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Identifying Cognitive and Postural Deficits Through Re-Baseline Evaluations

Brian J. Mizeski

IDENTIFYING COGNITIVE AND POSTURAL DEFICITS THROUGH RE-BASELINE EVALUATIONS

by

BRIAN J. MIZESKI

(Under the Direction of Nicholas Murray)

ABSTRACT

Introduction**:** Baseline evaluations provide vital information for clinicians, as they are a representation of an athlete's healthy clinical state. It has been recommended when an athlete recovers from a concussion, they be administered a re-baseline evaluation, as the effects of a single concussion are not well documented. Limited literature was found which examines re-baseline examinations following a concussion. ***Purpose*****:** The purpose of this study was to evaluate cognitive and postural deficits, in athletes who sustained a concussion, at the conclusion of the athletic season. ***Methods*****:** 38 concussed athletes (CONC) were matched on sport and gender with 38 healthy controls (NORM). All athletes were administered a baseline and re-baseline assessment including the Standardized Assessment of Concussion (SAC) and the Balance Error Scoring System (BESS). Within the CONC group, 9 athletes were identified and matched on the same criteria to be evaluated using center of pressure (CoP) metrics. CoP metrics included Sample Entropy (SampEn) and Peak Excursion Velocity (PEV) in Mediolateral (M/L) and Anteroposterior (A/P) directions, and a 95% Confidence Ellipse (95% CE) during eyes open (EO) and eyes closed (EC) static stances. Twelve repeated measure ANOVAs were used to evaluate differences between evaluations, with statistical significance set 0.05 *a priori.* ***Results:*** Repeated measure ANOVAs revealed the SAC was statistically significant over time (p = .004) but not between groups. There was no significance observed with the BESS for time (p = 0.339) or group (p = 0.164). SampEn in the A/P direction, during EO static stance did reveal a statically significance between group x time interaction at re-baseline (p = .023) No significance was

observed for SampEn EO – M/L, SampEn EC – M/L & A/P, PEV EO & EC – M/L & A/P, or 95% CE in an EO or EC condition. ***Discussion:*** The results of this study indicate re-baseline evaluations should include the SAC to assess changes in cognition. The BESS may not be an applicable assessment for re-baseline evaluations as athletes returned to baseline values. CoP metrics allow for a more sensitive assessment for postural imbalances, however only SampEn may be beneficial to include during re-baseline evaluations. Future research should examine the use of re-baseline evaluations on a yearly basis, which may show changes in cognition and posture.

INDEX WORDS: Baseline, Re-Baseline, Cognition, Posture, Concussion

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by

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DEDICATION

This thesis is dedicated to my family and friends who have been there for me; and who have helped me get to where I am today. Without your help and support I would not have been able to complete this thesis. Thank you all for your words of wisdom and support during the last two years.

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CHAPTER 1: INTRODUCTION

The Centers for Disease Control and Prevention estimates between 1.6 - 3.8 million concussions occur in sports and recreational activities annually, with more than 50% of all concussions going unreported throughout all levels of competition[2]. The National Athletic Trainers' Association defines concussion as a head trauma induced alteration in mental status that may or may not involve loss of consciousness[3]. However, more common within concussion literature, concussion has been defined as a "complex pathophysiological change affecting the brain from biotraumatical forces"[4]. There are a variety of signs and symptoms that may present when clinicians evaluate concussive injuries. The 3 most common symptoms include headache, dizziness, and confusion; which occur 86%, 67%, and 59% of concussions, respectively. Of those who sustain a concussion, 30% of people will present with balance dysfunction[5].

Two common clinical assessments to evaluate concussion include the Standardized Assessment of Concussion (SAC)[6] and the Balance Error Scoring System (BESS)[7]. Each assessment adds additional information to the concussion status of an athlete by independently evaluating different aspects of cerebral function[8]. The SAC is a verbally administered cognitive assessment, evaluating different cerebral functions: orientation, concentration, as well as immediate and delayed recall. The BESS has been widely accepted as a reliable, yet subjective, postural control assessment that measures potential impairment[7].

Cognitive impairments related to concussion have been extensively studied from baseline to multiple days post injury (PI)[9-11]. The SAC was designed to assess acute cognitive function is 95% sensitive, 76% specific, and is a reliable assessment for concussion evaluation PI. The SAC has been a recommended assessment tool during baseline evaluations[3] as it provides vital

information for each athlete in a "healthy clinical state"[3]. However, no research was found that examines the SAC as an assessment that may need to be re-administered after recovery.

Balance plays an important role as it aids athletes in their sport specific movements. When a suspected head injury occurs, balance deficits present in just over ¼ of cases. These balance deficits are most commonly assessed using the BESS. The BESS is a subjective balance assessment which has shown to be highly specific, 91%, to detect injury[12]. Post - Injury, the athletes have shown to return to their individual baseline value around 3-7 days[4]. As a subjective examination, the BESS has not been shown to be sensitive enough to detect potential balance deficits multiple days PI[7]. Multiple factors may alter initial baseline assessment, which may influence BESS scores PI[13-15]. While the BESS has been extensively studied post – injury, no studies were found that examined the BESS as it relates to the need to be re-baselined after concussion recovery.

Where subjective balance assessments, such as the BESS, may not be sensitive to identify postural deficits after 3-7 days PI, more objective assessments can be utilized detect lingering deficits after athletes have returned to play (RTP)[16]. These objective assessments utilize center of pressure (CoP) metrics to quantify the amount of postural sway athletes present with. When comparing baseline values to PI and RTP, Powers and colleagues determined concussed athletes to still present with postural deficits after returning to competition[16]. CoP are more sensitive to detecting postural imbalances, however only one study has evaluated the use of re-baseline evaluations incorporating objective measurements.

Re-baseline evaluations have been recommended for any athlete who has sustained a concussion[3]. Re-baselines allow clinicians to document recovery and assess the presence of future concussions, as the effects of a single concussion are not yet fully understood. As

previously mentioned, only one study has investigated the utility of re-baseline evaluations[17]. A 2015 study by Lynall and colleagues evaluated concussed athletes using a balance and computerized neurocognitive assessments[17]. The study was primarily focused on the neurocognitive assessment, ultimately finding no clinical applicability for re-baseline evaluations. Limited literature currently exists on the need for a re-baseline clinical assessment following concussive injury.

Therefore, the purpose of this study was to evaluate cognitive and postural deficits, in athletes who sustained a concussion, at the conclusion of the athletic season compared to healthy control athletes. It is hypothesized that previously concussed athletes would present with significant differences during re-baseline for both the SAC and BESS, as well as presenting with significant differences when evaluating CoP metrics compared to healthy control athletes.

CHAPTER 2: METHODOLOGY

2.1 RESEARCH SETTING

Baseline and re-baseline evaluations for the current study were conducted in the biomechanics laboratory of a single NCAA Division I university in southern Georgia. The biomechanics laboratory is a spacious, multi-purpose area that provides room for a multitude of various research projects that take place at the university.

2.2 STUDY DESIGN

Concussed athletes (CONC) and healthy control athletes (NORM) were recruited for a prospective non-randomized pretest – posttest study. The CONC athletes sustained a diagnosed concussion during the 2014 – 2015 or 2015 – 2016 athletic years. The CONC and NORM athletes were administered baseline and re-baseline evaluations, which included the SAC, BESS, and a Center of Pressure (CoP) metric assessment. A complete breakdown of all variables for the current study can be found in Table 1.

Table 1: Dependent and Independent Variables

Dependent Variables	Independent Variables
SAC Total Score	*Time*
BESS Composite Score	*CONC Athletes*
SampEn Eyes Open – Anteroposterior	*NORM Athletes*
SampEn Eyes Open – Mediolateral	
PEV Eyes Open – Anteroposterior	
PEV Eyes Open – Mediolateral	
95% Confidence Ellipse Eyes Open	
SampEn Eyes Closed – Anteroposterior	
SampEn Eyes Closed – Mediolateral	
PEV Eyes Closed – Anteroposterior	
PEV Eyes Closed – Mediolateral	
95% Confidence Ellipse Eyes Closed	

2.3 PARTICIPANTS

Seventy-six athletes (32 males, 44 females) were recruited for this study. The CONC and NORM athletes participated in a variety of varsity level athletics, including male and female cheerleaders. A complete breakdown of athletes by sport can be found in Table 2.

Table 2: All Participants by Sport Evaluated with SAC & BESS

Sport	# Per Sport
Football	20
Cheerleading	16
Men's Soccer	10
Women's Track & Field	8
Women's Soccer	6
Women's Basketball	6
Women's Swim & Dive	6
Women's Volleyball	2
Baseball	2

# = number of athletes who reported participating in that sport.
N = 76 (38 CONC & 38 NORM), CONC = Concussed Athletes,
NORM = Healthy Control Athletes

Thirty-eight CONC athletes (16 males, 22 females) sustained a diagnosed concussion within their respective sport during the 2014 – 2015 or 2015 – 2016 athletic seasons. A NORM group of 38 (16 males, 22 females) athletes were matched by sport and gender, and were recruited with help of the supervising athletic trainer for each sport at the university. The NORM athletes were uninjured and without a documented concussion during the duration of this study. Following concussive injury all CONC athletes completed a progressive return to play protocol and were cleared by the team physician. Tables 3 and 4 outline the inclusion and exclusion criteria for both CONC and NORM athletes in this study. All individuals signed an informed consent to participate in the current study, which was approved by the University Institutional Review Board.

Table 3: CONC Athlete Criteria for Inclusion and Exclusion

Inclusion	Exclusion
Concussion diagnosis by team athletic trainer or team physician	Concussion diagnosis by independent athletic trainer or physician
Between 18 – 30 years’ old	<18 years old & >30 years old
Cleared to return to play by team physician	Not cleared to return by team physician

Table 4: NORM Athlete Criteria for Inclusion and Exclusion

Inclusion	Exclusion
Athlete at university	Concussion diagnosed during athletic season
Between 18 – 30 years old	<18 years old & >30 years old

Within the CONC participants, CoP data was analyzed for 9 athletes, who were also matched to a control group based on sport and gender. Nine CONC athletes were identified whom had completed the postural assessment during baseline and had complete CoP data for the variables examined in this study: Sample Entropy, Peak Excursion Velocity, and 95% Confidence Ellipse. Table 5 outlines athletes by sport, who were identified to have CoP metrics evaluated.

Table 5: Athletes by Sport – Analyzed CoP Metrics

Sport	# Per Sport
Cheerleading	4
Women's Soccer	4
Women's Swim & Dive	2
Baseball	2
Volleyball	2
Football	2
Women's Track & Field	2

Note: # = number of athletes who reported participating in that sport.
N = 18 (9 CONC & 9 NORM), CONC = Concussed Athletes, NORM = Healthy Control Athletes

2.4 DATA COLLECTION

All athletes were administered a baseline concussion evaluation during their individual pre-participation physical exam. This evaluation is conducted prior to an athlete participating in any type of practice or competition. Re-baseline examinations were conducted for the CONC athletes at the conclusion of the athletic season in which they sustained their concussion. The NORM athletes were randomly selected to be re-baselined during the 1st week of the academic semester after the conclusion of the athletic season in which they competed.

2.5 INSTRUMENTS & PROCEDURES

Baseline to Re-baseline

We were not able to account for the timing of the re-baseline from the documented concussion for each CONC participant and thus prevented the current study from regulating time between each evaluation. A CONC athlete in this study may have been administered their baseline evaluation in 2012 or 2013, making them a junior or senior at the time of their concussive injury. The athletes were administered re-baseline assessments on average (CONC) 582 ± 382 days and (NORM) 393 ± 413 days. The amount of time between evaluations is larger

for the CONC group, however the NORM group's closely matches the time between evaluations Lynall and colleagues reported in 2015, of 397 days for their concussed participants[16,17]. When analyzing the CoP metrics at re-baseline; the average time between evaluations was 370 ± 198 days for CONC and 256 ± 167 days for NORM athletes.

Standardized Assessment of Concussion

The SAC was verbally administered to each individual athlete at 2 time points, baseline and re-baseline. There are 4 SAC sections that evaluate orientation, concentration, as well as immediate and delayed recall. The 4 sections are scored and the scores are combined for a total SAC score. Thirty points represents the highest possible SAC score, higher scores indicating higher levels of cognition. The administration of the SAC followed the protocol first used by McCrea and colleagues[6].

Balance Error Scoring System

The BESS is used to subjectively measure balance impairments. A composite score is determined from 6 individual 20 s trials. Athletes were evaluated at baseline and re-baseline on a hardwood surface and a 1.5 inch airex pad in 3 different stances: double leg, single leg non – dominant, and tandem stance with the non – dominant foot back. The administration of the BESS follows the protocol set forth by Guskiewicz in 2001[7]. The highest score an athlete can receive on the BESS is 60/60 with lower scores indicating better overall balance. All BESS evaluations were video recorded in both at the frontal and sagittal plane. To check for accuracy in scoring, the primary researcher evaluated all athletes, either in person or by video, to account for any potential discrepancies between evaluators.

CoP Metric Assessment

CoP was evaluated during 4 trials of quiet static standing at both baseline and re-baseline with 2 trials in an eyes open (EO) condition and 2 trials in an eyes closed (EC) condition. Before the assessment began, athletes were instructed to remove shoes and socks, as well as any jewelry or items in their pockets. When the assessment began, athletes were instructed to stand as still as possible with their feet, medial malleoli, and knees touching on a Wii Balance Board (WBB) (Nintendo Corporation, Redmond, WA, USA). The WBB was placed on top of a force platform (1000 Hz; AMTI Inc., Watertown, MA, USA) measuring 0.40 m x 0.60 m. For static stance in the EO condition athletes were instructed to look at a target directly in front of them, approximately 1.40 m away. The CoP metrics were collected via the force platform; no data was collected via the WBB. Each static stance trial lasted 30 s, which was chosen based on reliability of this time frame[18].

2.6 DATA ANALYSIS

In order to obtain CoP metrics, ground reaction forces were obtained from the force platform using the Vicon Motion Capture System (Vicon Motion Systems LTD, version 1.8.5, Oxford, UK.). The raw data obtained from the force platform were processed and exported through the Vicon system to evaluate CoP metrics. A custom Matlab code was utilized to filter data with a cutoff frequency of 30 Hz. The CoP metrics filtered included Sample Entropy (SampEn), Peak Excursion Velocity (PEV), and 95% Confidence Ellipse (95% CE). All 3 CoP metrics were evaluated in an EO and EC condition in the Anteroposterior (A/P) and Mediolateral (M/L) directions.

SampEn is a nonlinear entropic metric used to assess the complexity and regularity of postural sway by time – dependent CoP signals. It has been shown in the literature to be a more sensitive entropic metric[19]. SampEn provides a value between zero and two, lower values are indicative of more regularity, whereas, higher values have more irregularity. The algorithm used to calculate SampEn is shown in Table 6.

Additionally, PEV was evaluated to determine maximum velocity of the entire CoP time series. Lower velocity indicates better postural control, as velocity reflects the overall efficiency in relation to the postural control systems[20]. PEV was calculated by dividing CoP excursions by the force platform sampling frequency. The algorithm used to calculate PEV is shown in Table 6.

95% CE quantifies 90 – 95% of the total area in the A/P and M/L directions. As an index to indicate overall postural performance, larger surfaces may indicate decreased performance, whereas, smaller surface areas will show increased performance[21]. Table 6 outlines the algorithm used to obtain the Confidence Ellipse metric.

Table 6: CoP Metric Algorithms

SampEn=	$-\boldsymbol{ln}\frac{\sum_{i=1}^{n-m*r}\boldsymbol{A_i}}{\sum_{i=1}^{n-m*r}\boldsymbol{B_i}}$
PEV=	$\int_{n}^{n+1}\frac{1}{fs}(AP[n+1]-AP[n])$
95% CE=	$\sqrt{\frac{2(n-1)}{n(n-2)}}F(1-a),2,n-2\cdot\lambda 1 \approx \sqrt{x_2^2\cdot\frac{\lambda 1}{n}}$

Notes: SampEn = Sample Entropy, PEV = Peak Excursion Velocity, 95% CE = Confidence Ellipse

2.7 STATISTICAL ANALYSIS

Twelve Repeated Measures Analysis of Variance (ANOVA) were run to determine differences between variables each variable between baseline and re-baseline scores for time and within groups.

Table 7: Repeated Measure Analysis of Variance (RM ANOVA)

Group	Baseline	Re-Baseline	Time
CONC Athletes			
NORM Athletes			

Notes: CONC = Concussed athletes, NORM = Healthy control athletes

Descriptive statistics, observed power, homogeneity, skewness, and kurtosis were examined with statistical significance set at 0.05 *a priori*. Dependent Sample t – tests were

analyzed for all significant results to determine at which evaluation significant results were present. All statistical analysis was calculated using SPSS version 23 (IBM corp., 2016).

2.8 OPERATIONAL DEFINITIONS

- Standardized Assessment of Concussion (SAC) – verbal assessment for cognition
- Balance Error Scoring System (BESS) – subjective balance assessment
- Center of Pressure (CoP) Metrics – variables including: Sample Entropy (SampEn), Peak Excursion Velocity (PEV), and 95% Confidence Ellipse (95% CE).
- Baseline Evaluation – Initial evaluation conducted during pre-participation evaluation
- Re-baseline Evaluation – Follow up assessment, administered the semester following concussive injury
- Cognition – mental action or process of acquiring knowledge and understanding through
- Balance – The ability to maintain upright posture
- Postural Control – Maintain a desired orientation in response to internal or external perturbations

CHAPTER 3: RESULTS

3.1 SAC

The scores between baseline and re-baseline was statistically significant over time ($F(1,74) = 8.649$, $p = 0.004$), However no effect was observed between groups ($F(1,74) = 0.000$, $p = 1.000$) from baseline to re-baseline evaluation. Independent sample t-test revealed a significant difference, $p = 0.004$, between the evaluations from baseline (*mean* = 26 ± 2), to re-baseline (*mean* = 27 ± 2). Figure 1 outlines the means and standard deviations for CONC and NORM at each evaluation.

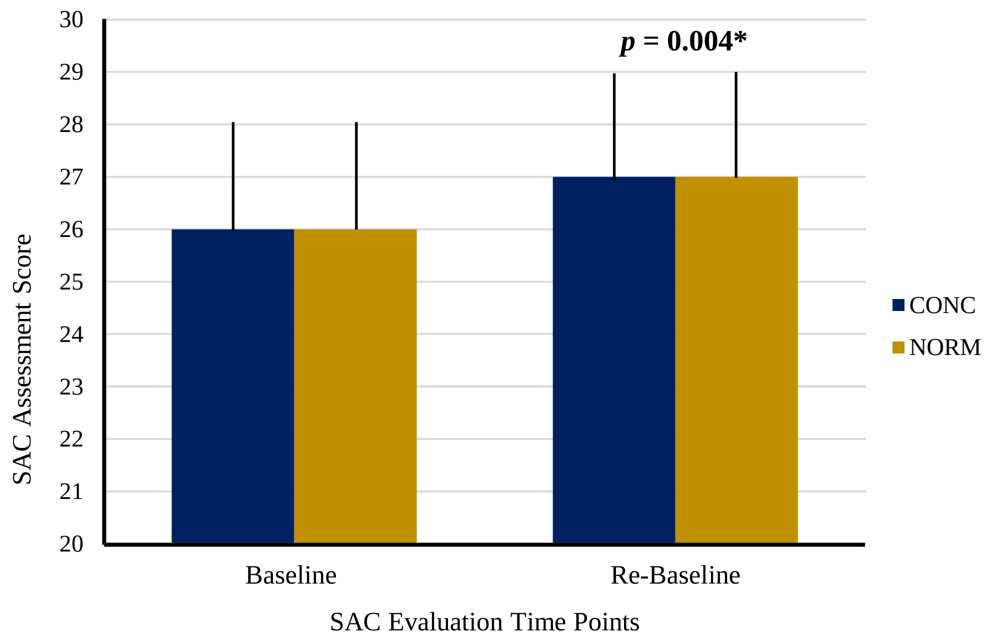

Figure 1: SAC Concussion Scores for Concussed and Control Participants from Baseline to Re-baseline

Notes: The maximal score an athlete can receive is 30/30. Higher scores indicate increased levels of cognition.
$p = 0.05$, Statistical significance was observed for SAC over time.

3.2 BESS

No main effects were observed for time ($F(1,74) = .926$, $p = .339$) or group ($F(1,74) = 1.977$, $p = .164$) between baseline and re-baseline evaluations of the BESS. CONC athletes

returned to baseline values (Pre - *mean*= 15 ± 7; POST – *mean* = 15 ± 7), Whereas, the NORM athletes in this study appeared to improve by an average of 3 errors between Baseline (*mean* = 17 ± 7) to Re-Baseline (mean= 14 ± 4) between evaluations, while not statistically significant. The average BESS composite score for CONC and NORM athletes is presented in Figure 2.

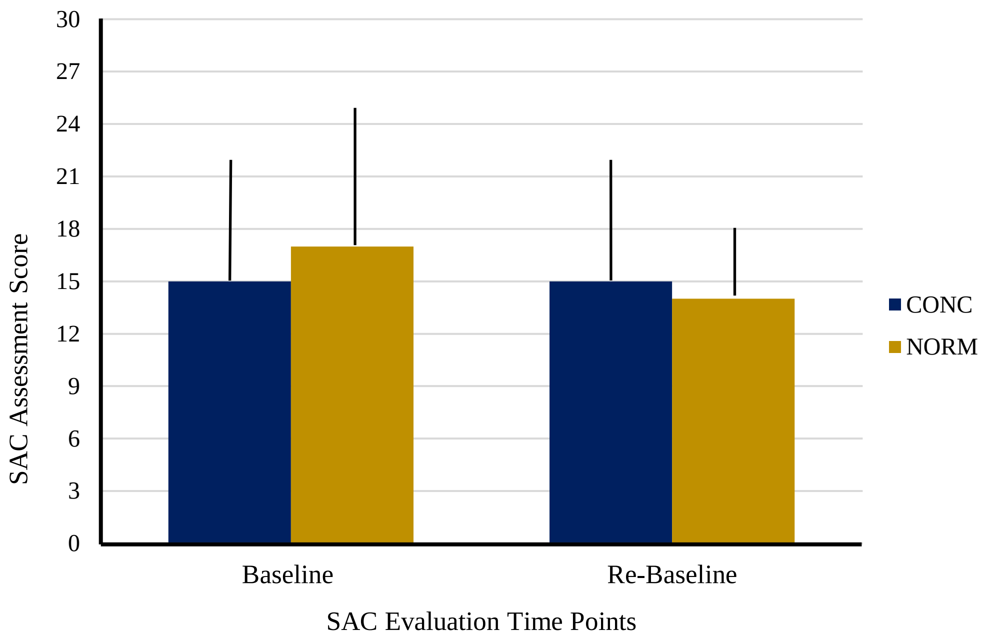

Figure 2: BESS Composite Scores for Concussed and Control Participants from Baseline to Re-baseline

Notes: The maximal score an athlete can receive is 60/60. Lower scores indicate better overall postural control.
$p = 0.05$, no statistical significance observed

3.3 CoP METRIC ASSESSMENT

SampEn M/L during EC static stance position, PRE – 0.610 ± 0.158, POST – 0.663 ± 0.204, revealed no significant main effects for time (F(1,16) = .627, p = .440) or group (F(1,16) = 1.006, p = .331). During EO static stance, SampEn M/L, PRE – 0.491 ± 0.136, POST – 0.569 ± 0.138, similar results were observed with no significant effects for time (F(1,16) = 2.642, p = .124) or group (F(1,16) = .909, p = .355). SampEn in the A/P direction with EC during static stance, PRE – 0.657 ± 0.121, POST – 0.689 ± 0.119, did not identify significant main effects for

time (F(1,16) = 1.057, p = .319) or group (F(1,16) = .085, p = .774). During SampEn in the A/P direction with EO static stance, PRE – 0.564 ± 0.158, POST – 0.542 ± 0.139, no significant main effects were observed for time (F(1,16) = .277, p = .606). However, a significant group by time effect was observed at re-baseline (F(1,16) = 6.316, p = .023). The average SampEn EO in the A/P direction for both groups at baseline was 0.564, compared to re-baseline, 0.543. Table 6 presents the differences between baseline and re-baseline evaluations for both CONC and NORM athletes.

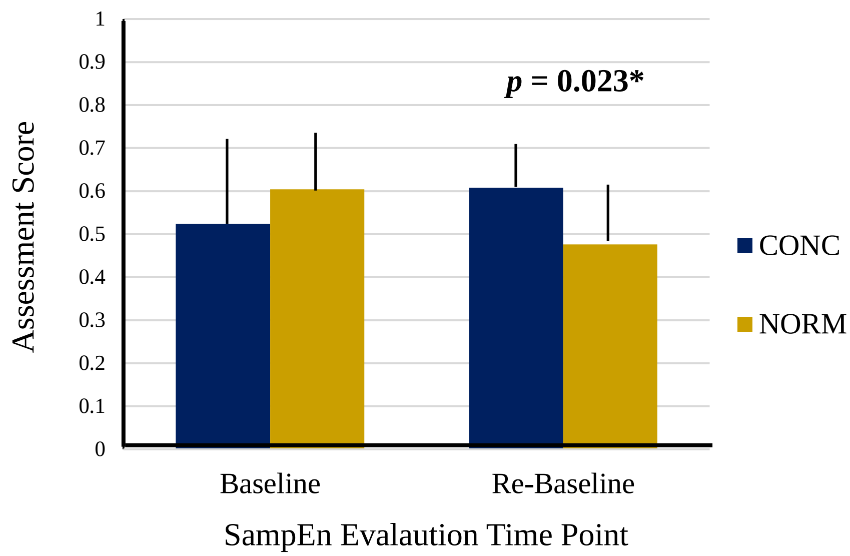

Figure 3: *SampEn EO – A/P from Baseline to Re-Baseline*
Notes: *p* = .005, Statistical significance was observed in SampEn EO - A/P direction between CONC and NORM athletes.

During EC static stance, PEV in the M/L direction, PRE – 0.066 m/S ± 0.028m/S, POST – 0.066m/S ± 0.026m/S, did not display significant results for time (F(1,16) = .005, p = .946) or group (F(1,16) = .071, p = .793). EO static stance PEV in the M/L direction, PRE – 0.049m/S ± 0.020m/S, POST – 0.041m/S ± 0.011m/S, revealed no main effects for time (F(1,16) = 1.793, p = .199) or group (F(1,16) = .053, p = .820). When evaluating PEV A/P during EC static stance, PRE – 0.080m/S ± 0.023m/S, POST – 0.076m/S ± 0.019m/S, no main effects were noted for

time (F(1,16) = .214, p = .650) or group (F(1,16) = 2.748, p = .117). EO PEV A/P, PRE – 0.050m/S ± 0.016 m/S, POST – 0.049m/S ± 0.014m/S, revealed no main effects for time (F(1,16) = .033, p = .859) or group (F(1,16) = 3.196, p = .166).

Between baseline and re-baseline evaluations, no main effects were observed using 95% Confidence Ellipse for time or groups. During EC stance, PRE – 0.000mm ± 0.000mm, POST – 0.038mm ± 0.160mm, no main effects were observed for time (F(1,16) = 1.009, p = .330) and group (F(1,16) = .997, p = .333). When evaluating 95% Confidence Ellipse during EO static stance, PRE – 0.000mm ± 0.000mm, POST – 0.022mm ± 0.091mm, there was no main effect observed for time (F(1,16) = .986, p = .335) or groups (F(1,16) = .989, p = .335).

CHAPTER 4: DISCUSSION

4.1 Overview

The purpose of this study was to evaluate cognitive and postural deficits, in athletes who sustained a concussion, at the conclusion of the athletic season compared to healthy control athletes. It is hypothesized that previously concussed athletes would present with significant differences during re-baseline for both the SAC and BESS, as well as presenting with significant differences when evaluating CoP metrics compared to healthy control athletes. We aimed to (1) compare levels of cognition between CONC to NORM athletes during re-baseline evaluations after the conclusion of the athletic season, (2) use a clinically accepted balance assessment to identify postural impairments following a concussion, and (3) utilize a more objective measurement to quantify postural impairments during re-baseline evaluations. It was hypothesized that athletes would (1) present with significant differences when evaluated with the SAC at re-baseline, (2) re-baselined athletes would exhibit significant differences in BESS composite scores, and (3) concussed athletes would have significant differences when evaluating CoP metrics. The 4th hypothesis expected CONC athlete to have significant differences compared to the NORM athletes in this study at re-baseline evaluations.

The hypotheses of this study were only partially met. The SAC demonstrated a significant time effect for both groups at re-baseline, supporting the 1st hypothesis. When evaluating BESS, neither CONC or NORM athletes presented with statistically significant differences between group or evaluation. The CONC athletes returned to baseline composite score, whereas, the NORM athletes did improve by three errors, while not significant, rejecting the 2nd and 4th hypothesis. We evaluated 10 CoP metrics with only one, SampEn EO – A/P,

displaying statistically significant interaction for group by time. This partially supports the 3rd and 4th hypotheses for this study.

4.2 SAC

McCrea and colleagues[9-11] have studied the SAC in-depth following concussive injury. The baseline means for the SAC in this study (*mean* = 26 ± 2) support the baseline SAC scores observed from seminal research by McCrea[6] (*mean* = 26 ± 2). Maddocks and colleagues[22] have suggested the use of the SAC may only be beneficial in the immediate assessment of concussion, with the sensitivity ranging from 0.72 – 0.78[10]. However, no study was found that has investigated the utility of SAC as a re-baseline assessment tool. This research study found no major differences between CONC and NORM athletes, conversely we did observe statistical significance between evaluation time points. Between baseline and re-baseline evaluation both CONC and NORM athletes presented with a 1 ± 2 – point improvement. This change between evaluations could indicate a continuation of cognitive development or more simply, complete healing from injury. McCrea observed an improvement from PI to 48 hours PI (27 ± 3), which mirrors the scores observed in this study (27 ± 2). The change between evaluations could also be also be attributed to certain sections of the SAC being considered "too easy" [23], or potential practice effects. CONC athletes in this study would have been exposed to the assessment at minimum one time more, at PI, than NORM athletes who were only administered the assessment at 2 time points – baseline and re-baseline evaluation. Within the NORM athletes, the lack of a documented concussion may have allowed for cognitive improvement between baseline and re-baseline evaluations. Cognitive development has been suggested to continue well into an athlete's early 20's[24]. It has been recommended athletes undergo yearly baseline testing to

account for these potential changes in cognition[3], however there is no known research that evaluates the SAC during re-baseline evaluations. The results of this study support the idea of yearly re-evaluation for the SAC.

4.3 BESS

The BESS research results suggest that after concussion, athletes can return to baseline within 3 to 7 days[4]. Additionally, BESS balance deficits do not linger past 7 to 10 days. As with the SAC, there is no known research that examines the BESS during re-baseline evaluations.

Recent literature has evaluated the BESS at multiple days' post injury. A study by Guskiewicz and colleagues[7] assessed the BESS in concussed athletes matched to a healthy control at 4 time points; baseline, 1, 3, and 5 days' post injury. The control athletes averaged 9 ± 4 errors with the BESS. Contrastingly, concussed athletes demonstrated a significant decline from baseline, 12 errors, to post injury evaluation, 15 errors. At day 5 post injury, concussed athletes on average had all returned to their BESS baseline score. These results compare directly to the results for CONC athletes in the current study - who returned to baseline values at re-baseline, 15 errors ± 7 errors. It has been suggested that athletes who are administered the BESS at multiple time points may experience practice effects. Valovich and colleagues[14] documented that practice effects may be contingent upon the difficulty of the task, as the athletes improved during single leg stance on a firm surface during multiple evaluations. Individual stances were not evaluated during the current study, however CONC athletes returned to baseline values. The results of this study refutes the conclusions which suggest CONC athletes have practice effects when evaluated with the BESS, as the CONC athletes did not clinically or statistically improve at re-baseline evaluation.

The current study observed no significant effects for time when evaluating BESS composite scores. Concussed athletes are expected to return to baseline scores within 3 to 7 days' post injury. Burk and colleagues[25] evaluated the BESS to determine if changes in balance occur over an athlete season. Ninety days' post baseline evaluation showed a significant decrease between testing time points, baseline - 9 errors ± 3 and post season – 8 errors ± 3. The CONC athletes returned to baseline in the current study, however, they did exhibit larger standard deviations of 7 errors. While there is no concussed group in Burk's study, the change observed between evaluations 90 days is supported by changes similar to what we observed in this study for our NORM athletes from baseline (17 errors 7) to re-baseline (14 errors ± 4) It has been suggested that a decrease of 7 – 9 errors is indicative of concussive injury[24], which may provide evidence as to the lack of statistical significance found in this study. We noted an improvement trend for NORM athletes suggesting that non-concussed athletes improve over the course of time from initial baseline assessment by 3 errors. These improvements, within the NORM groups, could be the result of the lack of a diagnosed concussion or potential training improvements over course of an athletic season.

When comparing the time between evaluations for the BESS, re-administration has occurred in the literature 30 days after the initial evaluation[14] Our athletes were not re-evaluated until, on average, 582 (CONC) and 393 (NORM) days. This time frame may be too large to ultimately detect postural impairments as the BESS has been suggested to return to baseline values within 3 – 7 days[4]. Given the results of the current study, the re-administration of the BESS during re-baseline may not be clinically applicable once an athlete has returned to baseline values after a concussive injury.

4.4 CoP Metric Assessment

SampEn has been shown in the literature to be a more sensitive entropic metric to detect regular or irregular time series signals[19]. Higher entropy values reflect a more irregular and less repeatable signal, whereas, individuals who display lower SampEn values, may display either a confined or fluid motor pattern and improved postural control. However, previous research has focused on evaluating approximate entropy (ApEn) within concussed populations.[26] ApEn was statistically significant in the M/L direction at 48 – 96 hours PI. Our results do not support those of Cavanaugh as we did not observe significant changes at re-baseline. For SampEn in the EO condition there was no significance effect for either group, CONC (0.608 ± 0.106) or NORM (0.476 ± 0.142). There was a significant group x time interaction at re-baseline in the A/P direction. These results could indicate varying postural control strategies utilized by athletes to maintain their CoP during re-baseline evaluations. Between visual conditions, EO static standing is inherently easier, as it allows for sensory information to be interpreted from the visual, vestibular, and somatosensory systems. EC static standing did not elicit any significant effects for time or group. The lack of significant change in the EC condition may be attributed to complete return to normal for CONC athletes. Whereas, the NORM athletes, had no diagnosed injury and were able to train and compete, ultimately allowing the possibility to have an improved re-baseline evaluation. SampEn EO in the A/P direction was the only CoP metric that was statistically significant. When we examine the differences between A/P and M/L directions, the degrees of freedom in the ankle could be responsible for the results of this study. There are inherently more degrees of freedom at the ankle in the A/P direction, than the M/L direction, and may result in more or less fluidity for postural control mechanics in CONC and NORM athletes during re-baseline.

The design of this study and metrics evaluated closely match those performed by Powers and colleagues[16], who evaluated 9 concussed athletes, matched with a healthy control. Powers and colleagues[16] observed statistical significance between groups and on visual condition for both velocity (25 ± 2) and displacement (16 ± 3) in the A/P direction during the post injury evaluation with EC[16]. During return to play evaluations significant differences were also observed between group and for time, suggesting postural deficits were still present after return to play, *mean* = 26 days ± 14 days[16]. While return to participation and post injury were not directly evaluated in the current study, CoP metric re-baseline occurred 370 ± 198 days (CONC) and 256 ± 167 days (NORM) after initial evaluation and we found no statistical significance when interpreting PEV in either the A/P or M/L directions. It can be hypothesized that, during EC static stance the athlete's base of support is aided by the type of stance (feet together, ankles touching) decreasing the amount of velocity in the M/L and A/P directions. In regard to visual condition – EO – static stance is inherently easier as the athlete is aided by visual stimuli.

Upon evaluation of 95% CE, we did not observe statistical significance in either the EO or EC conditions. Used to evaluate the magnitude of CoP displacements, a larger surface area would increase the magnitude of CoP displacement, dependent upon the athlete's base of support. The athletes in this study stood on a 0.58 m x 0.45 m force platform which is relatively small. It can be hypothesized we did not find statistical significance as miniscule changes at each evaluation may be due to athlete's base of support relative to the size of the force platform.

4.5 Baseline to Re-baseline

Lynall and colleagues[17] observed a significant improvement of the Sensory Organization Test (SOT) composite score from baseline to re-baseline. The current study did not specifically

evaluate the SOT, but when evaluating force plate metrics, a significant difference between groups for SampEn in the A/P direction was revealed during EO static standing. During re-baseline evaluation, CONC and NORM athletes, displayed a lower SampEn value, 0.543, indicating a more controlled motor pattern during quiet standing, which may be attributed to training advancements. On the contrary, CONC and NORM athletes during baseline evaluations displayed a higher value of SampEn, 0.565. This may indicate less fluidity of the neural networks and subsequently less control during quiet standing, which may be due to a lack of 100% effort by the athletes at baseline. These findings may reflect multiple varying postural control strategies utilized by a multitude of athletes, and support the findings of Lynall et al that postural control strategies may differ when re-evaluated after concussive injury. CONC athletes may have also taken the re-baseline evaluation more seriously after sustaining their concussion, then they did during baseline. While they suggested the utility of re-baseline assessments is limited, our study is the first of its kind to evaluate clinical and laboratory concussion assessments which may provide more clinical applicability during re-baseline evaluations.

4.6 Conclusion

Previous literature has suggested re-baseline evaluations be re-administered on a yearly basis[3.] However, the clinical applicability of re-baseline assessments has not been fully investigated. Previous research has utilized assessments which may not be clinically assessable for the majority of clinicians and athletic trainers who administer these assessments[16,17,26]. As this study is the first to investigate differences between baseline and re-baseline using commonly utilized assessments, we can recommend re-baseline evaluations include cognitive assessments, such as the SAC, to account for cognitive growth.

There is no evidence to support the utilization of the BESS as a re-baseline assessment for CONC athletes. When a concussed athlete has returned to baseline PI, the PI evaluation should be a sufficient evaluation, as we did not observe obvious practice effects. Re-baseline evaluations could easily incorporate the BESS as it only takes approximately 3 minutes to administer. The observed change for NORM athletes between time points could indicate training and competition does improve balance in non-injured athletes[27], which may lend though to its consideration as a yearly re-baseline evaluation.

Objective laboratory assessments have shown to be more sensitive to detect postural impairments, although these assessments are not readily available to a majority of clinicians. The results of the current study do not indicate there are postural deficits during re-baseline assessment, but support the idea that athletes may have different strategies to maintain CoP and may limit the clinically applicability. The time between evaluations may be a factor as to why we did not see statistical significance in the current study. Future research should examine the applicability of re-baseline evaluations on a yearly basis to detect postural and cognitive changes with or without a diagnosed concussion.

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APPENDIX A: LITERATURE REVIEW

EPIDEMIOLOGY OF CONCUSSION

The term concussion is derived from the Latin word concussus, which means to shake violently.[1] Broadly speaking, the term concussion may be used to describe a clinical state and the event which brings about the clinical state.[2] There have been multiple definitions in the literature that have been used to exemplify concussion. In 2012, the Concussion in Sport Group engaged in a round table discussion focused on concussive injury. The most commonly used definition of concussion is a "complex pathophysiological process affecting the brain by traumatic biomechanical forces."[3] Other definitions found in the literature include a mild traumatic brain injury resulting from biomechanical insult to the brain that initiates a destructive neurometabolic cascade of events[4] and a clinical syndrome characterized by immediate and transient posttraumatic impairment of neural functions.[5] Concussion can be caused by either a direct blow to the head, face, neck or any part of the body that causes forces to travel to the head.[3] Impairments are typically rapid and short-lived neurologic issues that resolve spontaneously.[3] However, symptoms can occur either minutes to hours later, and may not be detected on immediate post-injury evaluations.[3]

A great deal of research has been focused on the epidemiology of concussion between high school athletes and collegiate athletes.[6-10] An estimated 57 million people worldwide have been hospitalized with one or more traumatic brain injury (TBI).[11] The terms TBI and concussion are often used interchangeably in the sporting context, particularly in the literature concerning concussion.[3] Approximately 44 million boys and girls in the United States participate in organized youth sports.[12] The Centers for Disease Control and Prevention estimates that 1.6-3.8 million concussions occur in sports and recreational activities annually.[7] During a 10 year

period emergency department visits for 8 to 13 year-old children affected by concussion in organized team sports have doubled and in the 14 to 19 year old age group there was an increase of 200%.[8] The National Colligate Athletic Association (NCAA) reports over the last 10 years the rate of concussion has stayed consistent with 2.5 concussion occurring for every 1000 athlete exposures (AE).[13] Fifty-five percent of all collegiate concussions are comprised of athletes participating in the sport of football. [9]

In 2007, a study was conducted which included a national sample of 180 universities 100 high schools, including a wide range of sports. These studies concluded that concussion accounted for 5.8% and 8.9% of injury in college athletics and high school, respectively. In both college and high school athletics, concussions from contact sports, are also well documented. Multiple researchers have focused on football and the incidence rate of concussions; Guskiewicz et al[14], Dompier et al[15], and Shankar et al[6] have all conducted research focusing on the epidemiology of concussion between high school and collegiate football players. Concussions among football players occur more often in games than in practice, and contact with another player or opponent is presented in three studies as being the highest risk play for a concussive impact.[6,14]

Following initial head impact, there is a neurophysiological change that occurs in the brain, which is believed to be responsible for the subsequent metabolic disturbances concerning post-concussion. This disturbance can elicit concussive symptomology; such as a feeling of being stunned or seeing bright lights, brief loss of consciousness, lightheadedness, vertigo, loss of balance, headaches, cognitive and memory dysfunction, tinnitus, blurred vison, difficulty concentrating, lethargy, fatigue, personality changes, inability to perform daily activities, sleep disturbances, and motor or sensory symptoms.[1] Guskiewicz and colleagues have documented the

prevalence of certain signs and symptoms which are most commonly associated with concussion and found headache, dizziness, and confusion were the three most commonly reported symptoms among high school and collegiate athletes; 86%, 67%, & 59% respectively.[14] Another symptom of a concussion involves inability to maintain balance and balance disturbances are reported in 30% of injuries.[16]

ANATOMY AND PHYSIOLOGY FROM INJURY

With limited understanding of the biomechanical framework following head injury, Giza et al[4] attempted to review the underlying pathophysiologic processes of concussive brain injury and report potential neurometabolic changes. However, when discussing metabolic changes that occur following head injury, it is important to remember that studies have only been conducted on laboratory rat models and the results applied to human subjects.[17]

Immediately after biomechanical injury to the brain, there is disruption of neuronal membranes, axonal stretching, and opening of voltage-dependent K+ channels, which leads to a marked increase in extracellular K+.[18] Excessive extracellular K+ is taken up by surrounding glial cells,[19] allowing the brain to maintain physiologic K+ levels after mild perturbations.[20] This massive excitation is then followed by a wave of relative neuronal suppression that has been termed spreading depression.[21] Early loss of consciousness, amnesia, or other cognitive dysfunction may be manifestations of a posttraumatic spreading depression–like state.[4] Immediately after injury, in an effort to restore homeostasis, energy pumps are activated and trigger an increase in glucose use.[22,23] An increase in glucose use has been seen in rat models to last for up to 30 minutes. However, increased glucose metabolism may last up to 4 hours, after more severe injury.[4] Accelerated glycolysis leads to increased lactate production, and is seen

after both ischemic[24] and concussive[25] brain injury. Elevated lactate levels can result in neuronal dysfunction by inducing acidosis, membrane damage, altered blood brain barrier permeability, and cerebral edema.[26] This dysfunction has the potential to leave neurons vulnerable to a subsequent ischemic injury.[4] In a setting of increased glucose use (hyperglycolysis),[4] cerebral blood flow (CBF) may be reduced up to50% of normal.[27] Additionally, calcium accumulation is seen within hours of experimental concussion and may persist for up to 2 to 4 days.[28] Excess intracellular Ca^2+ may also be sequestered in mitochondria,[29] resulting in impaired oxidative metabolism and, and ultimately, energy failure.[4] After the initial period of hyperglycolysis, cerebral glucose use is diminished by 24 hours post injury and remains low for 5 to 10 days.[17] Whether the brain is relatively more protected or if the brain is more susceptible to secondary injury because it is unable to respond adequately to further energy demands is unknown.[4]

BALANCE AND POSTURAL CONTROL

Balance plays a vital role in the maintenance of fluid, dynamic movement common in sport, and is defined as the process of maintaining the center of gravity (CoG) within the body's base of support.[30] Doettl 2015[31], defines imbalance as the inability to maintain a vertical upright position while standing still or during locomotion as a result of concussion and neurological dysfunction. 30% of sport related concussions will present with balance disturbances and dizziness has been reported in 75.6% of cases.[9] Dizziness can be caused by a constellation of symptoms including vertigo and lightheadedness with motion as a result of vestibular injury following concussion.[31] After concussion, problems with the vestibular system are considered most likely to be responsible for the individual's inability to maintain balance.[30] Balance

disturbances have been noted to return to normal within 72 hours; however, prolonged damage may last more than 7 days beyond the initial injury.[30]

BASELINE EVALUATION & ASSESSMENT

Clinicians are able to rely on baseline concussion screening to identify signs and symptoms related to neurocognition, symptomology, and balance.[32,33] Baseline testing is used to aid sports medicine clinicians with information vital to concussion assessments.[34] Athletes can present with a variety of signs and symptoms following a concussion and in order to adequately assess concussive injury, a battery of tests should be performed. The National Athletic Trainers Association[34] recommends baseline assessments that include a neurological history, incorporating a physical and symptom evaluation.[34] Kelly et al[35] documented the use of a multifaceted approach to concussion evaluation and found that the use of at least three different assessment tools are utilized at baseline, during evaluation, and for the return to play process; 71.2%, 79.2%, and 66.9% respectively.[35]

In 2013, Zimmer et al documented differences in baseline assessments for 437 athletes from 28 different teams using measures of the SAC, BESS, and a neurocognitive exam.[36] No differences were observed for the SAC, however, researchers did observe a significant difference for the neurocognitive exam and a significant difference in administration of the BESS (p=.002).[36] These differences were correlated to the height of the participant, as participants who were taller had a tendency to perform worse on the BESS.[36] In 2015, Cripps et al[32] sought to investigate if self-reporting of symptoms varied by type of collection method. It was determined that participants reported a significantly higher amount of symptoms on computer based assessments during baseline, as opposed to written or verbal assessment.[32] Athletes' baseline

performance has also been shown be significantly lower when tested in group settings as opposed to individual settings.[37]

Along with the positive aspects of baseline testing, negative aspects also exist. There has been an idea which suggests athletes may purposely try to perform poorly on baseline evaluations allowing a quick return to activity. This idea had been investigated by Erdal in 2012, but there were no significant results to support this notion. Intentionally underperforming on baseline assessments is difficult and lower baseline scores should be carefully reviewed.[38]

CONCUSSION ASSESSMENT

When evaluating an individual with a suspected concussion, specific testing which mirrors baseline assessments need to be included to adequately assess a patient with a concussion. There are many different clinical tests and evaluation methods used to detect concussions. Some of the more common testing methods include evaluation of self-reported symptoms, postural control, and neurocognitive functioning.[39] Graded Symptom Checklists (GSC)[40], the Standard Assessment of Concussion (SAC)[41,42], and the Balance Error Scoring System (BESS)[43] balance assessment are just a few of the specific concussion evaluation tools used during a concussion assessment. It is important to include baseline testing of athletes, which further allows for more information about a potentially concussed patient. Baseline testing use is predicated on the belief that a concussion results in impairment of cognition. It is also important to ensure that players are free of the effects of concussion before return-to-play. Measurement of cognition at baseline allows the reliable detection of cognitive impairment following concussive injury.[44] Values can be compared to baseline scores during initial assessment and during clinical decision making, to assist in making a return to play decision. When these tests are used

individually of themselves, they exhibit a low reliability[39] rate for assessment (<.70).[39,45] Since 2002, the use of a multifaceted approach has been recommended to evaluate concussive injury. A study published in 2014 reported over the last 10 years a multifaceted approach to concussion evaluation has been largely incorporated by Certified Athletic Trainer's (ATC's).[35]

GRADED SYMPTOM CHECKLIST

The Graded Symptom Checklist (GSC) is one of the most commonly used clinical measures in the assessment of concussion, due to the relatively high sensitivity (.89) to detect injury.[39,40] The GSC requires athletes to rate the presence/severity of 25 common concussion symptoms on a 0–6 Likert scale.[39,46] Higher numbers on the Likert scale indicate higher severity of an individual symptoms over others. The symptom checklist has been used in various studies and been shown to be a valid and reliable clinical tool.[47] In 2005, McCrea et al studied symptom severity in concussed populations. At time of injury, 89% of subjects reported increased symptoms. During follow up evaluation at one-day post injury, results revealed that only 74% of subjects complained of symptoms. One week post injury, the number of subjects who reported symptoms dropped drastically to 4%.[40]

STANDARDIZED ASSESSMENT OF CONCUSSION

The effects of concussion on mental status are usually not obvious or evident on neurological exam, and it is often difficult to detect and fully characterize the neurocognitive effects from injury.[48] The Standardized Assessment of Concussion (SAC) was developed to provide team physicians, athletic trainers, and other medical professionals[16] with an objective and standardized method of immediately assessing an injured athlete's mental status on the sport

sideline within minutes of having sustained a head impact.[42] The SAC represents the first instrument specifically designed with the intention of quantifiably measuring the immediate neurocognitive effects of concussion.[49] The SAC test was designed to assess the acute cognitive functions of an individual before and after suffering a suspected head injury within 5 minutes.

The SAC test evaluates 4 domains: orientation, immediate memory, concentration, and delayed memory, which are all frequently affected by concussion. There are 3 versions of the SAC that have been reported to be equivalent.[50] The immediate memory, concentration, and delayed memory sections contain unique items on each version, whereas the orientation section of all 3 versions is identical.

The immediate memory section of the SAC is focused on memorization and regurgitation of five words which are separated into 3 different lists to limit practice effects. The concentration portion focuses on the ability to regurgitate sets of three to six digits, in reverse. The orientation portion concentrates on the month, date, day of the week, year, and time. For the delayed memory portion, the person being tested is evaluated on the ability to repeat the original five words from the immediate memory test.[51] The tests are scored by adding the number of correct responses; 5 points can be scored in each of the orientation, concentration, and delayed memory sections, and 15 points within the immediate memory section to combine fora total of 30 possible points.[50]

Previous studies have demonstrated the clinical sensitivity of the Standardized Assessment of Concussion in evaluating concussions.[49,52] The sensitivity of the SAC has been reported to range between 0.72 and 0.78.[41] A 2001 study published by McCrea and colleagues investigated the efficacy of standardized mental testing on the sideline to detect abnormalities resulting from concussion.[42] Sixty-three concussed and fifty-five control subjects were evaluated

and the injured subjects performed significantly below pre-injury baselines. The research concluded a decline in SAC score at time of injury to be 95% sensitive and 76% specific.[42] However, Ragan et al in 2007[53] published results which questioned the validity of the SAC as a baseline measure. At baseline, 63-70% of items on the SAC were considered too simplistic, provided little information, and could be eliminated during baseline testing. All 5 orientation items and 87-100% of immediate memory items were deemed unacceptable.[53] After experiencing a concussion, the SAC would not be able to able to identify a 6 point decrease in cogitative ability, whereas a 3-point decrease is supposed to indicate a concussive injury.[41]

ROMBERG TEST

Originally created in the 19th century, the Romberg test was developed to assess balance deficits with reduced visual sensory input.[16] Traditionally, clinicians have used the Romberg test for assessing disequilibrium in head-injured athletes.[54] Tested individuals stand as quietly as possible during duration of testing. Their feet are placed together with the feet touching. Trials are alternated with visual sensory conditions including EO and EC.[43,54] After an extensive search of the literature, there are few studies using the Romberg test. This lack of research may be due to the Balance Error Scoring System (BESS) test incorporating the stances of the Romberg test. Therefore, the reliability and validity data of the Romberg test alone are limited.[16]

BALANCE ERROR SCORING SYSTEM

The Balance Error Scoring System (BESS) is the recommended postural control test of the 4th International Consensus Statement on Concussion.[3,55] The BESS was developed to provide clinicians with an inexpensive and practical tool for the assessment of postural

stability,[43] most commonly used during sideline evaluation.[56] Currently, it is regarded as the "clinical gold standard" for measuring balance deficits.[16]

Balance is defined as defined as the process of maintaining the center of gravity (CoG) within the body's base of support[30]. Management of balance related deficits will vary dependent upon the etiology of the deficit.[57] Somatosensory and proprioceptive information is transmitted and integrates the inner ear, allowing the body to process positional information in relation to gravity.[57] A balance disturbance is characterized as the inability to stand with an upright posture without deviating outside the limits of the base of support.[30] In response to internal or external perturbations, an individual's ability to maintain a desired orientation is known as postural control and can be inferred from Center of Pressure displacements.[58]

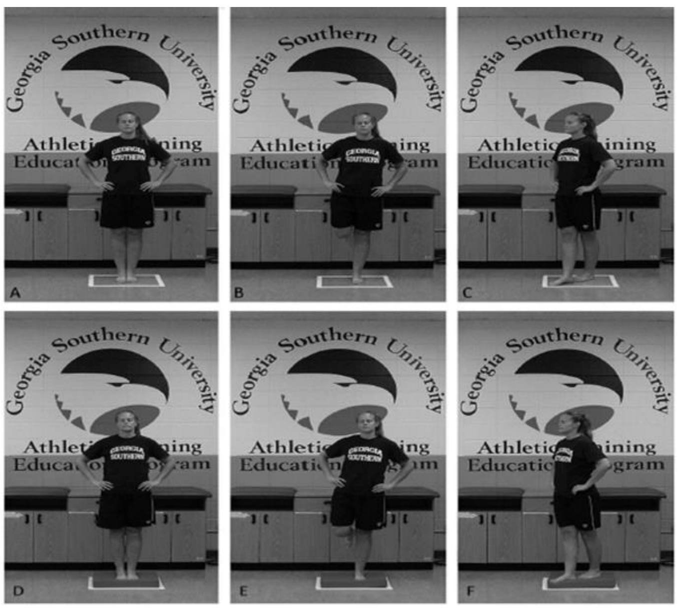

Figure 3: Balance Error Scoring System Stances

Notes: The BESS is comprised of six, twenty second trials. Three trials performed on a stable surface and three performed on a 1.5' airex pad. Stances include double leg, single leg (non-dominant foot), and tandem (non-dominant foot behind dominant)

A balance disturbance could place an athlete at greater risk for additional injury through falls or collisions.[16] Athletes who undergo BESS testing are instructed to close their eyes, place their hands on their hips, and stand in 3 different positions(single-leg stance, feet together, and tandem stance) on 2 different surfaces (firm and foam) for 20 seconds each (Figure 3).[43] Errors are defined as opening eyes, lifting hands off hips, stepping, stumbling or falling out of position,

lifting forefoot or heel, abducting the hip by more than 30^{o}, or failing to return to the test position in more than 5 seconds.[59] As recently as 2016, a change of 3 – 6 errors from baseline to post injury has been suggested to be indicative of a concussion.[60] Finnoff et al[61] examined each of the BESS stance trials to determine the reliably of the test. The intrarater reliability for the BESS ranged from 0.50 to 0.88, while the interrater reliability ranged from 0.44 to 0.83.[61] In another study, evaluation of the BESS revealed low to moderate intraclass and test–retest reliabilities limiting the validity of the interpretations of scores. (r = 0.60, 0.67)[62] There are a variety of variables that can impact overall BESS score, including specific sport, individual history of lower leg or ankle injury, fatigue from exertion,[63] repeat test performance, and neuromuscular balance training.[55] Rahn et al[64] evaluated a concussed and control group to determine the influence of a live sporting event on BESS performance. The concussed group displayed a significant decrease at both football and basketball games when compared to the non-concussed, P=0.004. In 2012, a study by Burk and colleagues administered the BESS to 58 college females. These athletes were tested on two different occasions, 90 days apart to evaluate changes in the BESS after an athletic season. The study observed a significant improvement (P=0.003) between preseason and post season performance (9.00 +/- 2.97 errors and 7.92 +/- 2.78 errors).[55] Following sport related concussion, it has been suggested that the BESS is a reliable and efficient mean to evaluate concussion.[31] However, current reliability would not be adequate for a measurement with implications for return to participation decisions.[62] On average, athletes who initially present with postural instability after concussion return to their baseline level of performance on the Balance Error Scoring System within 3 to 5 days of injury.[65]

LABORATORY BASED BALANCE ASSESSMENT

Medical professionals use an assessment battery to assess concussion, for which the reliability and validity have been studied;[16,39] however, other testing measures may be required to detect lingering deficits following concussion. Balance assessment is one area of concussion assessment that typically resolves in 3 – 5 days using standard clinical measures,[30] and may be overlooked following that time point. Balance assessments range from simple clinical sideline tests to complex laboratory testing. The most common assessments discussed in concussion literature are the Clinical Test of Sensory Organization and Balance (CTSIB) and the Sensory Organization Test (SOT),[65] which both incorporate the use of a laboratory grade force platform. Force Platforms provide objective values to assess balance control.[66] While, in the last ten years, there has been an increased interest in the use of the Nintendo Wii Fit as a measure to assess for postural control deficiencies following concussive injury. Previous authors have utilized the Nintendo Wii fit balance board and force platforms, in concussed and non-concussed populations.

CLINICAL TEST OF SENSORY INTEGRATION AND BALANCE

The CTSIB was originally developed in 1986 and involves 6 major scenarios that systematically removes conflict or sensory inputs.[67] The modified CTSIB involves a more complex force platform and is used more commonly in research.[16] Administration of the CTSIB includes alternation between EO or closed, standing on high density foam while looking toward an object. [16] A 1998 study measured the reliability of the unmodified CTSIB in older adults and reported an interclass correlation coefficient (ICC) of 0.98, these results suggest the CTSIB can be a useful test to assess balance deficits in an older population.[16]

SENSORY ORGANIZATION TEST

The sensory organization test (SOT) uses a force platform, a reference point, and a harness for safety while systematically disrupting afferent sensory information. This disruption is achieved by reducing spatial awareness cues via somatosensory or visual components.[54] Administration of the SOT requires individuals to maintain a quiet steady stance during six combinations of three trials.[54] The trials last 20 seconds each, allowing clinicians to determine a composite balance score and an equilibrium performance score.[54] Scoring on the SOT allows for a maximum of 100 points with higher scores correlate to better overall balance.[16] The reliability and validity values associated with the SOT have been studied in healthy populations but have not been heavily investigated in concussion literature, which limits generalizability.[68,69] Register-Mihalik and colleagues investigated the reliable change for concussion battery assessments, which included the SOT.[45] Results of the study[45] revealed the SOT composite score to have the highest sensitivity, which researchers concluded to be consistent in the literature.

NINTENDO WII FIT

The Wii Fit System was designed by Nintendo in 2007 to combine fun and fitness for people of all ages.[11] The Wii Fit balance games use visual displays to initiate dynamic movement in which lower body ground force data is transposed, meeting certain goals based upon the games requirements. These games are currently used by fitness and rehabilitation clinicians to assess and aid in the recovery from injury.[16] While limited in terms of weight capacity (150 Kg) and sampling frequency (30-50 Hz), the Wii Fit provides a portable and inexpensive platform that has been used in conjunction with force platforms for postural control studies. It is also considerably less expensive at $200 USD,[11] when compared to the SOT and CTSIB. Holmes et

al[70] evaluated the Nintendo Wii Balance Board as a measurement tool for the assessment of postural stability in individuals with Parkinson's. Examining the use of the Wii Fit in patients with Parkinson disease, which could provide additional insight into reliability and validity data for those with concussions.[16] Researchers were able to determine that the Wii Balance Board exhibited intraclass correlations of 0.96, 0.98, 0.92, and 0.94 among 4 trials.[70] The Wii Fit uses metrics of raw center of pressure (CoP) data to record anterior-posterior (AP) sway and medio-lateral (ML) sway.[11] The Wii Fit has a variety of games which upon completion can assess a balance score. When combined with clinical force platforms, a more accurate measure of CoP, or CoP displacements, is possible.[11] Before starting a test, the Wii Fit collects two forms of data. The first, a body test, measures balance control. The second metric calculated is a body control test, designed to calculate a dynamic and cognitive CoP control.[11]

In 2015, Goble et al conducted a comprehensive review of Wii Fit literature to document the clinical usage since the devices' inception. To date, the Wii Fit has been studied in populations with the purpose of training balance in healthy individuals and rehabilitating balance deficits. While still in its infancy, the Wii Fit has been shown to be an effective tool and no studies have reported negative effects from its use.[11] No studies were included in Goble's work, which investigated using the Wii Fit for concussion assessment. Murray et al was one of the first researchers to include the use of the Wii Fit during concussion evaluations compared to a non-injured controls.[71] Incorporating the Wii Fit Soccer Heading Game, eighteen athletes were categorized into two groups of not currently participating (NC) and athletes with concussions (AC).[71] Eleven healthy athletes comprised the NC group and the other seven athletes comprised the AC group. These athletes were evaluated at three different testing dates spanning a three-week time window, and were further assessed on their ability to complete static and dynamic

stances. Results revealed a significant difference in Peak CoP velocity between groups in the AP plane 24-48 hours and 8 days post injury, $p=0.05$ and $p=0.018$, respectively.[71] Significant differences were also observed in the AP and ML planes between groups when evaluating dynamic postural control at all three testing dates. The study conducted by Murray in 2014 is an important piece of research as it sets the groundwork for future studies to evaluate the Wii Fit in concussion assessment and management.

RETURN TO PARTICPATION

After a diagnosed concussion, cognitive and physical rest is vital to recovery.[3] Each patient and concussion should be treated uniquely as symptoms may present differently in each individual. Therefore, if a clinician suspects a concussion has occurred, the athlete should not be allowed to return to play during that day and should be monitored for 24-48 hours.[3] A daily examination should be performed to monitor recovery and the athlete should avoid excessive cognitive activity and should avoid physical activity as this may increase an individual's symptoms.[34] Objective assessments are recommended to be administered once the athlete is symptom free and compared to baseline assessments.[3] The decision to return an athlete to participation should not be made until objective assessments are at baseline values.[34] Cantu et al in 2001 documented a return to participation (RTP)[1] protocol, which was premised on the level of severity related to loss of consciousness(LOC) and number of total concussions. Lovell et al[72] investigated the importance of LOC for making return to play decisions and did not find significant evidence to support weighing LOC higher than other symptoms. Since then, there has been a recommendation to incorporate a gradual return to participation progression[3,34] Individual institutions have the ability to design RTP progressions specific to that institution's needs.

Gradual return to participation progressions should be structured with a step by step/day by day progression.[3] The RTP progression should not begin until the athlete no longer reports symptoms, presents with a normal clinical exam, and performs at or better than objective baseline assessments once symptom free.[34] When the RTP progression has been started, the progressions should start with light aerobic exercise, and progressively return the injured athlete back to full contact practices before a clearance to return to participation.[3] Athletes should only be allowed to make one progression per day and if the athlete experiences an onset of symptoms or decline in performance the progression for that day should be stopped immediately. Upon completion of a RTP progression, the injured athlete should be symptom free, have concussion assessment scores that are the same or better than baseline and be cleared by a physician who has specific training related to head injuries.[34]

RE-BASELINE EVALUATION

It is the recommendation of the National Athletic Trainers' Association that new baseline examinations should be completed for athletes with concussion.[34] If possible, all athletes should be re-baselined each year due to the testing environment[37,73] as well as possible practice effects[74], performance improvements[55], and fatigue[75,76]. After an extensive search of the literature, to date, only one study has been published on the utility of a concussion re-baseline protocol. Lynall et al 2015 evaluated thirty four athletes at three different time points; baseline, final post injury before return to play, and re-baseline before next competitive season.[33] The baseline measures tested mirror Zimmer et al 2013, using a neurocognitive exam, a balance composite score attained from the BESS, and total self-reported symptom scores similar to the Graded Symptom Checklist. The tested variables were compared to reliable change indices (RCIs) evaluating

individual participant change in scores between testing points. Researchers reported a significant increase in neurocognition ranging from $p<0.002 – 0.006$ and balance scores ($p<0.001$), as well as subjects reporting more symptoms at re-baseline than post injury ($p =0.003$).[33] The study by Lynall and colleagues, while including a balance assessment, was predominantly focused on neurocognitive testing results. Results, different from each evaluation point, did not exceed RCIs, suggesting re-baseline protocols provide little clinical utility.[33] The study conducted by Lynall is limited due to the use of the SOT balance assessment. This type of balance assessment tool may not be clinically applicable to clinicians providing care to concussed athletes.

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APPENDIX B - IRB FORMS

Georgia Southern University

Application for Research Approval

Investigator Information:		
Name of Principal Investigator: Nicholas Murray	Email: NMurray@georgiasouthern.edu	**For Office Use Only:** Protocol ID: ____________ Date Received:
Phone: 912.478.0203	Address: 0107-B Hollis Building 62 Georgia Ave Box 8076	
Department: Health and Kinesiology		
Name(s) of Co-Investigators: Barry Munkasy, Ph.D. George Shaver, Ph.D. Betty (Petty) Clouse, M.S. Nathan D'Amico, B.S. Klarie Ake, B.S. Megan Mormile, B.S. .	Title of Co-Investigator(s): Associate Professor of Biomechanics Director Academic, Regents Center Head Athetic Trainer Graduate Student, Exercise Science Graduate Student, Exercise Science Graduate Student, Exercise Science	
Personnel and/or Institutions Outside of Georgia Southern University involved in this research (Attach training certification):		

Project Information: (Note: funded project titles must match grant title)
Title: Postural Stability in Athletes following Concussion
Brief (less than 50 words) Project Summary: This project will assess neurocognitive function, balance, and static and dynamic postural stability following a concussion.

Compliance Information:				
Please indicate which of the following will be used in your research: (application may be submitted simultaneously)				
☒ Human Subjects (Complete *Section A: Human Subjects* below) ☐ Care and Use of Vertebrate Animals (Complete *Section B: Care and Use of Vertebrate Animals* below) ☐ Biohazards (Complete *Section C: Biohazards* below)				
Project Start Date: 5/31/2015 End Date: 5/31/2016 (no more than 1 year) Anticipated renewals ☐ year 2 ☒ year 3		**Check one:** ☐ **Student** ☒ **Faculty/Staff**		
Funding Source: ☐ Federal	☐ State	☐ Private	☐ Internal GSU	☐ Self-funded
Funding Agency:		☐ Not Applicable		

Section A: Human Subjects ☐ Not Applicable	
Number of Subjects (Maximum) 500	Date of IRB education completion:1/28/2014 **(attach copy of completion certificate)**
Purpose of Research:	*Please indicate if the following are included in the study*:

☒ For use in thesis/dissertation ☐ Completion of a class project ☒ Publication (journal, book, etc.) ☒ Poster/presentation to a scientific audience ☐ Results will **not** be published ☐ Other	☒ Informed Consent Document ☐ Greater than minimal risk ☐ Research Involving Minors ☐ Deception ☒ Generalizable knowledge (results are intended to be published) ☐ Survey Research ☐ At Risk Populations (prisoners, children, pregnant women, etc.) ☐ Video or Audio Tapes ☐ Medical Procedures, including exercise, administering drugs/dietary supplements, and other procedures

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

Section C: Biological Research ☒ Not Applicable ☐ Submitted Separately	
Biosafety Level: ☐ Exempt ☐ BSL 1 ☐ BSL 2 ☐ BSL 3	*Please indicate if the following are included in the study*: ☐ Use of rDNA ☐ Nonnative/invasive plant species ☐ Last EHS lab safety inspection date: _Attach Report______________ ☐ Last IBC biosafety lab inspection date: __Attach Report______

Signature of Applicant(s): (PI, CoPI) X	Date:
If student project please complete research advisor's information below *(note that advisor signature must be received before application will be reviewed.):*	
Research Advisor's Name:	Advisor's E-mail:
Advisor's Phone:	Advisor's Department: P.O. Box:
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	

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.

For optional email submission: Save the application forms to your computer. Complete the forms and name them beginning with your last name and first initial. Email the entire submission package to IRB@georgiasouthern.edu in a single email. Original signature pages may follow by mail or fax. (Signatures located on cover page, certification of investigator responsibilities and last page of application where certifications required.)

GEORGIA SOUTHERN UNIVERSITY
COLLEGE OF HEALTH & HUMAN SCIENCES
POST OFFICE BOX 8076
STATESBORO, GEORGIA 30460-8076
TELEPHONE (912) 681-0200

CONSENT TO ACT AS A SUBJECT IN AN EXPERIMENTAL STUDY

1. Title of Project: Identification of Persistent Impairments in Postural Control Following Concussion

Investigator's Name: Nicholas Murray, Ph.D. Phone: (912) 478 - 5268

Participant's Name ___________________________ Date:______________________

Data Collection Location: Biomechanics Laboratory, Georgia Southern University Campus

2. We are attempting to compare the balance, coordination and bodily control of individuals who have suffered a concussion and compare that to people who have not suffered a concussion. There will be 500 participants in this study, about half whom and half who have not suffered a concussion. The results of this study will help athletic trainers in the evaluation, treatment, and return to play decision making process in individuals who have suffered a concussion.

3. You are being invited to participate in this study because you have recently suffered a concussion or are a control subject. Additionally, you have no history of any nerve, inner ear or balance disorders, metabolic disorders, or significant injury to the lower extremity.

If you agree to participate in this study you will be asked to attend testing sessions lasting 25 min. You will be tested post-concussion, your return to play day and then every 7 days over the next 2 months. During the session you will be asked to both stand still, on 2 feet and 1 foot, walk at normal pace while solving mental challenges and play the Wii Soccer game. During the session you will stand and walk across force platforms and a carpet which measures the forces you create on the ground. You will also stand on a Wii balance board that is on top of a force platform and wear a headset. Finally, we will record your performance on the balance, cognitive, and neuropsychological testing, and your self-reported symptoms that you complete as part of your normal post-concussion assessment. The balance test will be video recorded.

4. The information we collect on your performance may be sent off campus for analysis, however any information sent will be devoid of identifying characteristics (no one will be able to tell it's you). The video recordings will not be sent off-campus.

5. Your performance during these tasks will be compared to your performance during your baseline test, if you performed one, when you began playing sports at Georgia Southern University.

6. The risk assumed during the testing is no greater than you experience during your normal daily activities. There is minimal risk of physical injury or mental discomfort while performing this experiment. There is a risk of falling during the gait and balance trials; therefore, a member of the research team will be in close proximity should you lose balance. The headset you will be wearing for the Wii Soccer game does not your impair vision and should sit comfortably on your head like a ball cap. If the headset becomes uncomfortable at any time, a member of the research team will immediately remove it. 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.

7. You will likely receive no direct benefit for participating in this study, however you will be provided your results, once calculated, if you so request. The results of this study may be used to better understand and treat individuals who have suffered concussions.

8. You will attend testing sessions over the next 2 months lasting about 25 min.

9. You understand that all data concerning yourself will be kept confidential and available only upon your written request to Nicholas Murray, Ph.D. You understand that any information about your records will be handled in a confidential (private) manner consistent with medical records. Your identity on all records will be indicated by a case number. You will not be specifically mentioned in any publication of research results. However, in unusual cases your research records may be inspected by appropriate government agencies or released to an order from a court of law. All information and research records will be kept for a period of 5 years after the termination of this investigation. The video recordings will be retained for seven years as required by the Georgia Board of Regents policy.

10. If you have any questions about this research project, you may call Nicholas Murray at (912) 478-5268. 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.

11. 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.

12. 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, Dr. Murray.

13. You understand that you may terminate participation in this study at any time without prejudice to future care or any possible reimbursement of expenses, compensation, employment status, or course grade except provided herein, 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.

14. You understand there is no deception involved in this project.

15. 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 regarding 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 (912) 478 – 5268.

16. You have been provided a copy of this form.

Title of Project: Identification of Persistent Impairments in Postural Control Following Concussion

Principal Investigator	**Other Investigator**
Nicholas Murray, Ph.D.	**Barry Munkasy, Ph.D.**
0107B Hollis Building	**0107D Hollis Building**
(912) 478 – 5268	**(912) 478 – 0985**
nmurray@georgiasouthern.edu	**bmunkasy@georgiasouthern.edu**

______________________________ ________________

Participant Signature **Date**

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

________________________________ _________________

Investigator Signature **Date**

Amendment Request

Georgia Southern University Institutional Review Board

Study Title __Postural Stability in Athletes following Concussion________________

Principal Investigator _Nicholas Murray__________________
*Advisor/Department*___School of Health and Kinesiology____________________

Protocol# __H16114_________ Amendment # __1_____
Please briefly describe each change in the protocol and its rationale. Additional pages may be used as necessary.
The protocol remains the same for this particular project. We are adding two additional research assistants onto the project to assist with data collection.

Personnel change (attach training certification):

Change (add or delete)	Name	Role on project	Training certificate attached
ADD	Katelyn Grimes	Research Assistant	YES
ADD	Brian Mizeski	Research Assistant	YES

Research changes (attach narrative update):	*Justification for changes:*
1.	
2.	
3.	
4.	
5.	

Consent form changes (attach informed consent update):	*Justification for changes:*
1.	
2.	
3.	
4.	
5.	

_____________________ _____3/29/2016________________________
Principal Investigator's Signature Date

____ _____________________________
Advisor's Signature (if student) Date

Amendments to approved protocol may be submitted at any time. If only minor changes are requested, review may be expedited. Substantial amendments will be considered at a convened meeting of the full IRB.

NOTE: No amendment to the awarded protocol can be implemented without notification from the Georgia Southern University Institutional Review Board.

For office use only:
____
IRB chair's signature
Date: ______________

Georgia Southern University
Office of Research Services & Sponsored Programs

Institutional Review Board (IRB)

Phone: 912-478-5465
Fax: 912-478-0719
IRB@GeorgiaSouthern.edu
Veazey Hall 3000
PO Box 8005
Statesboro, GA 30460-8005

To:	Nicholas Murray
From:	Office of Research Services and Sponsored Programs Administrative Support Office for Research Oversight Committees (IACUC/IBC/IRB)
Date:	05/03/2016
Expiration Date:	11/30/2016
Subject:	Status of Research Study Modification Request

After a review of your Research Study Modification Request on research project numbered **H16114** and titled **"Postural Stability in Athletes following Concussion"** your request for modification appears that (1) the research subjects are at minimal risk, (2) appropriate safeguards are planned, and (3) the research activities involve only procedures which are allowable.

Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that the Institutional Review Board has approved your modification request. **This amendment adds a single researcher (Emily Lasko) and deletes a single researcher (Klarie Ake).**

The expiration date of your original application approval remains in effect. If additional time beyond your expiration date is required to complete your data collection and analysis and there have been no further changes to the research protocol; you may request an extension of the approval period. If your project will require approval beyond 36 months from the initial approval date, a new submission and review will be required. In the interim, please provide the IRB with any information concerning any significant adverse event, **whether or not it is believed to be related to the study**, within five working days of the event. In addition, another change or modification of the approved methodology becomes necessary; you must notify the IRB Coordinator **prior** to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, you are required to complete a *Research Study Termination* form to provide the final information to allow your file to be closed.

Sincerely,

Ele Haynes (SS)

Eleanor Haynes
Compliance Officer

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

COURSEWORK REQUIREMENTS REPORT*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details.
See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

• **Name:** Brian Mizeski (ID: 5363014)
• **Email:** bm06389@georgiasouthern.edu
• **Institution Affiliation:** Georgia Southern University (ID: 1063)
• **Phone:** 2012474358
• **Curriculum Group:** Human Subjects-Social & Behavioral Research - Basic/Refresher
• **Course Learner Group:** Same as Curriculum Group
• **Stage:** Stage 1 - Basic Course
• **Description:** Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.
• **Report ID:** 18592648
• **Completion Date:** 02/03/2016
• **Expiration Date:** 02/02/2019
• **Minimum Passing:** 80
• **Reported Score*:** 82

REQUIRED AND ELECTIVE MODULES ONLY DATE COMPLETED

Belmont Report and CITI Course Introduction (ID: 1127) 02/02/16
Students in Research (ID: 1321) 02/02/16
History and Ethical Principles - SBE (ID: 490) 02/03/16
Defining Research with Human Subjects - SBE (ID: 491) 02/03/16
The Federal Regulations - SBE (ID: 502) 02/03/16
Assessing Risk - SBE (ID: 503) 02/03/16
Informed Consent - SBE (ID: 504) 02/03/16
Privacy and Confidentiality - SBE (ID: 505) 02/03/16
Conflicts of Interest in Research Involving Human Subjects (ID: 488) 02/03/16
Recognizing and Reporting Unanticipated Problems Involving Risks to Subjects or Others in Biomedical Research (ID: 14777) 02/03/16
Cultural Competence in Research (ID: 15166) 02/03/16
Records-Based Research (ID: 5) 02/03/16
Research with Prisoners - SBE (ID: 506) 02/03/16

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution
identified above or have been a paid Independent Learner.

CITI Program
Email: citisupport@miami.edu
Phone: 305-243-7970
Web: https://www.citiprogram.org

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

COURSEWORK TRANSCRIPT REPORT**

** NOTE: Scores on this Transcript Report reflect the most current quiz completions, including quizzes on optional (supplemental) elements of the
course. See list below for details. See separate Requirements Report for the reported scores at the time all requirements for the course were met.

• **Name:** Brian Mizeski (ID: 5363014)
• **Email:** bm06389@georgiasouthern.edu
• **Institution Affiliation:** Georgia Southern University (ID: 1063)
• **Phone:** 2012474358
• **Curriculum Group:** Human Subjects-Social & Behavioral Research - Basic/Refresher
• **Course Learner Group:** Same as Curriculum Group
• **Stage:** Stage 1 - Basic Course
• **Description:** Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.
• **Report ID:** 18592648
• **Report Date:** 02/03/2016
• **Current Score**:** 82

REQUIRED, ELECTIVE, AND SUPPLEMENTAL MODULES MOST RECENT

Students in Research (ID: 1321) 02/02/16
History and Ethical Principles - SBE (ID: 490) 02/03/16
Defining Research with Human Subjects - SBE (ID: 491) 02/03/16
Belmont Report and CITI Course Introduction (ID: 1127) 02/02/16
Records-Based Research (ID: 5) 02/03/16
The Federal Regulations - SBE (ID: 502) 02/03/16
Assessing Risk - SBE (ID: 503) 02/03/16
Informed Consent - SBE (ID: 504) 02/03/16

Privacy and Confidentiality - SBE (ID: 505) 02/03/16
Research with Prisoners - SBE (ID: 506) 02/03/16
Conflicts of Interest in Research Involving Human Subjects (ID: 488) 02/03/16
Cultural Competence in Research (ID: 15166) 02/03/16
Recognizing and Reporting Unanticipated Problems Involving Risks to Subjects or Others in Biomedical Research (ID: 14777) 02/03/16
For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution
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COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COURSEWORK REQUIREMENTS REPORT*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details.
See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.
• **Name:** Brian Mizeski (ID: 5363014)
• **Email:** bm06389@georgiasouthern.edu
• **Institution Affiliation:** Georgia Southern University (ID: 1063)
• **Phone:** 2012474358
• **Curriculum Group:** CITI Health Information Privacy and Security (HIPS)
• **Course Learner Group:** CITI Health Information Privacy and Security (HIPS) for Clinical Investigators
• **Stage:** Stage 1 - Basic Course
• **Description:** This course for **Clinical Investigators** 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.
• **Report ID:** 18592649
• **Completion Date:** 02/02/2016
• **Expiration Date:** N/A
• **Minimum Passing:** 80
• **Reported Score*:** 85
REQUIRED AND ELECTIVE MODULES ONLY DATE COMPLETED
Basics of Health Privacy (ID: 1417) 02/02/16
Health Privacy Issues for Researchers (ID: 1419) 02/02/16
Basics of Information Security, Part 1 (ID: 1423) 02/02/16
Basics of Information Security, Part 2 (ID: 1424) 02/02/16
Protecting Your Computer (ID: 1425) 02/02/16
Picking and Protecting Passwords (ID: 1449) 02/02/16
For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution
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CITI Program
Email: citisupport@miami.edu
Phone: 305-243-7970
Web: https://www.citiprogram.org

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COURSEWORK TRANSCRIPT REPORT**

** NOTE: Scores on this Transcript Report reflect the most current quiz completions, including quizzes on optional (supplemental) elements of the
course. See list below for details. See separate Requirements Report for the reported scores at the time all requirements for the course were met.
• **Name:** Brian Mizeski (ID: 5363014)
• **Email:** bm06389@georgiasouthern.edu
• **Institution Affiliation:** Georgia Southern University (ID: 1063)
• **Phone:** 2012474358
• **Curriculum Group:** CITI Health Information Privacy and Security (HIPS)
• **Course Learner Group:** CITI Health Information Privacy and Security (HIPS) for Clinical Investigators
• **Stage:** Stage 1 - Basic Course
• **Description:** This course for **Clinical Investigators** 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.
• **Report ID:** 18592649
• **Report Date:** 02/03/2016
• **Current Score**:** 85
REQUIRED, ELECTIVE, AND SUPPLEMENTAL MODULES MOST RECENT
Basics of Health Privacy (ID: 1417) 02/02/16
Health Privacy Issues for Researchers (ID: 1419) 02/02/16

Basics of Information Security, Part 1 (ID: 1423) 02/02/16
Basics of Information Security, Part 2 (ID: 1424) 02/02/16
Picking and Protecting Passwords (ID: 1449) 02/02/16
Protecting Your Computer (ID: 1425) 02/02/16
For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution
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Email: citisupport@miami.edu
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APPENDIX C – SAC/BESS EVALUATION FORM

Georgia Southern Athletic Training
Baseline Concussion Evaluation

Name ___________________________ Date ___________ Date of Injury ___________
Sport _________________ Examiner ______________________

Sac Test

Orientation (1 point for each correct answer)

What month is it?______________________________________	0	1
What is the date today? ________________________________	0	1
What is the day of the week? ____________________________	0	1
What year is it? _______________________________________	0	1
What time is it right now? (within 1 hour)__________________	0	1
Orientation Score _____________________________________	/ 5	

Immediate Memory

List	Trial 1	Trial 2	Trial 3	Alternate Word List		
Elbow	0 1	0 1	0 1	Candle	Baby	Finger
Apple	0 1	0 1	0 1	Paper	Monkey	Penny
Carpet	0 1	0 1	0 1	Sugar	Perfume	Blanket
Saddle	0 1	0 1	0 1	Sandwich	Sunset	Lemon
Bubble	0 1	0 1	0 1	Wagon	Iron	Insect
Total	/5	/5	/5			

Immediate memory score total ____________________ / 15

Concentration: Digits Backward

List	Trial 1	Alternate Digit List		
4-9-3	0 1	6-2-9	5-2-6	4-1-5
3-8-1-4	0 1	3-2-7-9	1-7-9-5	4-9-6-8
6-2-9-7-1	0 1	1-5-2-8-6	3-8-5-2-7	6-1-8-4-3
7-1-8-4-6-2	0 1	5-3-9-1-4-8	8-3-1-9-6-4	7-2-4-8-5-6
Total	**/4**			

Concentration: Months in Reverse Order

(1 point for entire sequence correct)

Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan **0** **1**

Delayed Recall Score __________________ **/5**

SAC Total Score: **/30**

Date Completed ____

BESS Test

Footwear (Shoes, Barefoot, Braces, Tape, Etc.) ______________________

Modified Balance Error Scoring System (BESS) testing

Which foot was tested (i.e. which is the non-dominant foot) Left | Right

Testing Surface (Hard floor, Field, Etc.) ________________________________

Condition – On Firm Surface

Double Leg Stance: ____________________________		**Errors**
Single Leg Stance (non-dominant foot): ____________		**Errors**
Tandem Stance (non-dominant foot at back): _______		**Errors**

Condition – On Firm Surface

Double Leg Stance: ____________________________		**Errors**
Single Leg Stance (non-dominant foot): ____________		**Errors**
Tandem Stance (non-dominant foot at back): _______		**Errors**

Total Score: _____________ **Baseline Score:**_____________

Types of Errors

1. Hands off iliac crest
2. Opening Eyes
3. Step, Stumble, or fall
4. Moving hips into >30 degrees of abduction
5. Lifting forefoot or heal
6. Remaining out of test position >5 seconds

The BESS is calculated by adding one error point for each error during the six(6) 20-second tests. Multiple Errors count as one.

Date Completed ____________________________________

Additional Notes:

APPENDIX D – ADDITIONAL INFORMATION

Research Question

The purpose of this study was to evaluate cognitive and postural deficits, in athletes who sustained a concussion, at the conclusion of the athletic season. It is the aim of this research to (1) compare levels of cognition in CONC to NORM athletes during re-baseline evaluations after the conclusion of the athletic season, (2) use a clinically accepted balance assessment to identify postural impairments following a concussion, and (3) utilize a more objective measurement to quantify postural impairments during re-baseline evaluations.

Hypotheses

It was hypothesized that previously concussed athletes will present with significant differences during re-baseline for both the SAC and BESS, as well as presenting with significant differences when evaluating CoP metrics compared to a healthy control group.

Assumptions

The data collected for the current study is based on several assumptions which include athletes putting forth total effort following instruction provided by test administrators. It was also assumed that all equipment was up to date and working properly, as well as, complete honesty from athletes in this study.

Delimitations

The sample population is delimited to athletes and cheerleaders were selected of convenience at a single university in South Georgia. The university at which this study is being conducted has a set concussion assessment and RTP protocol which has been set in place by the university's sports medicine department. Appropriate inclusion and exclusion criteria was noted and ensured over the course of the study.