The Clinical Utility of Recaptured Baselines after Return-to-Play

by

Alicia Miran Kissinger-Knox, M.S.

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We the undersigned committee, having examined the attached doctoral research project, "The Clinical Utility of Recaptured Baselines after Return-to-Play," by Alicia Miran Kissinger-Knox, M.S. hereby indicates its unanimous approval.

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Frank Webbe, Ph.D., Committee Chair
Professor, School of Psychology

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Philip Farber, Ph.D., Committee Member
Associate Professor, School of Psychology

_____

Julia Grimwade, Ph.D.
Professor, Biological Sciences

_____

Mary Beth Kenkel, Ph.D.
Dean, School of Psychology

Abstract

Title: The Clinical Utility of Recaptured Baselines after Return-to-Play

Author: Alicia Miran Kissinger-Knox, M.S.

Major Advisor: Frank Webbe, Ph.D.

Objective: The present study was designed to investigate the clinical utility of
recaptured baselines or "rebaselines" in collegiate athletes after return-to-play.
Several concussion management teams endorse the use of baseline neurocognitive
assessments at the beginning of an athlete's sports season to use as a measure of
comparison in the instance of concussion or head injury. Once physical and
cognitive symptoms are resolved, an athlete is requested to reestablish their
baseline for the rest of the season. It has been questioned whether this
"rebaselining" is necessary and warranted.

Method: Forty-one Division II collegiate athletes at Florida Institute of
Technology who sustained a concussion during the respective sport season were
studied across four testing sessions; baseline, post-trauma, follow-up, and
rebaseline. The Immediate Post-Concussion Assessment and Cognitive Testing
(ImPACT) was used to examine four composite scores; verbal memory, visual
memory, visual motor, and reaction time across the four testing sessions to assess
for significant change over time.

Results: As predicted, there were no significant differences found between the
follow-up assessments and rebaselines. Significant differences were found in all

composite scores between post-trauma evaluations versus follow-up and rebaseline assessments. Significant interactions were additionally noted for sex, sport, and first exposure to the ImPACT measure. No significant interactions were found between a prior history of concussion and the length of recovery across the testing sessions.

Conclusions: The current study found no empirical validity (and hence no clinical utility) for the procedure of rebaselining. Therefore, it is recommended that concussion management programs discontinue to use of rebaselines and use the follow-up assessment as an athlete's new baseline for the remainder of the sport season.

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Acknowledgements

"There is only one way to succeed in anything…
that is to give it everything."

-Vince Lombardi

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Introduction

The purpose of the current study was to investigate the clinical utility of administration and evaluation of recaptured baselines following concussed college athletes' return-to-play. In line with traditional protocol and best practice, the majority of collegiate concussion management programs administer athletes a baseline battery of assessments annually at the beginning of their respective sports season (Webbe & Zimmer, 2015). Approximately 94.7% of Division I athletic trainers who were surveyed in the National Collegiate Athletic Association (NCAA) have endorsed the use of baseline computerized neurocognitive measures for concussion (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009). At Florida Institute of Technology, the designated concussion management protocol is comprised of written and computerized baseline assessments, including the Sport Concussion Assessment Tool-3rd Edition (SCAT-3; now replaced by the SCAT-5), the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), the Brief-Patient Health Questionnaire-9 item (PHQ-9), the Rey Dot Counting Test (DCT), and the Rey Word Recognition Test (WRT). These measures include symptom self-reports, memory, motor and processing speed, impulse control, reaction time, balance, performance validity, and measures designed to evaluate an athlete's motivation towards an accurate portrayal of performance.

If the athlete, athletic trainers, or sports medicine staff questions whether the athlete has sustained a concussion or head injury during the school year, whether it is sport-related or otherwise, and as part of the trauma evaluation, the

athlete is re-administered the baseline battery to assess for neurocognitive and symptomatic changes. This assessment is referred to as a "post-trauma evaluation" and is compared to the original baseline battery for identification of possible head injury. The assessment measures on the post-trauma evaluation are the same as the baseline battery. In the instance of the athlete's testing indicating a concussion, the athlete is removed from team practices and competition. When the athlete reports that symptoms have abated, a follow-up assessment is conducted. If this assessment indicates that recovery has not occurred, the athlete continues the enforced rest from play for at least another week. If the follow-up assessment does not differ significantly from the original baseline the athlete is referred back to the athletic trainer who conducts a stepwise progression of physical tests preparatory to return to play.

Once an athlete has returned to play for a minimum period of one week, the athlete is revaluated with a "rebaseline" assessment with ImPACT, to set the athlete's baseline for the remainder of the sports season. There is considerable time and cost associated with the administration of rebaseline testing, in addition to practice effects due to multiple administrations that cloud the recovery picture. Athletes are evaluated at minimum four times if they are found to have sustained a concussion, and possibly more if their recovery period is long. The present study was designed to investigate whether rebaselines provide clinical information that is useful for future athlete evaluations.

Review of the Literature

The frequency of sport-related injury was recognized in the early twentieth century after the concern of multiple fatalities in the sport of football (Mendez, Hurley, Lassonde, Zhang, & Taber, 2005). In 1905 alone, collegiate football saw 18 fatalities and 159 severe injuries (Talavage, Nauman, & Leverenz, 2016; Stone, Patel, & Bailes, 2014). In 1906, recognizing the seriousness of this situation, President Theodore Roosevelt invited coaches from Yale, Harvard, and Princeton to discuss the future of the sport (Stone, et al., 2014). Roosevelt, a passionate fan, stated he would end football if a resolution were not reached regarding interventions to reduce the incidence of head injury related deaths (Maroon, et al., 2000). In attempts to save the game, a decision was reached, increasing the rules and penalties to offer more protection to athletes (Bartsch, Benzel, Miele, & Prakash, 2012). Additionally, Roosevelt prompted the establishment of the Intercollegiate Athletic Association of the United States, which later became the National Collegiate Athletic Association (NCAA) in 1910 (Stone, et al., 2014). Roosevelt's prodding also stimulated the introduction of the "forward pass," causing a reduction in injury by increasing the space of play (Bartsch, et al., 2012). The National Football League (NFL) was established in 1922 and with the introduction of the first helmet made of plastic by Riddell in 1940, and its mandated use, the initial work on concussion related to body acceleration was initiated (Bartsch, et al., 2012).

Approximately 1.5 million individuals partake in the sport of football in the United States every year, participating at the recreational, high school, collegiate, or professional level (Mendez, et al., 2005). While the incidence of head injury related fatalities decreased with the introduction of safety rules, the concern for injury has persisted as the incidence of injuries remains. With the evolution of stricter protections in football, there continues to be great emphasis placed on the safety of the sport, with more recent attention focused upon concussion-related injuries (Bartsch, et al., 2012).

Concussion

According to the Centers for Disease Control and Prevention (CDC), an estimated 1.7 million people sustain a traumatic brain injury (TBI) annually in the United States. Approximately 75-90% of these TBIs fall within the mild range of the severity continuum, and are referred to as mild traumatic brain injuries (mTBI), also known as concussions (Faul, Xu, Wald, & Coronado, 2010). Concussion is defined medically as a "clinical syndrome characterized by immediate and transient alteration in brain function, including alteration of mental status and level of consciousness, resulting from mechanical force or trauma" (American Association of Neurological Surgeons, 2017). Concussions can vary in severity, from brief periods of confusion and amnesia, to a more severe brain injury, including coma (McCrea, Kelly, Kluge, Ackley, & Randolph, 1997). There are approximately 300,000 sport-related concussions per year and there is an estimated 19% chance for an athlete to sustain a concussion during his/her respective sport season (The

University of Pittsburgh, 2017). At the 1st International Conference on Concussion in Sport in Vienna, the Concussion in Sport Group (CISG) gathered to define concussion as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (Aubry et al., 2002, p. 6). With that definition, revisions were made at the 4th International Conference on Concussion in Zurich to include the following additions about sport-related concussion:

1. Concussion may be the caused either by a direct blow to the head, face, neck or elsewhere on the body with an "impulsive" force transmitted to the head.

2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.

3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury, as such, no abnormality is seen on standard structural neuroimaging studies.

4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. (McCrory, et al., 2013, p. 250).

If there are concerns regarding whether an athlete has sustained a concussion due to a hit or injury, signs recognizable to others, such as teammates, athletic trainers, or coaches may include the athlete forgetting the current play,

exhibiting uneasy or clumsy movements, appearing to be dazed or confused about his/her position, or being unsure of the score of the game (The University of Pittsburgh, 2017). The 4th International Conference additionally divided concussion symptoms self-reported by athletes into three disparate categories encompassing cognitive, somatic, and neuropsychiatric symptoms (McCrory, et al., 2013). Cognitive symptoms include signs of poor concentration, attention, and/or memory dysfunction. Additionally, athletes may display difficulty with orientation, such as what the current date, play, or location of the game is. Physical symptoms may include headaches, a feeling of pressure in the head, loss of consciousness, blurred vision, dizziness, nausea, vomiting, fatigue, feeling foggy, confusion, sensitivity to light and noise, slurred speech, ringing in the ears, and others. Headaches are reported to be the most common symptom following a concussion (Guskiewicz, Weaver, Padua, & Garrett, 2000). Behavioral or neuropsychiatric changes may include psychological adjustment difficulties, sleep disturbance, such as sleeping more or less than usual, irritability, nervousness, emotionality, or loss of initiative (Pruthi, 2017; Centers for Disease Control and Prevention, 2017; Okonkwo, Tempel, & Maroon, 2014). In adults, the typical resolution of concussive symptoms is approximately 7-10 days in a 'simple' concussion; however, recovery can be prolonged due to persistent symptoms lasting many days to weeks in a 'more complicated recovery.' Complicated concussions can be due to multiple hits over time, loss of consciousness for more than one minute, and more (McCrory et al., 2004). It is recommended that athletes be referred to healthcare experts in

concussion if their concussive symptoms persist for longer than 10-14 days (McCrory, et al., 2017) or display a more complicated recovery. In order to obtain a more accurate measure of physical concussive symptoms, cognitive functioning, and postural stability in athletes with suspected head injury, researchers have devised methods of objective assessment through neuropsychological evaluations (McCrory, et al., 2013).

Background of Baseline Testing

In recent years, attention has been drawn to the study of sport-related concussion and the evaluation of the neuropsychological measures used in diagnosing and assessing progress over the course of the injury. Baseline assessments are administered to athletes at the beginning of their respective sports season, preferably before the athlete's first practice, in order to provide a reference for comparison in the event that the athlete sustains a head injury (Lynall, Schmidt, Mihalik, & Guskiewicz, 2016; CDC, 2017). Neuropsychological baseline assessments typically measure cognitive abilities, such as memory, attention, and language, physical symptoms and psychological functioning through self-report symptom scales, and sensory and motor functioning (Randolph, McCrea, & Barr, 2005; Putukian, 2011).

In one of the first pioneering studies to incorporate the use of new methodology of repeated baseline neuropsychological assessment for concussion in sports, Barth and colleagues examined head trauma in collegiate football athletes (Barth, et al., 1989). The University of Virginia study, which consisted of a total of

2,350 football players at 10 universities, including the University of Pittsburgh and Ivy League colleges, evaluated mild head injury prior to the start of the football season and after concussion through the use of neuropsychological testing (Lovell & Collins, 1989). This practice was different from prior testing methods of the time, because the traditional method of evaluation included averaged group norms, and testing occurred only after a suspected concussion was reported (Webbe & Zimmer, 2015). The assessments Barth and colleagues used included the Trail Making Test A & B, the Wechsler Adult Intelligence Scale (WAIS) Vocabulary, Aaron Smith's Symbol Digit Test, and the Paced Auditory Serial Addition Task (PASAT). Overall, Barth and colleagues found that neuropsychological testing had the ability to measure the effects of decline following concussions. Neurocognitive decline was noted in attention, concentration, and problem solving approximately 24 hours after participants experienced the traumatic event. The majority of athletes' symptoms subsided within five days post-trauma and returned to baseline values (Bailes, et al., 1999). When neuropsychological testing displayed no significant difference from the initial baseline testing, athletes were considered cognitively recovered (Barth, et al., 1989). This study provided the genesis for the practice of preseason neuropsychological testing administration, as well as offering a basis for concussion recovery time protocols (Webbe & Zimmer, 2015). The Barth et al. study led directly to the creation of the NFL's Pittsburgh Steelers' battery for concussion management (Lovell & Collins, 1998; Johnson, Kegel, & Collins, 2011). The professional football team's test battery consisted of the

Hopkins Verbal Learning Test (HVLT), Trail-Making Test A & B, Controlled Oral Word Association Test (COWAT), Digit Span from the Wechsler Memory Scale-Revised (WMS-R), Symbol Digit Modalities (SDMT), and the Grooved Pegboard Test (Lovell & Collins, 1998). The Pittsburgh Steelers began testing athletes at the beginning of the sports season to establish a baseline, setting precedent for a quick administration time of 45 minutes per athlete. The football players were then tested within 24 hours of sustaining a concussion and then five days following that evaluation (Lovell & Collins, 1998). This neuropsychological battery for the Pittsburgh Steelers enabled the team's concussion management program to identify concussions in cases that would have otherwise been viewed as cleared (Bailes, et al., 1999).

Without a baseline measure to assist in evaluation of an individual's scores, norm-referenced comparison scores may result in a number of false-positive and false-negative errors. These errors may cause one without a concussion to appear concussed or may lead to a concussed athlete to appear healthy (Roebuck-Spencer, Vincent, Schlegel, & Gilliland, 2013; Webbe & Zimmer, 2015). Baseline testing reduced the amount of variance and error that was present in normative comparisons by focusing on the individual and controlling for extraneous variables (Guskiewicz, et al., 2004; Webbe & Zimmer, 2015). Additionally, the study of concussion is intricately individualized in every athlete (Iverson, Lovell, & Collins, 2003; Broglio, et al., 2014; Webbe & Zimmer, 2015). Individual differences may persist in performance on a number of tests, in addition to their recovery pace and

time (Iverson, et al., 2003). Numerous extraneous variables could account for why the individual did poorly, especially in the instance of multiple concussions (Lovell & Collins, 1998). Athletes presenting with multiple concussions, may display an 'atypical' recovery pattern when compared to those with only one concussion (Roebuck-Spencer, et al., 2013). Baseline values allow the examiner to determine whether the results of the individual's assessment is 'normal' when compared to his/her own previous tests instead of comparisons to others. In a study by Zimmer et al., researchers found differences in performance on baseline measures depending on the athlete's sport, further supporting the claim for individual changes on the measure rather than normative comparisons (Zimmer, Piecora, Schuster, & Webbe, 2013).

In a study supporting the clinical utility of baseline comparison versus comparison to group norms, Roebuck-Spencer, et al. assessed 8,002 active duty military service members with pre- and post-deployment screenings via the Automated Neuropsychological Assessment Metrics (ANAM4). The ANAM4 is an individual neurocognitive baseline measure administered to the military when deploying to be used as a comparison in the case of suspected TBI (Roebuck-Spencer, et al., 2013). Researchers used both norm-referenced and baseline data to compare performance on the measure and found that norm-referenced comparisons resulted in a higher number of false-positives as compared to individual baseline information. Although the sample in this study was comprised of a military population, the study provides insight into the importance of baseline evaluation

and is generalizable to sport-concussion testing (Roebuck-Spencer, et al., 2013).

Additionally, in a study of 51 concussed rugby players, Gardner et al. used

ImPACT and CogSport neuropsychological batteries to evaluate the diagnostic

efficacy of concussion without initial baseline information. The study concluded

baseline testing is preferred over normative comparisons (Gardner, Shores, &

Batchelor, 2012), due to the individualized nature of concussions and the

"variability of presentation" (McCrory, et al., 2013, p.96). The rationale behind

baseline testing was to set an accurate methodology for testing athletes pre- and

post-trauma in order to reduce error variance by measuring between individuals

rather than using normative comparisons, thus increasing the reliability and validity

of post-trauma measures (Webbe & Zimmer, 2015).

Baseline Testing

On-Field or Sideline Evaluation

In addition to baseline testing as a source of cognitive information,

precursor standardized objective sideline and mental status assessments assist in the

triage of those with possible concussion and are often administered quickly on the

field of play (Cantu, 1998; Aubry, et al., 2002). Examples of sideline testing

include Maddock's Questions (Maddocks, Dicker, & Sailing, 1995) and the

Standardized Assessment of Concussion (SAC) (McCrea, et al., 1998). Both

measures are screening tools used to evaluate cognitive function, physical

symptoms, and balance in a rapid manner, generally less than five minutes

(Randolph, et al., 2005). As athletes may not report symptoms consistent with a

head injury, sideline measures enable athletic trainers and medical staff to be aware of any mental status changes during the time of play (Johnson, et al., 2011). Sideline measures are typically endorsed in times of critical return-to-play decisions within the same game or day (Randolph, et al., 2005). These assessments often lead to more extensive neuropsychological evaluation in the form of post-trauma testing.

Pencil and Paper Testing

Before baseline testing was readily available to athletic trainers, team physicians, and neuropsychologists in the form of computerized assessment, neuropsychological testing was time consuming and not cost-effective, as the testing had to be completed one-on-one, through paper and pencil assessments (Webbe & Zimmer, 2015). Neuropsychologists often had to limit their time to 30 minutes per athlete, which dramatically differed from the average length of 4- to 6-hours for traditional neuropsychological testing (Lovell & Collins, 1998). Due to the difficulty of evaluating multiple athletes in a short period of time, some programs hesitated to adopt the baseline approach (Webbe & Zimmer, 2015).

Computerized Testing

To maximize trainer and examiner's time in evaluations, some existing paper and pencil measures were introduced in computer format. Computerized neurocognitive assessments provided psychologists and health care professionals ease of administration, increased test-retest reliability due to reduced practice effects, accessibility to larger groups of athletes, reduction of testing time, and

better accuracy in measuring athlete's reaction time (Johnson, et al., 2011). Practice

effects are often seen with repeated test administration over time; however, these

effects are lessened with computerized assessments due to the availability of

numerous forms of the measure. Computerized assessments additionally reduced

the amount of human error, provided data storage options to enable further

research, and created ease of report writing (Bailes, et al., 1999; Collie, Darby, &

Maruff, 2001). Introduced in the 1990's, computerized neuropsychological testing

has been used in the NFL and the National Hockey League (NHL), as well as high

school and collegiate level sports (Webbe & Zimmer, 2015). Examples of

computerized assessments included ImPACT, CogSport, and HeadMinder

Concussion Resolution Index (CRI) (Randolph, et al., 2005). Additional symptom

measures included the Pittsburgh Steelers Post-Concussion Scale (Maroon, et al.,

2000), Head Injury Scale (Piland, Motl, Ferrara, & Peterson, 2003), CogScreen,

MicroCog (Bailes, et al., 1999), Sport Concussion Assessment Tool (SCAT-3),

Post Concussion Symptom Scale (McCrory, et al., 2005), Concussion Resolution

Index (Erlanger, et al., 2003), and others.

Best Practice Guideline

The initial aim of baseline testing was applied as a new practice guideline in

the field of concussion management and later evolved as a best practice guideline.

At the first International Conference on Concussion in Sport in Vienna, the

Concussion in Sport Group (CISG) consensus endorsed the use of baseline

assessment, stating, "Neuropsychological testing is one of the cornerstones of

concussion evaluation and contributes significantly to both understanding of the injury and management of the individual" (Aubry, et al., 2002, p.8). Although the initial recommendation was supported and neuropsychological testing for concussion was deemed "essential" (Maroon, et al., 2000), the benefits and clinical utility have been questioned and criticized. Specifically, more research was recommended to address baseline assessment's validity, test-retest reliability, and sensitivity in evaluating concussion (Randolph, et al., 2005). In support of norm-referenced groups, Echemendia, et al. (2012) reported similar diagnostic outcomes when baseline and post-trauma evaluations or norm-referenced group comparisons were used. While the study attracted attention regarding the value of baseline testing, a noted limitation is that the study employed only one concussion measure. Other neuropsychological assessments may produce different results, thus requiring further research for generalizability purposes (Echemendia, et al., 2012). The 2nd and 3rd International Conferences on Concussion in Sport in 2004 and 2008, respectively, continued to endorse the use of neuropsychological assessment in concussion evaluation as an aid in diagnosis and in return-to-play decisions (McCrory et al., 2005; McCrory et al., 2009).

At the 4th International Conference on Concussion in 2012 in Zurich, researchers concluded that baseline testing "was not felt to be required as a mandatory aspect of every assessment however it may be helpful or add useful information to the overall interpretation of these tests" (McCrory, et al., 2013, p. 96). Baseline testing is endorsed for specific circumstances, including a history of

mental health issues (e.g. anxiety or depression), sleep disorders, prior head injury/concussion, learning disability (e.g. attention deficit hyperactivity disorder, dyslexia), or headaches and migraines (Maroon, et al., 2000; Broglio, et al., 2014; Lynall, et al., 2016). These premorbid "modifiers" should be assessed prior to the baseline evaluation and included in the individual's specific recovery protocol (Putukian, 2011, p. 49). Additionally, researchers made it important to note that baseline and post-trauma evaluations should be used as supplemental measures in combination with the athletic trainer, team physician, and neuropsychologist's clinical judgment (Broglio, et al., 2014). Recommendations for clinical practice continue to support the use of neuropsychological assessment after the incidence of concussion as part of an athlete's overall treatment and concussion management (Guskiewicz, et al., 2004; McCrory, et al., 2013; Broglio, et al., 2014).

While the latest International Consensus Statement on Concussion in Sport commented that there was "insufficient evidence to recommend the widespread routine use of baseline neuropsychological testing" (McCrory, et al., 2013, p. 91), a majority of collegiate and professional sports associations have nonetheless implemented baseline testing annually as a best practice (Webbe & Zimmer, 2015; CDC, 2017). The conversation persists over the value and utility of baseline testing, with some researchers concluding, "Baseline testing followed by serial neuropsychological evaluations until the athlete's performance has returned to baseline or better represents a formal standard of best practice espoused by many

professional associations and multiprofessional panels" (Zimmer, et al., 2013, p. 659).

Return to Play

To evaluate the best methods for managing concussion in sport, the First International Conference on Concussion in Vienna began the discussion of graduated return-to-play (RTP) guidelines for both physical and cognitive rest in concussion management (Aubry, et al., 2002). The stepwise process allows medical personnel and athletic staff to monitor symptoms and performance of athletes reintegrating into practice and games. At the most recent conference on concussion, researchers classified the protocol for RTP to include six stages of rehabilitation, once athletes have been cleared medically (McCrory, et al., 2013). In the first stage of RTP, activity is restricted to attain both physical and mental rest for recovery. In the second rehabilitation stage, light exercise is permitted to include walking or cycling to increase heart rate. The third and fourth stages include exercise specific to the athlete's sport without head contact. Athletes are permitted to practice with their team by running training drills, lifting weights, and exercising. The fifth stage allows the athlete to return to full contact practice under the supervision of athletic trainers and coaching staff, and in the sixth stage, the athlete is allowed to RTP with no restrictions if they are able to progress through all stages (McCrory, et al., 2013, p.92). Recommendations for the process include that athletes do not RTP on the same day of injury and that each stage take a minimum of 24 hours to pass (McCrory, et al., 2013).

Rebaseline Testing

In attempts to obtain valid feedback regarding RTP in the case of concussed collegiate athletes, some concussion management programs have initiated the practice of "rebaselining" athletes annually (Lynall et al., 2016). The HeadMinder Concussion Resolution Index (CRI) professional manual recommends that it is "crucial" to establish a new baseline after resolution of player symptoms; however, specifics regarding time interval are unspecified (Headminder, Inc., 2007, p. 24). There are no recommendations regarding rebaselining provided in the ImPACT clinical manual (ImPACT Administration, Inc., 2016). This assessment serves as an updated benchmark for the remainder of the sports season and is conducted following the return of the athlete to practice and competition. The rebaseline battery is comprised of the same neuropsychological instruments provided across the three prior testing sessions.

There has only been one validated study that assessed the efficacy of rebaselining. In 2016, Lynall and colleagues investigated the clinical utility of baseline and rebaseline assessments in athletes after concussion (Lynall, et al., 2016). They recruited 34 NCAA Division I collegiate athletes participating in such sports as baseball, cheerleading, field hockey, softball, football, women's basketball, wrestling, and men and women's lacrosse and soccer. Athletes were administered two assessments; the computerized neurocognitive test, CNS Vital Signs, including a symptom checklist to rate the presence and severity of concussive symptoms on a scale from 0-6, and the sensory organization test (SOT)

for balance and postural stability. Testing was administered to athletes at initial baseline, at a post-trauma evaluation, final post-injury before RTP, and then again at rebaseline. The median number of post-injury evaluations was two, while the range extended to four evaluations. The median time in which the rebaselines were administered from the initial baseline was 397 days and 169.5 days from post-injury to rebaseline. Using reliable change indices for both measures across time, researchers found insufficient clinical utility for the administration of rebaseline evaluations after return-to-play for athletes sustaining one concussion throughout their respective sports season. Researchers concluded that due to the time, cost, and limited value of rebaseline evaluations, there is inadequate evidence to warrant the usefulness of this practice (Lynall, et al., 2016).

Limitations identified in Lynall et al. study point to the introduction of only one computerized neurocognitive measure (CNS Vital signs) and balance assessment (SOT). Additionally, conclusions were based on only 34 athletes and the range between the final post-injury and rebaseline assessment session was 37-333 days, thus a more robust sample and standardized timeframe for future studies is warranted for generalizability. All rebaseline research to date has focused on the annual baseline with the exception of the Lynall study that varied so much in time between assessments. A focus on the recapturing of baselines shortly after return to play is one variant that needs further empirical testing to support or oppose its use.

Rationale

The current study was designed to investigate the clinical utility of recaptured baselines or "rebaselines" after an athlete has returned-to-play following cognitive recovery from a concussion during the sport's season. While the rationale for baseline testing has been established, there remain questions regarding the application and usefulness of rebaselining. With only one study to address this question, more research is needed to determine empirically whether rebaselining is worthwhile clinically.

The purpose of the present study was two-fold. First, the study aimed to evaluate whether rebaselines provided incremental information useful in future clinical evaluations. Keeping with the prior research on the topic, it was predicted that rebaseline evaluations would not be a clinically useful practice in the protocol of concussion management. The aim also addressed whether rebaseline measurement does anything detrimental to the testing sample, such as introducing practice effects. A third purpose of the study was to compare the effectiveness of an athlete's latest follow-up assessment after concussion as the final rebaseline for the sport season. In the instance of a repeated concussion during the same season, the latest follow-up assessment the athlete received would serve as their new established baseline for comparison instead of their original baseline or rebaseline. This was accomplished by assessing if the clinical information provided in the rebaseline was different from the information already known from the follow-up examination that returned the athlete to play. Correct assessment of the evaluation

will enable accurate interpretation of concussive symptoms using the appropriate

baseline measure.

Methods

Participants

Data from a total of 41 National Collegiate Athletic Association (NCAA)

Division II student athletes from Florida Institute of Technology (FIT) were

utilized in this study. The athletes sustained a concussion during either the 2015-16

or 2016-17 athletic seasons, and they represented 10 sports and 14 teams, including

basketball, cheerleading, football, lacrosse, rowing, soccer, softball, swimming,

track and field, and volleyball. The average age of participants was 19.61

(SD=1.51) (51.2% females) with an average education level of 13.32 (SD=1.15).

A specific proposal for the present study received approval from the

Institutional Review Board (IRB) at Florida Institute of Technology. During the

concussion education session at the preseason collection of baseline information,

all potential participants consented to allow their de-identified information to be

used for research purposes.

Table 1. Demographic Characteristics of the Sample

	N	*Mean*	*SD*	*Range*
Age	41	19.61	1.52	18-23
Education	41	13.32	1.15	12-16
Duration of Recovery (days)	41	18.44	20.69	4-114
History of Prior Concussion	41	0.73	1.05	0-4
Days from Follow-Up to Rebaseline	41	31.02	17.33	6-97

Measures

ImPACT

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) Version 2.0 is a brief computer-administered neuropsychological battery that also contains questions for self-report of sport-related concussion symptoms (Iverson, et al., 2003). The testing takes approximately 22 minutes to complete an initial baseline and 18 minutes for a post-concussion follow-up. The assessment is divided into three sections addressing demographic information, concussive symptoms, and neuropsychological symptoms (Lovell, 2004). In the demographic and background information section, athletes enter knowledge of any prior concussion history, history of learning disabilities or psychiatric illness, and basic information, such as age, height, weight, and sport (Lovell, 2004).

The Post-Concussion Symptom Scale in ImPACT (PCSS) is a 22-item assessment of symptoms rated from 0 to 6 on a 7-point Likert scale (Lovell & Collins, 1998). The PCSS was adapted from the Pittsburg Steelers Post-Concussion Scale in concert with the NFL Pittsburgh Steelers' concussion management program in the late 1980's (Alla, Sullivan, Hale, & McCrory, 2009). Five additional items were added later, and included reported symptoms from collegiate and other professional athletes (Lovell, et al., 2006; Okonkwo, et al., 2014). The scale is administered during an athlete's pre-season baseline and again post-trauma and later in follow-up (Lovell, et al., 2006). Examples of concussive symptoms presented on the PCSS include headache, nausea, fatigue, sleep deficit, difficulty

concentrating, sensitivity to light, etc. (Lovell, 2004). Due to the overlap of symptoms associated with depression, anxiety, and other stress related difficulties, the scale is said to be a 'state' measure for current perceived symptoms, as they may additionally be present during baseline (Iverson, Brooks, Collins, & Lovell, 2006). In a study by Lovell, et al. on normative data for the PCSS, researchers found the internal consistency ranged from .88 to .94 in a population of 1,746 high school and collegiate athletes (Lovell, et al., 2006).

Within the testing portion and neuropsychological symptoms, the battery consists of composite scores pertaining to Verbal Memory, Visual Memory, Motor and Processing Speed, Impulse Control, and Reaction Time. The composite scores are comprised of six subtest modules, each contributing to multiple composite scores, measuring attention, working memory, reaction time, non-verbal problem solving, and processing speed (Elbin, Schatz, & Covassin, 2011). The Verbal Memory composite score consists of a visually presented word memory recognition task, symbol-number match and letter memory task, in addition to an interference task to evaluate for verbal learning and memory. This composite is similar to established memory tasks involving word lists (Iverson, et al., 2006). The Visual Memory composite score measures immediate and delayed memory, spatial memory, and recognition memory. The composite is comprised of abstract line design drawings and a memory test recognizing X's and O's following an interference task. During the interference task, participants rapidly click numbers sequentially from 25 to 1 (Iverson, et al., 2006). The Motor and Processing Speed

score averages all the interference tasks from the memory composites, while the

Impulse Control composite score accounts for the number of omission or

commission errors committed in the reaction subtests to assess for effort or

understanding of task instructions (Iverson, et al., 2003). The Reaction Time

composite score measures reaction time in milliseconds through the use of a color

matching test, the symbol-number matching task from the earlier memory

composites, and the average of the memory X's and O's interference task (Iverson,

et al., 2006; Iverson, et al., 2003). In addition to composite scores, researchers are

able to assess for change over time with the Reliable Change Index (RCI) score.

The RCI score uses the standard error of difference to establish a confidence

interval between the initial baseline and the post-trauma score to evaluate change

and reduce error for interpretation (ImPACT Applications, Inc., 2016). The score

measures an athlete's progression or regression over a period of time, allowing

examiners to determine the possibility of concussion. Additionally, the Cognitive

Efficiency Index (CEI) score was established to take speed and accuracy into

consideration for an athlete's score. The CEI is derived from the speed in reaction

time and accuracy on the symbol-matching task. Athletes with a high score in this

domain display a high degree of accuracy along with a quick reaction time. A score

of 0.20 or below suggests below average speed and accuracy. The range of scores

for the CEI is zero to 0.70 (Lovell, 2004). The correlation coefficients for ImPACT

composite scores range from .56 to .84, while test-retest coefficient scores range

from .65 to .86 (Iverson, et al., 2003). In order to reduce the possibility of practice

effects, the assessment consists of an extensive array of testing combinations

(Lovell, 2004). The measure has been deemed both sensitive and specific in the

"assessment of neurocognitive and neurobehavioral sequelae of concussion"

(Schatz, et al., 2006, p. 97).

Sport Concussion Assessment Tool-3rd Edition

The Sport Concussion Assessment Tool- 3rd Edition (SCAT-3) is a

standardized neurocognitive assessment tool used for evaluating potential signs of

sport concussion (McCrory et al., 2013). The SCAT-3 consists of nine individual

sections including a sideline assessment, Glasgow Coma Scale (GCS), Maddocks

Score, background information, symptom evaluation, Standardized Assessment of

Concussion (SAC), neck and cervical spine examination, balance examination,

coordination examination, and the SAC delayed recall portion (Concussion in Sport

Group, 2013; Hanninen, et al., 2015). The background information includes the

athlete's demographic information, such as their age, sport, education level, and

prior history of concussion to assist in further evaluation (Concussion in Sport

Group, 2013). The Standardized Assessment of Concussion (SAC) was developed

in 1997 to evaluate the presence of symptoms of concussion and mild TBI (McCrea

et al., 1998). The assessment consists of three parts: orientation, immediate

memory, and concentration. The SAC has been found to be a valid and reliable

measure for evaluating sport concussion (Barr & McCrea, 2001; Snyder, et al.,

2014). The Balance Error Scoring System (BESS) was developed in 2001 at the

University of North Carolina to measure postural stability (Guskiewicz, 2001;

Resch, McCrea, & Cullum, 2013). The BESS has proven to be a reliable postural

measure; however, learning effects for multiple administrations of the BESS have

been noted (Broglio, Zhu, Sopiarz, & Park, 2009; Snyder, Bauer, & Health

Impacts, 2014). In the SCAT-3, only the hard surface variant of the BESS is used.

Brief-Patient Health Questionnaire

The Brief-Patient Health Questionnaire- 9 item (PHQ-9) is a self-report

screening measure for depression (Kerr, et al., 2014). The PHQ-9 was derived

originally from the Primary Care Evaluation of Mental Disorders (Prime-MD;

Spitzer, Kroenke, & Williams, 1999). Previous studies have reported excellent

internal reliability of the measure, with a Cronbach's alpha of 0.89 (Spitzer, et al.,

1999) and 0.86 (Spitzer, et al., 2000), good diagnostic validity, excellent test-retest

validity (Kroenke, et al., 2001), and good construct validity for measuring major

depression and subthreshold depressive disorder in the general population (Martin,

et al., 2006).

Rey Dot Counting Test

The Rey Dot Counting Test (DCT) is a performance validity and motivation

measure developed by Andre Rey in 1941 for the detection of malingering and

suspect test-taking effort (Lezak, 1995; Binks, Gouvier, & Waters, 1997; Rose,

Hall, & Szalda-Petree, 1998; Boone, et al., 2002).

Rey Word Recognition Test

The Rey Word Recognition Test (WRT) is an additional performance

validity measure developed by Andre Rey in the 1940's for the detection of suspect

effort and feigned short-term memory malingering (Lezak, 1983; Boone, et al., 2000; Boone et al., 2002).

Procedure

All participants were administered a battery of assessments, including computerized neurocognitive testing, balance evaluation, and symptom checklist. Testing consisted of a PHQ-9, SCAT-3, Rey WRT, Rey DCT, and online ImPACT administration as part of the University's routine pre-sport participation baseline evaluation. Twenty-four to 48 hours after sustaining a possible concussion, athletes were re-administered their baseline evaluation. This evaluation, known as a "post-trauma," included the addition of a clinical interview to assess the nature of the trauma and the symptoms following the incident. For those student athletes diagnosed with a concussion, physical and cognitive rest were prescribed acutely, with return to moderate aerobic exercise as soon as it was tolerated with no exacerbation of symptoms. Participation in team practices and contests were suspended. When the athletes reported to their athletic trainers that they were symptom free (or no more symptomatic than at baseline), athletes were re-administered the same battery of assessments, known as a "follow-up" evaluation, to determine whether recovery was sufficiently complete to allow return-to-play. If athletes were cleared, they were allowed to participate in their sport's practice once again; however, if they were still deemed to be recovering, they were required to wait an additional amount of time before being re-administered the assessments. Approximately two weeks after the post-trauma evaluation, participants were

rebaselined to set their new baseline for the remainder of the season. It is important to note, the rebaseline procedure consisted of only the ImPACT computerized measure. The ImPACT assessment was measured across time for all participants. While a recommendation from the Headminder, Inc. group with respect to the CRI is to recapture baselines following return-to-play, the time interval from return to play and the new baseline is unspecified (Headminder, Inc., 2007). Due to no specific guidelines regarding timeframe with ImPACT, it was decided to arbitrarily selected two weeks of RTP before rebaseline. While the guideline was established, there was a minimum of 6 days to a maximum of 97 days from follow-up and return-to-play for a rebaseline assessment, with an average of 31 days (SD=17.33).

It is important to note that the present study did not include follow-ups where the athlete was still symptomatic. Athletes who were symptomatic at the time of their follow-up were told to sit out of their respective sports' practice for a designated amount of time before returning to complete another follow-up assessment and return-to-play. Follow-ups included in this study were only from athletes who had been deemed asymptomatic by self-report and testing. The number of follow-up evaluations ranged from 1-4 based on the individual athlete and severity of their concussion. The length of the athlete's recovery from post-trauma to follow-up included a minimum of 4 days to 114 days, with an average of 18.44 days (SD=20.69).

Results

Statistical Analyses

All analyses were conducted using IBM SPSS version 24.0. A series of repeated measures ANOVAs were conducted for each ImPACT composite. The within subjects analysis compared changes over successive test times, and the between factors included concussion history, sex, sport, duration of recovery, and academic major. Concussion history was split into two categories, those with a prior concussion history and those without. Athletic participation was divided into football and all other sports, and the duration of recovery was viewed with athletes who experienced a typical 7-14 day length of recovery versus those who took longer. Academic majors were divided into science, technology, engineering, and mathematics (STEM) and all others. All pairwise comparisons between testing sessions were assessed using the Sidak correction to limit the risk of Type I error by assuming independence of tests, while still producing conservative results. An alpha level of 0.05 was used for all inferential statistical analyses.

Composites

A One-Way Repeated-Measures ANOVA was run to compare the ImPACT composite scores of athletes across the four testing sessions: baseline, post-trauma, follow-up, and rebaseline. The composite scores consisted of verbal memory, visual memory, visual motor, and reaction time. While the impulse control composite score is included in the athlete's assessment, the composite is most often used to evaluate for maximum effort and does not present as a clinical decision

maker. As the composite is not frequently used in measures of assessing for concussion at the group level (Iverson, et al., 2003), the score was not included in the results of this study. Additionally, the Cognitive Efficiency Index (CEI) which evaluates for speed and accuracy was assessed across the testing sessions.

Table 2. Means and standard deviations for composites across testing sessions

Variables	Test Session Means (SD)			
	Baseline	Post-Trauma	Follow-Up	Rebaseline
Verbal Memory [a,b,d,e]	86.56 (10.81)	78.00 (12.57)	91.14 (7.52)	89.66 (10.06)
Visual Memory [a,d,e]	76.54 (10.51)	67.98 (14.88)	78.00 (12.06)	81.37 (12.76)
Visual Motor [a,b,c,d,e]	40.57 (4.74)	37.22 (8.22)	44.48 (5.43)	44.33 (5.06)
Reaction Time [b,d,e]	0.59 (0.07)	0.67 (0.23)	0.56 (0.05)	0.56 (0.06)
CEI [b,d,e]	0.33 (0.14)	0.28 (0.21)	0.42 (0.12)	0.38 (0.14)

Notes. Significant differences across testing sessions at the $p<0.001$ level. a. Baseline to Post-Trauma, b. Baseline to Follow-Up, c. Baseline to Rebaseline, d. Post-Trauma to Follow-Up, e. Post-Trauma to Rebaseline

Verbal Memory

For the verbal memory composites, a significant difference was found among the testing sessions ($F(3,120)=18.08$, $p<0.001$). Sidak pairwise comparisons were used to determine the nature of the differences between the testing sessions. Athlete's verbal memory composites were significantly lower during post-trauma testing ($M=78.00$, $SD=1.96$) than initial baseline ($M=86.56$, $SD=1.69$, $p=0.004$), follow-up ($M=91.14$, $SD=1.18$, $p<0.001$), and rebaseline ($M=89.66$, $SD=1.57$, $p<0.001$). Significant differences were also found between baseline and follow-up

testing (*p*=0.051). There were no significant differences between baseline and rebaseline testing, and between follow-up and rebaseline testing.

Visual Memory

For the visual memory composites, a significant difference was found among the testing sessions ($F(3,120)=12.33$, $p<0.001$). Sidak pairwise comparisons were used to determine the nature of the differences between the testing sessions. Athlete's visual memory composites were significantly lower during post-trauma testing (*M*=67.98, *SD*=2.32) than initial baseline (*M*=76.54, *SD*=1.64, *p*=0.017), follow-up (*M*=78.00, *SD*=1.88, *p*=0.003), and rebaseline (*M*=81.37, *SD*=1.99, *p*<0.001). There were no significant differences between baseline and follow-up testing, baseline and rebaseline testing, and between follow-up and rebaseline testing.

Visual Motor

For the visual motor composites, a significant difference was found among the testing sessions ($F(3,120)=29.05$, $p<0.001$). Sidak pairwise comparisons were used to determine the nature of the differences between the testing sessions. Athlete's visual motor composites were significantly lower during post-trauma testing (*M*=37.22, *SD*=1.28) than initial baseline (*M*=40.57, *SD*=0.74, *p*=0.040), follow-up (*M*=44.48, *SD*=0.85, *p*<0.001), and rebaseline (*M*=44.33, *SD*=0.79, *p*<0.001). Significant differences were also noted between baseline and follow-up testing (*p*<0.001) with follow-up scores being higher, and baseline and rebaseline

testing (*p*<0.001) with rebaseline scores being higher. There were no significant differences between follow-up and rebaseline testing.

Reaction Time

For the reaction time composites, a significant difference was found among the testing sessions ($F(3,120)=9.57$, *p*<0.001). Sidak pairwise comparisons were used to determine the nature of the differences between the testing sessions. Athlete's reaction time composites were significant higher and slower during post-trauma testing (*M*=0.67, *SD*=0.04) than follow-up (*M*=0.56, *SD*=0.01, *p*=0.008) and rebaseline (*M*=0.56, *SD*=0.01, *p*=0.012). Significant differences were also noted between initial baseline (*M*=0.59, *SD*=0.010) and follow-up (*p*=0.001). There were no significant differences between baseline and post-trauma testing, baseline and rebaseline testing, and between follow-up and rebaseline testing.

Cognitive Efficiency Index

There were significant differences for the CEI score across the testing sessions ($F(1,120)=10.07$, *p*<0.001). Sidak pairwise comparisons were used to determine the nature of the differences between the testing sessions. Athlete's CEI scores were significantly lower during post-trauma testing (*M*=0.28, *SD*=0.21) compared to follow-up (*M*=0.42, *SD*=0.12, *p*<0.001) and rebaseline assessment (*M*=0.38, *SD*=0.14, *p*=0.004). Additionally, there were significant differences between baseline (*M*=0.33, *SD*=0.02) and follow-up assessment (*M*=0.42, *SD*=0.12, *p*=0.001). There were no significant differences between baseline and post-trauma, baseline and rebaseline, and between follow-up and rebaseline assessment. It is

important to note that scores above 0.20 are within the average range for this measure.

Sex Differences

There was a significant interaction effect found for the visual memory composites ($F(3,117)=3.89$, $p=0.01$) with women ($M=77.45$, $SD=1.93$, $N=21$) performing significantly higher than men ($M=74.41$, $SD=1.98$). There were no significant interactions between the sex of the athletes for the verbal memory, visual motor, or reaction time composite scores, as well as the CEI.

Sport

Athletic participation/sport was divided into two categories, football or other. There was a significant interaction effect found for the verbal memory composites ($F(3,117)=3.40$, $p=0.020$) with other sports ($M=86.78$, $SD=1.29$, $N=30$) scoring significantly higher than football ($M=85.14$, $SD=2.13$) and a significant interaction effect for the visual memory composites ($F(3,117)=4.95$, $p=0.003$) with other sports ($M=76.65$, $SD=1.63$) scoring significantly higher than football ($M=74.11$, $SD=2.69$). There were no significant interactions for the visual motor or reaction time composites, or CEI. It is important to note that a confounding variable within this analysis was sex, as only male athletes are enrolled on the football team.

History of Concussion

History of concussion was split into two categories, 1) no prior concussion history and 2) more than one concussion throughout the athlete's life. Twenty-four athletes reported they never sustained a concussion and 17 athletes sustained one or

more concussions. There were no significant interactions between history of concussion and any of the major composite scores, or CEI.

First Exposure to ImPACT

For an evaluation of practice effects, an athlete's first exposure to the ImPACT assessment was split by those who had not engaged previously in the testing versus those who had been administered the test in the past. There was a significant interaction for the visual motor composite ($F(3,117)=4.28$, $p=0.007$), with those never taking ImPACT scoring higher ($M=41.70$, $SD=1.03$, $N=23$) than those who had taken ImPACT ($M=41.59$, $SD=1.16$). No significant interactions were found for verbal memory, visual memory, or reaction time composites or CEI.

Length of Recovery

The time at which athletes received their final follow-up evaluation and were cleared for return-to-play was defined as their length of recovery. Since the interval between the trauma and final follow-up was variable, the group of athletes ($N=25$) who recovered within a typical 7-14-day period was compared to those who took longer. Athletes who took longer than 14 days to recover were placed in a 'more complicated recovery' concussion category ($N=16$). There were no significant interactions for the length of recovery time and the four composites, as well as the CEI.

Academic Majors

In order to pursue possible explanations of females scoring higher on the visual memory composite scale, the academic majors of the students were

dichotomized into STEM and non-STEM. STEM majors included biology, engineering, mathematics, physical sciences, and psychology (N=24; female N=15; male N=9) non-STEM majors included business, communications, sports education, and liberal arts (N=17; female N=6; male N=11). There were no significant interactions for academic major and the four composites or the CEI. Additionally, no interactions were found between academic major and sex for all composites.

Discussion

Review of Results

The current study was designed to evaluate the clinical utility of baselines recaptured after an athlete has returned-to-play following recovery from a concussion. In line with the first aim of the current research and as predicted, results suggest that conducting a rebaseline in the same year as an athlete's follow-up evaluation was unnecessary and unwarranted. The study ultimately concludes the rebaseline process does not provide incremental clinical value for future evaluations, and suggests the practice should be considered redundant with an athlete's follow-up assessment.

The first purpose of the present study, moreover, addressed the effectiveness of an athlete's follow-up assessment as his/her final evaluation for the remainder of the sports season, in comparison to the athlete's original baseline and rebaseline. Consistent with previous research that employed a different computerized cognitive test (CNS Vital Signs; Lynall et al., 2016), the present study found no significant differences between follow-up and rebaseline testing on any composite scores measured on ImPACT. These results suggest that an athlete's final follow-up evaluation may be used as their new rebaseline for the continuation of the season in which a concussion occurs.

The second purpose of the study addressed whether rebaseline measurement did anything detrimental to the concussion-management protocol, such as contributing practice effects. Practice effects are defined as "score increases due to

factors such as memory for specific test items, learned strategies, or test sophistication, that complicate the interpretation of change" (Calamia, Markon, & Tranel, 2012, p. 543). Similar to previous research (Lynall et al., 2016) but through the use of different measures, we noted significantly improved scores from original baseline to follow-up evaluation in all domains except visual memory. Prior research suggests this trend may be due to practice effects and/or the belief that athletes are confusing the shapes seen in the earlier administration of the assessment (Lynall et al., 2016). Although the ImPACT test employs multiple forms of the subtests across the testing conditions (baseline, post-trauma, follow-up, and rebaseline), repeated test administration can be expected to enhance understanding of procedural sets so that practice effects will emerge. Practice effects can be viewed as familiarity with the structure and format of the assessment, which may enable the athlete to complete the process quicker than those without such prior knowledge.

In concert with practice effects, during follow-up evaluations, collegiate athletes may be strongly motivated to provide their best performance and return-to-play due to a host of reasons, including retaining their position on the team, preserving their scholarship, or being on the field of play to support their team (Bailey, Echemendia, & Arnett, 2006). While motivation may be at play for the follow-up evaluations, this theory is weakened for rebaseline evaluations, since the athletes have already been allowed to return-to-play. Their performance on the testing does not have an impact on their participation in their respective sport, thus

one would expect their performance to return to original baseline measure. Although it can be posited that since the athletes have already returned to play, the rebaseline would not generate as much motivation to perform as the follow-up, there are no data to suggest the athletes believe that poor or poorer performance on rebaseline would be ignored. There may still lie concern regarding whether the examiner is assessing the athlete's symptomatology once they have returned to play, thus the motivation to do well may still be present. The present study suggests there is reasonable evidence to conclude that follow-up scores will be higher than the original baseline. The current findings compliment the Lynall et al., 2016 suggestion that the improvement in test performance may well reflect a practice effect. While the current results indicate that all testing after the initial post-trauma assessment was higher than both the original baseline and post-trauma evaluation, the mechanism for this difference is unclear.

The present study's results additionally addressed different variables that may interact with the athlete's performance on composite scores across time. The CEI was assessed, and consistent with results of the composite scores, all scores for post-trauma were significantly lower than others with the exception of the baseline assessment. All median scores for the CEI across sessions were within the average range of 0.20 or above for performance, suggesting athletes performed with the appropriate amount of speed and accuracy. When looking at sex of the athlete, prior research reported that following a concussion, female athletes performed significantly worse on measures of visual memory compared to concussed men

(Covassin, Schatz, & Swanik, 2007; Rieder & Jansen, 2011). The present results are inconsistent with these findings; female athletes actually performed significantly higher on measures of visual memory; however, this measurement was taken across the four testing sessions, meaning women could have performed worse while concussed, but performed higher overall.

To further investigate this difference between sexes, academic major was divided into STEM majors and non-STEM majors. Prior research found that participants who majored in a STEM field or if they were male performed higher on tasks of spatial ability compared to other majors and females (Yoon & Mann, 2017). The results of the present study found no significant differences between STEM majors and the composite scores, suggesting academic major did not influence the visual memory composite score compared to sex.

In prior studies of computerized neurocognitive performance using ImPACT, researchers found no significant differences between groups for those with a prior history of three or less concussions versus those without (Iverson, Brooks, Lovell, & Collins, 2006; Broglio, Ferrara, Piland, & Anderson, 2006). Consistent with the previous research and encouraging news, the current study found no significant interactions between a prior history of concussion and composite scores across the four testing sessions. Similarly, the current research found athletes who took the typical 7-14 days to recover from concussion versus those with a more complicated recovery did not display significant differences across composite scores for the four testing sessions, suggesting that aggregate or

long-term effects of three or less concussions may be relatively minor (Iverson, Brooks, Lovell, & Collins, 2006).

To highlight the different sports that were represented in this study, the athletic sport variable was divided into football and all others, due to the chance that the nature of football or the greater collision in football could provide some discrepant findings. The present study found a significant interaction for sport and both the verbal and visual memory composite scores with athletes in the other sports performing significantly higher. It is critical to note that a confounding variable within this analysis was sex, as only male athletes played football, while the remaining sports consisted of both males and females. Future research should seek to address this finding, whether due to the physicality of the sport, sex, or some underlying factor for football players. Furthermore, the current study found that athletes who experienced their first exposure to the ImPACT measure, compared to those who were familiar, scored significantly higher on the visual motor composite, leaving additional questions as to the finding.

Limitations and Future Directions

In comparison with the Lynall, et al., 2016 study's use of the CNS Vital Signs, the current study incorporated the use of a more widely used neurocognitive measure. Since its development in 2006, ImPACT has been administered more than 12 million times at over 7,400 high schools, 1,000 colleges and universities, 900 clinical centers, 475 credentialed consultants, 200 professional teams, and select military units (ImPACT Applications, Inc., 2016). To add to the prior literature, the

present study included athletes who sustained more than one concussion to the pool

of participants, addressing concerns noted by Lynall et al., 2016 about multiple

concussions. Also, the current study provided a shorter window of time from

follow-up to rebaseline evaluation. The Lynall study reported a range of 37 to 333

days for rebaseline testing, with a mean of 169.5 days (Lynall et al., 2016). The

current study condensed this timeframe to a range of 6 to 97 days, with a mean of

31.02 days from the final follow-up assessment to rebaseline.

Limitations associated with this study are important to acknowledge. While

the present study's sample size was greater than the solitary study in the literature

that addressed rebaselining (Lynall et al., 2016), the size still was smaller than

desirable. As such, it would add confidence to generalizability to have a larger

sample. Additionally, pertaining to generalizability, the present study used only

collegiate athletes. Furthermore, by splitting the sample into smaller groups to

evaluate for specific variables, such as sex, sport, and history of concussion, the

smaller sample size produced a limitation in the significance of an outcome.

Differences were noted in the time between baseline and follow-up assessments, as

well as follow-up and rebaseline. However, since the results were consistent

regarding changes in composites across testing intervals, this may not be a major

limitation. One aim was to see if rebaseline assessment did anything detrimental to

the concussion protocol for athletes. It was found this to be difficult to determine

due to varying factors, such as practice effects and motivation of the athlete. Future

research could explicitly assess for these variables. While the specific cause may be

unclear as to why scores were higher in follow-up and rebaseline than in the original baseline, attribution of practice effects and/or motivational effects remains consistent with conclusions from previous studies. Despite these limitations, the main results of the current study had no ambiguity regarding the finding of no support for recapturing baseline following return to play.

Conclusions

Similar to prior research, it was predicted that rebaselines would not be a clinically useful practice; however, by contributing analyses with an increased number of participants and with the introduction of different concussion evaluation measures, this study provided new empirical evidence for elimination of the rebaseline procedure. In reference to clinical applications in collegiate concussion management programs, the present research suggests that rebaselining following return-to-play in athletes within the same year is both unnecessary and unwarranted. Due to the time and cost associated with planning, administration, and review of the rebaseline process, and no evidence for clinical value, there is a strong evidence base for this conclusion at least in the college milieu. Additionally, there is reasonable evidence that the athlete's follow-up testing will be higher than their original baseline.

The study unambiguously supports the use of athletes' final follow-up evaluation as their rebaseline for the remainder of the sports season in the instance of an additional concussion.

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