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Examination of the Psychometric Properties of the SCAT3 and SCAT5 Baseline Testing Data on NCAA Division III College Athletes

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EXAMINATION OF THE PSYCHOMETRIC PROPERTIES OF THE SCAT3 AND SCAT5 BASELINE TESTING DATA ON NCAA DIVISION III COLLEGE ATHLETES

by

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Abstract

Medical professionals continue to revise on-field sport-related concussion (SRC) assessment tools to increase their validity and reliability. Multiple versions of the Sport Concussion Assessment Tool (SCAT) have been created, with the newest revision (SCAT5) published in 2017. This version contains changes from a required five-item word list to an optional ten-item word list in the *immediate memory* and *delayed recall* sections. The purpose of this study was to determine the underlying and latent structure of the SCAT3 and SCAT5 on pre-test data, in addition to evaluating the internal consistency and ceiling effects of the instrument. An exploratory factor analysis was conducted on the Standardized Assessment of Concussion (SAC) portion of the SCAT, with a comparison of proportions for floor and ceiling effects. Results for this study showed the factor structure for both SCAT versions did not adequately align with the four sections of the assessment. Overall internal reliability of the SCAT5 was higher than previously reported for other SCAT versions ($\alpha = 0.764$) and statistical differences were present for ceiling effects between the SCAT3 and SCAT5 for *immediate memory* $(\chi^2(1, 427) = 218.290, p<.0000)$ and *delayed recall* $(\chi^2(1, 427) = 90.43, p<.0000)$. Findings reveal that the assessment tool structure may be different than what is intended. Despite these concerns, healthcare practitioners should evaluate their SRC decision-making processes to determine if this assessment should be utilized in their testing battery and consider its priority in the return-to-play process.

Keywords: Sports-related concussion, exploratory factor analysis, concussion assessment

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List of Abbreviations

Athletic-exposures (A-E)

Balance Error Scoring System (BESS)

Certified Athletic Trainer (ATC)

Confirmatory factory analysis (CFA)

Exploratory factor analysis (EFA)

Glasgow Coma Scale (GCS)

Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT)

Kaiser-Meyer-Olkin (KMO)

National Collegiate Athletic Association (NCAA)

Post-Concussive Symptom Scale (PCSS)

Sport Concussion Assessment Tool (SCAT)

Sports-related concussion (SRC)

Standard deviation (SD)

Standardized Assessment of Concussion (SAC)

Chapter 1

Introduction

Sports-related concussion (SRC) have received increased scrutiny from the media over the past two decades (Ku, 2017). In response to this pressure, medical professionals who routinely work with athletes are continually critiquing and evaluating the best protocols for SRC detection, treatment, return-to-play, and return-to-learn. At the forefront of these SRC discussions is the sideline assessment. Medical professionals want to know what tools are available and useful to properly and efficiently detect a SRC during a practice or competition. Although numerous sideline assessment tools have been developed and modified over the course of the last decade, research has questioned their effectiveness, validity, and reliability. These SRC assessments test for various deficiencies in cognition, balance, vestibular-oculomotor, and symptoms, all of which have been observed in players following a head injury.

One primary goal of SRC assessments is to test for cognitive impairments following an injury because cognitive deficits have been observed post-injury for athletes across many sports (Collie, Makdissi, Maruff, Bennell, & McCrory, 2006). This research by Collie et al. (2006) delineates that these cognitive dysfunctions can occur within information processing, memory, and attention subgroups. Various assessment tools have been created to assess SRC as researchers increase their focus on enhancing diagnosis and return-to-play criteria.

The Sport Concussion Assessment Tool (SCAT), created in 2004, by the Concussion in Sport Group during the Second International Conference on Concussion in Sport, is one attempt to standardized sideline SRC assessment (McCrory et al., 2005; Yengo-Kahn et al., 2016). When creating the SCAT, McCrory et al. (2005) combined existing tests to create a comprehensive assessment that would explore neurological and neurocognitive functions; elements of the

following tests were included: Standardized Assessment of Concussion (SAC), Post-Concussive Symptom Scale (PCSS), modified Maddock's questions, on-field observations, and return-to-play guidelines. The SCAT was revised to create the SCAT2 in 2008 during the Third International Conference on Concussion in Sport (McCrory et al., 2009). Modifications to the SCAT2 included the addition of the Glasgow Coma Scale (GCS), alternate word lists for the *immediate memory* and *delayed recall* sections of the test, and a modified version of the Balance Error Scoring System (Yengo-Kahn et al., 2016). In 2013, the SCAT3 revision (see Appendix A) had very few modifications but included an additional balance testing option and a neck examination section (McCrory et al., 2013a).

Annual meetings of concussion experts continue to occur as knowledge of SRC assessment grows and informs necessary changes for assessment and management. During the 5^{th} International Consensus Conference on Concussion in Sport, the newest revision of the SCAT (SCAT5) was discussed and subsequently published in 2017 (Echemendia et al., 2017b). The SCAT5 (see Appendix B) includes significant adjustments to the *immediate memory* and *delayed recall* portions of the assessment. This is where the optional use of a ten-item word list, instead of the traditional five-item word list (used in all previous versions of the SCAT), could be utilized. It should be noted that practitioners still retain the option of using the five-item word lists though the goal of providing the new ten-item word lists is to limit the reported ceiling effect. A ceiling effect is defined as a maximal score on the section. This means that if there are 15-items the participant gets all 15 correct. However, Echemendia et al. (2017b) note that this new format needs to be tested to determine if it is psychometrically viable.

In this research, I utilized exploratory factor analysis (EFA) to determine the psychometric properties of the SCAT5 in comparison to the SCAT3 with an additional focus on

the ceiling effects present in the *immediate memory* and *delayed recall* sections of both tests. This research contributes to the conversation on whether the variables tested in the SCAT5 have the same structure as the SCAT3 or if changes still need to be made to the assessment for it to be effectively utilized in clinical practice.

Related Studies

The following section explores studies that relate to the research topic, specifically baseline testing, Standardized Assessment of Concussions, psychometric properties, and ceiling effects.

Baseline testing. Some assessment tools require baseline assessments to help determine the presence of a SRC (Benedict et al., 2015; McCrea et al., 1998; McElhiney, Kang, Starkey, & Ragan, 2014; Sufrinko et al., 2017). Baseline testing allows for a post-injury comparison to the athlete's pre-injury abilities, which provides a more individualized assessment with the potential to minimize possible confounding variables (i.e. learning disabilities, previous injury, etc.). While these instruments have shown some relationship in diagnosing SRC, no single test comprehensively assesses all aspects of a concussion. As a result, clinicians are cautioned to use clinical judgment while using these instruments for diagnosis and return-to-play criteria (Echemendia et al., 2017a). Some tools that have been utilized that require baseline testing include Standardized Assessment of Concussions (SAC) (McCrea, 2001b), Sport Concussion Assessment Tool (SCAT) (Chin, Nelson, Barr, McCrory, & McCrea, 2016), King-Devick test (Brommer, Fowler, Hons, Gerwing, & Payne, 2016), ImPACT (Allen & Gfeller, 2011), CogSport (Collie et al., 2006), and Balance Error Scoring System (BESS) (Yengo-Kahn et al., 2016). Of these SRC assessments, the SCAT is the most commonly-used sideline assessment (Echemendia et al., 2017a).

Standardized Assessment of Concussion. The section of the SCAT under primary focus in this research study is historically referred to as the Standardized Assessment of Concussion (SAC). The SAC, generated in 1997, is one of the earliest tools created for cognitive SRC assessment (Yengo-Kahn et al., 2016). The SAC was incorporated into the earliest version of the SCAT and uses *orientation*, *immediate memory*, and *concentration* questions to help clinicians recognize and diagnose SRCs (McCrory et al., 2005). In 1998, McCrea explored the SAC's psychometric properties and found a significant difference between SAC baseline testing values and scores following a SRC, which suggests that the assessment can detect changes in cognitive function (McCrea et al., 1998).

Psychometric properties. In 2009, more published research contradicted McCrea's research by concluding that most SAC items have unacceptable psychometric properties with 76% of the items established as too easy (Ragan, Herrmann, Kang, & Mack, 2009). Based on the deficiencies in the psychometric properties discovered by Ragan et al. (2009), research was undertaken to find more psychometrically-sound words for the *immediate memory* and *delayed recall* sections of the SAC (McElhiney et al., 2014). McElhiney et al. (2014) focused on changing the difficulty of the words given and not on the repetition of the words. Therefore, they utilized a 10-item list repeated once, instead of the standard three repetitions, with a wide variation in words. This change maintained the total overall score for the SAC. This 10-item list was psychometrically sound (McElhiney et al., 2014). However, none of these words are found within the SCAT5 and, to the author's knowledge, no evaluation of the 10-item lists repeated three times (as is directed on the SCAT5) presently exists. Therefore, it is necessary to conduct research utilizing the format of the SCAT5 while repeating the a 10-item word list three times to determine if any structural changes have occurred with the revision.

The examples above illustrate the conflicting evidence on the psychometric properties of the SAC and SCAT regarding the instruments' validity, practice effects, and ceiling effects (Hecimovich & Marais, 2017; Ragan et al., 2009) and none of the studies reviewed thus far have reported any exploratory or confirmatory factor analysis, hence the need for a study like this one. Test-retest reliability on the SCAT ranges from .31 to .71 with an overall coefficient of .64 (McCrea, Kelly, & Randolph, 2007). McCrea, Kelly, and Randolph (2007) suggest that this low correlation occurs because there is minimal variation in score along with a small ceiling effect. Barr and McCrea (2001) reported the sensitivity and specificity of the SAC as .94 and .76 respectively with test-retest reliability at .55. Additionally, a practice effect was present when the test was administered after 120 days for male high school and college football athletes (Barr & McCrea, 2001). Barr and McCrea (2001) state that a practice effect can occur when a patient repeatedly takes an assessment, thus their score improves because they know how the test works and the items on it. This can be a problem because most institutions' serial testing strategy for baseline testing use the same instruments and word list annually. This phenomenon can possibly lead to a ceiling effect and is part of the reason for this study.

Ceiling effect. The ceiling effect of the *orientation* and *immediate memory* sections of the SAC portion of the original SCAT have been compiled and critically evaluated (Echemendia & Julian, 2001). McCrea et al. (1998) showed that a perfect score or ceiling effect was achieved for 7% of all subjects. They claimed this percentage as insignificant, yet it meant that there is the possibility that seven percent of the patients who took the SCAT were not being accurately assessed (McCrea et al., 1998). Ragan and Kang (2007) noted that the assessment is flawed during baseline testing and can lead to a misdiagnosis of a SRC, meaning that an assessor may conclude that an injury did not occur when one really did. In contrast, McCrea et al. (1998)

found a mean score of 14.51 out of 15 for all subjects taking the 5-item SAC test, which shows that most athletes scored at the top of the range of the memory assessment. According to McElhiney et al. (2014), this ceiling effect needs to be further examined with a mixed gender population to see if it exists using the SCAT3 and whether this ceiling effect is mitigated through use of the SCAT5 10-item list.

Problem

An emphasis on SRCs has grown over the past two decades along with scrutiny by athletes, parents, and media about the ability of sideline assessment tests to recognize and diagnose SRCs (Ku, 2017). These involve ethical and legal implications for physicians and healthcare professionals engaged in the recognition, diagnosis, and treatment of SRCs (Kirschen, Tsou, Bird Nelson, Russell, & Larriviere, 2014; Pachman & Lamba, 2017). Giving the best standard of care is a priority for healthcare professionals, so they continue to examine ways to assess, diagnose, and treat SRCs. These medical professionals aim to better understand SRCs through an extensive body of research that has been published in the last decade. SRC research explores physiological changes in the brain, on-field assessment, diagnostic procedures, and recovery processes including return-to-learn and return-to-play protocols. Yet despite growing SRC research, it is evident that several gaps still exist in the literature, including the need for objective SRC assessments (Elkington & Hughes, 2016) and sound objective measures that do not have a ceiling effect on mixed gender samples (Yengo-Kahn et al., 2016).

Purpose Statement

Medical professionals continue to revise on-field SRC assessment tools to increase their validity and reliability (Echemendia et al., 2017a; Echemendia et al., 2017b). Thus, multiple versions of the SCAT have been created over the last decade with the newest revision (SCAT5)

published in 2017 (Echemendia et al., 2017b). This version contains changes from a required five-item word list to an optional ten-item word list in the *immediate memory* and *delayed recall* sections of the test. These changes aim to address two issues within the SCAT instrument: specifically, ceiling effects and “sandbagging” (Echemendia et al., 2017b).

A ceiling effect occurs when an athlete takes the assessment and receives a perfect score. This means that there is a high likelihood that the athlete could receive a higher score if more variables were present. “Sandbagging” occurs when athletes purposefully study for the test ahead of time and/or pretend to remember less than they are capable of remembering on the baseline test in order to increase their chances of scoring well on a post-injury test in the event that they actually do have a SRC. This practice increases the chances that they could be returned to play sooner, but essentially invalidates the test results. What is particularly difficult about this practice is that there are no measurable data on how often it happens. While sandbagging can be assessed on the SCAT3 and SCAT5 to confirm participants have offered their best effort on a pretest, this question was not administered in the data set for this study. This is a significant concern because clinicians rely on these concussion assessments to return athletes to participation. Having said this, clinicians are also cautioned to utilize a battery of assessments before making a final return-to-play decision. Further research should focus on what influence this has on SCAT5 baseline testing.

The *immediate memory* portion of the SCAT instructs patients to repeat any words they can remember after a clinician reads a list of words. These words are to be spoken at a rate of one word per second. Immediately following the cessation of the words, the patient is to begin repeating as many words as s/he can remember in any order. This same word list is repeated by the assessor for a total of three attempts. The *delayed recall* section utilizes the same word list

but requires that the patient recall all the words on his/her own. This *delayed recall* occurs at the very end of the test and no less than five minutes after the *immediate memory* portion.

Test results for the SAC, which used a five-item word list, indicated that seven percent of patients received a perfect score on the entire test with no scores reported by section (i.e. *orientation*, *immediate memory*, *concentration*, and *delayed recall*) (McCrea et al., 1998). This means patients hit the ceiling on the test by being able to reach the maximum score, whether or not they had a SRC. This ceiling effect impedes the differentiation of post-injury assessment because patient ability is likely to be greater than five-items during baseline testing, yet only five words are tested. This effect would create a discrepancy between the patient's ability and observed score (Ragan & Kang, 2007), subsequently impeding the diagnosis of a SRC.

The SCAT5 version contains changes from a required five-item word list to an optional ten-item word list in the *immediate memory* and *delayed recall* sections of the test. Due to this structural change, a psychometric evaluation of the SCAT5 is necessary to determine if the structure of the assessment has changed and if a ceiling effect still exists with the ten-item word list. The literature specifically calls for further research on the structural change in the SCAT5 and to this author's knowledge, no such evaluation has been conducted. Other research provides a solid argument that SRC assessments are not psychometrically sound and should be re-evaluated to assess each item for difficulty level and discrimination capabilities (Ragan & Kang, 2007). Specifically, if these SRC assessments do not provide a valid baseline measure, then results from these assessments post-injury are questionable.

Research Questions

This research aimed to answer two questions:

RQ1. Are there differences in the factor structure and internal reliability between the SCAT3 and SCAT5 subsections of *immediate memory* and *delayed recall* assessments in an analysis of baseline data?

RQ2. Are there differences in the proportions of floor/ceiling effects for the SCAT3 and SCAT5 subsections of *immediate memory* and *delayed recall* assessments in an analysis of baseline data?

Rationale

SCAT is an assessment given to athletes before they are cleared for sports participation and is used as a baseline comparison for SRC identification during pre- and post-injury assessment (Yengo-Kahn et al., 2016). SCAT measures four functional components that can be impacted when an injury occurs: symptom evaluation, cognitive screening, neurological screening, and delayed recall. The cognitive screening is based on the Standardized Assessment of Concussion (SAC) and includes three sections: *orientation*, *immediate memory*, and *concentration*. The *delayed recall* section is included as a separate section at the end of the SCAT assessment to give test-takers enough time between the *immediate memory* testing and the recall portion to effectively test memory. It is important to note that the words used in the *immediate memory* section are also used in the recall section. More weight is given to the immediate recall section because patients are to recall the list three times while the *delayed recall* only requires a single word list. One key reason the SCAT3 was revised and updated was that research indicated a ceiling effect on the *immediate memory* and *delayed recall* portions of the exam because athletes were only given a five-item word list to recall (Echemendia et al., 2017a). This ceiling effect was limited to the *immediate memory* and *delayed recall* portions of

the assessment, and these were the portions that were revised in the SCAT5. Therefore, these portions of the SCAT5 are the focus of this research.

Significance of the Study

The newest revision of the SCAT extended the number of items tested for *immediate memory* from three attempts of a five-item word list (SCAT3) to three attempts of a ten-item word list (SCAT5). This changed the value of the *immediate memory* section score to 30 points instead of 15, thus placing more value on the total SCAT score and providing more opportunity for patient error in *immediate memory* (see Table 1). Creating more opportunities for variation in patient baseline cognitive data may help clinicians in their patient diagnosis and return-to-play protocols because it holds the potential to help them expose subtle changes in cognitive ability.

Due to the importance of identifying SRCs and establishing safe and effective return-to-play protocols, it is essential to research whether a ceiling effect exists in the ten-item word list for *immediate memory* and *delayed recall* tests. If the ceiling effect remains, then SCAT5 will need to be evaluated by other researchers to determine how other populations respond to the SCAT5 and inform future clinical use.

Table 1

Number of Questions and Points on SCAT3 and SCAT5

	SCAT3		SCAT5	
Cognitive Sections	Questions	Points	Questions	Points
Orientation	5	5	5	5
Immediate Memory	5	15	10	30
Concentration	5	5	5	5
Delayed Recall	5	5	10	10
Total	**20**	**30**	**30**	**50**

Limitations and Delimitations

There are several limitations to this study regarding the data collection, de-identification of participants, researcher's relationship with participants, engagement of participants, and generalizability. Data for this study were collected over multiple years and compiled using a medical database. Multiple administrators collected the data with no guarantee that they followed the SCAT written instructions. These variations could skew the data analysis in unanticipated ways.

De-identification of information was performed by the medical database report module and age was not a reportable variable. Therefore, birthdates were reported and converted into the participants' ages. Because of the researcher's association with many of the participants, previous knowledge existed of birthdays and the possibility of identification of the participants after de-identification increased.

Another limitation focused on the engagement of participants in taking the assessment. Because the assessment was a requirement by the university's athletic administration, it is possible that participants did not give their best effort and therefore, results could be skewed.

This study will not be able to be generalized to the collegiate student-athlete population because the exploratory factor analysis (EFA) methodology is only exploratory in nature and does not answer a research hypothesis.

The delimitation of this study centers on the subjectivity of methodology for EFA. This subjectivity restricts the conclusions that can be drawn from the exploratory analysis on the SCAT.

Definitions of Terms

Baseline assessment – A test administered to an athlete prior to the beginning of an athletic season and prior to injury.

Ceiling effect – A maximum score on a section of an assessment.

Delayed recall – The ability to remember a given set of words after a minimum of five minutes.

Immediate memory – This refers to recalling information after a few seconds and can also be called short-term memory ("Short-term memory," n.d.).

Return-to-play – The criteria that needs to be met by an athlete with a SRC in order to be cleared for full sport participation.

Return-to-learn – The criteria that needs to be met by an athlete with a SRC in order to be cleared to return to classroom activities of reading, homework, notetaking, and listening to lectures.

Sports-related concussion – A traumatic brain injury that may be caused by a direct hit to any part of the body that transmits to the head and results in neurological impairment that can create symptoms that may increase over time but cannot be seen on neuroimaging. (McCrory et al., 2017).

Organization of Study

Chapter 2 outlines the prevalence of SRC within the collegiate setting and the role of baseline testing. This explanation is followed by the history of cognitive testing within the context of SRC injury including the reliability and validity, ceiling effects, and previous analysis of the test structure of the SAC and SCAT. Chapter 3 contains a discussion of the methodology for this proposed study. This chapter includes the research design, the sample size, data collection procedures, statistical analysis decisions, and ethical considerations. Chapter 4 reports the results of two EFAs, the reliabilities of the entire test, and of the corresponding subsections. These results are followed by a description of the floor and ceiling effect differences. Chapter 5 discusses the findings as they relate to the comparison of assessment structure, reliabilities, ceiling effects, and implications for practice.

Chapter 2

Review of the Literature

Sports-related concussion (SRC) awareness has increased over the last two decades, leading healthcare providers to look for the most effective ways to analyze and better current examination, diagnosis, return-to-play, and return-to-learn policies. As this search continues, experts in the field are continuing to revise testing protocols and instruments to increase reliability, validity, sensitivity, and specificity. As a response to this search for the best sideline assessment tool for SRCs, the 5th International Consensus Conference on Concussion in Sport published a fourth revision of the Sport Concussion Assessment Tool (SCAT), called the SCAT5. This revision focused on changing the number of items repeated on the *immediate memory* and *delayed recall* portions of the assessment.

A large body of research exists related to SRC and continues to grow annually. This literature review takes a focused look at SRC with research associated with the following key terms: The Sport Concussion Assessment Tool (SCAT), the Standardized Assessment of Concussion (SAC), epidemiology within the National Collegiate Athletic Association (NCAA), and SRC baseline testing. All research conducted utilizing the SAC or SCAT in any form for post-SRC assessment was excluded from this literature review unless mean scores for non-injured collegiate participants, or baseline data, were recorded. This choice was made to focus this literature review on the baseline psychometric properties of the SCAT5 as compared to the SCAT3 and not on how these tests give evidence to SRC diagnosis or return-to-play decisions. Additionally, it is important to recognize the prominent researchers who focus on baseline testing and its effects on diagnosis, return-to-play, and return-to-learn policies. Included in this list are

researchers such as: Michael McCrea, Steven Broglio, Kevin Guskiewicz, Robert Cantu, Ruben Echemendia, Paul McCrory, William Barr, and Margot Putukian.

This review of literature focuses first on the prevalence of SRC in NCAA athletics to contextualize a discussion of the role and usefulness of baseline testing for SRC assessment, along with the available research on the psychometric properties and ceiling effects for the SAC and the SCAT.

SRC Epidemiology

SRC prevalence is not fully understood in NCAA-affiliated institutions because there is no requirement to provide injury data. Over the last three decades, the NCAA has tried to create a clearer portrait of SRC prevalence through the enactment of an injury surveillance program that began in 1982 with the express purpose of better documenting and understanding all injuries that occur during collegiate sports participation (Dick, Agel, & Marshall, 2007). This program gathers information from a convenience sample of 250 institutions, approximately fifteen percent of all participating institutions that are willing to volunteer their injury data to the NCAA Injury Surveillance System. This percentage is acceptable for a research sample size but requires inferences to be made about the population that may not reflect the true prevalence of SRC.

The first SRC research compiled from the NCAA surveillance program was published in 2007 with data from 1988 to 2004 (Hootman, Dick, & Agel, 2007). Hootman et al. (2007) reported an SRC occurrence rate of .28 per 1000 athletic-exposures (A-E) for all NCAA sports when combining all SRCs during this period. The athletic-exposure or (A-E) designation refers to the number of times an athlete has the possibility of becoming injured due to play. This can occur either through a practice or competition. These A-Es are only counted if the athlete participated in the practice or competition and may vary greatly from institution to institution

because some coaches may only play small numbers of athletes on their rosters and others may play most or all. Given this, SRCs accounted for 5% of all injuries reported during this 25-year interval. Additionally, annual SRC rates were reported that showed variation in the data. From 1988-89, the rate was .17 and remained constant until a significant jump to .26 during the 1995-96 season. Another large increase occurred in 1997-98, from .26 to .32 and continued to increase through the 2001-02 season. Eventually the rate gradually returned to 1997-98 levels in 2003-04. Hootman and colleagues attribute these increases in SRC injury rates to two factors: an increase in the diagnosis and treatment of SRCs but may also account for an increase in SRC injuries.

It is important to note that around the time of the creation of the SAC in 1997, the rates of SRC incidence per A-E increased (McCrea et al., 1998). This increase in incidence may be due to the introduction of this new SRC sideline assessment tool that helped improved detection, such that the rate increase may not ultimately reflect an increase of injury (Hootman et al., 2007); yet the SRC incidence rate continued to rise. In 2005-06, it was reported from the NCAA ISS data, which included 180 NCAA institutions, that SRC rates increased to .43 per 1000 A-E with a practice rate of .28 per 1000 A-E and 1.02 per 1000 A-E during competition. This suggests that SRC are still occurring at a significant rate and therefore, sideline assessment tools need to be psychometrically sound for future generations (Gessel, Fields, Collins, Dick, & Comstock, 2007).

The next epidemiological SRC study was not released until 2015, almost a decade later and reported a very different portrait. The SRC data collected from 2009-2014 estimated from the NCAA Injury Surveillance System convenience sample that 10,560 SRCs occurred annually in collegiate athletics with an overall SRC occurrence rate of 4.47 per 1000 A-E (Zuckerman et al., 2015). Unlike Hootman et al. (2007), Zuckerman et al. (2015) did not report annual SRC

occurrence rates. This lack of descriptive statistics about annual SRC incidence rate makes it difficult to discern whether a rise in SRC occurred over time or all at once. These data show a staggering difference compared to the two previous studies that gave overall SRC occurrence rates at .28 and .43 per 1000 A-E. It is possible that the incidence rate of SRC increased exponentially over the last decade but other factors may have influenced these statistics, including an increase in the number of student-athletes, and more dangerous styles of play. This research utilized a convenience sample from the NCAA Injury Surveillance System that only collects data from approximately fifteen percent of the population and therefore may not be a true representation of the population. Additionally, SRC diagnosis has increased over the past 20 years and therefore, researchers concluded that SRCs may not be increasing in number but rather that the diagnosis and reporting of SRCs that would have previously gone undetected has improved (Gessel et al., 2007; Hootman et al., 2007; Zuckerman et al., 2015).

Research shows that an increase in the SRC rate has increased over the last two and a half decades and may not be attributed solely to an increase in the injury rate but may have resulted from more objective, specific, and valid assessment tools. Because researchers believe that assessment tools play a role in the increase of the SRC occurrence rate, it is necessary to explore the tools used to determine these conclusions. To understand how these tools work, an exploration of the research will examine how baseline testing has been utilized within SRC protocols and how these assessments have been improved over the last two decades.

Testing Paradigms

Even though research shows that SRC rates have increased exponentially over the last two and a half decades, researchers believe that SRC rates have only slightly increased and that another variable may be attributed to this change. This change relates to the ability to diagnose

SRC as assessment tools have become more sophisticated during this time and may have a greater effect on the occurrence rate. There are many assessment tools that can be utilized in the diagnosis and treatment of SRC. The focus here is on sideline assessments as one improvement added to the SRC protocol to assist clinicians in diagnosing SRC on the field in a timely fashion. To fully understand how the problems associated with psychometric properties of baseline testing occur, it is necessary to review the two testing paradigms: individual-centered standard and criterion-referenced standard (Ragan & Kang, 2007).

Individual-center standard focuses on the individual as compared to themselves and follows two assumptions: the participants’ abilities are normally distributed and all ability levels can be measured. This standard is similar to a norm-referenced standard, but instead of comparing the datum to a norm, the athlete is compared to their pre-injury baseline SRC datum. When a SRC is suspected, the clinician will re-test the athlete using the same assessment tool and then compare the results to their baseline score. If the difference is greater than the confidence interval, then mental status change is confirmed (Ragan & Kang, 2007).

In contrast to the individual-center standard, researchers like McCrea et al. (1998) have proposed the use of a criterion-referenced standard. This standard utilizes the mean and standard deviation (SD) scores for a specific population and baseline testing becomes unnecessary (Ragan & Kang, 2007). Therefore, athletes will only be diagnosed with a SRC if their score is more than one SD from the mean value. The problem occurs when the ability level of the athletes differs significantly. For example, if the cut-off score for a SRC diagnosis is 25 and two athletes sustain a SRC, resulting sideline testing may reveal that one scored a 28 and the other a 25, yet both athletes have a SRC. The criterion-reference standard disregards the possibility that one athlete has a higher cognitive ability than the other, and thus this testing measure would require greater

cognitive impairment for a SRC to be diagnosed. Therefore, if the assumptions of normality and ability discrimination are met with appropriate test validity, then individual-centered standard should be the choice for neuropsychological testing prior to and following a SRC (Ragan & Kang, 2007).

Baseline Testing. Even though Ragan and Kang (2007) conclude that individual-centered standard should be the choice for SRC testing, it is necessary to acknowledge the evolution of these sideline assessments. Individual-center standard, otherwise known as baseline testing, is a requirement of many SRC assessment tools. This baseline testing is essential because minimal or no normative data had been published prior to the publication of these assessment tools. Therefore, individualized baseline testing became the only way for clinicians to observe changes between pre-injury and post-injury abilities. These individualized baseline tests were used to compare SRC post-injury data to determine the absence or presence of a SRC.

Baseline testing for SRC usually occurs at the beginning of the academic year prior to the start of any school-sanctioned practices and competitions. When baseline testing occurs, it can include many different diagnostic tests including but not limited to SAC, SCAT, BESS, ImPACT, CogSport, and Sway. Test choice is currently determined by individual institutions and not mandated by the NCAA (NCAA Sport Science Institute, 2017). Presently, NCAA institutions are requested by the NCAA Sport Science Institute to have a SRC management plan that is available to the public through paper and web-based interfaces that includes institutional procedures for SRC education, pre-participation assessments, recognition and diagnosis of SRC, post-SRC management, returning athletes to competition, and returning students to the classroom. The specific request by the NCAA is that baseline testing be performed for all athletes prior to the start of their season. This baseline testing should include a minimum of four

basic components: a medical history related to brain injury or SRC, symptom evaluation, cognitive testing, and balance testing (NCAA Sports Science Institute, 2017).

These types of tests give clinicians an individualized comparison to utilize when an athlete sustains a SRC. This comparison can help with the initial diagnosis of the injury by providing a point of reference for the cognitive, balance, and neuropsychological abilities of the athlete. It is important to note that most SRC diagnoses occur on the field and therefore sideline assessment tools have been created for this specific reason, including the SAC and the SCAT. These sideline assessments are endorsed by the NCAA Sport Science Institute (2007) and were created to help clinicians overcome their lack of equipment, time, and testing atmosphere (McCrea et al., 2007).

Baseline testing is not a new concept and was first utilized for SRC in a research protocol created by Jeffery Barth and colleagues (1989) to determine neuropsychological and psychosocial changes following SRC in collegiate football players using Gronwell's PASAT. The PASAT examines concentration, attention, and immediate memory recall through an auditory numeric material manipulation (Barth et al., 1989). This baseline testing protocol is still currently utilized and can be seen in the research that focuses on the creation of normative data, and identifying the validity and reliability of SRC assessment tools (Echemendia & Julian, 2001).

As previously mentioned, some assessment tools require baseline SRC assessments to help determine the presence of a SRC (Benedict et al., 2015; McCrea et al., 1998; McElhiney et al., 2014; Sufrinko et al., 2017). While these instruments have shown some relationship in diagnosing SRCs, no single test comprehensively assesses all aspects of a SRC. As a result, clinicians are cautioned to use clinical judgment while using these instruments for diagnosis and

return-to-play criteria (Echemendia et al., 2017a). Some tools that have been utilized, whether they require a baseline assessment or not, include the Standardized Assessment of Concussions (SAC) (McCrea, 2001b), Sport Concussion Assessment Tool (SCAT) (Chin et al., 2016), King-Devick test (Brommer et al., 2016), Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) (Allen & Gfeller, 2011), CogSport (Collie et al., 2006), and Balance Error Scoring System (BESS) (Yengo-Kahn et al., 2016).

There are conflicting data on the usefulness of baseline testing. A majority of the research has a positive view of baseline testing with only a few impartial studies to support its use. These are accompanied by expressions of concerns about the psychometric properties of the tests, themselves. Research that views baseline testing positively focuses on the usefulness of the data when comparing it to post-injury scores. According to McCrea (2001a), baseline testing is the preferred method of pre-screening athletes because it provides greater control of variability from variables that may influence the pre-injury and post-injury assessment. Some examples of these variables would include learning disabilities and previous history of SRC. During the same year the 1st International Symposium on Concussion in Sport was held in Vienna, baseline testing was agreed to be beneficial and needed even though these experts acknowledged the limitations of SRC assessments (Aubry et al., 2002). It is important to remember that at this time the SAC was currently in use but the SCAT's creation was still pending. This view of baseline testing remained the same three years later at the 2nd International Symposium on Concussion in Sport in Prague but in response to the lack of a consensus of a psychometrically strong sideline assessment tool, the SCAT was created (McCrory et al., 2005). Over the last decade, additional research has placed baseline testing in a positive light with regards to exertional testing of the SAC (Koscs, Kaminski, Swanik, & Edwards, 2009), variations in Post Concussion Symptom

Scale (PCSS) (Guskiewicz et al., 2013), disparities in post-injury care (Kirschen et al., 2014), standard of care (Broglio et al., 2014; Pachman & Lamba, 2017), and diagnostic accuracy (King, Brughelli, & Hume, 2014).

Even though there are researchers who view SRC baseline testing as favorable, there are still discussions that sideline assessments (i.e. SAC and SCAT) are not useful. The first mention of issues with baseline testing were published in 2001 along with many of the other studies on SRC. One major concern was that serial testing could cause problems with practice effects, player motivation, and non-injured athlete comparisons (Echemendia & Julian, 2001). Specific issues observed with SAC implementation included athletes rehearsing the recall lists months prior to assessment, changes in the rate of digit presentation (if faster than the expected rate of one second per number, then outcomes change), and ceiling effects. Echemendia and Julian concluded in 2001 the SAC should not be used as a clinical tool and only for research purposes until it could be properly validated. Other research with a negative view of baseline testing focuses on the item difficulty of the SAC, stating that baseline testing is not beneficial if the instrument does not differentiate between a wide variety of abilities. Following the analysis of item difficulty, it was determined that most of the items were too easy and therefore did not reflect the variation in abilities necessary to be a valid test that would warrant baseline testing (Ragan et al., 2009).

Other critiques for baseline testing is in the usefulness of these assessments for physicians when performing a physical exam (Matuszak, McVige, McPherson, Willer, & Leddy, 2016). These researchers suggest that alternative tools should be utilized to determine the mental status of patients, yet upon further inspection of the appendices provided with this research, the mental status testing utilized the same exact principles of the SAC assessment with the only

differences being slight variations in words and numbers. The reality is that many physicians screening patients for SRC are under many of the same time constraints as athletic trainers engaging in sideline assessments, and therefore the practicality of utilizing a more detailed instrument is limited.

In comparison to general physician guidelines, assessment trends in SRC evaluation for neuropsychologists were reported that only fifteen percent utilize baseline testing and 92 percent will evaluate a SRC post-injury without baseline data (Lemonda, Tam, Barr, & Rabin, 2017). The research did not explore the reasoning behind this choice for the minimal use of baseline testing but Lemonda et al. speculated that neuropsychologists have numerous tests that can be utilized during office visits that have been validated and include normative data across specific age groups but may only have one version of the test, making serial testing imprudent. Additionally, they discussed the possible difficulty of athletes receiving medical reimbursements for these tests. This ability to use precise instrumentation, reimbursement opportunities, and lack of serial testing options may play a role in a neuropsychologist's choice to engage in baseline testing.

When Chin and colleagues (2016) were assessing reliability and validity for the SCAT3, they concluded that there were numerous variables that could inhibit proper baseline testing and therefore it was better to use normative data that had been carefully screened to use as a comparison when evaluating SRC incidences. Issues discussed included testing environment, athlete's motivation, testing resources, and the fact that the general body of research is ambiguous in its attempt to show the value of baseline testing. In contrast to this negative perspective on baseline testing, it is important to remember that a majority of the research sees baseline testing in a positive light.

As previously discussed, there is research that fully supports baseline testing and research that sees only the flaws. Yet other research presents the argument neutrally. According to a systematic review by YeYengo-Kahn et al. (2016), there needs to be more research completed on SCAT with and without the baseline testing present to determine if the SCAT can detect a SRC in either circumstance. Currently, there are no published studies on utilizing only normative data to diagnose an SRC. Other groups report that baseline testing can be helpful, but is not necessary for sideline SRC management (Hyden & Petty, 2016). In a systematic review by Echemendia et al. (2017a), it was concluded that symptom checklist, SAC, and mBESS were useful to clinicians for immediate diagnosis of SRCs with or without baseline measurements. It is important to remember that it has been three decades since the creation of the SAC and a little over a decade since the creation of the SCAT. During this time, normative data options have increased and more and more clinicians are utilizing these assessment tools.

Normative Data. As the arguments in favor of, negative to, or neutral toward baseline testing continue, it is essential to understand how normative data plays a role in this discussion. Normative data, also called norms, utilize a large sample dataset that reflect the intended population to determine test score estimates of population values following administration of an assessment (Zimmerman, 2011). Norms will be presented for both the SAC and the various versions of the SCAT because these are the two sideline assessments utilized for on-field assessment for SRC. It is important to note that Ragan and Kang (2007) refer to the data as criterion-referenced standard and not as normative data. Their argument is that true normative data would show require the researcher to show that the two assumptions of normative data are met including the normal distribution of all scores and all abilities would be present. This literature review only explores research related to baseline norms for non-concussed athletes

because the intent is to show how the structure of the baseline SRC assessment tool is affected by the increase in items.

The first normative data published on the SAC only established norms for male high school and college football athletes (N = 568). Presented below in Table 2, researchers reported a total score mean and corresponding standard deviation (SD) in addition to the four sections: *orientation*, *immediate memory*, *concentration*, and *delayed recall* for all non-concussed participants (McCrea et al., 1998). These data did not differentiate mean scores between high school and college athletes.

Table 2

Normative Data for Non-Concussed High School and Collegiate Football Players

	SAC	
Cognitive Sections	Mean	Standard Deviation
Orientation	4.82	.43
Immediate Memory	14.51	.98
Concentration	3.40	1.27
Delayed Recall	3.84	1.11
Total Score	26.58	2.23

Note: Adapted from "Standardized Assessment of Concussion (SAC): On-Site Mental Status Evaluation of an Athlete," by M. McCrea, J. P. Kelly, C. Randolph, J. Kluge, E. Bartolic, G. Finn, B. Baxter, 1998, *Journal of Head Trauma Rehabilitation*, 13, p. 32. Copyright 1998 by Aspen Publishers, Inc.

Normative data for the SAC that includes both genders are available but there is a large disparity between the male and female sample sizes with 88% of the sample (N = 517) as male and only 12% female (N = 73). As can be observed in Table 3, there are minimal differences between mean and SD scores across genders. When comparing overall collegiate data to McCrea et al. (1998), the values are nearly identical. It is important to point out that data was also

presented by sport but this data included all education levels including junior high and senior high athletes. As a result, these data cannot be utilized to generalize this data for collegiate athletic participants. It is also important to note that 81% of the male subjects across education level were football players (McCrea et al., 2007) and therefore, the data is skewed toward male football players and does not reflect all other sports and genders. Additionally, these data came from the third edition of the *Standardized Assessment of Concussion: Manual for Administration, Scoring and Interpretation* and the date of the data collected for this normative data could not be established. It is possible that this is the original normative data collected prior to the first edition which was published in 1998. If this is the case, these data are possibly out of date and need to be re-evaluated in the twenty-first century. At the very least, a larger sample size should be utilized to draw conclusions about female collegiate athletes.

Table 3

Normative Data for Non-Concussed Collegiate Mixed-Gender Athletes

Cognitive Sections	SAC	
	Mean	Standard Deviation
Orientation	4.85	.39
Immediate Memory	14.52	.94
Concentration	3.57	1.17
Delayed Recall	3.57	1.07
Total Score	26.86	2.04

Note: Adapted from "Standardized Assessment of Concussion: Manual for Administration, Scoring and Interpretation," by M. McCrea, J. P. Kelly, C. Randolph, J. Kluge, E. Bartolic, G. Finn, B. Baxter, 2007. Copyright 2007 by CSMi Medical Solutions.

Normative data for the SCAT were compiled from 2005-07 about a mixed-gendered sample of college athletes (Shehata et al., 2009). The data were not reported in a mean and SD format as previously observed in the SAC norms, but were presented as the percentage of participants who completed the task. Reported data combined the number of correct answers to the following sections: PCSS, immediate 5-word recall, delayed 5-word recall, months in reverse, and digits backward. Within this data set, no total score for the SCAT were calculated or reported. Ninety-six percent of the sample (N = 249) successfully repeated all five words. When separated into gender, 98.3% of women (N = 60) and 95.8% of men (N = 189) completed this task perfectly. *Delayed recall* scores were significantly less with 36.9% of all participants successfully remembering all words. The greatest contrast in this section is that only 29.6% of men had perfect recall compared to 60% of women. These data suggested that the test is a poor

measure of cognitive ability if 98% of women and 95% of men hit the ceiling on the SRC assessment for *immediate memory* and 36% for *delayed recall*.

SCAT2 and SCAT3 normative data for college athletes from a wide variety of sports who were 18-23 years old show no differences in athletes with and without a SRC history (Zimmer, Marcinak, Hibyan, & Webbe, 2015). Zimmer et al. (2015) describe the normative data split by gender with a female mean as 91.65 with a SD of 5.58 for total SCAT2 scores. The men’s mean values were 90.83 with a SD of 5.6. This standard deviation is important when utilizing this normative data post-injury. The researchers also divided the data into pertinent sections of the SCAT2 assessment that could be evaluated separately, including the symptom score, SAC, and balance. Mean scores were provided for all portions of the assessment, but only SAC mean scores are provided because of the focused nature of this literature review. SAC mean scores for females were 27.63 with a SD of 1.87 and males’ mean SAC scores were 26.97 with a SD of 2.05. These values reflect the previous work of McCrea and colleagues with individual female scores one point higher than males (McCrea et al., 1998; McCrea et al., 2007). Zimmerman et al. (2015) exhorts clinicians to be cautious in their diagnosis of a SRC with a score more than 1 SD from the mean and consider that real impairment is present if more than 1.5 SD from the mean when comparing post-injury SCAT assessments to the normative data (Zimmer et al., 2015). Currently, no normative data has been published for the SCAT5.

Sport Concussion Assessment Test

The Sport Concussion Assessment Tool, or SCAT, is one of the more common tools used to assess SRCs and is endorsed by practitioners (Aubry et al., 2002; McCrory et al., 2013). There are multiple versions of the SCAT: SCAT, SCAT2, SCAT3, and SCAT5. It is important to note

that there was no SCAT4 revision published. The two most recent versions are the SCAT3 and SCAT5 published in 2013 and 2017, respectively.

The format of the original SCAT included sections for Signs, Memory (modified Maddocks questions), Post Concussion Symptom Scale (PCSS), cognitive assessment, and neurological screening. The sign section included three questions in respect to loss of consciousness, convulsions, and balance impairments. The memory section used a modified version of the Maddocks questions while the cognitive assessment includes three subsections. The subsections included a one-time only 5-item word list (the practitioner could come up with any five words of their choice) for immediate recall, a recitation of the months of the year in reverse order, and the last section asks participants to recall numbers in reverse-order. This last subsection begins with three numbers and ends with six. Participants are given two chances to pass any given level before moving on to the next set of numbers (McCrory et al., 2005).

In 2009, the second modification of the SCAT occurred, named the SCAT2. Modifications included were the addition of the Glasgow Coma Scale (GCS), three trials for the *immediate memory* section, alternate word lists for the immediate and *delayed recall* sections, and a modified version of the Balance Error Scoring System (McCrory et al., 2009). In 2013, the third revision, SCAT3, had very few modifications but included an additional balance testing option and a neck examination section (McCrory et al., 2013). The last modification occurred in 2017, named the SCAT5. The major change to this version was in the number of words repeated for the *immediate memory* and *delayed recall* sections. All the previous versions of the SCAT used a 5-item word list and this was increased to an optional 10-item word list for the SCAT5 (Echemendia et al., 2017b).

The scoring of these versions has changed over time with the addition of various sections. The first version of the SCAT did not provide a total score (McCrory et al., 2005) while the SCAT2 had a maximum of 100 points (McCrory et al., 2009), and SCAT3 excludes a maximum score (McCrory et al., 2013). The SCAT5 does not provide a total score either and therefore, it is difficult to compare normative data from version to version (Davis et al., 2017).

In the most recent systematic review focused on sideline screening, researchers concluded that the SCAT is “the most-well established and rigorously developed instrument for sideline testing” (Patricios et al., 2017, p. 893). When the SCAT was created, the goal was for patient education and SRC assessment by healthcare providers (McCrory et al., 2005), which is similar to the SAC goal of creating a SRC assessment for athletic trainers and other healthcare professionals (McCrea et al., 1998). This shows that both assessments were created for healthcare providers and in an effort to simplify the SRC assessment thus making SAC a natural subsection of the SCAT.

Even though researchers report that SCAT tests are the most rigorously developed sideline assessment tool (Patricios et al., 2017), it is necessary to understand that the quality of the instrument has been called into question over the years. Specific issues with the SCAT include the limitations of a short sideline assessment in both content and length, along with the challenge of creating a psychometrically-viable test for clinicians who have no previous experience with neuropsychological testing (McCrea, 2001a). As a result of the condensed assessment, a ceiling effect has been noted, specifically in the SAC portion of the SCAT. Researchers believe that this ceiling effect exists because the item difficulty is quite low (Ragan & Kang, 2007). Therefore, Ragan and Kang (2007) concluded that observed ability cannot reflect the true ability of an athlete, much less of many athletes. This skewness in both the SAC

and SCAT versions is pronounced, and mostly likely not related to a lack of normality in cognitive function. Instead, researchers believe it is related more to the lack of item difficulty.

Other issues with SCAT testing include practice effects, reliability, and lack of sensitivity and specificity. When utilizing the SCAT assessments for baseline testing and post-injury assessment, serial testing is required. Serial testing requires that athletes to be testing annually and in the case of SRC injury, daily until baseline values are achieved. Therefore, one athlete could have taken all three versions of the SCAT prior to injury. This is problematic when there are only three sets of words or numbers as seen on the SCAT3 (McCrory et al., 2013). In other words, athletes who are tested annually and post-injury will have a familiarity with these words because there is limited variation. Other ways that athletes can practice include participants rehearsing the months of the year in reverse order or inflating PCSS to have a higher baseline score and therefore have a lower chance of being diagnosed with a SRC, but there is no research to substantiate this claim. Other practice effects have looked at changes in SAC values for pre-season, mid-season, and post-season where no significant differences were determined in non-concussed collegiate football players (Miller, Adamson, Pink, & Sweet, 2007).

Since the SCAT was created as a compilation of already-existing assessment tools, there is little data on the reliability of the entire test. Therefore, data are published by assessment section and are presented as such in literature. The overall reliability of the SCAT has not been documented but the reliability of the SAC has. It has been reported anywhere between .42 and .71 (Guskiewicz et al., 2013). This value describes the internal consistency of the instrument and good values can vary but .70 or above is considered acceptable (Laerd Statistics, 2015a).

Sensitivity and specificity for SAC were also calculated based on an all-male sample of high school and college football players, which is problematic because these values do not reflect

the entire population of athletes including females and non-football male athletes. Therefore, the generalizability of the data to females and other sports is limited. Barr and McCrea concluded that a one-point decrease between baseline and post-SRC score determines the presence of a SRC. Following this conclusion, they measured this same data set for sensitivity and specificity, which was .94 and .76 respectively (Barr & McCrea, 2001). Sensitivity reveals the true positive rate, meaning that there is a 94% chance of successfully detecting a SRC when using the SAC. Specificity is the true negative rate, meaning that there is a 76% chance of not having a SRC when the assessment is used. The same year, McCrea (2001a) published another study with what appears to be the exact same sample where he reported a slightly higher sensitivity at .95 and the same specificity as Barr and McCrea (2001). It has also been reported that sensitivity was as high as .80 and specificity was between .89 to .98 over the seven days that collegiate football players were evaluated using the SAC (McCrea et al., 2005). These specificity and sensitivity values show that there is a good chance that the SAC will accurately diagnose a concussion but is less likely to properly clear athletes of having sustained a SRC. Additionally, Guskiewicz et al. (2013) reported that sensitivity ranges from .80 to .94 with the highest occurring during the first 48 hours. Specificity was reported from .76 to .91. Therefore, research concluded that a change in mental status is noted with a 2 to 4-point change below baseline values which means that little variation in testing score is needed to diagnose a SRC. This is problematic because there is minimal variation in the cognitive abilities and if the small nuisances in the score are inaccurate, then a SRC could be misdiagnosed.

The last significant issue with the SCAT is the choice of words utilized during the *immediate memory* and *delayed recall* portions of the SCAT assessment. Only one published article is available focused on word choice and the SAC. McElhiney et al. (2014) utilized a 10-

item list with one repetition, instead of using 5-item word list repeated three times, with a wide variation in words, thus not changing the overall total score for the SAC. These words (penguin, magazine, tornado, luggage, splinter, cottage, mushroom, vehicle, demolish, and gutter) were determined to be psychometrically sound. But although these words were found to be of value, none were found within the SCAT5. This suggests that the current words utilized on the SCAT5 may not be difficult enough to be considered psychometrically sound. Following the release of the SCAT5, no other research on repeating of the 10-item lists repeated three times presently exists.

In the newest revision of the SCAT, the SCAT5, experts hope to improve the validity, reliability, sensitivity, and specificity of the assessment while reducing ceiling effects by improving item-difficulty (Echemendia et al., 2017b). The SAC, SCAT3, and SCAT5 assessments have three forms that utilize different words and numbers. Traditionally they are named Form A, Form B, and Form C. When evaluating item difficulty through an item-analysis, a majority of the SAC had unacceptable psychometric properties when evaluated by forms, meaning that the words were too easy. Each form's acceptable item percentages are as follows: Form A = 33%, Form B = 30%, Form C = 27% with 76% of the items being too simplistic (Ragan et al., 2009). Therefore, the items need to be more difficult by changing the word lists and adding more words. Currently, there is no research performed on the SCAT5 with regards to psychometric properties.

Conclusion

Experts in SRC want clinicians and other healthcare professionals to have a psychometrically sound sideline assessment tool for the diagnosis of SRC. This is essential because the number of SRC in collegiate athletics is has increased over the past ten years,

although questions still exist as to whether it is from an increase in more sound sideline assessment tools, from an increase in student-athlete participation, or from more dangerous techniques utilized during practice and competitions. Though most experts agree that baseline testing is the best standard of care, it is important to note that there are numerous questions about the ability of these sideline tests to accurately detect the presence of a SRC.

The SCAT5, as the newest version of the SCAT offers some changes with the number of *immediate memory* and *delayed recall* words on the assessment. The goal is to help improve the item-difficulty, validity, reliability, sensitivity, and specificity of the assessment. Because no research has been performed on the SCAT5, this research determined whether the factor structure of this assessment remains the same as compared to the SCAT3 or if the additional words changed the structure of the exam, therefore affecting the validity, reliability, sensitivity, and specificity of the instrument.

Chapter 3

Methodology

This chapter outlines the methodology for this study. This was a quantitative, non-experimental, and exploratory research study on the structural differences between the SCAT3 and SCAT5, including an emphasis on the proportion of ceiling effects found specifically within the *immediate memory* and *delayed recall* portions of the assessment for both versions of the test. The purpose of this study was to answer the following research questions:

RQ1. Are there differences in the factor structure and internal reliability between the SCAT3 and SCAT5 subsections of *immediate memory* and *delayed recall* assessments in an analysis of baseline data?

RQ2. Are there differences in the proportions of floor/ceiling effects for the SCAT3 and SCAT5 subsections of *immediate memory* and *delayed recall* assessments in an analysis of baseline data?

To answer these research questions, I analyzed historical SRC data from one NCAA Division III institution with a variety of sports. All athletes who have completed both SCAT3 and SCAT5 assessments at the chosen institution were included in the data set regardless of gender, sport, or age. I analyzed the data using exploratory factor analysis (EFA), Cronbach's alpha, and proportions of the correct responses. The remainder of this chapter provides the specific details of the methodology.

Research Design

This quantitative study used a non-experimental, exploratory method to determine if differences exist in the factor structure, internal reliability, and ceiling/floor effects of the SCAT3 and SCAT5. I utilized exploratory factor analysis (EFA) on the SCAT3 and SCAT5 to

determine the underlying structure of the assessments. The goal of EFA is to reduce the number of variables (or items) in order to determine what kind of underlying factor structure exists (Laerd Statistics, 2015b; Osborne, 2014). This method helped determine the extent to which the five-item and ten-item word lists in the *immediate memory* and *delayed recall* portions were similar in latency. Additionally, internal reliability was assessed using Cronbach’s alpha to determine how consistent respondents were across items and formats. Proportions of floor and ceiling effects were also reported.

Sampling and Participation. Data were collected from a large and established secondary data set created by an NCAA Division III institution’s sports medicine staff compiled over multiple years of SRC baseline testing. The secured secondary data set was kept in a HIPPA-approved, password-protected environment. The data set came from an institution whose policy required all contact and collision sports athletes to receive annual baseline SRC testing before clearance to participate in university-sponsored athletic activities. Subsequently, the data set encompassed SRC data for athletes who played a variety of sports: football, volleyball, basketball, soccer, baseball, softball, lacrosse and track and field. In this study, all participants who completed the 2016 (SCAT3) and/or 2017 (SCAT5) baseline testing were included in the data set.

Participants for SCAT3 (N = 416) and SCAT5 (N = 395) met the recommended minimum sample size of 10 subjects per variable (Laerd Statistics, 2015b), because a total of 30 variables (words) are used on the SCAT3 and the SCAT5, as evidenced in Table 4. Table 5 indicates how a minimum of 300 participants should be used, to correspond with 30 variables.

Table 4

Example of Word Lists used on for immediate memory and delayed recall on SCAT3 and SCAT5

SCAT3			SCAT5					
List A	List B	List C	List A		List B		List C	
Elbow	Candle	Baby	Finger	Candle	Jacket	Dollar	Baby	Elbow
Apple	Paper	Monkey	Penny	Paper	Arrow	Honey	Monkey	Apple
Carpet	Sugar	Perfume	Blanket	Sugar	Pepper	Mirror	Perfume	Carpet
Saddle	Sandwich	Sunset	Lemon	Sandwich	Cotton	Saddle	Sunset	Saddle
Bubble	Wagon	Iron	Insect	Wagon	Movie	Anchor	Iron	Bubble

Table 5

Number of variables and appropriate sample size for EFA

	SCAT3	SCAT5
Number of Word Lists	3	3
Words per List	5	10
Sample Size per Variable	10	10
Total Sample Size Needed	**150**	**300**

Variables. There are three versions of each SCAT: A, B, and C. Each patient was only given one word-list during the examination and words were recalled in any order remembered. This included a five-item word list for SCAT3 and a ten-item word list for the SCAT5. A total of fifteen usable words for the SCAT3 were available when combining all three lists. A total of thirty useable words were available when combing the three lists for the SCAT5. Because of the limited variation of the words between the SCAT3 and SCAT5, fifteen of the 45 words from the

SCAT3 were utilized on the SCAT5, thus creating 15 duplicate variables. This resulted in a final variable list of 30 words. Therefore, 30 variables were utilized in this study as can be seen in Table 5, even though there are 45 words in the table. These variables were used for both the *immediate memory* and *delayed recall* potions of the SCAT3 and SCAT5.

Data were compiled from a secure medical database and de-identified through a report function within the medical database except for the participants' birthdays to determine age. Once the data were cleaned, it was analyzed using an EFA to determine the underlying structure of the assessments and the proportion of ceiling effects were calculated from the data set.

Timeline. This timeline outlines the various stages of this research:

1. February 2018, data use approval obtained (see Appendix C)
2. Late February 2018, research proposal accepted.
3. Early March 2018, IRB approval was obtained (See Appendix D).
4. Middle of March 2018, data was retrieved and cleaned from Sportsware Online for the SCAT3 and SCAT5 *immediate memory* and *delayed recall* sections along with age, academic standing, and race/ethnicity. During this process, the data was de-identified to protect the confidentiality of the participants and limit researcher bias.
5. Late March 2018, statistical analysis of data was performed.
6. Early April 2018, chapters 4 and 5 were written.
7. Late April 2018, dissertation defense was completed.

Data Analytics. RQ1. Are there differences in the factor structure and internal reliability between the SCAT3 and SCAT5 subsections of *immediate memory* and *delayed recall* assessments?

The data analysis included:

1. Cleaning the data
2. Choosing an extraction method
3. Determining the number of factors for analysis
4. Determine appropriate rotational method
5. Interpreting results
6. Cronbach's alpha was run to determine internal reliability

The following provides greater detail on the rationale and processes of the EFA. I cleaned the data to limit bias or derailment of analysis by specifically looking for and eliminating types of mis-responses and missing data (Osborne, 2014). Following the cleaning, an extraction method was determined and a principle component analysis factoring method was utilized (Osborne, 2014). Assumptions for factor analysis were evaluated including multicollinearity, Bartlett's test of sphericity, and Kaiser-Meyer-Olkin (KMO). Other extraction techniques have difficulty meeting these assumptions and show little benefit when used over these previous techniques (Osborne, 2014).

Next, I determined the number of factors that should be analyzed followed by a decision to use an oblique rotation because a correlation existed among the variables. This step increased the ease of interpreting the results of EFA (Osborne, 2014). There are two different types of rotations: orthogonal and oblique. Each depends on the correlation between factors. This correlation, if any, was determined, therefore, an oblique rotation was applied (Osborne, 2014). The fifth step in the EFA process was to interpret the results. It was essential to determine if the results were sensible. EFA aims to create results that are meaningful but sometimes fails to provide functional and practical application with respect to an instrument's conceptual or theoretical framework. It is possible for EFA to provide results, but they may not be useful to the

researcher based on the framework; therefore, careful scrutiny of these results was imperative (Osborne, 2014). Additionally, reliability of the EFA was determined by running a Cronbach's alpha. The final step in the EFA was to see if the results could be replicated through an additional EFA or CFA analysis to help determine the strength and relevance of the findings (Osborne, 2014). This step was beyond the scope of this research and was not included in the analysis.

The data set was created by the institution's sports medicine staff and included one subset of NCAA Division III athletics. Additionally, the decision to use EFA to examine the data means this study cannot be generalized to all NCAA Division III institutions because exploratory factor analysis is used to explore data and not used to confirm a hypothesis (Osborne, 2014). Nevertheless, the information obtained from this research adds to the current body of literature by determining if differences exist in the assessment structures and in the proportion of ceiling effects for the SCAT3 (with a five-item word list) compared with the SCAT5 (with a ten-item word list). This is important to determine because the structure of the instrument is essential to the validity and reliability of the test. Additionally, the presence of ceiling effects is inversely associated with the number of test-items; i.e., presence is more likely with tests of fewer items. If there are high proportions of ceiling effects in one version, then it is plausible that a high grouping of scores is a result of test-format defects, leading to construct-irrelevant invariance. In other words, detecting true differences in a student-athlete's ability to accurately recall words becomes problematic. Thus, athletes who are suspected of sustaining a SRC but score highly because of the ceiling effect due to *immediate memory*/*delayed recall* bias, have their mental and physical health endangered if they are truly concussed but test as a false-negative.

RQ2. Are there differences in the proportions of floor/ceiling effects for the SCAT3 and SCAT5 subsections of *immediate memory* and *delayed recall* assessments?

To analyze the second research question, I identified the number of participants with either zero or 15 correct responses on the SCAT3 *immediate memory* portion. The zero showed a floor effect, meaning that the participant could not score lower. In contrast, 15 correct responses showed a ceiling effect meaning that the participant could not score higher. These scores were summed and differences in average score were examined. Additionally, the same procedures were followed for the SCAT5, with the exception that the ceiling score was 30 based on the three attempts of the 10-item construct. Floor and ceiling effects were then calculated for *delayed recall* which was zero and five for SCAT3 and zero and ten for SCAT5. I ran a chi-square test to determine statistical significant differences between groups on an independent sample. An independent sample was created because there is no statistical test for differences of proportions that exists for dependent groups. The independent group was created by determining all participants who had the same sport, age, and birthdate. Once these commonalities were discovered, the participant was excluded from the sample.

Ethical Issues

At the time of this study, I was a full-time employee of the institution where the data was collected. My role as assistant athletic trainer was to collaborate with the other sports-medicine staff members to review medical policies, review student-athletes medical history, oversee and participate in compiling baseline testing, clearing them for participation, evaluating and rehabilitating sports-related injuries and general medical conditions, and provide practice and game coverage. Because my employment encompassed numerous tasks, I had a personal working relationship with many of the student-athletes who participated in this study. Though I

made every effort to treat the data in an unbiased manner, particularly by having the medical database de-identify the data prior to statistical analysis, there was the possibility that this relationship could constitute a conflict of interest.

As a member of the sports-medicine team at the participating institution, I helped to collect approximately 10 percent of the data contained in the database analyzed. Therefore, I had some prior knowledge of participants’ names and scores. I addressed this issue by maintaining transparency with my committee about knowledge. I reduced my ability to identify participants by running a report through the medical database to de-identify the data, except for date of birth to determine age, before data analysis procedures began. Finally, I structured the study so as to quantitatively analyze the data in such a way that did not incentivize my knowing participants’ identities/scores.

Permission for the use of the data set was obtained from the Director of Sports Medicine at the given institution and IRB approval was obtained prior to the compilation of data.

Chapter 4

Results

The purpose of this study was two-fold: to explore the factor structure of the Sport Concussion Assessment Tool (SCAT) versions three (SCAT3) and five (SCAT5) during baseline testing. Additionally, this study sought to determine and compare the proportion of floor and ceiling effects of the *immediate memory* and *delayed recall* portions of these assessment tools.

The research questions guiding this study were:

RQ1. Are there differences in the factor structure and internal reliability between the SCAT3 and SCAT5 subsections of *immediate memory* and *delayed recall* assessments in an analysis of baseline data?

RQ2. Are there differences in the proportions of floor/ceiling effects for the SCAT3 and SCAT5 subsections of *immediate memory* and *delayed recall* assessments in an analysis of baseline data?

To answer the first research question, this chapter reports the demographic information of participants including gender, sport, and age. This is followed by a presentation of exploratory factor analyses (EFAs) as well as internal consistency estimates for both SCAT versions. In answer to the second research question, proportions for the floor and ceiling effects for the *immediate memory* and *delayed recall* portions of the assessment are reported.

Participants

Two groups of participants were utilized for this study. For RQ1, all participants at George Fox University who took the SCAT3 $(N = 416)$ or the SCAT5 $(N = 395)$ assessment were included in two separate EFAs. Gender distributions for the SCAT3 were 33.4% $(N = 139)$ female and 66.6% $(N = 277)$ male. The SCAT5 had a distribution of 35.7% $(N = 141)$

female and 64.3% ($N = 254$) male. The SCAT3 and SCAT5 were administered to participants in August 2016 and 2017, respectively. Sports participation for SCAT3 and SCAT5 are presented in Table 6 with the largest participation being football for both assessments. For the SCAT3, soccer, baseball, and basketball were the next three most-played sports, while for the SCAT5, track & field, soccer, and baseball were the top four most-played sports represented in the sample. The ages of participants for the SCAT3 ranged from 18 to 26 ($M = 20.91, SD = 1.456$) while the age range for SCAT5 participants was 19 to 24 ($M = 19.94, SD = 1.417$).

Table 6

Sport Demographics for SCAT3 and SCAT5 Sample

SCAT3		SCAT5	
Sport	Count (%)	Sport	Count (%)
Football	143(34.4)	Football	120(30.4)
Soccer	60(14.4)	Track & Field	54(13.7)
Baseball	55(13.2)	Soccer	53(13.4)
Basketball	46(11.1)	Baseball	42(10.6)
Track & Field	36(8.7)	Basketball	32(8.1)
Softball	32(7.7)	Tennis	26(6.6)
Lacrosse	18(4.3)	Softball	24(6.1)
Volleyball	15(3.6)	Volleyball	16(4.1)
Other	10(2.4)	Other	12(3.0)
Cross Country	1(.2)	Lacrosse	11(2.8)
		Cross Country	5(1.3)
Total	416 (100)		395 (100)

For RQ2, participants who took both SCAT3 and SCAT5 were eliminated from the sample to create two distinctive, independent samples. This was accomplished by matching participants' gender, birthdate, and sport. If all three were identical on both lists, those data were deleted from the sample. This decision was made because there are no statistical methods to determine statistical differences of proportions for dependent groups. Therefore, independent

samples were created for SCAT3 ($N = 224$) and SCAT5 ($N = 203$). Gender distributions for these samples were as follows: SCAT3 had 33.9% ($N = 76$) female and 66.1% ($N = 148$) male while the SCAT5 had 37.9% ($N = 77$) female and 62.1% ($N = 126$) male. Sports participation for SCAT3 and SCAT5 are presented in Table 7 with the most participants engaged in football for both assessments. Within the SCAT3 sample, baseball, basketball, and soccer were the next three highest participation rates, while the SCAT5 indicated football was followed by track & field, baseball, and tennis. The ages of participants for the SCAT3 ranged from 20 to 26 ($M = 21.15, SD = 1.621$) while the age range for SCAT5 participants was 19 to 24 ($M = 19.24, SD = 1.252$).

Table 7

Sport Demographics for SCAT3 and SCAT5 Independent Sample

SCAT3		SCAT5	
Sport	Count (%)	Sport	Count (%)
Football	66(29.5)	Football	46(22.7)
Baseball	38(17.0)	Track & Field	32(15.8)
Basketball	29(12.9)	Baseball	27(13.3)
Soccer	28(12.5)	Tennis	26(12.8)
Track & Field	21(9.4)	Soccer	21(10.3)
Softball	18(8.0)	Basketball	15(7.4)
Lacrosse	11(4.9)	Other	10(4.9)
Other	6(2.7)	Softball	9(4.4)
Volleyball	6(2.7)	Volleyball	9(4.4)
Cross Country	1(.4)	Cross Country	4(2.0)
		Lacrosse	4(2.0)
Total	224 (100)		203 (100)

Exploratory Factor Analysis for SCAT3

An EFA was conducted, using IBM SPSS version 24, for the Standardized Assessment of Concussion (SAC) portion of the SCAT3 that measures *orientation*, *immediate memory*,

concentration, and *delayed recall* for a sample of 416 NCAA Division III collegiate athletes. Statistical assumptions for the use of EFA were assessed prior to the analysis including multicollinearity, overall Kaiser-Meyer-Olkin (KMO), and Bartlett's test of sphericity. Once these assumptions determined the appropriateness for factorization of an initial EFA, principle component analysis extracted the factor structure with a single varimax rotation. The solution sought to extract four components based on the original four sections of the SAC portion (*orientation, immediate memory, concentration,* and *delayed recall*) of the SCAT3. Following the analysis of this factorization, an oblique rotation was applied to determine if the factor loadings changed among the four components.

Multicollinearity was the first assumption assessed in the EFA process. This was assessed by using the determinant which was reported as .04. If the determinant is above .00001, factorization can occur (Laerd Statistics, 2015b). Therefore, multicollinearity does not occur for this data set. This means that the variables do not have high correlations amongst themselves thus eliminating the potential for multiple variables measuring exactly the same thing (Mertler & Vannatta, 2010). This was additionally shown through the inspection of the correlation matrix. Following the inspection, it was determined that at least one correlation coefficient was greater than 0.3 for all variables (see Appendix E) and none were highly correlated, thus the assumption was met.

The second assumption states that Bartlett's test of sphericity was statistically significant. The SCAT3 EFA showed Bartlett's test of sphericity ($\chi^2(435) = 1304.73, p < .0000$) to be statistically significant. The null hypothesis was that the correlation matrix and identity matrix are identical. Having identical matrices can be a problem since it practically means that there were not a sufficient number of correlations (and therefore structure) to the underlying latent

variables. Given that Bartlett's test was statistically significant, the null hypothesis was rejected, implying that the two matrices were indeed different. This indicated that the data factorization for structure or dimension was warranted.

The last assumption states that a moderate overall KMO measure should be .60 or above. This statistic examined sampling accuracy, specifically sample size per variable and the proportion of variance in the variables that might have common variance. This EFA reported a proportion of 0.57 which is "miserable" by some standards (Dziuban & Shirkey, 1974, p. 359) and is a violation of the assumption of sampling adequacy. Nevertheless, and consistent with other research, the EFA was run given that: (1) the other two assumptions were met, and (2) the sample size (416) was appropriate for factoring 30 variables at a ratio of close to 13:1 subjects to variables (Osborne, 2014).

EFA revealed that 13 factors had eigenvalues greater than one. Based on the four sections of the SCAT3 assessment (*orientation, immediate memory, concentration*, and *delayed recall*) the EFA was conducted using four factors which accounted for 8.58%, 6.27%, 5.89%, and 5.52% of the total variance, respectively. These values are presented in Table 8. A scree plot is used to determine the number of components used to conduct the EFA and gives a graphical depiction that should bend and level off (Mertler & Vannatta, 2010). Figure 1 depicts the scree plot for these data, which did not accurately depict the four factors because there was no true bend in the line and leveling off did not occur. The ambiguity of the line bend made it difficult to determine if four factors were the best choice for the SCAT3 EFA. Additionally, since no leveling of the line occurs, it was difficult to determine if the remaining factors were equal in size (Mertler & Vannatta, 2010). The implications associated with these issues are discussed further in the structure section of Chapter 5.

The four-factor solution explained 26.2% of the total variance, therefore an oblique rotation was applied to determine if changes to factor loading occurred. After the oblique rotation was applied, the variables did not load in the way that the assessment tool intended. This means that not all of the *orientation*, *immediate memory*, *concentration*, and *delayed recall* questions loaded into separate factors. In many of the factors, there were multiple variables from 2 or more assessment categories. The factor loadings of the rotated solution are presented in Table 9. All factor loadings less than 0.2 were suppressed when the EFA was conducted, which accounts for the blanks in Table 9.

Table 8

Eigenvalues for SCAT3 EFA using Principle Component Analysis

Factor	Initial Eigenvalues			Extraction Loadings			Rotation
	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total
1	2.575	8.584	8.584	2.575	8.584	8.584	2.331
2	1.882	6.274	14.857	1.882	6.274	14.857	1.917
3	1.767	5.891	20.748	1.767	5.891	20.748	1.886
4	1.656	5.521	26.269	1.656	5.521	26.269	1.747

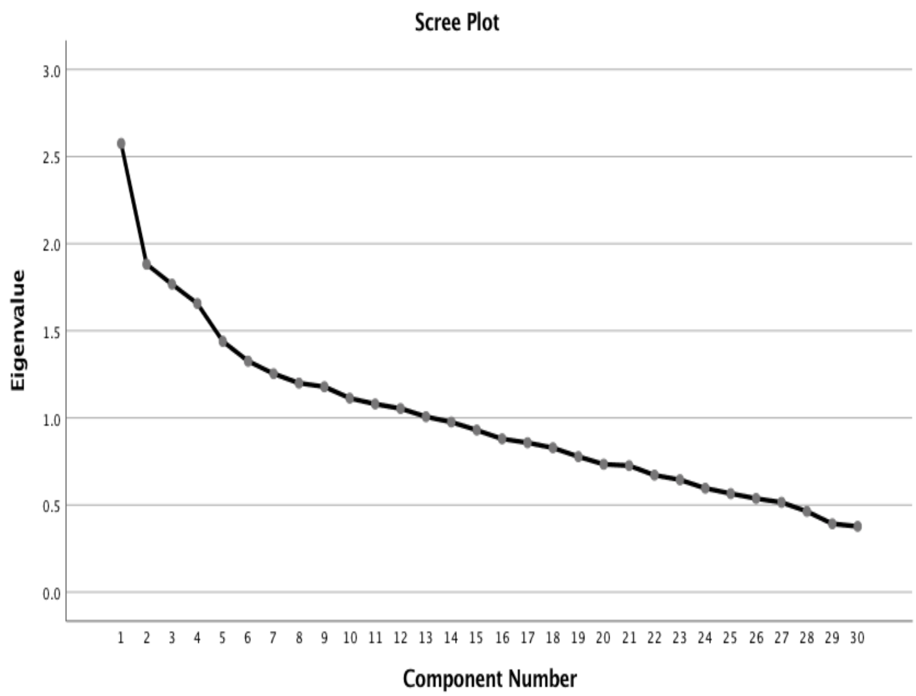

Figure 1. SCAT3 scree plot from principle component analysis and oblique rotation.

Table 9 *Structure Matrix Factor Loading for SCAT3*

Item ($N = 30$)	Factors			
	F1	F2	F3	F4
C1	0.680			
IM3_5	0.645			
IM3_2	0.604			
IM3_4	0.568			
IM2_2	0.499			
IM2_5	0.467			
IM2_4	0.415			
O_Date				
IM3_3				
DR1		0.628		
DR5		0.617		
DR2		0.587		
DR4		0.586		
DR3		0.424		
O_Month		0.264		
O_Time		0.205		
O_Year				
IM2_3			0.631	
IM1_2			0.628	
IM1_3			0.591	
IM1_4			0.562	
O_Day			0.239	
IM1_5			0.225	
C3				0.790
C4				0.653
C2				0.585
C_Months				0.353
IM3_1				
IM1_1				
IM2_1				

Note Extraction Method: Principal Component Analysis Rotation Method: Oblimin with Kaiser Normalization

Reliabilities for SCAT3

Cronbach's alpha was utilized to examine the internal consistency of the SAC portion of the SCAT3. The internal consistency values reported in this chapter are based off the categories found in Table 10 (Manerikar & Manerikar, 2015). The following sections explore the

reliabilities and factor name assignments. Additionally, this section is broken into two categories because the variables did not load on the exact factors as outlined in the SCAT3 assessment. Therefore, the first section reports the reliabilities for the variables that loaded on the factors during the EFA; the second section reports idealized reliabilities. Idealized reliabilities are the result of variables if they are divided into their assigned sections (i.e. *orientation, immediate memory, concentration,* and *delayed recall*) along with a total internal consistency measure for the entire SAC assessment.

Table 10

Cronbach's Alpha Classifications

Cronbach's Alpha	Internal Consistency
$\alpha \geq .9$	Excellent (High-Stakes testing)
$0.7 \leq \alpha < .9$	Good (Low-Stakes testing)
$0.6 \leq \alpha < .7$	Acceptable
$0.5 \leq \alpha < .6$	Poor
$\alpha < .5$	Unacceptable

Adapted from Manerikar, V., & Manerikar, S. (2015). Cronbach ' s Alpha. *Aweshkar Research Journal*, *19*(1), 117–119.

Factor naming and structure. Factor labels were determined by observing the similarities of variables within the factor loading found in Table 9. This table shows that the four assigned sections of the SCAT3 were not all represented. It was determined that *immediate memory* loaded onto two separate factors and therefore, two factors have been labeled as such. The implications of this are further discussed in the structure section of Chapter 5.

Factor 1 – Immediate Memory 1. Internal consistency for immediate memory 1 was poor ($\alpha = 0.589$) and it does not increase if any of the items are removed, as evidenced in Table 11.

Table 11

Reliability Scale for SCAT 3 Factors

Variable Name	Internal Consistency	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	α, if Item Deleted
Immediate Memory 1	0.589				
C1		5.88	0.219	0.428	0.543
IM3_5		5.88	0.199	0.417	0.520
IM3_2		5.88	0.210	0.351	0.544
IM3_4		5.88	0.208	0.311	0.552
IM2_2		5.90	0.187	0.273	0.568
IM2_5		5.91	0.166	0.284	0.584
IM2_4		5.89	0.191	0.304	0.552
Delayed Recall	0.512				
DR1		5.19	0.998	0.371	0.408
DR5		5.06	1.175	0.326	0.442
DR2		5.14	1.099	0.295	0.451
DR4		5.11	1.097	0.345	0.427
DR3		5.19	1.137	0.197	0.505
O_Month		4.94	1.488	0.111	0.519
O_Time		4.99	1.412	0.087	0.523
Immediate Memory 2	0.367				
IM2_3		4.69	0.380	0.266	0.313
IM1_2		4.70	0.345	0.280	0.275
IM1_3		4.71	0.336	0.246	0.283
IM1_4		4.75	0.295	0.222	0.286
O_Day		4.70	0.390	0.075	0.374
IM1_5		4.82	0.262	0.105	0.441
Concentration	0.530				
C3		2.06	0.543	0.509	0.250
C4		2.36	0.639	0.370	0.410
C2		1.77	0.893	0.316	0.480
C_Months		1.87	0.892	0.132	0.599

Factor 2 – Delayed Recall. The internal consistency of factor 2 is poor α = 0.512. If two variables, O_Month and O_Time, were removed, the internal consistency increased but not enough to change the category strength to acceptable.

Factor 3 – Immediate Memory 2. This factor was named immediate memory 2 because there were more loadings of immediate memory than orientation. Internal consistency was unacceptable α = 0.367. It should be noted that if the variable O_Day was removed, then the internal consistency would increase but not enough to change the "poor" status.

Factor 4 – Concentration. All but one of the concentration variables loaded onto factor 4. Internal consistency was poor α = 0.530 as seen in Table 11. It should be noted that if the variable C_Months was removed, the internal consistency increases, resulting in the factor being acceptable.

Idealized Reliabilities. As mentioned above, the variables from each of the four assessment sections (*orientation, immediate memory, concentration,* and *delayed recall*) did not load as expected onto a single corresponding factor. Therefore, the reliabilities presented here include the reliabilities if all variables had loaded onto the expected corresponding factor. This choice was made to determine if the reliabilities of the actual assessment sections are appropriate, regardless of factor loading.

Orientation. As seen in Table 12, the internal consistency for the *orientation* subsection was negative, α = -0.084. A negative internal reliability can mean two things, either the researcher's coding is incorrect or the participants scores are sporadic. If the researcher does not code the responses properly, for instance, instead of a "1" it should be a "5," then this phenomenon can occur. This is unlikely for this research because the values were "0" and "1." Additionally, it is possible that participants' scores show high variability, which means that the

items do not group together because they do not belong together. This is the most likely reason because the *orientation* variables loaded on all four factors.

Table 12

Reliability Scale for SCAT3 Idealized Factors

Variable Name	Internal Consistency	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	α, if Item Deleted
Orientation	-0.084				
O_Day		3.91	0.086	-0.070	0.009
O_Date		3.88	0.102	-0.008	-.100
O_Month		3.87	0.122	-0.027	-.078
O_Year		3.92	0.077	-0.035	-.068
O_Time		3.87	0.122	-0.027	-.078
Immediate Memory	0.485				
IM1_1		13.56	0.743	0.023	0.490
IM1_2		13.58	0.663	0.230	0.453
IM1_3		13.59	0.647	0.226	0.452
IM1_4		13.63	0.610	0.182	0.471
IM1_5		13.70	0.527	0.192	0.494
IM2_1		13.56	0.753	-0.025	0.491
IM2_2		13.58	0.678	0.189	0.463
IM2_3		13.57	0.694	0.261	0.456
IM2_4		13.58	0.659	0.310	0.438
IM2_5		13.60	0.608	0.345	0.416
IM3_1		13.56	0.748	0.005	0.491
IM3_2		13.56	0.719	0.153	0.474
IM3_3		13.56	0.748	0.005	0.491
IM3_4		13.57	0.714	0.153	0.473
IM3_5		13.57	0.699	0.233	0.460
Concentration	0.503				
C1		2.69	1.141	0.077	0.530
C2		2.77	0.910	0.311	0.436
C3		3.06	0.554	0.512	0.231
C4		3.35	0.652	0.371	0.374
C_Months		2.87	0.905	0.136	0.537
Delayed Recall	0.537				
DR1		3.25	0.901	0.358	0.444
DR2		3.20	0.989	0.294	0.486
DR3		3.25	1.007	0.217	0.537
DR4		3.17	0.997	0.332	0.464
DR5		3.12	1.061	0.329	0.472

Immediate Memory. Of the 15 *immediate memory* variables six loaded onto factor 1. As evidenced in Table 12, the internal consistency of the 15 variables was unacceptable (α = 0.485). Note that if five of the variables were removed (IM1_1, IM1_5, IM2_1, IM3_1, and IM3_3), internal consistency increases, but does not change the category strength.

Concentration. The internal consistency for *concentration*, as seen in Table 12, is poor (α = 0.503). If the two variables of C1 and C_Months were removed, internal consistency improves but not in category strength.

Delayed Recall. The internal consistency was poor (α = 0.537).

Total. The internal consistency for all variables in the SAC portion of SCAT3 was poor (α = 0.525) as is evidenced in Table 13. It should be noted that if seven items were removed, the internal consistency increases but remains poor.

Table 13

Reliability Scale for SCAT3 All SAC Items

Internal Consistency ($\alpha = 0.525$)				
Item ($N = 30$)	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	α, if Item Deleted
O_Day	26.14	4.013	0.071	0.524
O_Date	26.12	4.070	0.048	0.525
O_Month	26.10	4.079	0.141	0.522
O_Year	26.15	4.016	0.060	0.526
O_Time	26.10	4.137	-0.065	0.529
IM1_1	26.10	4.110	0.018	0.526
IM1_2	26.12	4.036	0.089	0.522
IM1_3	26.13	4.004	0.107	0.520
IM1_4	26.17	3.948	0.102	0.522
IM1_5	26.24	3.818	0.128	0.520
IM2_1	26.10	4.126	-0.022	0.527
IM2_2	26.12	4.005	0.145	0.518
IM2_3	26.11	4.047	0.149	0.519
IM2_4	26.12	3.977	0.216	0.513
IM2_5	26.13	3.924	0.204	0.511
IM3_1	26.10	4.118	0.003	0.527
IM3_2	26.10	4.050	0.164	0.519
IM3_3	26.10	4.118	0.003	0.527
IM3_4	26.11	4.056	0.126	0.521
IM3_5	26.11	4.037	0.171	0.518
C1	26.10	4.084	0.124	0.522
C2	26.18	3.854	0.172	0.512
C3	26.47	3.411	0.268	0.491
C4	26.76	3.367	0.309	0.480
C_Months	26.28	3.753	0.145	0.518
DR1	26.35	3.500	0.266	0.492
DR2	26.30	3.742	0.140	0.519
DR3	26.35	3.751	0.108	0.528
DR4	26.26	3.573	0.287	0.489
DR5	26.21	3.769	0.197	0.507

Exploratory Factor Analysis for SCAT5

A similar EFA was conducted for the SAC portion of the SCAT5, utilizing the same criteria outline for the SCAT3. An EFA was conducted for the *orientation, immediate memory,*

concentration, and *delayed recall* subsections of the SCAT5 for a sample of 395 NCAA Division III collegiate athletes.

Multicollinearity was the first assumption assessed in the EFA process. This was assessed by using the determinant which was reported as .000003. If the determinant is above .00001, factorization can occur. Therefore, multicollinearity does occur for this data set and the assumption was not met. Multicollinearity within a dataset can be a result of high correlations existing between the variables and there is the potential that variables exist that measure exactly the same thing (Mertler & Vannatta, 2010). Upon inspection of the correlation matrix (see Appendix F) no correlations were above 0.85. However, numerous correlations were observed below 0.15, meaning there were correlations among the variables that were not sufficient to show a lack of multicollinearity. Additionally, it was determined that at least one correlation coefficient was greater than 0.3 for all variables (see Appendix F) and none were highly correlated. Therefore, there was conflicting data on if the multicollinearity assumption was met.

The second assumption states that Bartlett's test of sphericity is statistically significant. The SCAT5 EFA showed Bartlett's test of sphericity ($\chi^2(1225) = 4767.42, p < .0000$) to be statistically significant. The null hypothesis is that the correlation matrix and identity matrix are identical. Having identical matrices is a problem since it practically means that there are not a sufficient number of correlations and therefore structure to the underlying latent variables. Given that Bartlett's test was statistically significant, the null hypothesis was rejected, implying that the two matrices are indeed different. This indicated that the data can be factorized for structure or dimension.

The last assumption states that a moderate overall KMO measure should be .60 or above. This EFA reported a 0.69 which is near "middling" by some standards (Dziuban & Shirkey,

1974) and therefore the assumption is met. Even though the determinant was low, an EFA was still conducted based on Bartlett's test of sphericity being significant and the higher KMO value which implies that structure does exist.

EFA revealed that 17 factors had eigenvalues greater than one. Based on the four sections of the SCAT5 assessment (*orientation, immediate memory, concentration,* and *delayed recall*) the EFA was conducted using four factors which accounted for 9.78%, 6.65%, 5.89%, and 5.43% of the total variance, respectively. These values can be viewed in Table 14. A scree plot is used to determine the number of components used to conduct the EFA and gives a graphical depiction that should bend and level off (Mertler & Vannatta, 2010). Figure 2 depicts the scree plot, which did not accurately depict the four factors because there was no true bend in the line and no leveling off occurred. This made it difficult to determine if four factors were the best choice for the SCAT5 assessment EFA because no true bend existed. Additionally, since no leveling of the line occurred it was difficult to determine if the remaining factors were equal in size (Mertler & Vannatta, 2010). These issues are discussed further in the structure section of Chapter 5.

The four-factor solution explained 26% of the total variance, therefore an oblique rotation was applied to determine if changes to factor loading occurred. The variables did not load in the way that the assessment tool intended. This means that not all the *orientation, immediate memory, concentration,* and *delayed recall* questions loaded into separate factors. In many of the factors, there were multiple variables from two or more assessment categories. The factor loadings of the rotated solution can be found in Table 15. All factor loadings less than 0.2 were suppressed when the EFA was conducted, which accounts for all blanks in Table 15.

Table 14

Eigenvalues for SCAT5 EFA using Principle Component Analysis

Factor	Initial Eigenvalues			Extraction Loadings			Rotation
	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total
1	4.895	9.789	9.789	4.895	9.789	9.789	3.306
2	3.327	6.654	16.444	3.327	6.654	16.444	2.189
3	2.716	5.431	21.875	2.716	5.431	21.875	2.041
4	2.055	4.110	25.985	2.055	4.110	25.985	2.038

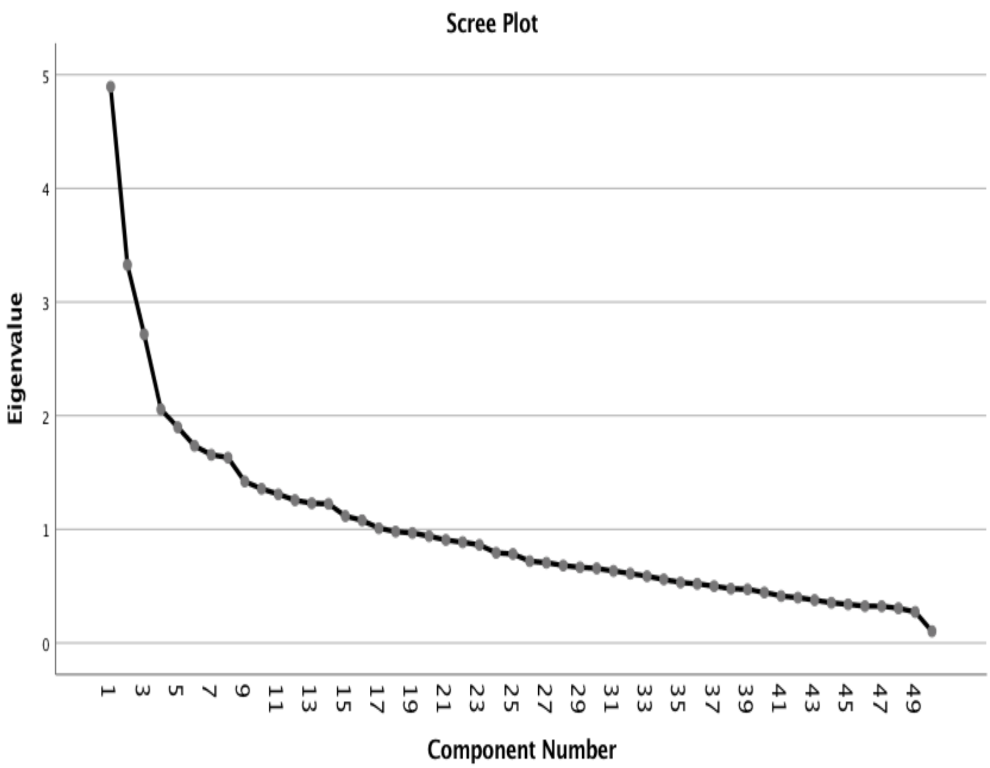

Figure 2. SCAT5 scree plot from principle component analysis and oblique rotation.

Table 15

Factor Loading using Structure Matrix for SCAT5

Item ($N = 30$)	Factors			
	F1	F2	F3	F4
IM2_2	0.552			
DR4	0.513			
IM3_4	0.481			
IM3_3	0.474			
IM2_4	0.467			
IM3_5	0.464			
DR5	0.432			
IM1_2	0.432			
IM1_1	0.429			
IM2_1	0.414			
IM1_3	0.401			
IM2_3	0.394			
C4	0.380			
IM3_2	0.375			
IM2_5	0.352			
DR3	0.323			
C3	0.296			
DR2	0.286			
IM3_10		0.679		
IM1_10		0.610		
IM2_10		0.607		
IM2_9		0.566		
DR10		0.514		
IM3_9		0.451		
IM2_8		0.427		
IM1_9		0.425		
IM1_8		0.353		
DR9		0.349		
C_Months		0.251		

Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization.
Factor loadings < 0.2 were suppressed.

Table 15 (continued)

Factor Loading using Structure Matrix for SCAT5

Item ($N = 30$)	Factors			
	F1	F2	F3	F4
O_Month			-0.902	
O_Year			-0.849	
O_Day			-0.714	
C1			-0.641	
O_Time			-0.593	
O_Date			-0.376	
IM3_1			-0.373	
C2			-0.262	
DR7				-0.564
IM3_7				-0.562
DR6				-0.499
IM3_6				-0.478
IM2_6				-0.460
DR8				-0.438
IM1_4				-0.427
IM3_8				-0.413
IM1_6				-0.383
IM2_7				-0.336
IM1_7				-0.311
DR1				-0.294
IM1_5				

Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization.
Factor loadings < 0.2 were suppressed.

Reliabilities for SCAT5

Cronbach's alpha was utilized to examine the internal consistency of the SAC portion of the SCAT5. The following sections explore the reliabilities and factor name assignments. Additionally, this section is broken into two categories because the variables did not load on the exact factors as outlined in the SCAT5 assessment. Therefore, the first section reports the reliabilities for the variables that loaded on the factors during the EFA and the second section reports the idealized reliabilities. The idealized reliabilities are the result of the variables if they

were divided into their assigned sections (i.e. *orientation, immediate memory, concentration,* and *delayed recall*) along with a total internal consistency measure for the entire SAC assessment.

Factor naming and structure. Factor labels were determined by observing the similarities of variables within the factor loading in Table 15. Table 15 demonstrates the four assigned sections of the SCAT3 were not all represented. It was determined that *immediate memory* loaded onto two separate factors and therefore, two factors were labeled as such. The implications for this are further discussed in the structure section of Chapter 5.

Factor 1 – Immediate Memory 1. Of the 30 *immediate memory* variables, 12 loaded onto factor 1. The variables that loaded were the first five words in each list. As indicated in Table 16, the internal consistency was good ($\alpha = 0.722$).

Table 16

Reliability Scale for SCAT 5 Factors

Variable Name	Internal Consistency	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	α, if Item Deleted
Immediate Memory 1	0.722				
IM2_2		12.78	8.672	0.371	0.705
DR4		12.87	8.463	0.385	0.702
IM3_4		12.82	8.639	0.348	0.706
IM3_3		12.80	8.644	0.369	0.705
IM2_4		12.92	8.441	0.364	0.704
IM3_5		12.77	8.765	0.341	0.707
DR5		12.89	8.610	0.313	0.709
IM1_2		12.79	8.818	0.300	0.711
IM1_1		12.68	9.067	0.353	0.710
IM2_1		12.70	9.028	0.317	0.711
IM1_3		13.05	8.488	0.311	0.710
IM2_3		12.86	8.746	0.277	0.713
C4		13.20	8.514	0.304	0.711
IM3_2		12.74	8.990	0.270	0.714
IM2_5		12.91	8.741	0.253	0.716
DR3		12.91	8.806	0.230	0.718
C3		12.93	8.810	0.219	0.719
DR2		12.84	8.952	0.202	0.720
Immediate Memory 2	0.693				
IM3_10		6.10	5.274	0.526	0.646
IM1_10		6.38	5.277	0.388	0.664
IM2_10		6.21	5.300	0.420	0.659
IM2_9		6.19	5.286	0.440	0.656
DR10		6.27	5.359	0.368	0.668
IM3_9		6.14	5.504	0.363	0.669
IM2_8		6.34	5.504	0.286	0.682
IM1_9		6.33	5.597	0.246	0.689
IM1_8		6.55	5.628	0.252	0.687
DR9		6.35	5.488	0.292	0.681
C_Months		6.07	5.937	0.183	0.694
Orientation	0.673				
O_Month		4.84	0.280	0.747	0.585
O_Year		4.85	0.278	0.642	0.592
O_Day		4.86	0.261	0.523	0.596
C1		4.85	0.298	0.435	0.637
O_Time		4.87	0.250	0.389	0.639
O_Date		4.92	0.214	0.268	0.772

Table 16 (continued)

Reliability Scale for SCAT 5 Factors

Variable Name	Internal Consistency	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	α, if Item Deleted
Delayed Recall	0.649				
DR7		5.92	5.527	0.384	0.612
IM3_7		5.80	5.540	0.422	0.606
DR6		5.97	5.548	0.369	0.614
IM3_6		5.90	5.546	0.380	0.612
IM2_6		6.03	5.689	0.305	0.626
DR8		5.97	5.720	0.292	0.629
IM1_4		6.03	5.867	0.227	0.641
IM3_8		5.82	5.864	0.258	0.635
IM1_6		6.30	6.079	0.218	0.640
IM2_7		5.96	5.919	0.205	0.645
IM1_7		6.11	5.922	0.214	0.643
DR1		5.66	6.148	0.207	0.642

Factor 2 – Immediate Memory 2. All words towards the end of the *immediate memory* list loaded on factor 2. Only one *concentration* variable loaded on this factor and the remainder were spread out among the other factors. As evidenced in Table 16, the internal consistency for *immediate memory 2* was acceptable ($\alpha = 0.693$). It is important to note that if the C_Months variable was removed the internal consistency would increase slightly but not enough to change the category strength.

Factor 3 – Orientation. All five of the *orientation* variables loaded onto factor 3. Internal consistency was acceptable ($\alpha = 0.673$) as indicated in Table 16. It is important to note that if the date question was removed, the internal consistency would increase to good ($\alpha = 0.772$) because eliminating some variables may help improve the internal consistency.

Factor 4 – Delayed Recall. Only four of the 10 *delayed recall* variables loaded on factor 4. The others were dispersed among the first two factors with four variables loading on the first factor and two variables loading on the second factor. The other factors that loaded in this area were *immediate memory* variables in the middle of the word list. The internal consistency presented in Table 16 and was acceptable ($\alpha = 0.649$).

Idealized Reliabilities. As mentioned above, the variables from each of the four assessment sections (*orientation, immediate memory, concentration,* and *delayed recall*) did not load as expected onto a single corresponding factor. Therefore, the reliabilities presented here include the reliabilities if all variables had loaded onto the expected corresponding factor. This choice was made to determine if the reliabilities of the actual assessment sections are appropriate, regardless of factor loading.

Orientation. As indicated in Table 17, the internal consistency is acceptable for the *orientation* subsection ($\alpha = 0.637$). It should be noted that if the O_Day variable within the *orientation* section is removed, the internal consistency would increase to good ($\alpha = 0.752$).

Table 17

Reliability Scale for SCAT5 Idealized Factors

Variable Name	Internal Consistency	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	α, if Item Deleted
Orientation	0.637				
O_Day		3.93	0.165	0.267	0.752
O_Date		3.87	0.213	0.504	0.541
O_Month		3.85	0.232	0.700	0.536
O_Year		3.88	0.202	0.377	0.591
O_Time		3.86	0.230	0.603	0.544
Immediate Memory	0.617				
IM1_1		18.94	13.661	0.194	0.610
IM1_2		19.05	13.617	0.108	0.615
IM1_3		19.31	13.271	0.151	0.612
IM1_4		19.41	13.334	0.131	0.614
IM1_5		19.46	13.726	0.025	0.626
IM1_6		19.68	13.639	0.089	0.617
IM1_7		19.49	13.469	0.099	0.618
IM1_8		19.54	13.503	0.096	0.618
IM1_9		19.31	13.663	0.041	0.624
IM1_10		19.37	13.360	0.123	0.615
IM2_1		18.96	13.519	0.229	0.607
IM2_2		19.05	13.381	0.196	0.608
IM2_3		19.12	13.417	0.146	0.612
IM2_4		19.19	13.148	0.209	0.606
IM2_5		19.17	12.982	0.264	0.600
IM2_6		19.41	12.867	0.264	0.599
IM2_7		19.34	13.249	0.155	0.612
IM2_8		19.32	12.874	0.263	0.599
IM2_9		19.17	13.241	0.184	0.608
IM2_10		19.20	13.408	0.128	0.614
IM3_1		18.92	13.755	0.183	0.612
IM3_2		19.00	13.536	0.172	0.610
IM3_3		19.06	13.362	0.195	0.608
IM3_4		19.09	13.185	0.241	0.603
IM3_5		19.04	13.217	0.269	0.602
IM3_6		19.28	12.715	0.316	0.593

Table 17 (continued)

Reliability Scale for SCAT5 Idealized Factors

Variable Name	Internal Consistency	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	α, if Item Deleted
Immediate Memory	0.617				
IM3_7		19.18	12.906	0.285	0.597
IM3_8		19.20	12.912	0.277	0.598
IM3_9		19.12	13.219	0.211	0.606
IM3_10		19.09	13.257	0.216	0.605
Concentration	0.453				
C1		2.85	1.040	0.158	0.461
C2		2.92	0.864	0.283	0.383
C3		3.15	0.616	0.340	0.310
C4		3.42	0.604	0.305	0.349
C_Months		3.01	0.812	0.183	0.438
Delayed Recall	0.491				
DR1		5.74	3.267	0.319	0.436
DR2		5.81	3.315	0.225	0.458
DR3		5.87	3.326	0.181	0.471
DR4		5.84	3.361	0.176	0.473
DR5		5.86	3.337	0.181	0.471
DR6		6.06	3.195	0.217	0.460
DR7		6.01	3.228	0.202	0.465
DR8		6.05	3.129	0.257	0.446
DR9		6.04	3.349	0.129	0.490
DR10		5.95	3.297	0.171	0.475

Immediate Memory. The internal consistency evidenced in Table 17 was acceptable ($\alpha = 0.617$). It should be noted that if *immediate memory* variables 1_5 and 1_9 were removed, the internal consistency would increase but would not change in relation to category strength.

Concentration. The internal consistency evidenced in Table 17 is unacceptable for the concentration section of the SCAT5 ($\alpha = 0.453$). If the first *concentration* variable of C1 was removed, the internal consistency would increase but not enough to change the strength category.

Delayed Recall. The internal consistency evidenced in Table 17 was unacceptable (α = 0.491).

Total. The internal consistency evidenced in Table 18 was good (α = 0.764) for all variables in the SAC portion of SCAT5. If three items (IM1_5, IM1_8, IM1_9) were removed, the internal consistency increases but remains as good internal consistency.

Table 18

Reliability Scale for SCAT5 All SAC Items

Internal Consistency ($\alpha = 0.764$)				
Item ($N = 50$)	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	α, if Item Deleted
O_Day	34.22	33.797	0.158	0.762
O_Date	34.16	33.982	0.226	0.762
O_Month	34.15	34.034	0.328	0.762
O_Year	34.17	34.007	0.154	0.762
O_Time	34.15	34.046	0.272	0.762
IM1_1	34.20	33.683	0.228	0.760
IM1_2	34.31	33.641	0.134	0.763
IM1_3	34.57	33.078	0.184	0.762
IM1_4	34.67	33.110	0.176	0.762
IM1_5	34.72	33.846	0.049	0.767
IM1_6	34.94	33.634	0.126	0.763
IM1_7	34.75	33.471	0.118	0.764
IM1_8	34.80	33.607	0.099	0.765
IM1_9	34.57	33.692	0.076	0.766
IM1_10	34.63	33.321	0.139	0.764
IM2_1	34.22	33.534	0.238	0.760
IM2_2	34.31	33.290	0.217	0.760
IM2_3	34.38	33.369	0.165	0.762
IM2_4	34.45	32.750	0.266	0.758
IM2_5	34.44	32.790	0.263	0.758
IM2_6	34.67	32.612	0.265	0.758
IM2_7	34.60	33.246	0.153	0.763
IM2_8	34.58	32.599	0.269	0.758
IM2_9	34.44	33.043	0.213	0.760
IM2_10	34.46	33.259	0.167	0.762
IM3_1	34.18	33.864	0.205	0.761
IM3_2	34.26	33.494	0.202	0.761
IM3_3	34.32	33.330	0.200	0.761
IM3_4	34.35	32.968	0.266	0.758
IM3_5	34.30	33.102	0.272	0.758
IM3_6	34.54	32.203	0.346	0.754
IM3_7	34.44	32.364	0.343	0.755
IM3_8	34.46	32.645	0.283	0.757

Table 18 (continued)

Reliability Scale for SCAT5 All SAC Items

Internal Consistency ($\alpha = 0.764$)				
Item ($N = 50$)	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	α, if Item Deleted
IM3_9	34.38	32.907	0.260	0.758
IM3_10	34.35	33.039	0.251	0.759
C1	34.15	33.955	0.350	0.761
C2	34.22	33.578	0.228	0.760
C3	34.46	32.985	0.219	0.760
C4	34.72	32.394	0.309	0.756
C_Months	34.31	33.272	0.218	0.760
DR1	34.30	32.953	0.301	0.757
DR2	34.36	32.973	0.255	0.758
DR3	34.43	32.977	0.228	0.760
DR4	34.39	32.717	0.293	0.757
DR5	34.42	32.660	0.296	0.757
DR6	34.62	32.339	0.314	0.756
DR7	34.56	32.485	0.291	0.757
DR8	34.61	32.279	0.325	0.755
DR9	34.60	33.098	0.179	0.762
DR10	34.51	32.575	0.283	0.757

To summarize the findings of RQ1, the SCAT3 and SCAT5 factor structure loaded differently than what the original SAC researchers intended. This means that the intended factors of *orientation*, *immediate memory*, *concentration*, and *delayed recall* did not load the variables corresponding to their intended subsection. This indicates that the structure of the assessment needs further scrutiny to determine if there are other latent variables that are being assessed. Additionally, the reliabilities of the subsections and overall assessment are substantially increased for the SCAT5, compared to SCAT3. This means that the increase in variables does appear to have strengthened the internal consistency of the assessment. The next section of this chapter reports the findings pertaining to RQ2.

Floor and Ceiling Proportions

The SCAT3 ($N = 224$) showed that *immediate memory* scores ranged from 9 to 15 ($M = 14.53, SD = .893$) and no participants ($x = 0$) received a floor effect on the *immediate memory* section. Within the *delayed recall* portion, the range was from 0 to 5 ($M = 4.04, SD = 1.143$) with 2.3% of the participants scoring a zero ($N = 5$) or floor effect on this portion of the assessment. In contrast, 68.8% ($N = 154$) of participants received a ceiling effect ($x = 15$) on the *immediate memory* portion and 43.8% ($N = 98$) did on the delayed memory portion ($x = 5$). This means that there was a large section of the sample that received a maximal score or ceiling effect on these sections of the SCAT3.

The SCAT5 ($N = 203$) showed that *immediate memory* scores ranged from 12 to 29 ($M = 19.85, SD = 3.562$) with no participants ($x = 0$) receiving a floor effect on the *immediate memory* section. Within the *delayed recall* portion, the range was from 0 to 10 ($M = 6.62, SD = 1.945$) with 0.5% of the participants scoring a zero (N=1) or floor effect on this portion of the assessment. Similar to the floor effect, no participants exhibited a ceiling effect ($x = 30$) on the *immediate memory* portion. A ceiling effect was present 3.9% ($N = 8$) for the *delayed memory* portion ($x = 10$). This means that very few participants, if any, exhibited a floor or ceiling effect on the SCAT5.

A Chi-square analysis was run to determine the statistically significant differences for floor and ceiling frequencies across the SCAT3 and SCAT5 *immediate memory* and *delayed recall* sections. Statistical significance was present for *immediate memory* ceiling ($\chi^2(1, 427) = 218.290, p < .0000$) and *delayed recall* ceiling ($\chi^2(1, 427) = 90.43, p < .0000$). No data could be computed for *immediate memory* floor because no participant received a zero on this portion of the assessment. The *delayed recall* floor was not significantly different

$(\chi^2(1, 427) = 2.33, p = .127)$. This means that there were differences in the participants that received a ceiling effect in both subsections of the test, suggesting that the SCAT5 had a smaller percentage of maximal scores.

Conclusion

The EFA analysis of the SCAT3 and SCAT5 showed conflicting evidence of the appropriate factor loading based on the four portions of the assessment: *orientation*, *immediate memory*, *concentration*, and *delayed recall*. This indicates that the variables provided did not load onto the expected factors and therefore, the test may not be testing what it intends. There is evidence to suggest that the reliability of the assessments is questionable yet there is some improvement to the reliability of the SCAT5 over the SCAT3 because of the new 10-word list format. Additionally, the SCAT5's overall internal consistency increased significantly over the SCAT3. The ceiling effect present in the *immediate memory* and *delayed recall* portions of the test was significantly improved for the SCAT5, yet the floor effects between the two versions remained unchanged. This indicates that participants taking the SCAT5 will be less likely to earn a maximum score on these two subsections of the assessment. Therefore, the assessment seems to provide enough variables to appropriately measure ability in these areas.

Chapter 5

Conclusion

Assessment tools used for the detection of sports-related concussions (SRCs) are essential to athletic trainers and other allied healthcare professionals. Many different assessment tools have been created over the last 20 years and continue to be revised. One of these assessment tools, the Sport Concussion Assessment Tool (SCAT), was recently revised in April of 2017 from the SCAT3 to the SCAT5. The main changes were to the *immediate memory* and *delayed recall* portions of the assessment where the 5-item word list was changed to an optional 10-item word list. With the publication of the SCAT5, this optional 10-item list was provided free of charge to the public. Assessment administrators are not required to utilize the 10-item list but the medical software utilized for the historical dataset only provides the 10-item word list when a SCAT is administered. To this author's knowledge, no published data on the structure of the SCAT5 assessment and its ceiling effects exists.

Subsequently, this study examined the differences in the factor structure and internal reliability between the SCAT3 and SCAT5. The 2017 revision of the Standardized Assessment of Concussion (SAC) portion of the assessment was specifically addressed. This was accomplished through an exploratory factor analysis (EFA) that utilized a principle component analysis with an oblique rotation. Additionally, floor and ceiling effects were analyzed using an independent sample and chi-square to determine if differences in the proportions exist between SCAT versions in the *immediate memory* and *delayed recall* subsections of the assessment.

This chapter explains the implications of this study, including insights into test administration issues and participation, why some EFA assumptions were not met, and why the subsections (*orientation, immediate memory, concentration,* and *delayed* recall) did not load as

expected on either version of the SCAT. The ceiling effects are also compared to other historical data. Limitations and future research ideas are also discussed.

Discussion of Findings

This section is partitioned into two: one is focused on the findings as they relate to the EFA on each of the SCAT3 and SCAT5 assessments, and the second is focused on the floor/ceiling effects with respect to the comparison across assessments. It is essential to note that this researcher found no published research utilizing an EFA or confirmatory factory analysis (CFA) on the SAC portion of the SCAT, regardless of assessment version. The dataset for this study was only for baseline testing and therefore only applies to the SCAT assessment tool in this pre-injury testing capacity.

Test administration. There are many variables specific to the test-administration procedures (i.e. time-of-day/season, assessor training, bias) that can create random variance across test-sessions within the dataset. Such randomness can add construct-irrelevant variance to the error terms in the composite scores of the assessment results. This section discusses issues in regard to test sessions, test proctoring, testing time of day and testing environment. Participants were tested annually at three different sessions: either fall sports screenings, all other sports screenings, and upon entrance into the sport, whether by transfer or participation. Therefore, random variances can occur because participants are tested at different times throughout the year. Other issues potentially affecting test outcomes include differences among individual test administrators, such as clarity of voice, or timing of word, question, or number presentation, or errors in reporting. Some test administrators are learning the tool for the first time while others have over a decade of experience. All administrators are given a tutorial by a highly experienced proctor prior to every testing session. The day and time of each screening varies annually and is

dictated by the athletics administration. This can affect both the energy levels and the cognitive abilities of participants. Additionally, on screening days, there were multiple stations operating throughout the gymnasium and the volume fluctuated. Therefore, the testing environment was not quiet and may have affected the cognitive ability of participants. The random variance resulting from these test administration issues likely contributed to the poor factor structures and poor to moderate reliabilities. Future research that better controls for test administration issues may find an improvement in the factor structures and reliabilities.

Participants. The total sample size for both EFAs was similar and gender was approximately equal with both versions. Sports participation was comparable between samples with participation in football representing the largest subset in SCAT results. One difference between the two samples was the number of track-and-field participants and tennis participants both significantly increased from the SCAT3 to the SCAT5. It seems as though this could have been the result of a policy change by the university which required all track-and-field and tennis athletes to engage in baseline concussion assessments. Prior to 2017, only select track-and-field participants (pole value, steeple chase, and hurdles) were required to be assessed. Participants were not included in the SCAT5 sample if administrators did not mark the assessment as "baseline" on the medical software when the assessment was administered. Therefore, it is possible this study worked with an underrepresented sample of multiple sports (i.e. lacrosse, softball, basketball, and soccer) for the SCAT5. Also, the average age of the participants was a year higher for the SCAT3 participants than the SCAT5 participants, yet the standard deviations were almost identical, which accounts for the differences in mean age scores.

The independent samples used to determine if floor/ceiling effects existed had a gender distribution of approximately one-third female, for the SCAT3 with a slightly larger sample of

females for the SCAT5. Differences between the two independent groups with respect to sport of participation were primarily due to the inclusion of tennis on the SCAT5 and a large decrease in lacrosse participants from the SCAT3 to SCAT5. Variability in sports participation is mainly dependent on the number of new and exiting athletes. The average age of participants for the independent sample was a year and a half above the SCAT5 participants' average age. This difference was primarily due to a larger number of SCAT3 participants in the 24 and above grouping, as well as the fact that none fell in the under 19-year grouping. The age group differences may have resulted in a larger disparity between ceiling effects than exists in other samples. As age increases, so do cognitive abilities (Rushton & Ankney, 1996) and potentially the number of testing experiences. Therefore, it is possible that the ceiling effects reported in this study for the SCAT3 are not as elevated for younger populations and that there would have been more participants who achieved a ceiling effect on the SCAT5 if the average age was identical.

Structure of SCAT3 and SCAT5. The following section explores the similarities and differences between the factor structure of the SCAT3 and SCAT5. Specifically, it addresses the issues of violation of assumptions, unexpected factor loading, and reliabilities.

Violation of assumptions. To create a clear picture of the structure of the various versions of the SCAT, it was necessary to examine how neither version of the SCAT met all the assumptions required for an EFA. Only two of the three assumptions for conducting an EFA for the SCAT3 and SCAT5 were observed. Both passed Bartlett's test of sphericity, but the SCAT3 violated the Kaiser-Meyer-Olkin (KMO) assessment and the SCAT5 violated multicollinearity (as observed by the determinant of the correlation matrix). Therefore, an argument could be made that EFA was not the appropriate statistical method to evaluate these assessments. However, the decision to utilize the EFA was made because two assumptions were met in each

instance and neither violated the Bartlett's test for sphericity. Bartlett's is key, because statistical significance implies that the correlation matrix and the identity matrix are not identical. This can be observed by finding the diagonal of the identity matrix. If all the diagonal correlations are 1's and the off diagonals are 0's, this indicates that each variable is only correlated with itself. If this test fails, it shows that the variables may not have been correlated with themselves. Therefore, because the Bartlett's test was passed, this indicates that the data were able to be factorized for structure or dimension.

Factor loading. When comparing the factor structure of the SCAT3 and SCAT5, there are some similarities in total variance and scree plot attributes. The factor structure accounts for approximately 26% of the total variance, which indicates that the factor structure has relatively low explanatory power. As a result, a large portion of the variance within the data cannot be attributed to the actual subsections (*orientation*, *immediate memory*, *concentration,* and *delayed recall*). This is problematic because it is unclear what other factors play a role in the assessments both as an instrument and as subsections. Moving from the 5-item word list to the 10-item word list did not change the total variance between versions, meaning that the structural changes between the SCAT3 and SCAT5 did not improve the explanatory value of the factor structure as it related to the *orientation*, *immediate memory*, *concentration*, and *delayed recall* constructs. The weak total explanatory variance is concerning because it indicates that there is relatively little explanatory power for what the retained factors are able to explain when considering the total number of items. Further research should focus on determining if the explanatory variance can be increased, perhaps by changing either the questions or the word choices. If the explanatory variance increases, then healthcare practitioners can be more confident that the assessment is really testing what it claims.

The scree plots show the appropriate number of factors to be extracted during the EFA by the presence of a bend or elbow in the line on the graph. Both versions were similar in shape but differed in the number of possible bends or eligible factors to be extracted. Both scree plots had no true “bend or elbow” (Mertler & Vannatta, 2010, p. 234) with multiple inflection points for both versions. The SCAT3 showed bends at factors 2 and 5 while the SCAT5 at factors 4, 8, and 14 (see Figure 1 and Figure 2). Therefore, it was difficult to determine the appropriate number of factors to extract. This bend in the plot should have occurred at 4 in both versions to clearly show that four factors was the best option. I did not focus on these numbers to determine the factor extraction because the four subsections of the assessment should have been the four factors extracted (*orientation, immediate memory, concentration,* and *delayed recall*). It is important to note that the SCAT5 first bend is at 4, which is the number of factors/subsections that were extracted. It is possible that as the number of items on the assessment increase, the factor structure becomes stronger. Additionally, the scree plot is supposed to level off after the bend and in both assessments, they continue to decline but never level off, which indicates that the variables are not loading perfectly onto the factor structure. An imperfect factor loading may call into question the psychometric properties of the SCAT and whether this test should be utilized for SRC sideline assessment. Further research should focus on determining the appropriate number of factors and possible factors that might be missing from the SCAT5 assessment.

There is a lack of clarity on how items loaded onto the four factors, inferring for instance, that the assessment says that it is testing *immediate memory* but is not. For example, when the *immediate memory* variables are recorded, they loaded onto two different factors with the implication that *immediate memory* variables are testing different constructs. Ideally, all

immediate memory variables would have loaded onto the *immediate memory* factor. The only departure from this occurred with the *delayed recall* factor for SCAT3 and *orientation* factor for SCAT5. In this case, all *delayed recall* variables loaded onto the *delayed recall* factor and the same for *orientation* for SCAT5. Therefore, there is conflicting data on the psychometric properties of both versions of the SCAT which leads to the conclusion that this assessment may not be assessing what it claims. Healthcare practitioners need to determine if this is the most accurate sideline assessment or it another tool needs to be created. The next section explores possibilities for these unique factor loadings as they relate participants' interpretation of the items.

The question that most needs to be addressed is how these items are being interpreted by the examinee. Specifically, it is possible that individuals code for the position of the item in a sequence when given lists of information to recall (Henson, 1999). The coding of the position of the word or number can increase or decrease the effectiveness of recalled information. This is suggested in the disparity of variable loadings based on their location within the word-lists. This means that the order of the words presented may affect how the participant recalls it because the word-list is repeated for three trials for the *immediate memory* subsection. For example, in the SCAT3 *immediate memory* items located at 2, 4, and 5 for the second and third trials load together while all of the variables from the first *immediate memory* trial all load onto a different factor. This could mean that the position of the word within the trial carries more weight than the first trial of the *immediate memory* utilizes short-term memory but the subsequent trials utilized long-term memory. For SCAT5, the groupings of *immediate memory* factor into location as well. In factor 1, most of the first five words are represented except for three variables. In factor 2, all but one of the last three words (i.e. words 8, 9 and 10) load and in factor 4, all words from

location 6 and 7 are present (see Table 15). The net result is that participants may use a mixture of short- and long-term memory during various subsections of this assessment. Therefore, it is possible that they know that because they will need to recall these words at the end of the screening process, they change how the words are coded in their memory, which could account for the unexpected factor loading reported in the EFA.

Another example of unexpected factor loading can be found in how the first *concentration* item does not load within the *concentration* factor but loads with *immediate memory 1* with the SCAT3. All other *concentration* items load together which means that it is the only *concentration* variable that deviates from the intended factor. During the *concentration* subsection, the participant is given multiple numbers to repeat in reverse order with three values for the first variable up to six for the last. One possible explanation for this is that the first concentration exercise is really testing immediate memory because test-takers have no other numbers to remember at this point in the assessment. After this first question, the participant is expected to 'push' the old number out of short-term memory and then integrate the new number before it can be reversed. This mental exercise requires that participants be careful that none of the old and new numbers overlap. Thus, in a way, long-term and short-term memory must coordinate to complete some of the tasks within the SCAT. So, while the SCAT purports to assess long-term and short-term memory in separate ways through different portions of the test, there appears to be a significant overlap between the tasks, making it harder to diagnose decreases in the various aspects of cognitive function.

Another example of overlap in cognitive function occurs between orientation and long-term memory as evidenced within how the SCAT3 *orientation* items align with *delayed recall*. The possibility is that certain *orientation* items are already stored in long-term memory. An

example of this would be the question about the current month. When asked, “What month is it?” it is possible that participants could think in two ways about this question. One way is to just say the current month. But another way would be to consider the month in terms of the past 0-30 days, meaning that if it is more than one day into the month, participants would have to recall what the month is from previous knowledge. Therefore, it is possible that some of the *orientation* items utilize long-term memory, suggesting an inconsistent and unreliable measure of *orientation*. This implies that a healthcare practitioner cannot explicitly state that orientation, short-term or long-term memory is impaired but they could state that there is a cognitive dysfunction.

Reliabilities. Internal consistency was reported in two ways: with the factor loadings and as idealized values. This decision was made based on the lack of clarity in the factor structure matrix, therefore internal consistency was reported for each subsection and for the overall SCAT assessment. This enabled a determination of the strength of the variables’ groupings following the EFA. The SCAT3 internal consistency for the immediate memory 2 factor was unacceptable with immediate memory 1, concentration, and delayed recall factors having poor classification. After producing the idealized reliabilities, there was no change in internal consistencies between immediate memory or orientation (unacceptable) and delayed recall or concentration (poor) internal consistency. It is difficult to compare the reliability of the SAC portion of the SCAT3 to previous literature because all previous literature looks only at the reliability based on those who have sustained an SRC and not exclusively with baseline testing (McCrea et al., 1998; McCrea et al., 2007). The overall reliability of the SCAT3 assessment fell within the range found in literature (.42-.71), meaning that the sample used in this study reliably responded to SCAT3

items (Guskiewicz et al., 2013). This does not mean that the reliability of the SCAT3 was good or acceptable, but just that the values for this sample showed a similarity of results.

SCAT5 reliabilities are better than SCAT3 when loaded by factors with *immediate memory 1* as good and *immediate memory 2*, *orientation*, and *delayed recall* as acceptable. When the idealized reliabilities are conducted they significantly decrease the reliabilities to unacceptable for *delayed recall* and *concentration* but remain the same for *immediate memory* and *orientation* as acceptable. This suggests that the subsections in the SCAT are not adequately grouping the variables together and therefore, the structure of the exam is questionable. The overall internal consistency for all variables surpasses the reliabilities reported for the previous version of the SCAT (Guskiewicz et al., 2013). Therefore, it may be concluded that grouping all of the variables together with the SCAT5 provides more internal consistency, not from the factor structure, but from the additional variables found within the *immediate memory* and *delayed recall* subsections of the assessment. It is important to remember that the internal consistency values reported in the literature are based on those participants who have sustained a SRC and not on baseline testing as reported in this study. Therefore, further research needs to determine if these reliabilities remain consistent for post-injury assessments with the SCAT5.

Floor and ceiling effects. There were significant differences in the ceiling effects within the immediate memory and delayed recall portions of the assessment. This indicates that the SCAT5 significantly reduces the ceiling effects seen within the SCAT3. The average score for immediate memory on the SCAT3 was near the maximum score of 15 while the average score for the SCAT5 was more than 10 points away from the maximum. These results indicate it is less likely that participants will score near the maximal threshold on the SCAT5. Within the delayed recall, the same phenomenon occurs suggesting that a ceiling effect is less likely to occur and the

assessment has increased the difficulty of the assessment enough to capture most participants maximal cognitive ability on the tasks requested within the assessment.

There are statistically significant differences between ceiling effects of *immediate memory* and *delayed recall*. This means that by increasing the number of word items on the SCAT5 assessment, participants are less likely to get the maximal score. This allows a greater chance for capturing a more accurate assessment of cognitive ability. Further research should focus on whether increasing the word-item list to an even larger number would adequately reflect the abilities of each participant or if a 10-item word list is ideal.

Limitations

There were several limitations related to this research. The use of an EFA was the main limitation. The goal of an EFA is to explore the factor structure and not to test for differences between assessment structures. The only ways to evaluate differences are to visually inspect the EFA outputs (i.e. graphs and tables) and compare internal consistency values. Therefore, EFAs are somewhat subjective, which limits conclusions to the descriptions and comparisons provided. Additionally, the principle component analysis utilized as the extraction method may not have been the best choice and other methods may have created different results (Osborne, 2014). In hindsight, a better plan would have been to use a maximal likelihood factoring.

Another limitation was that this research only examined baseline data for SCAT3 and SCAT5. No conclusions about SCAT5 usability for SRC diagnosis can be formed because the data was not compiled on participants who were currently concussed or suspected of sustaining a SRC. Additionally, the variation in testing environment may have limited the outcomes, meaning that participants may have had higher scores if they were testing in a quiet environment isolated from their peers and with one or two researchers controlling for the variability between proctors.

This study did not account for athlete history of SRC injury or diagnosis of cognitive disorders. This means that this study excludes any impact on participant scores who have a history of SRC or a cognitive disorder (e.g. post-injury data).

A final limitation was that the participants were not evaluated in either the SCAT3 or the SCAT5 assessment on the truthfulness of their responses. As a result, some participants may have intentionally performed poorly or sandbagged, which influences the results of their assessment score. The reason athletes may sandbag is to have an easier and quicker path to return-to-play following a SRC. This is possible because the scores on SRC assessments are used as a comparison to their post-injury assessments. An athlete is only cleared for participation after a concussion when all post-SRC assessments return to pre-injury baseline scores, the athlete is asymptomatic, and they are able to tolerate intense exercise without the re-occurrence of symptoms. It is possible some athletes choose to mis-represent their symptoms on the pre-test in order to guarantee a quicker return-to-play after an injury. As a result, sandbagging may lead to artificially lower assessment scores. Therefore, it is essential that SRC assessments incorporate questions to prevent sandbagging as an additional safeguard to accurately reflect deficiencies in cognition.

Implications for Practice

Athletic trainers (ATCs) are usually the first healthcare providers to diagnose a SRC. Therefore, each ATC needs to decide what decision criteria they will use to assess and clear athletes for participation following a suspected SRC. Many athletic trainers utilize the SCAT3 or SCAT5 as a portion of their concussion protocol. Based on the structural inconsistencies within both assessments that were revealed in this research, practitioners should consider whether the SCAT assessments should be included within the battery of SRC assessments. Currently, there is

no universal protocol utilized by athletic trainers to diagnose a SRC; research certainly points to the need to administer multiple SRC assessments to avoid relying on a single data point (Broglio, Guskiewicz, & Norwig, 2017).

Some researchers claim that objective assessments exist to measure SRCs (Barr & McCrea, 2001; Guskiewicz et al., 2013)and others suggest that subjectivity is an overriding component of all SRC assessments (Broglio et al., 2017; McCrory et al., 2017). This study indicates the possibility that the SCAT is not effectively assessing what it claims to measure, warranting further consideration of the objective and subjective nature of assessing SRCs. Further research on ATCs' decision-making processes may be useful in this regard. Additionally, research on how political pressure from athletes, coaches, and athletic administrators affects ATCs' decisions should also be explored.

Suggestions for Future Research

Future research is essential to help athletic trainers and other allied healthcare professionals determine the best practices for sideline SRC assessment. This research should focus on determining if the total variance described by the assessment can be increased with changing either the questions or the word choice within the SCAT5. This research shows that the SAC assessment accounts for only 26% of the total explanatory variance. This is a weak percentage and needs to be explored to determine if this assessment should even be included in the SCAT5.

A closer look at the appropriate number of factor loadings and possible factors that might be missing from the SCAT5 assessment should also be explored. A deeper examination of the factor loading may reveal other latent variables present within the SCAT5 which may improve the total explanatory variance. Post-injury data collection on the SCAT5 needs to be explored to

determine if the internal consistency remains strong for the overall SAC assessment. If the internal consistency is confirmed for post-injury assessment, then further exploration of how short-term and long-term memory are reflected in each SAC questions should be identified.

Finally, it would be worthwhile for researchers to explore whether adding more than a 10-item word list could capture more variance in cognitive ability, or if the 10-item list on the SCAT5 is sufficient. Future research for SCAT5 could also focus on the comparison between baseline testing and post-injury assessment following a SRC to determine if the changes to the SCAT5 actually help in diagnosis and return-to-play decisions.

Conclusion

This study focused on how the structures of the SCAT3 and SCAT5 changed with the addition of a 10-item word list, while also comparing floor/ceiling effects between the two versions of the test. This research showed that the structures of the assessment changed when adding additional words to the assessment. Additionally, the ceiling effect that exists within the SCAT3 disappears in the SCAT5 in the *immediate memory* and *delayed recall* portions of the SAC assessment. This indicates that the SCAT5 is indeed a better assessment of athletes' cognitive abilities, when the optional 10-item list is used. Overall, the internal consistency of the SCAT5 is improved over the SCAT3, although there is still concern related to the uneven loading of the variables. This indicates that the SCAT5 is not assessing what the subsections labels suggest and may not test the variables that the designers intended for the cognitive assessment.

Despite these concerns, this research suggests that all athletic trainers and allied healthcare professionals who currently use the SCAT5 in their return-to-play protocol, should be utilizing the 10-item word list to mitigate the ceiling effects present in the SCAT3. Despite the

concerns present within the structure of the SAC portion of the SCAT, healthcare practitioners should still continue to make use of this sideline assessment, until a more psychometrically sound instrument for cognition is presented.

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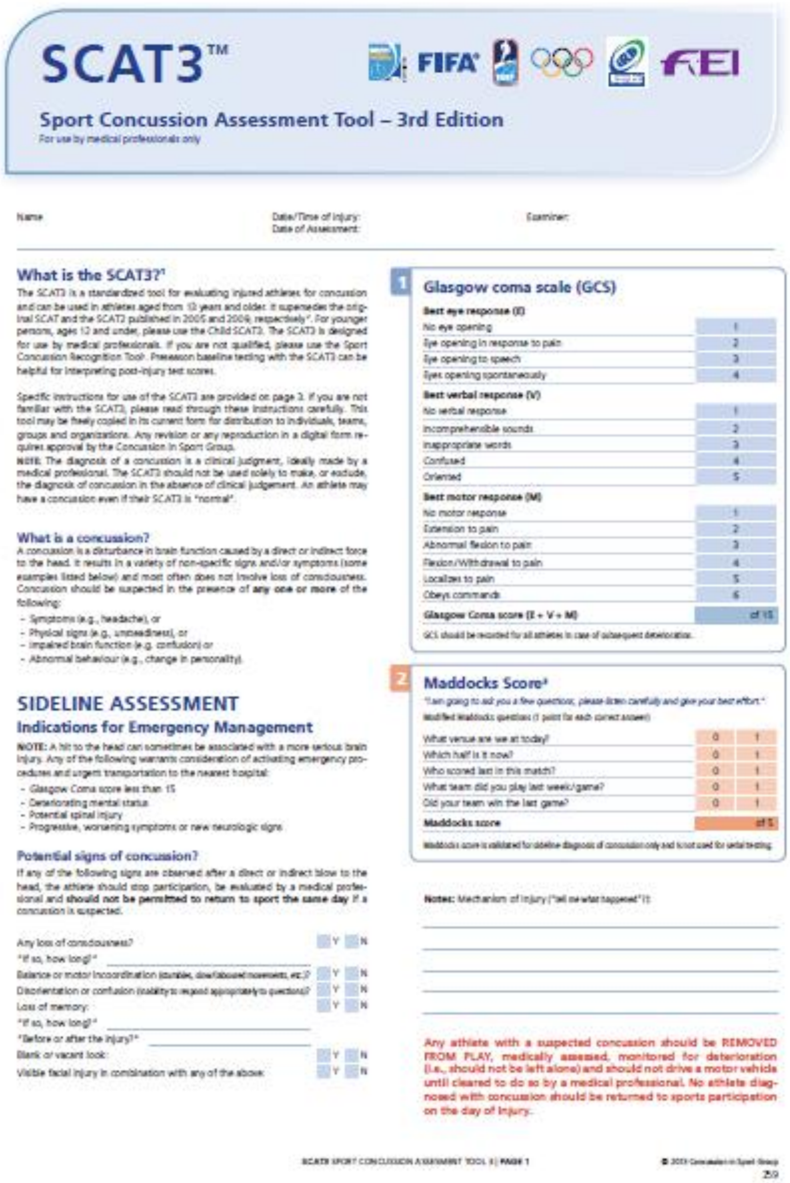
APPENDICES

Appendix A

Sport Concussion Assessment Tool 3 (SCAT3)



SCAT3™

Sport Concussion Assessment Tool – 3rd Edition

For use by medical professionals only

Name | Date/Time of Injury: | Examiner:
Date of Assessment:

What is the SCAT3?[1]

The SCAT3 is a standardized tool for evaluating injured athletes for concussion and can be used in athletes aged from 13 years and older. It supersedes the original SCAT and the SCAT2 published in 2005 and 2009, respectively[2]. For younger persons, ages 12 and under, please use the Child SCAT3. The SCAT3 is designed for use by medical professionals. If you are not qualified, please use the Sport Concussion Recognition Tool[1]. Preseason baseline testing with the SCAT3 can be helpful for interpreting post-injury test scores.

Specific instructions for use of the SCAT3 are provided on page 3. If you are not familiar with the SCAT3, please read through these instructions carefully. This tool may be freely copied in its current form for distribution to individuals, teams, groups and organizations. Any revision or any reproduction in a digital form requires approval by the Concussion in Sport Group.

NOTE: The diagnosis of a concussion is a clinical judgment, ideally made by a medical professional. The SCAT3 should not be used solely to make, or exclude, the diagnosis of concussion in the absence of clinical judgement. An athlete may have a concussion even if their SCAT3 is "normal".

What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific signs and/or symptoms (some examples listed below) and most often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (e.g., headache), or
- Physical signs (e.g., unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour (e.g., change in personality).

SIDELINE ASSESSMENT

Indications for Emergency Management

NOTE: A hit to the head can sometimes be associated with a more serious brain injury. Any of the following warrants consideration of activating emergency procedures and urgent transportation to the nearest hospital:

- Glasgow Coma score less than 15
- Deteriorating mental status
- Potential spinal injury
- Progressive, worsening symptoms or new neurologic signs

Potential signs of concussion?

If any of the following signs are observed after a direct or indirect blow to the head, the athlete should stop participation, be evaluated by a medical professional and **should not be permitted to return to sport the same day** if a concussion is suspected.

Any loss of consciousness?	Y	N
"If so, how long?"		
Balance or motor incoordination (stumbles, slow/laboured movements, etc.)?	Y	N
Disorientation or confusion (inability to respond appropriately to questions)?	Y	N
Loss of memory:	Y	N
"If so, how long?"		
"Before or after the injury?"		
Blank or vacant look:	Y	N
Visible facial injury in combination with any of the above:	Y	N

1 Glasgow coma scale (GCS)

Best eye response (E)	
No eye opening	1
Eye opening in response to pain	2
Eye opening to speech	3
Eyes opening spontaneously	4
Best verbal response (V)	
No verbal response	1
Incomprehensible sounds	2
Inappropriate words	3
Confused	4
Oriented	5
Best motor response (M)	
No motor response	1
Extension to pain	2
Abnormal flexion to pain	3
Flexion/Withdrawal to pain	4
Localizes to pain	5
Obeys commands	6
Glasgow Coma score (E + V + M)	of 15

GCS should be recorded for all athletes in case of subsequent deterioration.

2 Maddocks Score[3]

"I am going to ask you a few questions, please listen carefully and give your best effort."

Modified Maddocks questions (1 point for each correct answer)

What venue are we at today?	0	1
Which half is it now?	0	1
Who scored last in this match?	0	1
What team did you play last week/game?	0	1
Did your team win the last game?	0	1
Maddocks score		of 5

Maddocks score is validated for sideline diagnosis of concussion only and is not used for serial testing.

Notes: Mechanism of Injury ("tell me what happened"?):

Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle until cleared to do so by a medical professional. No athlete diagnosed with concussion should be returned to sports participation on the day of injury.

SCAT3 SPORT CONCUSSION ASSESMENT TOOL 3 | PAGE 1

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BACKGROUND

Name: ____________ Date: ____________

Examiner: ____________

Sport/team/school: ____________ Date/time of injury: ____________

Age: ____________ Gender: ☐ M ☐ F

Years of education completed: ____________

Dominant hand: ☐ right ☐ left ☐ neither

How many concussions do you think you have had in the past? ____________

When was the most recent concussion? ____________

How long was your recovery from the most recent concussion? ____________

Have you ever been hospitalized or had medical imaging done for a head injury? ☐ Y ☐ N

Have you ever been diagnosed with headaches or migraines? ☐ Y ☐ N

Do you have a learning disability, dyslexia, ADD/ADHD? ☐ Y ☐ N

Have you ever been diagnosed with depression, anxiety or other psychiatric disorder? ☐ Y ☐ N

Has anyone in your family ever been diagnosed with any of these problems? ☐ Y ☐ N

Are you on any medications? If yes, please list: ☐ Y ☐ N

SCAT3 to be done in resting state. Best done 10 or more minutes post excercise.

SYMPTOM EVALUATION

3 How do you feel?

"You should score yourself on the following symptoms, based on how you feel now".

	none	mild		moderate		severe	
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Trouble falling asleep	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6

Total number of symptoms (Maximum possible 22)

Symptom severity score (Maximum possible 132)

Do the symptoms get worse with physical activity? ☐ Y ☐ N

Do the symptoms get worse with mental activity? ☐ Y ☐ N

☐ self rated ☐ self rated and clinician monitored

☐ clinician interview ☐ self rated with parent input

Overall rating: If you know the athlete well prior to the injury, how different is the athlete acting compared to his/her usual self?

Please circle one response:

no different	very different	unsure	N/A

Scoring on the SCAT3 should not be used as a stand-alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion. Since signs and symptoms may evolve over time, it is important to consider repeat evaluation in the acute assessment of concussion.

COGNITIVE & PHYSICAL EVALUATION

4 Cognitive assessment

Standardized Assessment of Concussion (SAC)[4]

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		of 5

Immediate memory

List	Trial 1		Trial 2		Trial 3		Alternative 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									

Immediate memory score total of 15

Concentration: Digits Backward

List	Trial 1		Alternative 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 of 4					

Concentration: Month in Reverse Order (1 pt. for entire sequence correct)

Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan	0	1
Concentration score		of 5

5 Neck Examination:

Range of motion Tenderness Upper and lower limb sensation & strength

Findings: ____________

6 Balance examination

Do one or both of the following tests.

Footwear (shoes, barefoot, braces, tape, etc.) ____________

Modified Balance Error Scoring System (BESS) testing[5]

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

Testing surface (hard floor, field, etc.) ____________

Condition

Double leg stance:	Errors
Single leg stance (non-dominant foot):	Errors
Tandem stance (non-dominant foot at back):	Errors

And / Or

Tandem gait[6,7]

Time (best of 4 trials): ______ seconds

7 Coordination examination

Upper limb coordination

Which arm was tested: ☐ Left ☐ Right

Coordination score of 1

8 SAC Delayed Recall[4]

Delayed recall score of 5

SCAT3 SPORT CONCUSSION ASSESMENT TOOL 3 | PAGE 2

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Appendix B

Sport Concussion Assessment Tool 5 (SCAT5)

SCAT5.© SPORT CONCUSSION ASSESSMENT TOOL — 5TH EDITION
DEVELOPED BY THE CONCUSSION IN SPORT GROUP
FOR USE BY MEDICAL PROFESSIONALS ONLY

supported by

Patient details

Name: ______________________

DOB: ______________________

Address: ______________________

ID number: ______________________

Examiner: ______________________

Date of Injury: ______________ Time: ______________

WHAT IS THE SCAT5?

The SCAT5 is a standardized tool for evaluating concussions designed for use by physicians and licensed healthcare professionals[1]. The SCAT5 cannot be performed correctly in less than 10 minutes.

If you are not a physician or licensed healthcare professional, please use the Concussion Recognition Tool 5 (CRT5). The SCAT5 is to be used for evaluating athletes aged 13 years and older. For children aged 12 years or younger, please use the Child SCAT5.

Preseason SCAT5 baseline testing can be useful for interpreting post-injury test scores, but is not required for that purpose.Detailed instructions for use of the SCAT5 are provided on page 7. Please read through these instructions carefully before testing the athlete. Brief verbal instructions for each test are given in italics. The only equipment required for the tester is a watch or timer.

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Recognise and Remove

A head impact by either a direct blow or indirect transmission of force can be associated with a serious and potentially fatal brain injury. If there are significant concerns, including any of the red flags listed in Box 1, then activation of emergency procedures and urgent transport to the nearest hospital should be arranged.

Key points

- Any athlete with suspected concussion should be REMOVED FROM PLAY, medically assessed and monitored for deterioration. No athlete diagnosed with concussion should be returned to play on the day of injury.
- If an athlete is suspected of having a concussion and medical personnel are not immediately available, the athlete should be referred to a medical facility for urgent assessment.
- Athletes with suspected concussion should not drink alcohol, use recreational drugs and should not drive a motor vehicle until cleared to do so by a medical professional.
- Concussion signs and symptoms evolve over time and it is important to consider repeat evaluation in the assessment of concussion.
- The diagnosis of a concussion is a clinical judgment, made by a medical professional. The SCAT5 should NOT be used by itself to make, or exclude, the diagnosis of concussion. An athlete may have a concussion even if their SCAT5 is "normal".

Remember:

- The basic principles of first aid (danger, response, airway, breathing, circulation) should be followed.
- Do not attempt to move the athlete (other than that required for airway management) unless trained to do so.
- Assessment for a spinal cord injury is a critical part of the initial on-field assessment.
- Do not remove a helmet or any other equipment unless trained to do so safely.

Echemendia RJ *et al. Br J Sports Med* 2017;51:851–858. doi:10.1136/bjsports-2017-097506SCAT5

1

IMMEDIATE OR ON-FIELD ASSESSMENT

The following elements should be assessed for all athletes who are suspected of having a concussion prior to proceeding to the neurocognitive assessment and ideally should be done on-field after the first first aid / emergency care priorities are completed.

If any of the "Red Flags" or observable signs are noted after a direct or indirect blow to the head, the athlete should be immediately and safely removed from participation and evaluated by a physician or licensed healthcare professional.

Consideration of transportation to a medical facility should be at the discretion of the physician or licensed healthcare professional.

The GCS is important as a standard measure for all patients and can be done serially if necessary in the event of deterioration in conscious state. The Maddocks questions and cervical spine exam are critical steps of the immediate assessment; however, these do not need to be done serially.

STEP 1: RED FLAGS

RED FLAGS:

- Neck pain or tenderness
- Double vision
- Weakness or tingling/ burning in arms or legs
- Severe or increasing headache
- Seizure or convulsion
- Loss of consciousness
- Deteriorating conscious state
- Vomiting
- Increasingly restless, agitated or combative

STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

Lying motionless on the playing surface	Y	N
Balance / gait difficulties / motor incoordination: stumbling, slow / laboured movements	Y	N
Disorientation or confusion, or an inability to respond appropriately to questions	Y	N
Blank or vacant look	Y	N
Facial injury after head trauma	Y	N

STEP 3: MEMORY ASSESSMENT MADDOCKS QUESTIONS[2]

"I am going to ask you a few questions, please listen carefully and give your best effort. First, tell me what happened?"

Mark Y for correct answer / N for incorrect

What venue are we at today?	Y	N
Which half is it now?	Y	N
Who scored last in this match?	Y	N
What team did you play last week / game?	Y	N
Did your team win the last game?	Y	N

Note: Appropriate sport-specific questions may be substituted.

Name:

DOB:

Address:

ID number:

Examiner:

Date:

STEP 4: EXAMINATION GLASGOW COMA SCALE (GCS)[3]

Time of assessment			
Date of assessment			
Best eye response (E)			
No eye opening	1	1	1
Eye opening in response to pain	2	2	2
Eye opening to speech	3	3	3
Eyes opening spontaneously	4	4	4
Best verbal response (V)			
No verbal response	1	1	1
Incomprehensible sounds	2	2	2
Inappropriate words	3	3	3
Confused	4	4	4
Oriented	5	5	5
Best motor response (M)			
No motor response	1	1	1
Extension to pain	2	2	2
Abnormal flexion to pain	3	3	3
Flexion / Withdrawal to pain	4	4	4
Localizes to pain	5	5	5
Obeys commands	6	6	6
Glasgow Coma score (E + V + M)			

CERVICAL SPINE ASSESSMENT

Does the athlete report that their neck is pain free at rest?	Y	N
If there is NO neck pain at rest, does the athlete have a full range of ACTIVE pain free movement?	Y	N
Is the limb strength and sensation normal?	Y	N

In a patient who is not lucid or fully conscious, a cervical spine injury should be assumed until proven otherwise.

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OFFICE OR OFF-FIELD ASSESSMENT

Please note that the neurocognitive assessment should be done in a distraction-free environment with the athlete in a resting state.

STEP 1: ATHLETE BACKGROUND

Sport / team / school: ______________________

Date / time of injury: ______________________

Years of education completed: ______________________

Age: ______________________

Gender: M / F / Other

Dominant hand: left / neither / right

How many diagnosed concussions has the athlete had in the past?: ______________________

When was the most recent concussion?: ______________________

How long was the recovery (time to being cleared to play) from the most recent concussion?: ______________ (days)

Has the athlete ever been:

Hospitalized for a head injury?	Yes	No
Diagnosed / treated for headache disorder or migraines?	Yes	No
Diagnosed with a learning disability / dyslexia?	Yes	No
Diagnosed with ADD / ADHD?	Yes	No
Diagnosed with depression, anxiety or other psychiatric disorder?	Yes	No

Current medications? If yes, please list:

____

____

____

____

____

____

Name: ______________________

DOB: ______________________

Address: ______________________

ID number: ______________________

Examiner: ______________________

Date: ______________________

2

STEP 2: SYMPTOM EVALUATION

The athlete should be given the symptom form and asked to read this instruction paragraph out loud then complete the symptom scale. For the baseline assessment, the athlete should rate his/her symptoms based on how he/she typically feels and for the post injury assessment the athlete should rate their symptoms at this point in time.

Please Check: ☐ **Baseline** ☐ **Post-Injury**

Please hand the form to the athlete

	none	mild		moderate		severe	
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6
Trouble falling asleep (if applicable)	0	1	2	3	4	5	6

Total number of symptoms:	of 22
Symptom severity score:	of 132
Do your symptoms get worse with physical activity?	Y N
Do your symptoms get worse with mental activity?	Y N
If 100% is feeling perfectly normal, what percent of normal do you feel?	

If not 100%, why?

____

____

____

Please hand form back to examiner

Echemendia RJ *et al. Br J Sports Med* 2017;51:851–858. doi:10.1136/bjsports-2017-097506SCAT5

3

STEP 3: COGNITIVE SCREENING

Standardised Assessment of Concussion (SAC)[4]

ORIENTATION

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		of 5

IMMEDIATE MEMORY

The Immediate Memory component can be completed using the traditional 5-word per trial list or optionally using 10-words per trial to minimise any ceiling effect. All 3 trials must be administered irrespective of the number correct on the first trial. Administer at the rate of one word per second.

Please choose EITHER the 5 or 10 word list groups and circle the specific word list chosen for this test.

I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order. For Trials 2 & 3: I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before.

List	Alternate 5 word lists					Score (of 5) Trial 1	Trial 2	Trial 3
A	Finger	Penny	Blanket	Lemon	Insect			
B	Candle	Paper	Sugar	Sandwich	Wagon			
C	Baby	Monkey	Perfume	Sunset	Iron			
D	Elbow	Apple	Carpet	Saddle	Bubble			
E	Jacket	Arrow	Pepper	Cotton	Movie			
F	Dollar	Honey	Mirror	Saddle	Anchor			
					Immediate Memory Score			of 15
					Time that last trial was completed			

List	Alternate 10 word lists					Score (of 10) Trial 1	Trial 2	Trial 3
G	Finger Candle	Penny Paper	Blanket Sugar	Lemon Sandwich	Insect Wagon			
H	Baby Elbow	Monkey Apple	Perfume Carpet	Sunset Saddle	Iron Bubble			
I	Jacket Dollar	Arrow Honey	Pepper Mirror	Cotton Saddle	Movie Anchor			
					Immediate Memory Score			of 30
					Time that last trial was completed			

Name:

DOB:

Address:

ID number:

Examiner:

Date:

CONCENTRATION

DIGITS BACKWARDS

Please circle the Digit list chosen (A, B, C, D, E, F). Administer at the rate of one digit per second reading DOWN the selected column.

I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7.

Concentration Number Lists (circle one) List A	List B	List C			
4-9-3	5-2-6	1-4-2	Y	N	0
6-2-9	4-1-5	6-5-8	Y	N	1
3-8-1-4	1-7-9-5	6-8-3-1	Y	N	0
3-2-7-9	4-9-6-8	3-4-8-1	Y	N	1
6-2-9-7-1	4-8-5-2-7	4-9-1-5-3	Y	N	0
1-5-2-8-6	6-1-8-4-3	6-8-2-5-1	Y	N	1
7-1-8-4-6-2	8-3-1-9-6-4	3-7-6-5-1-9	Y	N	0
5-3-9-1-4-8	7-2-4-8-5-6	9-2-6-5-1-4	Y	N	1
List D	List E	List F			
7-8-2	3-8-2	2-7-1	Y	N	0
9-2-6	5-1-8	4-7-9	Y	N	1
4-1-8-3	2-7-9-3	1-6-8-3	Y	N	0
9-7-2-3	2-1-6-9	3-9-2-4	Y	N	1
1-7-9-2-6	4-1-8-6-9	2-4-7-5-8	Y	N	0
4-1-7-5-2	9-4-1-7-5	8-3-9-6-4	Y	N	1
2-6-4-8-1-7	6-9-7-3-8-2	5-8-6-2-4-9	Y	N	0
8-4-1-9-3-5	4-2-7-9-3-8	3-1-7-8-2-6	Y	N	1
		Digits Score:			of 4

MONTHS IN REVERSE ORDER

Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November. Go ahead.

Dec - Nov - Oct - Sept - Aug - Jul - Jun - May - Apr - Mar - Feb - Jan	0 1
Months Score	of 1
Concentration Total Score (Digits + Months)	of 5

4

STEP 4: NEUROLOGICAL SCREEN

See the instruction sheet (page 7) for details of test administration and scoring of the tests.

Can the patient read aloud (e.g. symptom check-list) and follow instructions without difficulty?	Y	N
Does the patient have a full range of pain-free PASSIVE cervical spine movement?	Y	N
Without moving their head or neck, can the patient look side-to-side and up-and-down without double vision?	Y	N
Can the patient perform the finger nose coordination test normally?	Y	N
Can the patient perform tandem gait normally?	Y	N

BALANCE EXAMINATION

Modified Balance Error Scoring System (mBESS) testing[5]

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

Testing surface (hard floor, field, etc.) ____________________

Footwear (shoes, barefoot, braces, tape, etc.) ____________________

Condition	Errors
Double leg stance	of 10
Single leg stance (non-dominant foot)	of 10
Tandem stance (non-dominant foot at the back)	of 10
Total Errors	of 30

Name: ____________________

DOB: ____________________

Address: ____________________

ID number: ____________________

Examiner: ____________________

Date: ____________________

5

STEP 5: DELAYED RECALL:

The delayed recall should be performed after 5 minutes have elapsed since the end of the Immediate Recall section. Score 1 pt. for each correct response.

Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order.

Time Started ______

Please record each word correctly recalled. Total score equals number of words recalled.

____

____

____

Total number of words recalled accurately: of 5 or of 10

6

STEP 6: DECISION

Domain	Date & time of assessment:		
Symptom number (of 22)			
Symptom severity score (of 132)			
Orientation (of 5)			
Immediate memory	of 15 of 30	of 15 of 30	of 15 of 30
Concentration (of 5)			
Neuro exam	Normal Abnormal	Normal Abnormal	Normal Abnormal
Balance errors (of 30)			
Delayed Recall	of 5 of 10	of 5 of 10	of 5 of 10

Date and time of injury: ____________________

If the athlete is known to you prior to their injury, are they different from their usual self?
☐ Yes ☐ No ☐ Unsure ☐ Not Applicable
(If different, describe why in the clinical notes section)

Concussion Diagnosed?
☐ Yes ☐ No ☐ Unsure ☐ Not Applicable

If re-testing, has the athlete improved?
☐ Yes ☐ No ☐ Unsure ☐ Not Applicable

I am a physician or licensed healthcare professional and I have personally administered or supervised the administration of this SCAT5.

Signature: ____________________

Name: ____________________

Title: ____________________

Registration number (if applicable): ____________________

Date: ____________________

SCORING ON THE SCAT5 SHOULD NOT BE USED AS A STAND-ALONE METHOD TO DIAGNOSE CONCUSSION, MEASURE RECOVERY OR MAKE DECISIONS ABOUT AN ATHLETE'S READINESS TO RETURN TO COMPETITION AFTER CONCUSSION.

Appendix C

Data Use Approval

GEORGE FOX UNIVERSITY

Office of Intercollegiate Athletics
414 N. Meridian St. #6149, Newberg, OR 97132
503.554.2910 | athletics.georgefox.edu

February 15, 2018

Dear Committee Chair,

I give permission to Jill Sikkema to conduct research using data in the George Fox University Sports Medicine medical database for her dissertation. The purpose of the study is to examine the psychometric properties of the Sport Concussion Assessment Tool (SCAT) versions 3 and 5 along with examining their ceiling effects.

Mrs. Sikkema will have access to the secure medical database report platform for the 2016 and 2017 baseline SCAT testing. She has permission to analyze, evaluate, and report on this data to answer the following research questions:

1. Are there differences in the factor structure and internal reliability between the SCAT3 and SCAT5 subsections of immediate memory and delayed recall assessments in an analysis of baseline data?
2. Are there differences in the proportions of floor/ceiling effects for the SCAT3 and SCAT5 subsections of immediate memory and delayed recall assessments in an analysis of baseline data?

Please contact me if you have any questions.

Sincerely,

Dale Isaak
Director of Sports Medicine
George Fox University
disaak@georgefox.edu
503-554-2916

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Appendix D

Institutional Review Board Approval

GEORGE FOX UNIVERSITY HSRC INITIAL REVIEW QUESTIONNAIRE **Page 6**

Title: EXAMINATION OF THE PSYCHOMETRIC PROPERTIES OF THE SCAT5 BASELINE TESTING DATA ON NCAA DIVISION III COLLEGE ATHLETES

Principal Researcher(s): Jill Sikkema

Date application completed: 2/27/18

(The researcher needs to complete the above information on this page)

COMMITTEE FINDING: For Committee Use Only

☒ (1) The proposed research makes adequate provision for safeguarding the health and dignity of the subjects and is therefore approved.

☐ (2) Due to the assessment of risk being questionable or being subject to change, the research must be periodically reviewed by the **HSRC** on a basis throughout the course of the research or until otherwise notified. This requires resubmission of this form, with updated information, for each periodic review.

☐ (3) The proposed research evidences some unnecessary risk to participants and therefore must be revised to remedy the following specific area(s) on non-compliance:

☐ (4) The proposed research contains serious and potentially damaging risks to subjects and is therefore not approved.

02/06/2018

Chair or designated member Date

Appendix E

Correlation Matrix for SCAT3

Items	O_Date	O_Day	O_ Month	O_Time	O_Year	C1	C2	C3
O_Date		-0.036	-0.016	-0.056	-0.016	-0.016	0.007	0.072
O_Day			-0.011	0.031	-0.011	-0.011	0.063	0.074
O_Month				-0.017	-0.005	-0.005	-0.021	0.090
O_Time					-0.017	-0.017	0.000	0.009
O_Year						-0.005	0.102	-0.054
C1							-0.021	0.090
C2								0.346
C3								
C4								
C_Month								
IM1_1								
IM1_2								
IM1_3								
IM1_4								
IM1_5								
IM2_1								
IM 2_2								
IM 2_3								
IM 2_4								
IM 2_5								
IM 3_1								
IM 3_2								
IM3_3								
IM3_4								
IM3_5								
DR1								
DR2								
DR3								
DR4								
DR5								

Item	C4	C_Month	IM1_1	IM1_2	IM1_3	IM1_4	IM1_5
O_Date	0.023	0.031	-0.020	-0.040	0.011	-0.024	0.027
O_Day	-0.023	0.046	-0.013	0.067	0.050	0.195	-0.066
O_Month	0.049	0.146	-0.006	-0.012	-0.014	-0.020	0.068
O_Time	0.059	0.047	0.104	-0.042	-0.048	0.011	-0.042
O_Year	-0.099	-0.033	-0.006	-0.012	-0.014	-0.020	0.068
C1	0.049	0.056	-0.006	-0.012	-0.014	-0.020	-0.029
C2	0.181	0.117	-0.026	-0.002	-0.017	0.075	0.015
C3	0.469	0.145	-0.007	0.045	0.027	0.027	0.068
C4		0.047	0.060	0.121	0.035	0.064	0.123
C_Month			0.106	-0.008	-0.031	0.006	0.009
IM1_1				-0.015	-0.017	0.084	-0.036
IM1_2					0.264	0.115	0.130
IM1_3						0.086	0.127
IM1_4							0.061
IM1_5							
IM2_1							
IM 2_2							
IM 2_3							
IM 2_4							
IM 2_5							
IM 3_1							
IM 3_2							
IM3_3							
IM3_4							
IM3_5							
DR1							
DR2							
DR3							
DR4							
DR5							

Item	IM2_1	IM2_2	IM2_3	IM2_4	IM2_5	IM3_1	IM3_2	IM3_3	IM3_4
O_Date	-0.011	-0.038	-0.025	0.117	0.119	-0.016	0.090	-0.016	0.075
O_Day	-0.008	-0.026	-0.017	0.085	0.047	-0.011	-0.015	-0.011	-0.017
O_Month	-0.003	-0.011	-0.008	-0.010	-0.014	-0.005	-0.007	-0.005	-0.008
O_Time	-0.012	0.026	-0.027	-0.036	0.056	-0.017	-0.024	-0.017	-0.027
O_Year	-0.003	-0.011	-0.008	-0.010	-0.014	-0.005	-0.007	-0.005	-0.008
C1	-0.003	0.205	-0.008	0.229	0.161	-0.005	0.349	-0.005	0.311
C2	-0.015	0.056	-0.034	0.013	-0.020	-0.021	0.057	-0.021	0.123
C3	0.064	0.059	0.006	0.090	-0.008	0.018	0.026	0.018	0.052
C4	0.035	0.021	0.078	0.035	0.094	0.049	0.069	0.049	0.031
C_Month	-0.023	-0.001	0.004	0.142	-0.005	0.056	-0.047	-0.033	0.004
IM1_1	-0.004	-0.014	-0.009	-0.013	0.126	-0.006	-0.008	-0.006	-0.009
IM1_2	-0.008	0.061	0.245	0.172	0.037	-0.012	-0.017	-0.012	-0.019
IM1_3	-0.010	0.123	0.207	0.142	0.085	-0.014	-0.020	-0.014	-0.022
IM1_4	-0.014	0.010	0.305	0.209	0.080	-0.020	-0.028	-0.020	-0.031
IM1_5	-0.021	-0.027	0.016	0.031	0.323	0.068	-0.041	-0.029	0.078
IM2_1		-0.008	-0.005	-0.007	-0.010	-0.003	-0.005	-0.003	-0.005
IM 2_2			0.119	0.181	0.042	-0.011	0.291	0.205	0.119
IM 2_3				0.135	-0.023	-0.008	0.215	-0.008	-0.012
IM 2_4					0.220	-0.010	0.155	-0.010	0.135
IM 2_5						-0.014	0.104	-0.014	0.200
IM 3_1							-0.007	-0.005	-0.008
IM 3_2								-0.007	0.215
IM3_3									-0.008
IM3_4									
IM3_5									
DR1									
DR2									
DR3									
DR4									
DR5									

Item	IM3_5	DR1	DR2	DR3	DR4	DR5
O_Date	-0.025	0.016	0.019	0.067	0.012	0.050
O_Day	-0.017	0.016	0.037	-0.092	0.012	-0.010
O_Month	0.311	0.039	0.137	0.039	0.061	0.081
O_Time	-0.027	0.124	0.034	-0.045	0.114	0.040
O_Year	-0.008	-0.041	-0.035	-0.041	-0.032	-0.026
C1	0.311	0.039	-0.035	-0.041	0.061	-0.026
C2	-0.034	-0.043	0.014	-0.023	0.065	-0.035
C3	0.052	0.051	-0.033	-0.028	0.007	-0.010
C4	0.078	0.084	0.028	0.049	0.035	0.056
C_Month	0.061	0.020	0.081	0.062	0.063	-0.005
IM1_1	-0.009	0.015	-0.043	-0.050	-0.039	-0.032
IM1_2	-0.019	-0.002	-0.087	-0.068	0.036	-0.064
IM1_3	-0.022	0.084	-0.008	-0.088	0.109	-0.035
IM1_4	0.053	0.023	0.015	-0.061	-0.056	0.008
IM1_5	0.078	0.019	-0.078	0.081	0.061	-0.051
IM2_1	-0.005	-0.029	-0.025	-0.029	-0.022	-0.018
IM 2_2	0.257	0.076	-0.046	-0.028	0.124	0.077
IM 2_3	-0.012	0.087	-0.001	-0.014	0.009	0.095
IM 2_4	0.135	-0.011	-0.034	0.027	0.064	-0.004
IM 2_5	0.312	0.019	-0.044	0.046	0.100	-0.002
IM 3_1	-0.008	0.039	-0.035	-0.041	-0.032	-0.026
IM 3_2	0.215	0.055	0.011	-0.001	0.086	0.191
IM3_3	-0.008	-0.041	-0.035	0.119	-0.032	-0.026
IM3_4	0.190	0.037	-0.056	-0.064	0.184	-0.041
IM3_5		-0.014	-0.001	-0.064	0.067	0.163
DR1			0.251	0.177	0.248	0.208
DR2				0.128	0.198	0.161
DR3					0.101	0.157
DR4						0.304
DR5						

Appendix F

Correlation Matrix for SCAT5

Items	O_Day	O_Month	O_Time	O_Year	C1	C2	C3
O_Date	0.221	0.295	**0.144**	0.248	0.155	**0.048**	**0.117**
O_Day		0.608	0.361	0.524	0.344	**0.089**	**0.057**
O_Month			0.456	0.865	0.574	0.188	**0.066**
O_Time				0.391	0.254	0.194	**0.105**
O_Year					0.495	0.155	0.040
C1						0.155	0.094
C2							0.277
C3							

Items	C4	C_Month	IM1_1	IM1_2	IM1_3	IM1_4	IM1_5	IM1_6	IM1_7
O_Date	**0.082**	**0.059**	**0.080**	**0.012**	**0.040**	**0.018**	**-0.106**	**0.031**	**0.008**
O_Day	**0.049**	**0.076**	**0.114**	**0.030**	**-0.017**	**0.099**	**0.049**	**0.071**	**0.114**
O_Month	**0.074**	**0.113**	0.222	**0.115**	**0.041**	**0.082**	**0.074**	**0.043**	**0.070**
O_Time	**0.079**	**0.092**	**0.123**	**0.021**	**-0.002**	**0.098**	**0.024**	**0.061**	**0.040**
O_Year	**0.034**	**0.087**	0.292	**0.088**	**0.014**	**0.095**	**0.086**	**0.050**	**0.080**
C1	**0.086**	**0.087**	0.186	**0.088**	**0.065**	**0.044**	**0.086**	**0.050**	**0.029**
C2	0.157	**0.108**	**0.041**	**0.061**	**0.078**	**0.037**	**0.045**	**0.054**	**0.008**
C3	0.278	**0.117**	**0.146**	**0.093**	**0.087**	**0.071**	**0.013**	**0.023**	**-0.007**
C4		**0.146**	0.151	0.169	0.150	**0.069**	**-0.051**	**-0.008**	**0.043**
C_Month			**0.050**	**0.020**	**-0.012**	**0.044**	**0.038**	**0.010**	**0.078**
IM1_1				0.333	**0.141**	**0.090**	**-0.042**	**-0.007**	**0.006**
IM1_2					0.278	**-0.002**	**0.033**	**-0.043**	-0.174
IM1_3						**0.103**	**0.004**	**0.061**	**-0.144**
IM1_4							**0.090**	**0.108**	**0.066**
IM1_5								**0.018**	**-0.104**
IM1_6									**0.036**
IM1_7									
IM1_8									
IM1_9									
IM1_10									
IM2_1									
IM2_2									
IM2_3									
IM2_4									
IM2_5									

Items	IM 1_8	IM 1_9	IM 1_10	IM 2_1	IM 2_2	IM 2_3	IM 2_4	IM 2_5	IM 2_6
O_Date	**0.017**	**0.076**	**0.025**	**0.078**	**-0.011**	**0.070**	**0.043**	**-0.050**	**0.018**
O_Day	**-0.087**	**0.055**	**-0.033**	0.216	**0.079**	**0.128**	**0.059**	**0.025**	**-0.009**
O_Month	**0.001**	**0.041**	**0.031**	0.184	**0.116**	**0.086**	**0.068**	**0.071**	**0.024**
O_Time	**-0.007**	**-0.003**	**-0.023**	**0.091**	**-0.014**	**0.019**	**0.050**	**0.026**	**0.015**
O_Year	**0.019**	**0.013**	**0.053**	0.152	**0.089**	**0.061**	**0.042**	**0.045**	**0.044**
C1	**0.072**	**0.064**	**0.103**	0.152	**0.089**	**0.120**	**0.097**	**0.045**	**0.095**
C2	**0.056**	**0.076**	**0.081**	**0.044**	**0.039**	**0.026**	**0.043**	**0.092**	**0.074**
C3	**-0.007**	**0.039**	**0.043**	**0.050**	**0.113**	**0.021**	**0.064**	**0.012**	**0.060**
C4	**0.033**	**0.071**	**0.058**	**0.126**	**0.096**	**0.001**	0.166	0.190	**0.110**
C_Month	**0.090**	**0.134**	**0.097**	**-0.018**	**0.005**	**-0.043**	**0.053**	**0.023**	**0.084**
IM1_1	**-0.019**	**-0.074**	**-0.121**	**0.115**	0.196	**0.128**	0.243	**0.021**	**0.048**
IM1_2	**-0.112**	**-0.089**	-0.164	**0.080**	0.258	**0.132**	0.116	**0.071**	**0.025**
IM1_3	**-0.108**	**-0.118**	-0.231	**0.087**	**0.082**	0.220	0.256	0.172	0.165
IM1_4	**-0.094**	-0.240	-0.189	**0.082**	**0.046**	**0.094**	0.221	**0.142**	0.156
IM1_5	**-0.076**	**-0.115**	**0.037**	**-0.060**	**0.041**	**-0.035**	**-0.023**	**0.145**	**0.141**
IM1_6	**-0.046**	**-0.116**	**-0.113**	**0.081**	**0.038**	**-0.001**	**0.015**	**0.071**	0.197
IM1_7	**0.067**	**-0.014**	**0.060**	**0.015**	**-0.125**	**0.039**	**0.070**	**0.026**	**0.014**
IM1_8		**0.004**	**0.144**	**0.023**	**-0.047**	**-0.043**	**0.028**	**-0.039**	**0.056**
IM1_9			0.286	**-0.025**	**0.011**	**-0.093**	**-0.012**	**0.068**	**0.026**
IM1_10				**-0.021**	**0.004**	**-0.093**	**-0.138**	**0.031**	**0.014**
IM2_1					0.278	0.213	**0.135**	**0.085**	**0.008**
IM2_2						0.184	**0.077**	0.165	**0.032**
IM2_3							**0.107**	**0.007**	**0.035**
IM2_4								**0.082**	**0.045**
IM2_5									**0.131**
IM2_6									

Items	IM 2_7	IM 2_8	IM 2_9	IM 2_10	IM 3_1	IM 3_2	IM 3_3	IM 3_4	IM 3_5
O_Date	**0.099**	**0.051**	**0.092**	**0.075**	**0.033**	**0.001**	**0.052**	**0.008**	**0.076**
O_Day	**0.048**	**-0.057**	**0.104**	**0.017**	0.153	**0.055**	**0.072**	**0.059**	**0.086**
O_Month	**0.095**	**0.039**	**0.071**	**0.128**	0.278	**0.144**	**0.110**	**0.099**	**0.123**
O_Time	**0.071**	**0.049**	**-0.004**	**0.074**	**0.100**	**0.052**	**0.087**	**0.003**	**-0.007**
O_Year	**0.059**	**0.062**	**0.045**	**0.094**	0.236	**0.115**	**0.083**	**0.073**	**0.095**
C1	**0.059**	**0.113**	**0.101**	**0.094**	0.236	0.192	**0.083**	**0.073**	**0.095**
C2	**0.062**	**-0.061**	**0.031**	**0.075**	**0.080**	**0.085**	**0.052**	**0.031**	**0.025**
C3	**0.019**	**-0.019**	**0.107**	**0.037**	**0.053**	0.157	**0.074**	**0.081**	**0.066**
C4	**0.037**	**0.109**	**0.089**	**0.095**	**0.018**	**0.054**	**0.094**	**0.092**	**0.111**
C_Month	**0.112**	**0.057**	**0.067**	**0.086**	**0.075**	**0.009**	**0.007**	**0.077**	**0.040**
IM1_1	**0.043**	**0.007**	**-0.003**	**-0.038**	0.163	**0.097**	0.237	0.183	**0.036**
IM1_2	**0.025**	**-0.031**	**-0.002**	**-0.053**	**0.110**	0.174	0.202	**0.048**	**0.098**
IM1_3	**0.027**	**0.008**	**-0.142**	**-0.116**	0.157	**0.059**	**0.104**	**0.145**	**0.101**
IM1_4	**0.079**	**0.096**	**-0.080**	-0.163	**0.064**	**0.030**	**0.036**	0.155	**0.042**
IM1_5	**-0.045**	**0.026**	**-0.069**	**-0.004**	**-0.034**	**0.070**	**-0.065**	**0.079**	**0.027**
IM1_6	**0.035**	**0.074**	**-0.026**	**0.012**	**0.070**	**0.052**	**0.004**	**-0.028**	**-0.031**
IM1_7	0.251	**0.033**	**0.061**	**-0.024**	**0.032**	**-0.032**	**0.052**	**0.048**	**0.057**
IM1_8	**0.026**	0.287	0.172	**0.135**	**-0.016**	**0.010**	**0.061**	**0.037**	**0.015**
IM1_9	**-0.039**	**0.035**	0.213	0.188	**0.001**	**0.041**	**-0.044**	**0.029**	**0.056**
IM1_10	**0.067**	0.153	0.220	0.374	**0.030**	**0.001**	**-0.042**	**0.024**	**0.093**
IM2_1	**-0.039**	**0.061**	**-0.016**	**-0.089**	0.263	**0.025**	0.331	**0.116**	**0.121**
IM2_2	**-0.145**	**0.002**	**-0.012**	**-0.107**	**0.078**	0.301	0.241	0.151	0.194
IM2_3	-0.166	**-0.069**	**0.020**	**-0.097**	**0.003**	**0.055**	0.268	**0.147**	**0.129**
IM2_4	**-0.010**	**-0.026**	**-0.110**	-0.152	**0.113**	**0.147**	0.153	0.279	**0.118**
IM2_5	**0.060**	**0.010**	**-0.129**	**0.008**	**0.035**	**0.126**	**0.024**	**0.133**	0.330
IM2_6	**0.028**	**0.096**	**-0.002**	**0.000**	**0.064**	**-0.032**	**-0.004**	**0.068**	**0.042**
IM2_7		**0.044**	**0.038**	**0.003**	**0.069**	**0.024**	**0.013**	**0.080**	**0.106**
IM2_8			0.188	0.184	**0.023**	**0.033**	**0.039**	**0.056**	**0.033**
IM2_9				0.246	**0.035**	**0.008**	**-0.005**	**-0.100**	**-0.036**
IM2_10					**-0.003**	**-0.010**	**-0.056**	**0.011**	**0.048**
IM3_1						**0.117**	**0.103**	**0.053**	**0.017**
IM3_2							**0.121**	**0.016**	0.154
IM3_3								**0.130**	**0.121**
IM3_4									0.174
IM3_5									
IM3_6									

Items	IM 3_6	IM 3_7	IM 3_8	IM 3_9	IM 3_10	DR1	DR2	DR3
O_Date	**0.059**	**0.046**	**-0.006**	**0.113**	**0.054**	**0.093**	**-0.005**	**0.096**
O_Day	**0.065**	**0.100**	**-0.022**	**0.044**	**0.015**	**0.082**	**0.008**	**0.106**
O_Month	**0.047**	**0.069**	**0.065**	**0.086**	**0.099**	**0.118**	**0.092**	**0.072**
O_Time	**0.010**	**0.052**	**0.044**	**0.019**	**0.071**	**-0.011**	**0.060**	**0.058**
O_Year	**0.020**	**0.043**	**0.039**	**0.061**	**0.135**	**0.092**	**0.066**	**0.047**
C1	**0.020**	**0.098**	**0.147**	0.179	**0.135**	**0.092**	**0.127**	**0.102**
C2	**0.002**	**0.086**	**0.014**	**0.113**	**0.100**	**0.068**	**-0.005**	**0.034**
C3	**0.052**	**0.048**	**0.021**	**0.059**	**-0.013**	**0.124**	**0.102**	**0.067**
C4	**0.109**	**0.113**	**0.067**	**0.025**	**0.079**	**0.113**	0.162	**0.057**
C_Month	**0.071**	**0.102**	**0.026**	**0.097**	**0.060**	**0.066**	**0.071**	**0.028**
IM1_1	**-0.014**	**0.062**	**0.097**	**-0.021**	**-0.026**	**0.059**	**0.091**	**0.094**
IM1_2	**0.104**	**0.005**	**0.016**	**-0.086**	**-0.085**	**0.087**	**0.091**	**0.018**
IM1_3	0.189	**0.045**	**0.131**	**0.017**	-0.170	**0.095**	**0.055**	**-0.020**
IM1_4	**0.139**	**0.113**	**0.070**	**0.011**	**-0.070**	**0.088**	**0.081**	**0.110**
IM1_5	**0.025**	**0.013**	**0.143**	**-0.035**	**-0.022**	**-0.053**	**0.027**	**0.046**
IM1_6	0.161	**0.106**	**0.056**	**0.014**	**-0.044**	**0.049**	**0.100**	**0.080**
IM1_7	**0.091**	0.198	**0.047**	**0.051**	**0.074**	**0.045**	**0.018**	**0.041**
IM1_8	**0.010**	**-0.050**	**0.047**	**0.132**	**0.129**	**0.102**	**-0.010**	**-0.059**
IM1_9	**0.008**	**0.019**	**0.008**	**0.098**	0.205	**-0.032**	**0.052**	**-0.012**
IM1_10	**0.014**	**0.015**	**0.043**	**0.072**	0.349	**0.031**	**-0.018**	**-0.002**
IM2_1	**0.107**	**0.099**	**0.066**	**0.000**	**0.071**	**0.113**	**0.078**	0.189
IM2_2	0.165	**-0.020**	**-0.008**	**-0.004**	**-0.032**	**0.054**	**0.144**	**0.096**
IM2_3	0.209	**0.062**	**0.065**	**-0.018**	**-0.043**	**0.003**	**0.076**	0.183
IM2_4	**0.144**	**0.130**	**0.056**	**-0.008**	**-0.058**	0.176	0.164	**0.078**
IM2_5	0.180	0.210	**0.064**	**0.020**	**-0.018**	**0.086**	**-0.005**	**0.024**
IM2_6	0.274	**0.113**	0.201	**0.106**	**0.055**	**0.074**	**0.069**	**0.010**
IM2_7	**0.105**	0.332	**-0.002**	0.154	**0.106**	**0.058**	**-0.034**	**0.026**
IM2_8	**0.043**	**0.017**	0.332	0.145	0.194	0.152	**0.114**	**0.098**
IM2_9	**0.033**	**0.078**	0.218	0.369	0.283	**0.011**	**0.075**	**-0.001**
IM2_10	**-0.008**	**0.020**	0.134	**0.131**	0.359	**0.077**	**0.060**	**-0.020**
IM3_1	**0.041**	**0.032**	**0.024**	**0.033**	**0.053**	0.359	**0.074**	**0.066**
IM3_2	**0.145**	**-0.031**	**-0.012**	**0.020**	**-0.098**	**0.102**	0.349	**0.046**
IM3_3	**0.040**	**0.045**	**-0.030**	**-0.023**	**-0.048**	**-0.033**	**0.028**	0.448
IM3_4	**0.089**	**0.137**	**-0.005**	**-0.115**	**-0.047**	**0.110**	**0.023**	**0.070**
IM3_5	0.157	**0.078**	**-0.059**	**0.015**	**0.054**	**0.090**	**-0.033**	**0.076**
IM3_6		**0.131**	**0.021**	**0.040**	**-0.038**	0.151	0.175	**0.110**
IM3_7			0.158	**0.101**	**0.083**	0.167	**0.052**	**0.134**
IM3_8				**0.141**	0.169	**0.045**	**0.135**	**0.036**
IM3_9					0.263	**0.019**	**0.048**	**0.092**
IM3_10						**0.059**	**0.038**	**0.029**

Items	DR4	DR5	DR6	DR7	DR8	DR9	DR10
O_Date	**0.060**	**0.004**	**0.014**	**0.082**	**-0.001**	**0.061**	**0.058**
O_Day	**0.039**	**0.112**	**0.079**	**0.094**	**0.008**	**0.083**	**0.111**
O_Month	**0.082**	**0.076**	**0.033**	**0.043**	**0.034**	**0.036**	**0.113**
O_Time	**0.013**	**-0.026**	**-0.018**	**0.057**	**0.039**	**-0.012**	**0.021**
O_Year	**0.057**	**0.051**	**0.056**	**0.015**	**0.006**	**0.008**	**0.131**
C1	**0.115**	**0.107**	**0.056**	**0.066**	**0.107**	**0.109**	**0.078**
C2	**0.039**	**0.024**	**0.070**	**0.139**	**0.036**	**0.098**	0.154
C3	**0.138**	**0.067**	**-0.038**	**0.053**	**0.023**	**0.070**	**0.081**
C4	**0.132**	**0.144**	**0.057**	**0.116**	**0.038**	**0.031**	**0.094**
C_Month	**0.051**	**0.104**	**0.042**	**0.009**	**0.114**	**0.123**	**0.126**
IM1_1	0.191	0.151	**0.033**	**0.017**	**0.015**	**0.041**	**0.000**
IM1_2	**0.056**	**0.049**	**0.103**	**0.055**	**0.000**	**-0.018**	**-0.007**
IM1_3	0.191	**0.124**	**0.129**	0.158	**0.087**	**0.033**	**-0.064**
IM1_4	**0.097**	**0.103**	0.163	**0.099**	**0.082**	**-0.008**	**0.024**
IM1_5	**0.038**	**-0.017**	**0.077**	**0.012**	0.192	**-0.031**	**0.072**
IM1_6	**-0.001**	**0.007**	0.154	**0.131**	**0.073**	**0.050**	**0.056**
IM1_7	**0.013**	**0.061**	**0.092**	0.200	**0.042**	**-0.026**	**-0.007**
IM1_8	**-0.021**	**0.024**	**0.040**	**0.022**	**0.044**	**0.115**	**0.080**
IM1_9	**0.070**	**0.040**	**0.012**	**-0.043**	**0.051**	**0.100**	**0.016**
IM1_10	**0.042**	**0.110**	**0.042**	**-0.052**	**0.082**	**0.001**	0.248
IM2_1	0.159	**0.121**	**0.024**	**0.147**	**0.008**	**-0.077**	**-0.007**
IM2_2	**0.137**	**0.113**	**0.110**	**0.007**	**0.114**	**0.056**	**0.026**
IM2_3	**0.128**	**0.086**	0.181	**0.062**	**0.057**	**-0.003**	**-0.012**
IM2_4	0.324	**0.127**	**0.109**	**0.112**	**0.028**	**0.097**	**0.071**
IM2_5	**0.115**	0.269	0.226	**0.126**	**0.099**	**-0.032**	**-0.021**
IM2_6	**0.097**	**0.001**	0.244	**0.120**	**0.123**	**0.013**	**0.119**
IM2_7	**-0.038**	**0.103**	**-0.012**	**0.195**	**-0.013**	**-0.014**	**0.075**
IM2_8	**0.000**	**0.073**	**0.084**	**0.032**	0.318	**0.071**	**0.148**
IM2_9	**-0.024**	**0.034**	**0.037**	**0.059**	**0.154**	0.279	**0.139**
IM2_10	**0.022**	**0.100**	**-0.011**	**-0.039**	**0.105**	**0.097**	0.278
IM3_1	**0.027**	**-0.012**	**-0.042**	**0.135**	**0.038**	**0.042**	**0.053**
IM3_2	**-0.009**	**0.111**	**0.118**	**-0.013**	**0.045**	**0.037**	**0.010**
IM3_3	**0.129**	**0.075**	**0.010**	**0.032**	**-0.064**	**-0.029**	**0.027**
IM3_4	0.544	**0.145**	**0.025**	**0.103**	**0.067**	**-0.047**	**0.081**
IM3_5	**0.146**	0.465	**0.077**	**0.051**	**0.025**	**-0.064**	**0.097**
IM3_6	**0.111**	**0.105**	0.582	**0.108**	**0.115**	**0.028**	**0.015**
IM3_7	**0.130**	**0.072**	0.142	0.456	0.160	**0.107**	**0.137**
IM3_8	**0.069**	**0.036**	**0.093**	**0.120**	0.480	**0.038**	**0.072**
IM3_9	**-0.021**	**0.099**	**0.098**	**0.145**	**0.128**	0.376	**0.147**
IM3_10	**0.058**	**0.047**	**-0.038**	**0.014**	0.155	0.178	0.519

Items	DR2	DR3	DR4	DR5	DR6	DR7	DR8	DR9	DR10
DR1	0.284	**0.121**	**0.053**	0.169	**0.124**	**0.143**	**0.115**	**0.124**	**0.108**
DR2		**0.081**	**0.073**	**0.047**	0.153	**0.039**	**0.123**	**0.134**	**-0.017**
DR3			0.161	**0.091**	0.148	**0.046**	**0.032**	**0.000**	**0.057**
DR4				**0.119**	**0.069**	**0.083**	**0.063**	**-0.041**	**0.122**
DR5					0.160	**0.042**	**0.087**	**-0.014**	**0.037**
DR6						**0.144**	**0.106**	**0.004**	**-0.036**
DR7							0.204	**0.037**	**0.053**
DR8								**0.095**	0.160
DR9									0.187
DR10									

Appendix G

SCAT3 Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Com.	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %
1	2.575	8.584	8.584	2.575	8.584	8.584	2.003	6.678	6.678
2	1.882	6.274	14.857	1.882	6.274	14.857	1.832	6.105	12.783
3	1.767	5.891	20.748	1.767	5.891	20.748	1.717	5.722	18.505
4	1.656	5.521	26.269	1.656	5.521	26.269	1.535	5.116	23.621
5	1.439	4.797	31.066	1.439	4.797	31.066	1.509	5.029	28.650
6	1.325	4.418	35.484	1.325	4.418	35.484	1.434	4.781	33.431
7	1.254	4.179	39.663	1.254	4.179	39.663	1.388	4.627	38.057
8	1.200	3.999	43.662	1.200	3.999	43.662	1.247	4.157	42.215
9	1.179	3.929	47.591	1.179	3.929	47.591	1.235	4.116	46.330
10	1.113	3.710	51.301	1.113	3.710	51.301	1.232	4.107	50.437
11	1.080	3.599	54.899	1.080	3.599	54.899	1.222	4.073	54.510
12	1.054	3.513	58.412	1.054	3.513	58.412	1.115	3.717	58.227
13	1.007	3.356	61.768	1.007	3.356	61.768	1.062	3.541	61.768
14	0.976	3.253	65.021						
15	0.930	3.100	68.120						
16	0.880	2.932	71.052						
17	0.857	2.858	73.910						
18	0.828	2.761	76.671						
19	0.778	2.592	79.263						
20	0.734	2.446	81.708						
21	0.726	2.420	84.128						
22	0.671	2.237	86.365						
23	0.645	2.149	88.515						
24	0.596	1.986	90.501						

Extraction Method: Principal Component Analysis.

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Com.	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %
25	0.565	1.884	92.385						
26	0.537	1.791	94.176						
27	0.515	1.716	95.892						
28	0.463	1.544	97.436						
29	0.392	1.306	98.742						
30	0.377	1.258	100.000						

Extraction Method: Principal Component Analysis.

Appendix H

SCAT5 Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Com.	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %
1	4.895	9.789	9.789	4.895	9.789	9.789	3.306	6.611	6.611
2	3.327	6.654	16.444	3.327	6.654	16.444	2.189	4.377	10.988
3	2.716	5.431	21.875	2.716	5.431	21.875	2.041	4.081	15.07
4	2.055	4.11	25.985	2.055	4.11	25.985	2.038	4.076	19.146
5	1.898	3.796	29.782	1.898	3.796	29.782	2.002	4.004	23.15
6	1.736	3.471	33.253	1.736	3.471	33.253	1.928	3.856	27.006
7	1.656	3.311	36.564	1.656	3.311	36.564	1.879	3.757	30.763
8	1.63	3.261	39.825	1.63	3.261	39.825	1.735	3.47	34.233
9	1.421	2.841	42.666	1.421	2.841	42.666	1.717	3.434	37.668
10	1.357	2.714	45.38	1.357	2.714	45.38	1.689	3.378	41.046
11	1.308	2.616	47.996	1.308	2.616	47.996	1.617	3.234	44.28
12	1.256	2.512	50.508	1.256	2.512	50.508	1.616	3.232	47.512
13	1.229	2.458	52.966	1.229	2.458	52.966	1.564	3.128	50.64
14	1.223	2.447	55.413	1.223	2.447	55.413	1.542	3.084	53.724
15	1.117	2.233	57.646	1.117	2.233	57.646	1.398	2.797	56.521
16	1.078	2.156	59.802	1.078	2.156	59.802	1.346	2.692	59.213
17	1.01	2.019	61.822	1.01	2.019	61.822	1.305	2.609	61.822
18	0.98	1.96	63.781						
19	0.968	1.936	65.717						
20	0.939	1.879	67.596						
21	0.906	1.812	69.408						
22	0.886	1.772	71.18						
23	0.862	1.725	72.904						
24	0.793	1.586	74.49						
25	0.783	1.565	76.055						
26	0.72	1.44	77.495						
27	0.705	1.411	78.906						
28	0.682	1.364	80.27						
29	0.665	1.33	81.6						
30	0.656	1.312	82.912						
31	0.633	1.266	84.178						
32	0.611	1.222	85.4						
33	0.587	1.174	86.574						

Extraction Method: Principal Component Analysis.

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Com.	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %
34	0.559	1.119	87.693						
35	0.531	1.062	88.755						
36	0.52	1.039	89.794						
37	0.5	1	90.795						
38	0.477	0.954	91.749						
39	0.472	0.944	92.692						
40	0.445	0.889	93.582						
41	0.413	0.826	94.408						
42	0.399	0.797	95.205						
43	0.377	0.753	95.958						
44	0.354	0.707	96.666						
45	0.34	0.679	97.345						
46	0.324	0.648	97.993						
47	0.323	0.646	98.639						
48	0.305	0.61	99.249						
49	0.272	0.544	99.794						
50	0.103	0.206	100						

Extraction Method: Principal Component Analysis.

Appendix I

Pattern Matrix for SCAT3

Item ($N = 30$)	Factors			
	F1	F2	F3	F4
C1	0.688			
IM3_5	0.643			
IM3_2	0.603			
IM3_4	0.572			
IM2_2	0.495			
IM2_5	0.461			
IM2_4	0.402			
O_Date				
IM3_3				
DR1		0.628		
DR5		0.611		
DR2		0.594		
DR4		0.575		
DR3		0.429		
O_Month		0.259		
O_Time		0.208		
O_Year				
IM2_3			0.637	
IM1_2			0.628	
IM1_3			0.595	
IM1_4			0.561	
O_Day			0.237	
IM1_5			0.212	
C3				0.785
C4				0.643
C2				0.585
C_Months				0.353
IM3_1				
IM1_1				
IM2_1				

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization

Appendix J

Pattern Matrix for SCAT5

Item ($N = 30$)	Factors			
	F1	F2	F3	F4
IM2_2	0.552			
DR4	0.513			
IM3_4	0.481			
IM3_3	0.474			
IM2_4	0.467			
IM3_5	0.464			
DR5	0.432			
IM1_2	0.432			
IM1_1	0.429			
IM2_1	0.414			
IM1_3	0.401			
IM2_3	0.394			
C4	0.380			
IM3_2	0.375			
IM2_5	0.352			
DR3	0.323			
C3	0.296			
DR2	0.286			
IM3_10		0.679		
IM1_10		0.610		
IM2_10		0.607		
IM2_9		0.566		
DR10		0.514		
IM3_9		0.451		
IM2_8		0.427		
IM1_9		0.425		
IM1_8		0.353		
DR9		0.349		
C_Months		0.251		

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
Factor loadings < 0.2 were suppressed.

Item ($N = 30$)	Factors			
	F1	F2	F3	F4
O_Month			-0.902	
O_Year			-0.849	
O_Day			-0.714	
C1			-0.641	
O_Time			-0.593	
O_Date			-0.376	
IM3_1			-0.373	
C2			-0.262	
DR7				-0.564
IM3_7				-0.562
DR6				-0.499
IM3_6				-0.478
IM2_6				-0.460
DR8				-0.438
IM1_4				-0.427
IM3_8				-0.413
IM1_6				-0.383
IM2_7				-0.336
IM1_7				-0.311
DR1				-0.294
IM1_5				

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
Factor loadings < 0.2 were suppressed.