testing paradigm suggesting the concussed population had either substantially recovered from their concussion or they benefited from the repeat administration of the single task assessments. The concussed group in this study had been recently exposed to the SAC through their post injury protocol an average of 1.6 ± 0.7 times prior to exposure of the SAC test in DT assessment. The concussed group in this study had been recently exposed to the BESS through their post injury protocol an average of 1.9 ± 0.8 times prior to exposure of the BESS test in DT assessment. With repeat ST administration of both the SAC and BESS tests, scores significantly above baseline values has been noted by the 3 –

5th post concussion administration and persisted to 90 days post-injury.^{15, 50} This suggests that the practice effect of SAC as a ST assessment was not reduced by use in a DT assessment.

The secondary finding of this study was the significant increase of SAC scores across time for both groups, whereas BESS scores were generally maintained across the testing sessions. It can be suggested from this that a practice effect was displayed with the cognitive task. In a past study that utilized the SOT with a procedural reaction time test, there was found to be an improved reaction time from testing session one to two, which was separated by 14 days. However, these cognitive task improvements were only found in the eyes open trials of the SOT, not in the closed eyes trials, or any trials of the BESS test. However, these improvements of the cognitive task were also accompanied by an improvement of SOT scores. The BESS test trials displayed no significant changes between testing sessions, or between administered as a ST or DT. It was concluded that the procedural reaction test (PRT) and procedural auditory task (PAT) are both relatively simple tasks, which may explain the significant improvements that were noted.

The cognitive task utilized in this study varies from past DT research. Typically tests uncommon in the clinical setting are utilized to assess cognition during a DT assessment, such as the PRT, PAT, auditory switch task and the Stroop test.^{30, 39, 42, 51} In regards to PRT, improvement was noted in this task between two DT testing sessions, when utilized with the SOT, in addition to a learning effect in the second session.³⁹ This improvement has also been supported by an improved reaction time speed during the eyes open portion of the SOT.³⁰ It is probable that these types of tasks are relatively simple in comparison to other computerized cognitive testing and thus the participants

were easily able to make improvements.³⁹ By this theory, it is possible that the SAC was too easy of a cognitive task when combined with the BESS test and thus improvements were made across the testing sessions. Stroop task performance has been shown to be not be affected by a difficult balance challenge, however this may be because the balance challenge was not difficult enough to require increased attentional demands, or that the cognitive and postural performance were independent of each other.⁵¹ The Stroop task has delayed reaction time when combined with the SOT, suggesting that the improvements in the postural task were made at the expense of the cognitive task.⁴² Auditory switch tasks have also been utilized within a DT assessment with the SOT, and delayed response times were noted in the switch trials for DT.³⁸ These differing results of the Stroop task and switch tasks may be related to the differing postural assessments used, and the threat to balance they create.⁵² The Stroop task is based on identifying errors within a color word-color font association which are likely more challenging than the SAC or PRT.^{30, 39, 42} The cognitive difficulty level, in combination with the threat level of the postural assessment, may give some explanation to the varying results of improved or worsened cognitive performance in a DT.

In the current study, BESS performance did not significantly change across the DT administrations. Previous studies have used a variety of postural assessments, including the BESS test, SOT performed on the NeuroCom Smart Balance Master, and balancing on a beam in the Romberg position.^{30, 38, 39, 42, 51} In a DT assessment, the amount of attention that the participant allocates to the postural task, and potentially prioritizes it, is dependent upon the level of threat of injury that is felt.⁵² No significant differences were found in DT BESS test scores across two testing sessions 14 days apart

with healthy subjects, yet improvements were found with the SOT with the same participants accompanied by improvements made in the cognitive task as well.³⁹ These results are similar to the current study, in which performance on the BESS failed to improve across testing sessions. Performance of the SOT has also been shown to improve or display no significant changes at the expense of cognitive functioning, when utilizing an auditory switch task, visual switch task, or Stroop test.^{30, 38, 42} The differing results of these postural stability assessments may be the result of an objective clinician score, versus the equilibrium and sway of a participant measured, as well as the level of threat of the BESS test not being high enough to require enough allocation to prioritize balance in a DT assessment.

The previous DT studies utilized healthy participants and attempted to extrapolate to a concussed population. The use of gait as the motor task is an area within DT research that has utilized concussed individuals. It has been repeatedly shown that changes in gait, specifically a conservative gait pattern, can be used to identify a concussed athlete from a healthy athlete during a DT assessment.^{7, 32, 34, 53, 54} The cognitive tasks utilized were auditory, and involved the Stroop test, reaction time, and working memory tasks.^{7, 32, 34, 53, 54} Although utilizing gait as the postural assessment tool has found consistent results with concussed individuals, this equipment is not readily available, or even plausible, for a clinician. A DT assessment needs to utilize equipment more readily available, allowing more clinicians to implement the assessment.

In past studies, the cognitive tasks are created to only last the length of time as the postural assessment. In the current study, the participant was instructed to continually answer questions, and was scored on their responses, past the time the postural

assessment was no longer graded. The participants were encouraged to maintain the balance stance through the entire time they were responding to questions, until they were told to 'stop'. Thus, the scoring of the both assessments could have helped display this increase in cognitive scores. Balance scoring was stopping at 20 seconds, or when the participant reached a maximum of 10 points per stance. Thus, the participant could have reached a maximal error score within the balance assessment, but continually answering the cognitive portion correctly. This would give the appearance of the participant displaying worsened balance, but improving their cognitive scores. This could explain the lack of the posture first principle and the practice effect that was displayed during the cognitive portion.

The posture first principle was not displayed by either group in this study in the DT assessment. Balance scores displayed no significant changes from recovery day to the 30 day follow up. The posture first principle is based upon posture, or balance, being prioritized during a DT assessment, thus it would either display improvement or no significant change.^{30, 38} A DT challenges the body to prioritize between a motor (balance) and cognitive task, and prioritization should be allotted to the task that has the highest level of threat, or injury, to the body.⁵² This portion of the principle is upheld by the lack of a significant change of the BESS scores within this study, however for posture to be prioritized, that must mean that the cognitive task receives less attention, and thus decreases in performance during a DT condition at the expense of the postural task. This did not hold true within the current study, as the cognitive aspect of the DT assessment improved over time. The level of threat that the participant feels during the postural assessment is directly related to how much allocation is placed upon the task. This

suggests that the BESS test did not require the level of attention that would be required for the balance task to be prioritized.

There were a variety of limitations in this study. It was limited by the amount of concussions that occur during the data collection time period and the investigators were able to utilize 14 of the 21 potential participants. Amongst the 7 non-recruited participants, five were excluded at the end of testing due to missing data points, one was excluded due to a lower leg injury, and another suffered a second concussion within 6 months of the first and was not tested a second time. It also was a limitation that the clinical staff at the institution administered the ST SAC and BESS to determine the recovery day for the DT administration. This was controlled for by the assumption that the clinicians are properly administering SAC and BESS according to the instructions. Video and memory card errors are a limitation to reviewing and video grading SAC and BESS. This was attempted to be controlled for having two views of each trial, thus some BESS tests were graded off the sagittal camera's view, rather than the frontal camera. This study was also limited by one athlete using incorrect footing on stances of the BESS, as well as another not using the same non-dominant leg as they used during their baseline assessment or post injury assessment. This was attempted to be controlled by always confirming what the proper stance and footing was as well and ensuring the athlete understood dominant vs non-dominant leg. One participant had their baseline BESS rescored via video mid-season, this was controlled by using the original baseline score, rather than the rescored baseline. Not all matched controls were given the same forms of SAC in order, and one participant was not completely evaluated on a section of SAC. This limitation was attempted to be controlled through each testing session by recording

the forms of SAC utilized. One participant also tested for their return to play session after the thirty day assessment, which was based upon the protocol by the institution.

Conclusion

DT testing is an emerging field for concussion related research; however, previous approaches have lacked clinical applicability. Herein, we utilized a BESS and SAC DT, two assessment tasks frequently utilized by clinicians, to assess post-concussion lingering impairments. The primary finding of this study was the absence of group differences at each of the three DT testing sessions. The secondary finding was a significant increase of SAC scores across time for both groups, whereas BESS scores displayed no significant differences. This suggests that the practice the SAC displays as a ST assessment was also evident in the DT assessment. Future research should begin to look for a cognitive and postural assessment that challenges the cognitive and postural domains, but is also plausible and feasible for a variety of clinicians implement within their concussion protocols.

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APPENDIX A
LIMITATIONS, DELIMITATIONS and ASSUMPTIONS

Limitations

This study is limited by the amount of concussions that occur during the data collection time period, as recruiting concussed participants is dependent upon the rate of injury at the institution. It is a limitation that the clinical staff administered the ST SAC and BESS. Also that the two tests may not take the same amount of time to administer when used a DT. It is a potential limitation that the practice effect of multiple administrations of SAC or BESS may be evident, depending on the quantity of times it is given to them following a concussion and previous history of concussion which was not controlled for. Video and memory card errors are a limitation to reviewing and video grading SAC and BESS. This study was also limited by the athlete using incorrect footing on stances of the BESS, as well as possibly not using the same non-dominant leg as they used during their baseline assessment or post injury assessment, and one had their baseline BESS rescored via video mid-season. Not all matched controls were given the same forms of SAC in order, and one participant was not completely evaluated on a section of SAC.

Delimitations

It is a requirement of the participants to be a Division I athlete at the selected institution, as well as to be currently on a return to play protocol as outlined by the institution.

Assumptions

It is also assumed that control participants will put forth maximal effort, as there is no return to play motivation for them. It can also be assumed that participants will be honest on their health history and demographics questionnaire, as well as on their graded symptom checklist.

APPENDIX B
LITERATURE REVIEW

Introduction

There are 1.6 to 3.8 million concussions occurring each year, and with this comes the task of diagnosing, assessing and treating this injury.¹ While many sports related injuries have a standard protocol, outlining a recovery time frame and ways to aid in recovery, this injury affects all athletes differently, and may take a variety of assessments to determine if the injury has occurred, the severity of it, and how long the recovery process may take.

When looking concussions as an overview, it is important to look at the epidemiology and symptomology of the concussion, the assessment and diagnosis of the concussion, the effects of concussion and the recovery period, as well as the dangers of repeated concussions, the long-term effects, and prevention issues, practice patterns and reporting issues.

One of the most important areas to pay close attention to regarding concussions is the initial testing and assessment. Baseline data for postural stability, as well as cognitive and neuropsychological function is collected and completed on athletes as part of a recommended multifactorial assessment.^{4, 5} Comparing post concussion data to baseline data can help to determine the greatest areas of deficit that the athlete is suffering from and also to give a general estimate of when that athlete is able to return to play. The variety of evaluations that are used in the athletic training setting involve a graded symptom checklist, assessment of the athlete's cognitive ability, neuropsychological assessment, and postural control task.⁴ While all of these areas need to be included in the

evaluation of a concussion, there are a few faults with these assessments. A graded symptom checklist can show that an athlete is asymptomatic by just circling 0's down the page. Computer neuropsych testing is effective, but an athlete's reaction time on the field is not assessed by how fast they click a mouse, but rather how fast can they decide to turn their entire body right instead of left, or simply contract a muscle. Balance testing is a great indicator of a postural stability deficit, but athletes are not static during play. Although a measure of postural stability can be assessed by analysis of a concussed individuals gait, not all sports settings are equipped with the technology to find these deficits.

The limitations of these current techniques creates a need for a new assessment that is sensitive to identifying lingering concussion impairments, is applicable to the athletic setting, and is feasible for a variety of clinicians. A new assessment that fits this criterion may be a dual-task paradigm. The dual task assessment will require the concussed athlete to balance, while testing their cognitive abilities. This task combines two areas that are already being assessed, but makes the test more applicable to what an athlete is returning to play to, having their body take on one task, while their brain must focus on another. The following is a general concussion overview and argument for the dual task paradigm.

Definition and History

A concussion is defined as a “complex pathophysiological process affecting the brain”, and is caused by biomechanical forces.⁴⁸ The pathophysiological process is defined below, as the neurometabolic cascade. The 4th International Conference on Concussion in Sport in Zurich provides four constructs to help further define concussion.

The first is that the concussion may be caused by a direct blow to the head, face or neck, but may also be caused by an indirect blow, meaning that an “impulsive” force from the rest of the body is directed towards the head.⁴⁸ The second feature is that concussions often cause a rapid onset of symptoms affecting the neurologic function, but these impairments may resolve quickly and spontaneously.⁴⁸ In some cases, symptoms may evolve and develop over a course of minutes to hours.⁴⁸ The third aspect is that neuropathological changes may occur with the concussion, but the symptoms that occur are often because of a functional change rather than a structural injury to the brain, thus not allowing changes to be seen on neuroimaging techniques.⁴⁸ Concussions also result in a wide set of graded symptoms, but do not always include loss of consciousness. The clinical and cognitive symptoms that occur typically begin to resolve, but may result in prolonged, lingering symptoms.⁴⁸ The National Athletic Trainers’ Association Position Statement as well as the Concussion (Mild Traumatic Brain Injury) and the Team Physician all have published similar definitions and key aspects of a concussion.^{55, 56}

There is a cascade of changes that begin to occur within the brain after a concussion, referred to by Giza as the neurometabolic cascade.²³ Immediately after an injury to brain, whether indirect or direct, there is a release of neurotransmitters and unchecked ionic fluxes occur triggered by neural depolarization.²³ The binding of excitatory transmitters, such as glutamate, to the receptors leads to further depolarization, involving an efflux of potassium and an influx of calcium, leading to a variety of changes. To begin to resolve this, the sodium-potassium pump works overtime, requiring a greater amount of adenosine triphosphate (ATP), triggering a stage of “hypermetabolism”, occurring simultaneously as a decrease in cerebral blood flow. There

is then an imbalance between the supply and demand of glucose and energy, which then creates a cellular energy crisis in the brain. It has been speculated that this hypermetabolism and resulting energy crisis leads to the possibility of the brain being more vulnerable to a second injury and second impact syndrome.²³ This period of increased glucose utilization occurs at the same time as a period of depressed metabolism. The energy crisis occurs due to calcium impairing mitochondrial oxidative metabolism, and activating pathways that lead to cell death. This calcium influx tends to peak around 2 days, and resolves around 4 days.²³

Reporting on the concussions has begun to increase over the last several years, but the acknowledgement of brain injuries has been around for centuries. Within the time of Antiquity to the 10th century, the term concussion was noted in myth and legend, although no medical accounts other than elementary grasps of head injuries were found. The literature from this time period showed that people did not acknowledge the difference from a mild to a severe traumatic brain injury. Hippocrates noted symptoms of a cerebral concussion to be that the patient becomes speechless, falls down immediately, loses their speech, cannot see and hear.⁵⁷ Within the 10-17th century, a turning point occurred and Rhazes, a Muslim physician, began to use the term *concussion* in its modern sense. In medieval medicine, it was being taught that symptoms after a concussion could rapidly disappear, and were the result of a transient paralysis of cerebral function. The “learned Doctor Read” also helped to create the 6 clinical stages of concussion, to be summarized as 1. A ringing in the ears, 2. Falling after the blow, 3. Swooning for a time, 4. Slumbering after the wound, 5. dazzling of the eyes, and 6. a giddiness which passes rapidly.⁵⁷

Within the 17th-19th centuries, the idea that a concussion was a transient phenomenon began to be turned away from, and replaced with the idea that it was a neuropathologic change. A new view was that a concussion was not a structural brain injury.⁵⁷ Within the 1700's to present, theories and hypothesis began to be developed speculating on what was occurring within the body after a head injury. There is a hypothesis of brain commotion, circulatory failure, acute compressive anemia, molecular vibration and “spinal concussion”, nerve shell shock, structural brain injury, and transient disruption of function. From the 20th century and beyond, it has been established that the features of a concussion involve a functional neuronal disturbance, although the argument still continues if it is a transient versus permanent disturbance.⁵⁷ However, with some concussions, there is a loss of brain cells, as some are irreversibly destroyed.⁵⁸ The cells which remain alive are now reported to be in a vulnerable state due to the metabolic dysfunction occurring in the neurometabolic cascade.⁵⁸

Epidemiology and Symptomology

It has been estimated that 1.6 to 3.8 million sports-related traumatic brain injuries (TBI) occur each year.¹ This estimation may be dramatically low due to potentially over 50% of concussions going unrecognized or unreported.² It has been reported sports are the second leading cause of traumatic brain injury to people ages 15-24, second only to motor vehicle accidents.⁵⁹ It was estimated that within the 2005-2006 academic school year, there were 57,216 high school football concussions.⁶⁰ From data collected in 1995-1997, it is estimated that 62,816 concussion cases occur each year, with football as the cause for the majority of them.⁶¹

For overall football, Guskiewicz reports that there is an overall rate of concussion per exposure of 0.70, and a rate of 1.28 per 100 contact exposures.⁶² The overall injury rate was 5.1%.⁶² Specifically for collegiate football, there is a rate of 0.81.²⁴ For high school athletics, there is a concussion rate of 0.64 for football, 0.54 for boy's hockey, 0.40 for boy's lacrosse, 0.34 for girl's soccer, 0.35 for girl's lacrosse and 0.21 for girl's basketball.⁶³

There has been a common trend over a variety of studies reporting on the symptoms most experienced by injured athletes. Guskiewicz reported headache as the top symptom, with 86% of injured athletes experiencing it, followed by dizziness affecting 67%, and confusion reported by 59%.⁶² Maddocks reported that 93% of athletes reported headache, 64% reported dizziness, and 75% reported blurred vision.⁶⁴ Erlanger stated that 93.6% of athletes reported a headache, 85.1% reported dizziness, and 83% reported confusion/disorientation.⁶⁵ Loss of consciousness (LOC) is also reported, although not as commonly as these other symptoms. The rate for LOC has been reported to be 8.9%, 7.69% and 6.4%.^{3, 50, 62} There are also reported rates for post traumatic amnesia (PTA), as 27.7%, 15.6%, 19.1%.^{3, 50, 62}

Assessment and Diagnosis

Most recently, in 2012 Register-Mihalik acknowledged the need for a multidimensional concussion assessment battery for assessing acute concussions, including areas of symptom checklists, neurocognitive examinations, and balance measures.⁵ It is important to continually look at all areas of the assessment, and realize

that although a neuropsychological exam may have the highest sensitivity when standing alone, it is not a stand-alone exam.^{4,5}

The process of diagnosing and assessing a concussion has changed throughout the years, from ‘Maddock’s questions’ in 1985 asking questions regarding name, date of birth, age and orientation of the athlete, to involving that in an extensive concussion assessment battery as described by Register-Mihalik.^{5,64} Maddocks acknowledges that concussive injuries may not always be accompanied by loss of consciousness, in which case another assessment must occur to determine if the athlete has a concussion. The next ‘objective’ measure to assess the athlete is post-traumatic amnesia. This involves asking the athlete questions to time, person and place, to determine their level of orientation. These questions may be applicable for an athlete who has a much more obvious or severe concussion, but a more sensitive assessment needed to be created to help diagnose those athletes who have a mild concussion.⁶⁴ Maddocks acknowledges the need to create a more extensive concussion assessment, with orientation questions being just a part of it. It is suggested to include an assessment of symptoms, new learning skills, and a formal neuropsychological assessment.⁶⁴

One of the most comparable portions of an assessment battery to Maddock’s questions is the Standardized Assessment of Concussion (SAC). It was developed to help clinicians identify concussions on the sideline during a competition or practice when an evaluation in the athletic training room was not an immediate option.⁵⁰ Mean SAC total score for all injured subjects immediately after injury was 4.2 points less than the mean score for the larger population of participants who underwent pre-season baseline testing at the start of the study.⁵⁰ However, the SAC examination does demonstrate a practice

effect, as scores that were initially below baseline immediately after injury rise above the baseline 48 hours after injury with repeat administration.⁵⁰ The SAC has a sensitivity of 0.80 at the time of injury, but decreases to 0.65 even at a post game assessment.⁷ This test is often administered throughout the recovery of an athlete, however by day 7, the sensitivity of this assessment is 0.14.⁷ If a test is not sensitive enough to detect lingering impairments from a concussion, further research and improvements must be made to the overall assessment.

Another portion of the multidimensional approach is the postural assessment. Many studies utilize the Sensory Organization Test, in which the test systematically ‘removes’ one of the senses of the body.⁶⁶ The available somatosensory and/or visual information is altered while the balance, via postural sway is measured.¹⁷ Although this test can help to measure postural sway, it is costly, and not all clinicians have access to this technology, and is impractical as a sideline assessment for an immediate injury. A more feasible and available postural control assessment is the Balance Error Scoring System, (BESS). The availability of a firm surface and a foam pad, with testing that takes under 5 minutes is more clinically applicable than utilizing the SOT. The sensitivity has been reported to be 0.34 at the time of injury, but decreases to 0.07 seven days post injury.⁷ The BESS test has been studied by a variety of researchers, with many having suggestions as to how to increase the reliability and sensitivity of the test. From Hunt, it is reported that excluding double leg firm and foam from the BESS test may help to produce more reliable results, as well as increasing the number of trials completed in each testing position.¹² However, there is a reported practice effect, so increasing trials may start to negatively affect the examination.⁹ Finnoff reported on the intrarater and

interrater reliabilities of the BESS test, reporting 0.74 for intrarater and 0.57 for interrater.¹¹ The reliabilities that Finnoff reported are inadequately low, as they are not as high as reliabilities that have been reported on in the past.^{11, 14} It is noted that the reliability for intrarater is higher than interrater.¹¹ Improvements for the BESS test from this study include eliminating the more subjective errors, so that reliability may be higher between testers. Although the intrarater reliabilities are higher, it is not always realistic that the same clinician who completes the baseline testing will be the same clinician that tests an athlete after an injury.

Neurocognitive testing has begun gaining popularity as part of the multidimensional concussion assessment, as it increases the sensitivity of the entire assessment. Broglio reports that a measure in any single domain is less than 70% sensitive to concussion, requiring a more multidimensional approach to assess concussions.⁴ When comparing portions of the assessment with the entire assessment, it is shown that the sensitivity of the entire battery increases as more tests are added. When looking at ImPACT combined with postural control (measured on SOT) and a self-reported symptom inventory, the total assessment sensitivity increases to 91.7% for identifying a concussion.⁴ Although the ImPACT test reported the highest sensitivity to concussion compared to HeadMinder CRI and a written neurocognitive exam, it is important to remember that this specific test, and neurocognitive tests in general, are not a 'gold standard' for identifying concussion, and should always be included within the assessment, not considered the only part.^{4, 5}

Another aspect of the diagnosis and assessment of a concussion that should not be ignored, is the clinical exam completed by the athletic trainer and physician. Although

extensive and sensitive testing has been created, it should never replace the clinical opinion and evaluation of a health care professional.⁵ Sideline evaluations can be completed by an athletic trainer, with a further clinical evaluation taking place in a medical office or even the emergency room. When a clinical evaluation takes place, it should include many aspects, such as a comprehensive history and detailed neurological examination, a determination of the clinical status of a patient, possibly involving gathering information from parents, coaches, teammates and eyewitnesses, as well as ruling out the need for neuroimaging to rule out a more severe brain injury.⁵⁷

Often times, after the concussion is assessed and diagnosed, the topic of grading the concussion comes up. There are three common approaches to grading a concussion.⁵⁵ Grading may be based on the signs and symptoms present at the initial time of injury assessment, and within 15 minutes after injury.⁵⁵ These grading guidelines most closely follow the American Academy of Neurology Concussion Grading Scale. The AAN grading scale classifies a grade 1 concussion as one that results in ‘transient confusion, no LOC, and symptoms and mental status abnormalities resolving in 15 minutes. Grade 2 is classified as one that results in transient confusion, no LOC, and symptoms and abnormalities lasting longer than 15 minutes. The last, Grade 3, occurs only with LOC. AAN guidelines are still often used as part of the assessment, however, Erlanger reported that the “AAN guidelines appear to be weak in predicting the severity of injury, as measured by the number or duration of symptoms”.⁶⁵ Although this approach immediately allows an athlete, coach and parent to know the potential severity of the concussion, injuries often change and are more prolonged than what was initially thought, which may cause problems if the concussion becomes more severe.⁵⁵

The second approach to grading concussions involves grading based on the presence of and duration of symptoms.⁵⁵ This grading guidelines is most closely related to the Cantu Evidence-Based Grading Scale. Cantu's scale requires the injury to be graded only after all the signs and symptoms have resolved, and the athlete is back to baseline. Cantu removes emphasis on LOC, and places more emphasis on prolonged symptoms. Cantu's scale is as follows: Grade 1: No LOC, with post traumatic amnesia (PTA) lasting less than 30 minutes, and post concussive signs and symptoms (PCSS) lasting less than 24 hours; Grade 2: LOC lasting less than 1 minute, or PTA lasting less than 30 minutes but less than 24 hours, and PCSS lasting longer than 24 hours, but less than 7 days; and Grade 3: LOC lasts longer than 1 minute, or PTA lasting longer than 24 hours, or PCSS lasting longer than 7 days.⁵⁸ Cantu reports that symptoms and duration should be the basis for a grading scale, with the duration of amnesia also utilized.⁵⁸

A third approach to grading a concussion is to not use a scale at all. This approach recommends focusing on the recovery of the athlete, via monitoring their symptoms, neuropsychological tests and postural-stability tests.⁵⁵ If the athletic trainer chooses to follow this, they place more focus on the athlete being symptomatic or asymptomatic. Once the athlete is asymptomatic, a progression to return to play is established and began.⁵⁵

As Cantu's revised scale indicates, there is a trend to avoid placing emphasis on loss of consciousness, and rather focus on the other signs and symptoms that the athlete is demonstrating. Past studies have shown that LOC is not as strong as an indicator as PTA is, with LOC having a rate of 8.9% and amnesia having a rate of 27%.⁶² Less emphasis should be placed on LOC as an indicator of a concussion within the grading scales.

Athletes who experience post-traumatic amnesia and retrograde amnesia are 4.2 and 10 times, respectively, more likely to be placed in a poor, prolonged recovery presentation group.⁶⁷ As Cantu states, it is illogical to grade a concussion as less severe when it causes symptoms that last months or years, than a concussion that is accompanied by brief unconsciousness and symptoms that resolve in minutes.⁵⁸

Immediate Effects, Recovery Period and Return to Play

As stated above, the athlete may experience a variety of signs and symptoms after the concussion, which many parts of the post-concussion assessment aim to target. This includes the somatic symptoms, such as a headache, cognitive such as difficulty concentrating and emotional symptoms. The athlete may also be experiencing physical signs such as loss of consciousness, amnesia, as well as behavioral changes and cognitive impairment. The athlete may show effects such as abnormal balance or postural stability, or sleep disturbances.⁴⁸

It has been reported that in regards to return to play of an athlete who has suffered a concussion, it has been stated that an athlete who is still suffering from postconcussion symptoms at both rest and exertion should not return to contact or collision sports.⁵⁸ It has been suggested that athletes should wait at least a 7-10 day period before returning to play, which can eliminate many of the reoccurring concussions.⁵⁵ This aligns with the reported typical recovery time of 5-7 days.¹¹ Symptoms are reported to clear in 3-5 days, but may take as long as day 7 to resolve.^{68, 69} Balance begins to return to baseline around days 3-5, and neuropsychological testing returns between days 2-7.^{3, 17} However, 10-15% of concussions will have persistent symptoms, which will last longer than 10 days from the time of injury.⁴⁸ Of football athletes who sustained a concussion, 10% took longer

than a week to fully recover.³ The basis behind this suggestion goes back to the neurometabolic cascade that begins in the brain immediately after injury, as the vulnerable stage that the brain is in begins to resolve around day 7.²³ Withholding an athlete during this vulnerable stage that occurs after a concussion can help eliminate repeat injuries to the head, including second concussions and second impact syndrome.

When the athlete is reporting in asymptomatic, a progressive return to play protocol should be started, as outlined by the 4th Consensus statement on concussion in sport.⁴⁸ It should progress from no activity, to light activity, sport specific drills, non contact and finally full-contact practice, all with the athlete remaining asymptomatic with exertion and rest.⁴⁸ As the NATA Position Statement: Management of Sport-Related Concussion, many programs are now requiring a 7 day period of the athlete reporting in asymptomatic before allowing return to play.⁵⁵ Athletes should not be allowed to return to play on the same day as the concussive injury, which may lead to repeat concussion and prolonged effects.⁴⁸

Repeated Concussions and Long-term Effects

Concussions can cause a wide range of immediate symptoms, but it also affects the athlete in the long term, especially with repeat concussions. It was found in 2000, that with a football player who sustains a concussion, he is three times more likely to sustain a second concussion within the same season.⁶² The relative risk for an athlete to sustain a concussion who already had a history of concussion is 5.8 times greater than an athlete with no history of concussion.⁷⁰ Athletes who sustain a concussion are also subject to Postconcussion Syndrome, defined as concussive symptoms lasting longer than 3 months.⁵⁶ Postconcussion syndrome may be an indicator for concussion severity, and also

increases the chances of that athlete developing depression.⁵⁶ Another risk that accompanies repeat concussion is second impact syndrome. This occurs within minutes of the second concussion occurring, and is a result of the athlete still being symptomatic from the first concussion.⁵⁶ Second impact syndrome is a result of the vascular enlargement that leads to an 50% increase in intracranial pressure and brain herniation, which then causes severe brain damage and death.⁵⁶ Another result of multiple concussions is chronic traumatic encephalopathy, a progressive neurodegenerative disease, caused by total brain trauma.^{56, 71} Emerging evidence is showing that repetitive head trauma that occurs in collision sports may be related to the development of a motor neuron disease.⁷¹ This disease however is not limited to those athletes who suffer concussions, and is only diagnosed after death, as the signs and symptoms do not normally start appearing until 40-50 years after the trauma.⁵⁶ The signs and symptoms include a decline of recent memory and executive function, mood and behavioral disturbances such as depression, impulsivity, aggressiveness, anger, suicidal behavior, and eventually progressing towards dementia.⁵⁶

It has been reported that having with having a moderate to severe TBI, within 1-3 years after suffering it, that person is 1.8 times more likely to report binge drinking, 11 times more likely to develop epilepsy, and 7.5 times more likely to die.¹ The person who has a TBI is also 1.5 times increased risk of developing depression, and 2.3-4.5 times more likely to develop Alzheimer's.¹

Prevention Issues, Practice Problems, and Reporting Issues

As concussions are affecting a great amount of athletes each year, the topic of how to prevent the concussions from occurring initially keeps arising. A study in 2006

compared the new Riddell Revolution helmet with a standard type helmet.⁷² Although the Revolution helmets displayed a lower rate and greater decreased relative risk, it is important to note that the helmet may reduce the risk of sustaining a concussion, but does not prevent it.⁷²

The medical and athletics field as a whole is becoming more aware of concussions and their long-term effects, and is aided by the publication of consensus and position statements regarding the proper care of a concussed athlete. The National Athletic Trainers' Association published a position statement in 2004, but only 3% of athletic trainers were utilizing the statement.⁷³ It is highly suggested that a management protocol is created for each setting and clinical setting, as to avoid rushed decisions that could potentially place the athlete's life in danger.⁷⁴ The use of a management and progressive return to play protocol for concussion resolution is supported by the 4th International Consensus statement.⁴⁸

Reporting issues affect athletes regarding concussions, like any other injury. Injury means not participating. In the case of concussion though, reporting issues are taken very seriously, due to the range of symptoms, syndromes and long-term effects sustaining concussions can have on the body. As was mentioned above, the effects of concussions can directly affect the athlete's current life, but also 40-50 years from injury, when the athlete may no longer be thinking of what happened during high school football. As McCrea reports, over half of high school football concussions go unreported, which could have lasting effects, after high school football is over.²

Dual- Task- Testing Balance and Cognition Together

The current concussion assessment is to test cognition, balance, symptoms and neuropsychological functioning of the athlete all independently of each other. These domains may be affected by the concussion independently of each other, but the testing of two domains simultaneously may help clinicians.⁷⁵ The sensitivity of the concussion battery continues to improve as more single task assessments are added, the question arises about completing dual-task testing. If the concussion battery is to assess the initial injury, but also to help make return to play decisions, then the return to play criteria testing should closely resemble the return. Broglio states, there is a simultaneous involvement of the cognitive, sensory and motor processing systems of the body during sport participation.³⁰ An athlete is never just concentrating on reaction time in a game without having a motor control action occurring at the same time. Likewise, an athlete is never static standing in the game without having to concentrate on another task at the same time. If return to play guidelines are to resemble the setting the athlete is returning to, then the area of a dual-task testing is the next direction the concussion assessment needs to head towards.

There are two theories about dual-task, and how the body chooses which task to apply more focus to. As Frazier states, there is the capacity theory and the bottleneck theory.²² The capacity theory views a dual-task situation as a limited set of general purpose resources, and when a the demands exceed this limit, a decrease in performance on one task or both tasks is seen.²² The bottleneck theory emphasizes a sequential way of organizing a dual task, and the body “postpones” one task to focus on the other.²² The bottleneck theory is a way of the body prioritizing tasks.

A paradigm needs to be created that simultaneously tests different areas of function, in a way that it accurately represents real sport scenarios.^{30, 42} Although not completely copying sport specific activities, having an athlete balance while testing their neurocognitive abilities may be more applicable to a sport situation than having them sitting in a chair, with their only focus being repeating a string of numbers backwards. Balancing while testing challenges the athlete more than just clicking a mouse to test reaction time, and causes the athlete to stand up right to be tested. With the concerns that surround returning to play too early, long term effects of concussion, and proper assessment of a concussion, then the ability to dual task test athletes should be available at every setting. If returning to play too early is a concern, then more all-encompassing ways of testing the athlete before allowing them to be full go is necessary. Further testing an athlete to reach a baseline in a dual task test creates even more of a conservative approach to concussions and the progressive return to play. More sensitive assessments will only help to solidify the return to play decision made by any clinician that their athlete is back to their baseline and ready to return.

There are a few researchers who have begun to research dual task testing, trying to determine the best equipment to obtain the most reliable and sensitive answers, and properly assess the concussion. A common choice for dual task equipment is to measure balance assessment and postural sway utilizing the SOT, or gait, or force plates, and to measure cognition using the Stroop exam, procedural auditory and visual task.^{38, 39, 42} Alternative approaches to using the SOT are being utilized, such as using the balance portion of the SOT along with a cognitive task given verbally or visually while balancing.^{30, 39} Although there are some clinicians who are already researching these

dual-task tests, such as Teel who looks at the SOT and Stroop Test, a dual-task test needs to be created that is easily accessible to a wide variety of clinicians.⁴² The problem that many dual-task paradigms create, is that not every clinician has access to an expensive equipment to assess the balance of every concussed individual, leaving some individuals unable to dual-task test their athletes.

Within Teel's study, the SOT and incongruent Stroop test were assessed as moderate to high level of reliability.⁴² Luke Ross utilizes another dual-task test that was created for athletes and diagnosing concussion. The Procedural Reaction Time and Auditory Task is used with the SOT and BESS, and is reported that BESS was more of a reliable and functional tool in the dual-task conditions.³⁹ Balance deficits have been revealed with a dual task assessment in concussed individuals.³⁹

Utilizing the BESS test for a dual task assessment is feasible and applicable for a variety of clinicians and easily identifies postconcussion deficits, as Guskiewicz states.¹⁸ A medium density foam pad is a very easily obtained piece of equipment, as many schools are not fortunate enough to have a biomechanics laboratory within their facilities to be able to measure differences using a gait analysis system, force plates or the SOT system. In a comparison study between BESS and SOT, Ross recommends the use of BESS in a dual task assessment for a variety of reasons. BESS is more readily available to clinicians, more cost effective, as well as takes less time to administer, may be more applicable to the sport setting than SOT.³⁹ BESS has the potential to be a more sensitive test for concussion than administering the same tests as single tasks.³⁹ All athletic trainers should have the opportunity to dual task test their athletes, and if a test is to be created, it should be applicable across many clinical settings.

As for the cognitive aspect of dual task testing, the SAC test should be utilized. It is easy to administer, clearly demonstrates deficits up to 48 hours after injury, and is very accessible by athletic trainers.⁵⁰ The Stroop task, auditory switch task or reaction time testing all involve the need for a computer set up and possibly screens for words to be projected on. The clinicians will then need to be trained in the administration of these examinations, whereas learning to administer the SAC takes a few seconds.

Recent literature has emphasized the need for a multidimensional approach, and this approach should include a dual-task concussion assessment. This would require the athlete to balance, while testing their cognitive skills. Concussion assessments are utilized to ensure that the athlete is ready to return to 100% of participation, and to do this, they must resemble the situations the athlete will encounter in their respective sport. This combines tests and makes them more closely related to what an athlete is return to play to, having their body take on one task, while their brain must focus on another. Residual deficits of balance have been detected when a concussed participant is required to focus on a demanding visual scene.^{18, 40}

Baseline data is key in the diagnosis and assessment of sports related concussions. Baseline data helps to create a time frame for the athlete, and to know what their 'norm' is that they must be back to before full participation is an option for them. The graded symptom checklist, multiple assessments of the athlete's neurocognitive ability, and a type of postural control and stability all test different aspects of the body and brain. Some tests rely on the athlete to be truthful in their self-report, such as the symptom checklist, but others such as the postural assessment, is a test graded by the clinician. It is important

that the assessment of an athlete's concussion includes a self-report from the athlete, while still having an objective assessment of the athlete.

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APPENDIX C
FIGURES AND TABLES

Group	Gender	Age (y/o)	Height (cm)	Mass (kg)	Concussion History
Concussed n=14	9 females	19.00±0.88	174.53±12.06	75.28±22.02	5 previous concussions
Healthy n=14	9 females	19.36±1.34	171.45±11.69	73.34±22.7	4 previous concussions

Table 1. Demographics of Participants- There were no significant differences between groups for any variables.

Group	PPE to Injury	PPE to REC	Injury to REC	Injury to RTP	Injury to D30	REC to RTP	RTP to D30	Total DT Testing Time
Concussed n=14	363.57±354.23	371.5±363.16	7.93±5.00	18.14±8.23	30.21±0.80	10.21±6.57	12.07±7.90	22.29±5.22
Healthy n=14	x	430.5±346.44	x	x	x	10.79±5.74	12.0±7.27	22.79±5.58

Table 2. Testing Timeline- There were no significant differences between groups for any variables.



CONSENT TO ACT AS A SUBJECT IN AN EXPERIMENTAL STUDY

1. Title of Project: The Effectiveness of a Dual Task Concussion Assessment for Identifying Impairments in a Concussed Population

Investigator's Name: Kristin Bockelman, ATC, LAT Phone: (989) 329 - 1148

Participant's Name _____ Date: _____

Data Collection Location: Biomechanics Laboratory, Georgia Southern University Campus

2. We are attempting to determine the influence of adding a cognitive task to a commonly used balance test. There will be approximately 200 subjects in this study. The results of this study may assist health care providers in tracking recovery from a concussion.
3. If you agree to participate in this study, you will be asked to perform one trial of the Balance Error Scoring System (BESS) test and one trial of the Standard Assessment of Concussion (SAC) individually and one trial combined. The BESS is a brief balance test which involves standing on two legs, a single leg, and tandem on either a firm or foam surface. The SAC is a brief cognitive test which involves orientation and memory type questions. Finally, you will be asked to complete a questionnaire on your sports injury history.
4. There is minimal risk associated with participating in this study. You could fall and injure yourself during the balance test and you could experience embarrassment during the cognitive test. You understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. You also understand that you are not waiving any rights that you may have against the University for injury resulting from negligence of the University or investigators. Should medical care be required, you may contact Health Services at (912) 478 – 5641.
5. You will likely receive no direct benefit for participating in this study, however you will be provided your results, if you so request. The results of this study may be used to better treat individuals who have suffered concussions.
6. You will attend three testing sessions lasting less than 30 minutes each. You will be videotaped and all recordings will remain on a password protected computer and stored for the duration of the study and at least 7 years as required by the Board of Regents.
7. You understand that all data concerning yourself will be kept confidential and available only upon written request to Kristin Bockelman. You understand that any information about you records will be handled in a confidential (private) manner consistent with medical records.
8. If you have any questions about this research project, you may call Kristin Bockelman at (989) 329-1148 or email (kb05910@Georgiasouthern.edu) or her advisor, Thomas Buckley at (912) 478-5268 or email (TBuckley@Georgiasouthern.edu). If you have any questions or concerns about your rights as a research participant in this study it should be directed to the IRB Coordinator at the Office of Research Services and Sponsored Programs at (912) 478-0843 or by email at: IRB@georgiasouthern.edu.

9. You will not receive compensation for your participation in this project. You will be responsible for no additional costs for your participation in this project.
10. You understand that you do not have to participate in this project and your decision to participate is purely voluntary. At any time you can choose to end your participation by telling the primary investigator, Kristin Bockelman or any other of the investigators.
11. You understand that you may terminate participation in this study at anytime without prejudice to future care or any possible reimbursement of expenses, compensation, employment status, or course grade, and that owing to the scientific nature of the study, the investigator may in his/her absolute discretion terminate the procedures and/or investigation at any time.
12. You understand there is no deception involved in this project.
13. You certify you are 18 years of age or older and you have read the preceding information, or it has been read to you, and understand its contents. Any questions you have pertaining to the research have been, and will continue to be, answered by the investigators listed at the beginning of this consent form or at the phone numbers given (989) 329-1148.
14. You will be given a copy of this consent form to keep for your records. This project has been reviewed and approved by the GSU Institutional Review Board under tracking number H14027.

Title of Project: The Effectiveness of a Dual Task Concussion Assessment for Identifying Impairments in a Concussed Population

Principal Investigator

Kristin Bockelman, ATC, LAT
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Other Investigator

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Other Investigator

Eric Shiflett
 (740)703-9058
 es03435@georgiasouthern.edu

 Participant Signature

 Date

I, the undersigned, verify that the above informed consent procedure has been followed

 Investigator Signature

 Date

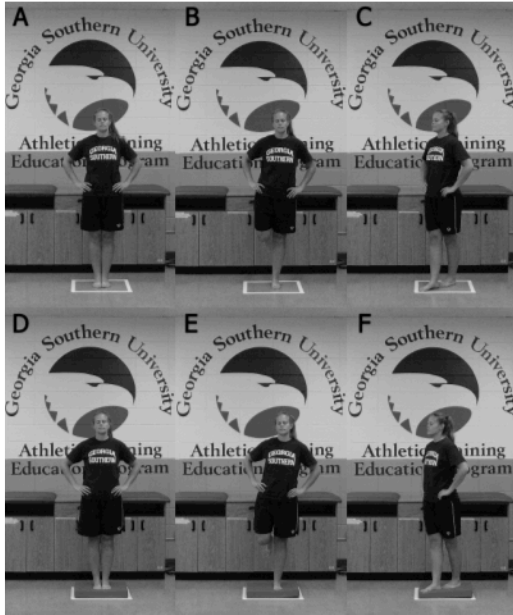
Figure 1. Informed Consent

Balance Error Scoring System Baseline Test

Subject ID: _____ Date: _____

Examiner's Name: _____ Time: _____

Foot Tested: Left _____ Right _____



Video Reviewer Name: _____

Date: _____

Live Scoring		
	Firm Surface	Foam Surface
Double Limb		
Single Limb		
Tandem Stance		
Totals		
BESS TOTAL		

Video Scoring		
	Firm Surface	Foam Surface
Double Limb		
Single Limb		
Tandem Stance		
Totals		
BESS TOTAL		

Figure 3. Error Scoring System (BESS) Score Sheet

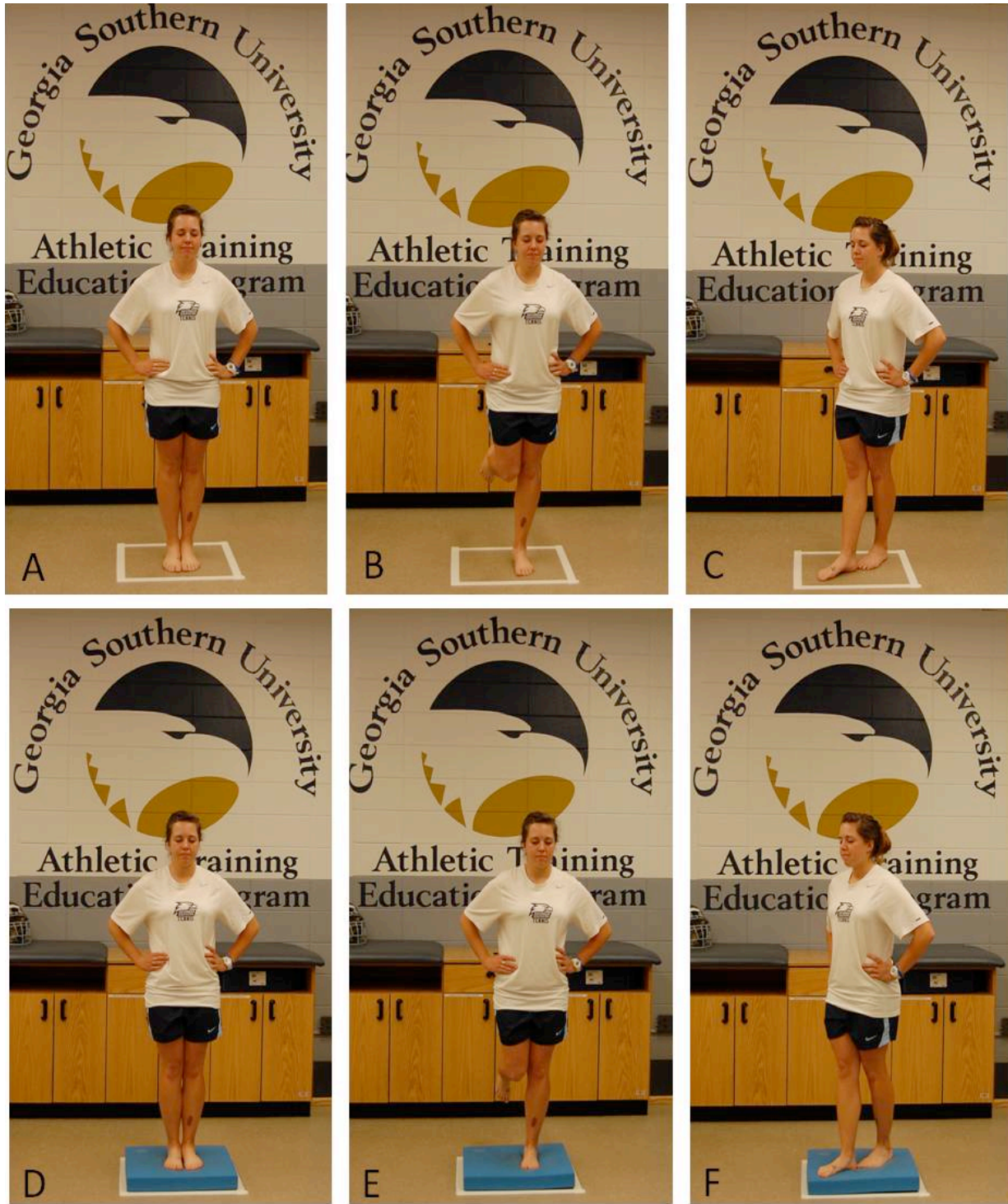


Figure 4. Demonstration of the BESS. A) Double leg firm, B) Single leg firm, C) Tandem firm, D) Double leg foam, E) Single leg foam, F) Tandem foam

Participant
Number: _____

The Effectiveness of a Dual Task Concussion Assessment for Identifying Impairments in a Concussed Population

Health History and Demographics Questionnaire

Age: _____ Gender: M F Sport _____

Height _____ cm Weight _____ kg

Date of most recent concussion (if applicable): _____

Currently on Concussion Return to Play protocol: Circle One: YES NO

History of Concussion: (Please list month and year) _____

History of Lower Extremity Injury (Please list month and year) _____

History of Neurological, Vestibular or Visual Deficits

Please list all medications currently taking

Figure 5. Health History and Demographics Questionnaire

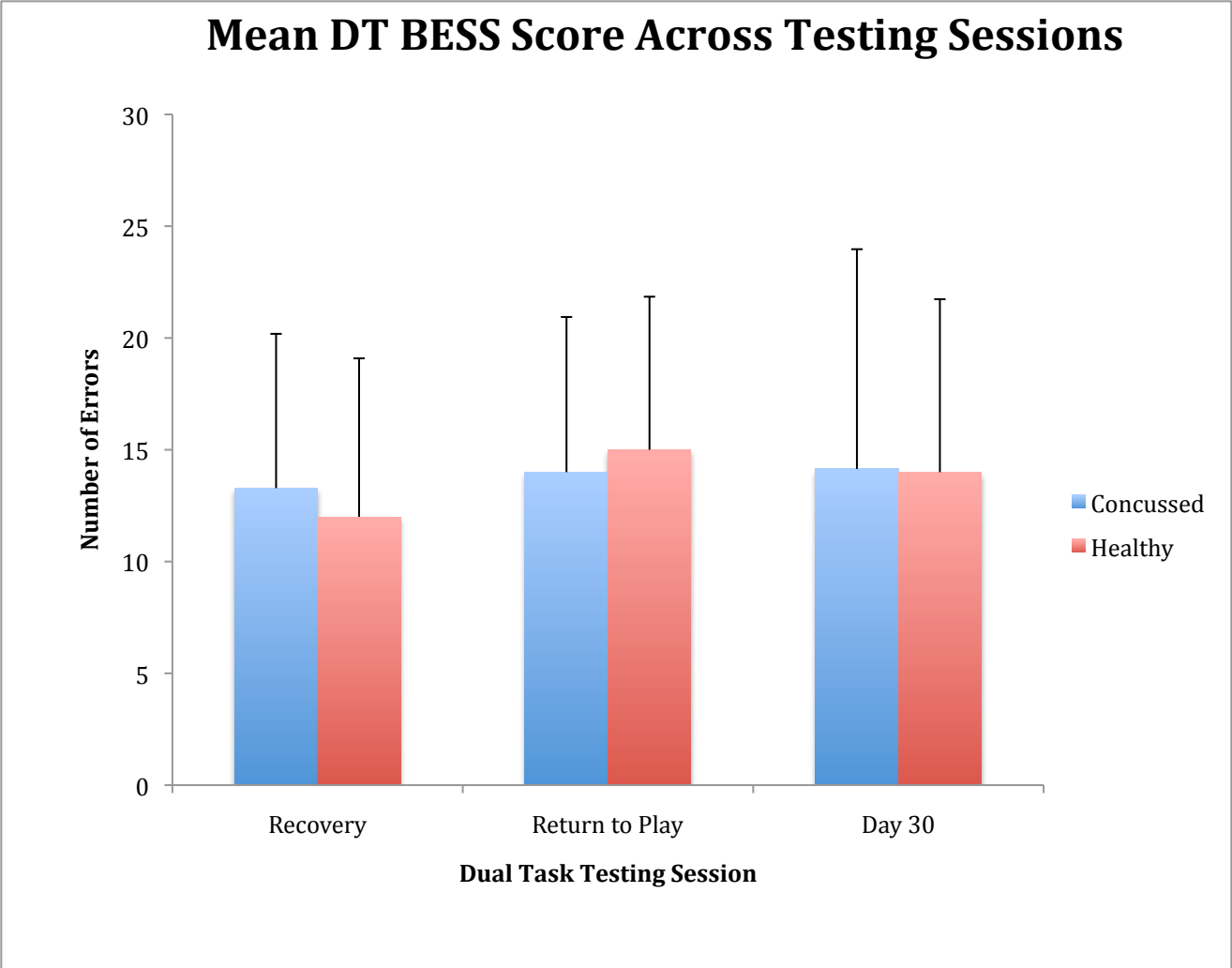


Figure 6. Mean BESS Scores Across Testing Sessions- No significant interaction found between group and session, no main effect found for group or session.

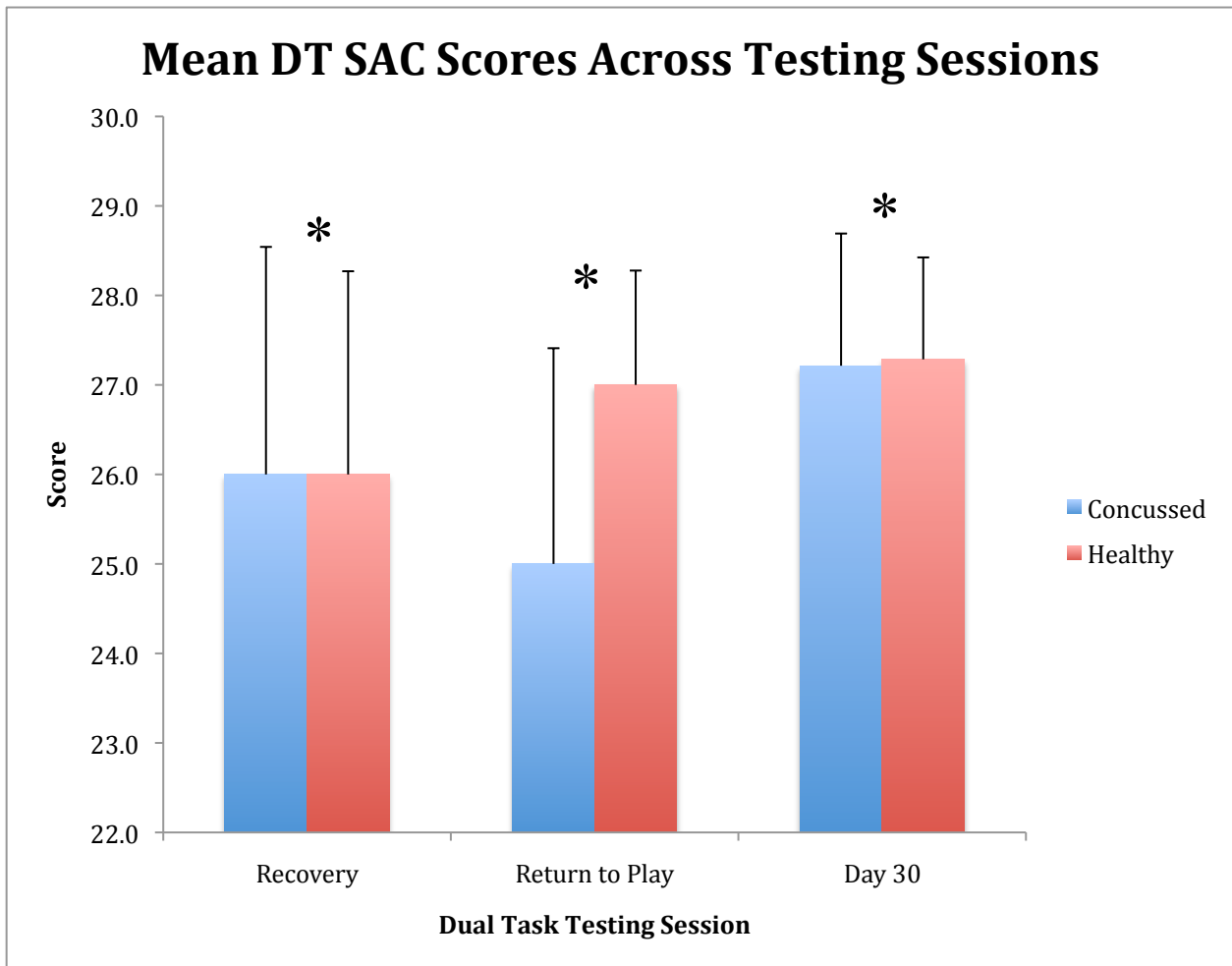


Figure 7. Mean SAC Scores Across Testing Sessions- No significant interaction found between group and session, no main effect found for group. *There was a significant main effect found for session, $p = .03$. There was significant differences between recovery day and day 30, $p = .01$ and between return to play day and day 30, $p = .04$.

APPENDIX D
NIH, CITI AND IRB FORMS

GEORGIA SOUTHERN UNIVERSITY INSTITUTIONAL REVIEW BOARD

INSTRUCTIONS FOR PREPARATION OF PROPOSAL NARRATIVE

Instructions: *Please respond to the following as clearly as possible. The Narrative should include a step by step plan of how you will obtain your subjects, conduct the research and analyze the data. Make sure the narrative clearly explains aspects of the methodology that provide protections for your human subjects. Your narrative should be read and understood by a general audience who does not have prior knowledge of your research and by committee members who may not be expert in your specific field of research. Your reviewers will only have the information you provide in your application. Explain any technical terms, jargon or acronyms. The narrative is a part of the complete application.*

The application may be submitted electronically at irb@georgiasouthern.edu (email attachment) or sent to the Office of Research Services and Sponsored Programs, at P. O. Box 8005, Statesboro, GA 30460, fax (912) 478-071.

Personnel. *Please list any individuals who will be participating in the research. Also please detail the experience, level of involvement in the process and the access to information that each may have.*

Kristin Bockelman, B.S., ATC, LAT
Thomas Buckley, Ed.D., ATC
Barry Munkasy, Ph.D.
Jody Langdon, Ph.D.
Kelsey Evans
Eric Shiflett

Kristin Bockelman will have primary responsibility for project design and interpretation of the data and will assist the other members of the research team with subject recruitment, data collection, and data analysis. Dr. Buckley and Dr. Munkasy will assist with project design and data interpretation and assist with subject recruitment, data collection, and data analysis. Dr. Langdon will primarily be responsible for data analysis. All five members of the research team will have access to all participant information and the NIH and CITI/HIPS training forms are attached.

Purpose. *1. Briefly describe in one or two sentences the purpose of your research. 2. What questions are you trying to answer in this experiment? Please include your hypothesis in this section. The jurisdiction of the IRB requires that we ensure the appropriateness of research. It is unethical to put participants at risk without the possibility of sound scientific result. For this reason, you should be very clear about how participants and others will benefit from knowledge gained in this project.*

The purpose of the study is to assess the feasibility of performing dual task (cognitive and motor) testing in healthy young adults and concussed young adults for the potential future application to post-concussion assessment. Specifically, we aim to investigate the effect of dual-task testing on performance of both the motor and cognitive tasks, in comparison to the effect of single task testing on performance. Secondly, we aim to ascertain if two investigators can perform the dual-task assessment while accurately scoring the assessment. We hypothesize that the addition of a secondary task will impair performance of both the cognitive and motor task at an initial testing date, a recovery test, and 30 day follow up test. We hypothesize two clinicians can accurately assess the test in real-time. There are no direct benefits to the participants in the study, but the results of this study may help develop an assessment more sensitive to tracking concussion recovery. Accurate assessment of concussion recovery may prevent premature return to play following a concussion, reducing the risk of further injury. The results of this study will also lead to a dual task assessment that utilizes tools that many clinicians have readily available.

Literature Review. *Provide a brief description of how this study fits into the current literature. Have the research procedures been used before? How were similar risks controlled for and documented in the literature? Have your instruments been validated with this audience? Include citations in the description.*

There are an estimated 1.6 – 3.8 million concussions which occur annually in the United States; however, this number likely underestimates the actual incidence rate as some evidence suggests that 50% of concussions may go unreported. (Langlois et al, 2006; McCrea et al, 2003). Accurate concussion assessment is imperative to minimize the risk of the fatal, but rate, second impact syndrome which occurs when a second concussion occurs prior to the resolution of the first concussion. (Cantu, 1998). Further, once an individual suffers one concussion, they are more likely to suffer a second concussion and over 90% of repeat concussions occur within the first 7 – 10 days post-injury. (Guskiewicz et al, 2003; McCrea et al, 2009). This second concussion is likely to present worse including increasing likelihood of loss of consciousness, more symptoms, and longer duration of symptoms. (Collins et al, 2002) This occurs despite the current clinical assessment battery suggesting that balance and cognitive impairments resolve within 5 – 7 days post-injury. (McCrea et al, 2003). However, this recovery occurs prior to self-reported symptom resolution which has led to multiple suggestions that the current clinical assessment battery lacks sensitivity in identifying lingering post-concussion impairments. (McCrea et al, 2003; Slobounov et al, 2010; Chen et al, 2007; Catena et al, 2011; amongst many others). Further sophisticated technological assessments have indicated that these lingering deficits persist for at least 28-30 days post-injury; however, these technologies have not

GEORGIA SOUTHERN UNIVERSITY INSTITUTIONAL REVIEW BOARD

INSTRUCTIONS FOR PREPARATION OF PROPOSAL NARRATIVE

moved beyond the clinical research world, likely in part due to the lack of qualified trained personal to administer the assessments and the cost-prohibitive nature of the assessments. (Slobounov et al, 2010; Chen et al, 2007; Catena et al, 2011) Thus, a need exists to identify a sensitive assessment technique to identify recovery from a concussion.

Dual-task assessments have been identified to be a sensitive measure of motor and cognitive functioning in a diverse array of patient populations. (Woolacott and Shumway-Cook, 2002) Briefly, the concept of dual task arose from the concept of elderly patients who “stopped walking while talking” likely due to insufficient resources to accomplish both tasks simultaneously. (Woolacott and Shumway-Cook, 2002) This concept has recently been extended to concussion research with early findings suggesting that dual task is an effective technique to identify lingering impairments. (Resch et al, 2011; Teel et al, 2012; Lee et al, 2012). However, these dual task studies suffer the same limitations in identifying the lingering impairments – namely, expensive equipment and substantial training not readily available to most clinicians. Therefore, there is a need for a concussion assessment that can indicate concussion occurrence and resolution, as well as be applicable and feasible for the athletic training setting.

The 4th International Consensus Statement on Concussions in Sports (4th CIS) recommends using the standard assessment of concussions (SAC), a brief neurocognitive screening tool entitled Standard Assessment of Concussion or SAC, (Appendix A) and the balance error scoring system (BESS), a simple balance test, (Appendix B) as screening tools for concussion management. However, the 4th CIS recommends the independent, or single task, administration of these tools. This study aims to combine the SAC and BESS into a dual task (cognitive and motor) testing paradigm, and administer to healthy young adults and concussed young adults to determine the influence of dual task assessment on cognitive and balance performance.

References

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- McCrea M, Guskiewicz K, Randolph C, et al. Effects of a symptom-free waiting period on clinical outcome and risk of reinjury after sport-related concussion. *Neurosurgery.* Nov 2009;65(5):876-882; discussion 882-873.
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- Woolacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. *Gait Posture.* Aug 2002;16(1):1-14.

Outcome. Please state what results you expect to achieve? Who will benefit from this study? How will the participants benefit (if at all). Remember that the participants do not necessarily have to benefit directly. The results of your study may have broadly stated outcomes for a large number of people or society in general.

The participants will not benefit from participation in the study. The potential benefit is to the sports medicine community in the potential development of a more sensitive assessment technique which is both commonly utilized (i.e., no new training required) and readily available to clinicians (as the single task assessment are already recommended by the 4th CIS). A more sensitive assessment technique may allow future clinicians to prevent premature return to participation and potentially reduce the risk of subsequent injury.

Describe your subjects. Give number of participants, and applicable inclusion or exclusion requirements (ages, gender requirements, etc.).

GEORGIA SOUTHERN UNIVERSITY INSTITUTIONAL REVIEW BOARD
INSTRUCTIONS FOR PREPARATION OF PROPOSAL NARRATIVE

We aim to recruit 200 participants to complete the study. The inclusion criteria will include current enrollment as a student at Georgia Southern University who is over the age of 18 and is open to both male and female participants. The exclusion criteria for control participants includes current or recent history of a concussion within the last 6 months, lower extremity injury within the last 6 months, neurological, vestibular, or medication which affects either cognitive or balance performance. (Appendix C), or reporting symptoms commonly experienced following a concussion on a graded symptom checklist (Appendix D). The exclusion criteria for concussed participants is as mentioned above for control participants, except that they will have been recently concussed and following a return to play protocol as outline by their institution. As participants will be compared within subjects; therefore, learning disabilities, attention deficit disorder, and other related disabilities, will not exclude individuals from participating in the study.

Recruitment and Incentives: *Describe how subjects will be recruited. (Attach a copy of recruitment emails, flyers or etc.) If provided, describe what incentives will be used and how they will be distributed.)*

There will be no incentives provided to participate in the study. Concussed participants will be recruited from the athletics department of the participating institution, as well as from the recreation activity center. Control participants will be recruited and matched based on gender, weight and sport from the athletics department and recreation activity center from the participating institution.

Research Procedures and Timeline: *Enumerate specifically what will you be doing in this study, what kind of experimental manipulations you will use, what kinds of questions or recording of behavior you will use. Focus on the interactions you will have with the human subjects. (Where applicable, attach a questionnaire, focus group outline, interview question set, etc.) Describe in detail any physical procedures you may be performing.*

The participants will be tested on three occasions and the test sessions will last approximately 30 minutes, including the explanation of the project, the informed consent process, the health history questionnaire (Appendix C), and the testing process. Following explaining the project and receiving oral and written informed consent, the individual will have their height and weight measured using a standard physician scale.

The BESS test (Appendix B) consists of the individual performing three stances (double, single, tandem) on two different surfaces (firm, foam). The individual is positioned in the respective stance position with their hands on their hip and eyes closed with each stance lasting 20 seconds. The BESS is scored by counting the number of errors (hands coming off the hips, eyes opening, step or stumble, toe/heel coming off of the ground, the hip flexing or abducting $\geq 30^\circ$, or remaining out of the test position for 5 seconds) committed during the 20 second test with a maximum score of 10 errors per stance of 60 errors total. The SAC test (Appendix A) is a brief neurocognitive screening tool which assesses an individual's orientation, immediate memory, concentration, and delayed recall. The screening is scored based on the number of correct answers (maximum score of 30) and the exam takes less than 5 minutes to complete. These tests will be video recorded with two camera placed orthogonally approximately 5m from the individual to allow for both frontal and sagittal views. The videos will be retained for three or more years and will be deleted following data analysis and eventual manuscript submission and acceptance.

The participants will perform the BESS and SAC simultaneously. Specifically, the two tasks will be combined as follows

	BESS Stance	SAC
1	Double Leg Firm	Orientation
2	Single Leg Firm	Immediate Memory Trial 1
3	Tandem Firm	Immediate Memory Trials 2 - 3
4	Double Leg Foam	Concentration 1 – 3
5	Single Leg Foam	Concentration 4 – 5
6	Tandem Foam	Delayed Recall

Data Analysis: *Briefly describe how you will analyze and report the collected data. Include an explanation of how will the data be maintained after the study is complete and anticipated destruction date or method used to render it anonymous for future use.*

The two primary dependent variables of interest will include the total score on the BESS and SAC, either single or dual task. As the two scores are opposite in nature (higher is better for SAC, worse for BESS), the BESS score will be inverted to create the combined score. The BESS will be scored as 60 (the maximum number of errors) minus the number of errors, thus a higher score will be better. The scores will be compared between the single task and dual task performance using within subjects analysis.

The video recordings of the BESS, both single and dual task, will be maintained for the duration of the study and retained as the data is analyzed and stored until the eventual manuscript is accepted for publication. Once all aspects of the study are completed and the required 7 years has passed, the digital video files will be deleted and the score sheets will be destroyed. The participants will be identified on the documentation only using an assigned participant ID which not include their name, social security number, or

GEORGIA SOUTHERN UNIVERSITY INSTITUTIONAL REVIEW BOARD

INSTRUCTIONS FOR PREPARATION OF PROPOSAL NARRATIVE

Eagle ID. As the participant will clearly be visible on the video, the video files will be stored, prior to their deletion, on the laboratory computer which is password protected and the laboratory itself has limited key access.

Special Conditions:

Risk. *Is there greater than minimal risk from physical, mental or social discomfort? Describe the risks and the steps taken to minimize them. Justify the risk undertaken by outlining any benefits that might result from the study, both on a participant and societal level. Even minor discomfort in answering questions on a survey may pose some risk to subjects. Carefully consider how the subjects will react and address ANY potential risks. Do not simply state that no risk exists. Carefully examine possible subject reactions. If risk is no greater than risk associated with daily life experiences state risk in these terms.*

There is minimal risk associated with participation in this study. There is a risk of falling during the BESS test; however, a member of the research team will stay in close proximity to the individual (i.e., “spot”) in the event they begin to fall. Two faculty members on this project have conducted hundreds of trials of the BESS (through other IRB approved projects) and have had no incidents of falls or injuries while performing the BESS. Further, the BESS is the recommended postural stability assessment test by the International Concussion Consensus Statement for acutely concussed individuals who would possess known balance impairments; despite this, the research team is not aware of any published or anecdotal reports of injury associated with BESS performance even in the concussed population. There is a minimal risk of embarrassment for incorrectly answering questions on the SAC test; however the assessment will occur in the Biomechanics laboratory – a relatively private area with minimal observation of the test occurring. These two risks are limited in comparison to the potential benefit of developing a new assessment technique to improve the tracking of post-concussion recovery.

Research involving minors. *Describe how the details of your study will be communicated to parents/guardians. If part of an in-school study (elementary, middle, or high school), describe how permission will be obtained from school officials/teachers, and indicate whether the study will be a part of the normal curriculum/school process. Please provide both parental consent letters and child assent letters (or processes for children too young to read). If not applicable indicate N/A or delete this section.*

There are no minors associated with this study.

Deception. *Describe the deception and how the subject will be debriefed. Briefly address the rationale for using deception. Be sure to review the deception disclaimer language required in the informed consent. **Note:** All research in which active deception will be used is required to be reviewed by the full Institutional Review Board. Passive deception may receive expedited review. If not applicable indicate N/A or delete this section.*

There is no deception associated with this study.

Medical procedures. *Describe your procedures, including safeguards. If appropriate, briefly describe the necessity for employing a medical procedure in this study. Be sure to review the medical disclaimer language required in the informed consent. If not applicable indicate N/A or delete this section.*

There are no medical procedures associated with this study.

Cover page checklist. *Please provide additional information concerning risk elements checked on the cover page and not yet addressed in the narrative. If none, please state "none of the items listed on the cover page checklist apply." The cover page can be accessed from the IRB forms page. (Note – if a student, make sure your advisor has read your application and signed your cover page. (Your advisor is responsible for the research you undertake in the name of GSU.)*

Reminder: No research can be undertaken until your proposal has been approved by the IRB.

Research Compliance Combined Cover Page
Georgia Southern University
Application for Research Approval

Investigator Information:		
Name of Principal Investigator: Kristin Bockelman	Phone: (989) 329-1148	For Office Use Only: Protocol ID: _____ Date Received:
Email: Kb05910@georgiasouthern.edu <small>(Note: Georgia southern email addresses will be used for correspondence.)</small>	<input type="checkbox"/> Faculty; <input type="checkbox"/> Doctoral; <input type="checkbox"/> Specialist; <input checked="" type="checkbox"/> Masters <input type="checkbox"/> Undergraduate	
Department Name and PO Box: Health and Kinesiology Box 8076		
Name(s) of Co-Investigators: Thomas Buckley Barry Munkasy Jody Langdon	Phone: (912) 478-5268 (912) 478-8014 (912) 478-5378	
Email addresses: tbuckley@georgiasouthern.edu (F) bmunkasy@georgiasouthern.edu (F) jlangdon@georgiasouthern.edu (F)	<input checked="" type="checkbox"/> Faculty; <input type="checkbox"/> Doctoral; <input type="checkbox"/> Specialist; <input checked="" type="checkbox"/> Masters <input type="checkbox"/> Undergraduate <i>(If multiple: identify by initial letter behind name. E.g., F for faculty)</i>	
Department Name and PO Box: Health and Kinesiology Box 8076		
Personnel and/or Institutions Outside of Georgia Southern University involved in this research (Attach training certification): None		
Project Information: (Note: funded project titles must match grant title)		
Title: The Effectiveness of a Dual Task Concussion Assessment for Identifying Impairments in a Concussed Population		
Brief (less than 50 words) Project Summary: The purpose of this study is to evaluate the influence of dual task testing paradigm on traditional single task concussion assessment tests. Also to assess cognitive and physical impairments following a concussion using a dual task paradigm.		
Compliance Information:		
<i>Please indicate which of the following will be used in your research: (application may be submitted simultaneously)</i>		
<input checked="" type="checkbox"/> Human Subjects (Complete Section A: Human Subjects below) <input type="checkbox"/> Care and Use of Vertebrate Animals (Complete Section B: Care and Use of Vertebrate Animals below) <input type="checkbox"/> Biohazards (Complete Section C: Biohazards below)		
<input type="checkbox"/> Do you or any investigator on this project have a financial interest in the subjects, study outcome or project sponsor. (A disclosed conflict of interest will not preclude approval. An undisclosed conflict of interest will result in disciplinary action.) NO		
Project Start Date: 8/1/2013 End Date: 8/1/2014 (no more than 1 year) Anticipated renewals <input type="checkbox"/> year 2 <input checked="" type="checkbox"/> year 3	Check one: <input checked="" type="checkbox"/> New submission <input type="checkbox"/> Resubmission # _____	
Funding Source: <input type="checkbox"/> Federal <input type="checkbox"/> State <input type="checkbox"/> Private	<input type="checkbox"/> Internal GSU	<input checked="" type="checkbox"/> Self-funded/non-funded
Funding Agency:		<input checked="" type="checkbox"/> Not Applicable

Section A: Human Subjects <input type="checkbox"/> Not Applicable	
Number of Subjects (Maximum) 200	Date of IRB education completion: 2/15/13 (attach copy of completion certificate)
<i>Purpose of Research: (Check all that apply)</i> <input checked="" type="checkbox"/> Publication/use in thesis/dissertation <input checked="" type="checkbox"/> Publication (journal, book, etc.) <input checked="" type="checkbox"/> Poster/presentation to a scientific audience <input type="checkbox"/> Completion of a class project <input type="checkbox"/> Presentation to GSU audience only <input type="checkbox"/> Presentation in outside of GSU <input type="checkbox"/> Results will not be published <input type="checkbox"/> Other	<i>Please indicate if the following are included in the study (Check all that apply):</i> <input checked="" type="checkbox"/> Informed Consent Document <input type="checkbox"/> Greater than minimal risk <input type="checkbox"/> Research Involving Minors <input type="checkbox"/> Deception <input checked="" type="checkbox"/> Generalizable knowledge (results are intended to be published) <input type="checkbox"/> Survey Research <input type="checkbox"/> At Risk Populations (prisoners, children, pregnant women, etc) <input checked="" type="checkbox"/> Video or Audio Tapes <input type="checkbox"/> Medical Procedures, including exercise, administering drugs/dietary supplements, and other procedures

Section B: Care and Use of Vertebrate Animals <input checked="" type="checkbox"/> Not Applicable	
<i>Purpose of use/care of animals:</i> <input type="checkbox"/> Research <input type="checkbox"/> Teaching <input type="checkbox"/> Demo only <input type="checkbox"/> Student participation in faculty work <input type="checkbox"/> Class Project <input type="checkbox"/> Exhibition <input type="checkbox"/> Display	<i>Please indicate if the following are included in the study:</i> <input type="checkbox"/> Physical intervention with vertebrate animals <input type="checkbox"/> Housing of vertebrate animals <input type="checkbox"/> Euthanasia of vertebrate animals <input type="checkbox"/> Use of sedation, analgesia, or anesthesia <input type="checkbox"/> Surgery <input type="checkbox"/> Farm animals for biomedical research (e.g., diseases, organs, etc.) <input type="checkbox"/> Farm animals for agricultural research (e.g., food/fiber production, etc.) <input type="checkbox"/> Observation of vertebrate animals in their natural setting

Section C: Biological Research <input checked="" type="checkbox"/> Not Applicable <input type="checkbox"/> Submitted Separately	
<i>Biosafety Level:</i> <input type="checkbox"/> Exempt <input type="checkbox"/> BSL 1 <input type="checkbox"/> BSL 2 <input type="checkbox"/> BSL 3	<i>Please indicate if the following are included in the study:</i> <input type="checkbox"/> Use of rDNA <input type="checkbox"/> Non native/invasive plant species <input type="checkbox"/> Last EHS lab safety inspection date: Attach Report _____ <input type="checkbox"/> Last IBC biosafety lab inspection date: Attach Report _____

Signature of Applicant(s): (PI, CoPI)	Date:
x <i>Kristen Boehm</i>	8/4/13
<i>If student project please complete research advisor's information below (note that advisor signature must be received before application will be reviewed):</i>	
Research Advisor's Name: Thomas Buckley	Advisor's E-mail: tbuckley@georgiasouthern.edu
Advisor's Phone: (912) 478 - 5268	Advisor's Department: Health and Kinesiology P.O. Box: 8076
If student project - Signature of faculty member who is responsible for the student conducting research. If faculty project - Signature of department head or chair.	
By signing this cover page I acknowledge that I have reviewed and approved this protocol for scientific merit, rational and significance. I further acknowledge that I approve the ethical basis for the study.	
Signature of Committee Chair/Research Advisor (if student) Department Chair (if faculty):	Date:
x <i>Thomas Buckley</i>	8/3/13

Please submit this protocol to the Georgia Southern University Research Compliance Office, c/o The Office of Research Services & Sponsored Programs, P.O. Box 8005. The application should contain all required documents specific to the committee to which you are applying. Questions or comments can be directed to (912)478-5465 or IRB@georgiasouthern.edu Fax 912-478-0719.

IRB Application Cover Page



Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **Kristin Bockelman** successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 04/25/2013

Certification Number: 1127622

CITI Collaborative Institutional Training Initiative

Human Subjects-Social & Behavioral Research - Basic/Refresher Curriculum Completion Report Printed on 2/15/2013

Learner: Kristin Bockelman (username: Bockelmk)

Institution: Georgia Southern University

Contact Information Department: Health and Kinesiology-Athletic Training

Phone: 9893291148

Email: bockelmk@gmail.com

Human Subjects-Social & Behavioral Research - Basic/Refresher: Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

Stage 1. Basic Course Passed on 02/11/13 (Ref # 9763258)

Required Modules	Date Completed	
Belmont Report and CITI Course Introduction	02/11/13	3/3 (100%)
Students in Research	02/11/13	10/10 (100%)
History and Ethical Principles - SBR	02/11/13	5/5 (100%)
Defining Research with Human Subjects - SBR	02/11/13	5/5 (100%)
The Regulations and The Social and Behavioral Sciences - SBR	02/11/13	5/5 (100%)
Assessing Risk in Social and Behavioral Sciences - SBR	02/11/13	5/5 (100%)
Informed Consent - SBR	02/11/13	5/5 (100%)
Privacy and Confidentiality - SBR	02/11/13	5/5 (100%)
Conflicts of Interest in Research Involving Human Subjects	02/11/13	5/5 (100%)
Elective Modules	Date Completed	
Records-Based Research	02/11/13	2/2 (100%)
Research with Prisoners - SBR	02/11/13	4/4 (100%)
Research with Children - SBR	02/11/13	4/4 (100%)
Vulnerable Subjects - Research Involving Workers/Employees	02/11/13	4/4 (100%)

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.

<https://www.citiprogram.org/members/learners/learnstage.asp?strKeyID=52FD7130-3EBC-4CB7-ACEA-6707A0C6376C-14577205&gradebook=30242>

1/2

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator

[Return](#)

CITI Collaborative Institutional Training Initiative

CITI Health Information Privacy and Security (HIPS) Curriculum Completion Report Printed on 2/15/2013

Learner: Kristin Bockelman (username: Bockelmk)

Institution: Georgia Southern University

Contact Information Department: Health and Kinesiology-Athletic Training

Phone: 9893291148

Email: bockelmk@gmail.com

CITI Health Information Privacy and Security (HIPS) for Students and

Instructors: This course for **Students and Instructors** will satisfy the mandate for basic training in the HIPAA. In addition other modules on keeping your computers, passwords and electronic media safe and secure are included.

Stage 1. Basic Course Passed on 02/15/13 (Ref # 9763278)

Required Modules	Date Completed	
About the Course	02/15/13	1/1 (100%)
Privacy Rules: Introduction to Federal and State Requirements*	02/15/13	8/10 (80%)
Privacy Rules: Students and Instructors*	02/15/13	3/4 (75%)
Security Rules: Basics of Being Secure, Part 1*	02/15/13	no quiz
Security Rules: Basics of Being Secure, Part 2*	02/15/13	5/5 (100%)
Completing the Privacy and Security Course	02/15/13	no quiz
Elective Modules	Date Completed	
Security Rules: Protecting your Computer*	02/15/13	8/8 (100%)
Security Rules: Picking and Protecting Passwords**	02/15/13	6/8 (75%)

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[Return](#)