Concussion Reporting Rates at the Conclusion of a Collegiate Athletic Career

Frances C. Gilbert
Georgia Southern University

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CONCUSSION REPORTING RATES AT THE CONCLUSION OF A COLLEGIATE ATHLETIC CAREER

by

FRANCES GILBERT

(Under the Direction of Thomas Buckley)

ABSTRACT

Context: Concussions are common sports-related head injuries, with an estimated 1.6-3.8 million sport-related traumatic brain injuries occurring each year. Proper diagnosis of a concussion often lies in self-reporting symptoms, however, an estimated 50-80% of concussions remain unreported. More than half of college athletes indicate they have no head injury knowledge including potential consequences, however, more than 80% would have reported a head injury if they had understood the potential risks. This lack of knowledge may create the potential for unrecognized concussive injury, therefore causing vast underreporting. Objective: The purpose of this study is to evaluate the current reported rates, unreported rates, and potentially unrecognized rates of concussions in collegiate athletes who have recently completed their athletic career. Design: Cross-sectional, retrospective study. Setting: Questionnaire was conducted in a private location as available at host institutions’ athletic training facilities. Participants: We recruited 133 collegiate student-athletes (64.7% female; age: 20.92±1.41; 3.04±1.39 years of collegiate athletic experience), who had completed their collegiate athletic career within the previous six months, and had no intention of playing at a professional level, from thirteen colleges and universities of varying athletic division levels. Intervention: Participants were administered a twenty-one item injury history questionnaire, either
online or hardcopy. Six of the twenty-one items pertain specifically to concussions, with the remainder acting as distractors. Test-retest reliability =0.92. **Main Outcome**

**Measures:** The dependent variables include reported concussion rates, unreported rates, and potentially unrecognized rates of concussion. Reported and unreported rates were based on self-reported numbers, while the potentially unrecognized rates were determined by reported potential concussive symptoms. All variables were analyzed with descriptive statistics. Chi-square was used to analyze lower extremity injury and potential concussive injury. **Results:** Of all participants, 34.1% (45/132) reported suffering a concussion during their collegiate career. The acknowledged unreported rate was 12.8% (17/133), with the primary reasons for not reporting concussion being that the athlete did not want to be pulled from games or practices, or future games or practices. The potentially unrecognized concussion rate was 18.8% (25/133) with the most common symptom being “knocked silly” or “seeing stars”. Overall, 42.9% (57/133) of participants acknowledged at least one of the three primary dependent variables. Athletes who reported an acute lower extremity injury were 2.0 times more likely to have a potential concussive injury. **Conclusion:** The results of this study suggest that there is still a lack of concussion reporting and potential lack of recognition in collegiate athletics. This study emphasizes the need for continued education of athletes and coaches, and well as the necessity of suspicion and awareness by athletic trainers to improve athlete reporting.

**INDEX WORDS:** Concussion, Reporting rates, College athletes
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FRANCES GILBERT

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FRANCES GILBERT

Major Professor: Thomas A. Buckley
Committee: A. Barry Joyner
G. Trey Burdette

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CHAPTER 1
INTRODUCTION

Concussions are common sports-related head injuries caused by a direct or indirect blow to the head, initiating a complex pathophysiological process that affects the brain.\(^1\) An estimated 1.6-3.8 million sport-related mild traumatic brain injuries occur each year, however, this number only accounts for those concussions that are recognized.\(^2\) It is estimated that concussions account for 5-6% of all reported collegiate injuries, yet approximately 50-80% of concussive injury cases may remain unreported.\(^3-7\) If left unrecognized or improperly cared for, the effects of concussions can outlast the short-term, transitory symptoms, potentially causing lifelong consequences, particularly if subsequent concussions occur.\(^8-13\) Outwardly visible signs commonly associated with concussion are rare, making self-report of symptoms imperative.\(^14\) This emphasizes the necessity for injury recognition and concussion awareness amongst athletes, parents, coaches and healthcare providers alike, which may improve overall reporting rates.\(^15-18\)

Most published unreported rates are from the early 2000’s, prompting a need to evaluate the current reporting and recognition rates of concussion and the reasons as to why they may not be reported.\(^3,17\)

Since obvious concussive signs are relatively uncommon, the primary means for identifying concussive injury involves self-reported symptoms.\(^14\) Two of the most commonly associated signs of concussion are loss of consciousness (LOC), which only occurs in 5-8% of incidences, and post-traumatic amnesia (PTA), which happens in fewer than 30% of cases, allowing athletes to potentially hide or not recognize potential injuries, leading to a large underreporting of concussions.\(^3,14,19,20\) The importance of reporting a concussion lies in being able to seek out appropriate medical intervention for the injury. Once an initial injury occurs,
there is a window of vulnerability of at least seven to ten days in which an athlete may have continued impairments in lingering symptoms, cognition, and postural stability, in addition to being more susceptible to sustaining a subsequent concussive injury.\textsuperscript{9, 21} By sustaining multiple concussive injuries, specifically three or more, there is evidence of a dose response, in which an athlete would be three to six times more likely to suffer another concussion with LOC, PTA, confusion, or an altered mental state.\textsuperscript{8-10} After concussive injury, there appears to be a decrease in reaction time and processing speed, or visual spatial disorientation, which may disrupt neuromuscular functions.\textsuperscript{22} This disruption theoretically may predispose an athlete to further injury, and has been suggested that within ninety days of concussion, an athlete is almost four times more likely to suffer a lower extremity muscle or ligament injury.\textsuperscript{23} Multiple concussions have also been linked to depression, Alzheimer’s disease, long term mild cognitive impairments, and late-life memory impairments, emphasizing the long term deficiencies that may result.\textsuperscript{24-28}

Concussions alone make up a significant portion of collegiate athletic injuries. In epidemiological studies involving fifteen collegiate sports, approximately 5-6% of all collegiate injuries in a year are concussions, and they affect approximately 4-5% of all collegiate football players each year.\textsuperscript{6, 7, 19} A limitation to evaluating self-reported concussion history is that it is only moderately reliable: two separate studies both found 62% of individuals accurately reported concussion history, and one noted that players were just as likely to over-report as they were to underreport a concussion.\textsuperscript{29, 30} Gender may also play a role in concussion reporting as multiple studies suggest that females have a higher incidence of concussion rate in sports both genders played, however several factors may contribute to this data. Females may be predisposed biomechanically due to weaker neck musculature, or smaller head to body ratios, such as a smaller head compared to soccer ball size.\textsuperscript{31} Additionally, cultural reasoning may lead to
improved reporting, due to females increased likelihood to be honest, reduced social pressure to play injured as compared to male athletes, and the societal thought that parents and coaches may be more protective of female athletes.\textsuperscript{32,33} However, current incidence rates could be underestimated due to underreporting.

During a high school or college football season, approximately 50-80\% of concussions may go unreported, leading researchers to believe that previous incidence rates may be underestimating, and that the actual incidence may be closer to 15\%.\textsuperscript{3,5,34} The responses as to why the suspected concussions were not reported included identify pressure to play and lack of knowledge as the greatest factors of underreporting, with athletes specifying the four most common reasons as they did not think it was serious enough, did not think it was a concussion, did not want to leave the game, or did not want to let down a teammate.\textsuperscript{3} By addressing the lack of knowledge concerning signs, symptoms, and consequences of concussion, 83\% of athletes have said they would have reported a concussion if they had understood.\textsuperscript{17,34} However, it is well understood that social demands and pressures will also play a role in concussion reporting.\textsuperscript{3,4,17,35} Despite athletes knowing signs and symptoms, and understanding the dangers of playing with concussion, when faced with concussive scenarios all reported they would continue to play, either immediately or with a short break.\textsuperscript{36} They would hesitate to report any symptoms to their coach if they were not severe or debilitating, potentially marking coach approachability as an additional underreporting rationale.\textsuperscript{36} The lack of concussion reporting has individual reasoning and potentially lies largely upon concussion knowledge of individuals involved in healthcare decisions.

In addition to societal pressures, there is a potential lack of knowledge and understanding of concussions that may reduce an individual’s ability to report a concussive injury. When
reviewing a concussive symptom survey in comparison to a pre-participation screening, approximately half of all athletes reported having one or more symptoms of a concussion after a head injury, however 83-93% report no concussion history, suggesting a large number of potentially unrecognized injuries.\textsuperscript{37, 38} Approximately 20% of collegiate athletes have reported a prior history of concussion, while 30% have claimed to have dizziness following a direct blow to the head.\textsuperscript{17} This leaves one-third of concussive blows unaccounted for and undiagnosed. Additionally, 66-73% of high school and college football athletes that acknowledge an unreported concussion, did not think their head injury was serious enough.\textsuperscript{3, 5} However, an increased knowledge of concussions has been seen to have a significant association with increased likelihood to report concussive injury, yet less than 50% of athletes report having any knowledge of head injuries.\textsuperscript{17, 19, 35, 39, 40} Register-Mihalik et al report that while intention to report did not predict actual reporting behavior, those athletes continued play with symptoms less often.\textsuperscript{41} Some research argues that knowledge is not the issue, but that coach approachability adds a barrier in reporting of concussion signs and symptoms.\textsuperscript{36, 40} This adds support to educating not only athletes, but coaches as well to improve communication and provide an open environment for athletes to report concussive injuries.\textsuperscript{36, 40}

In addition to the common risks we associate with concussions and lack of recognition and reporting, potential risk for lower extremity injury has also become a topic of interest. Studies have seen that decreased reaction times, processing speeds, and visual acuity on the ImPACT test may be linked to increased non-contact ACL injuries, and that decreased balance test performance may also be associated with risks for non-contact lower extremity injury.\textsuperscript{22, 42} One abstract has suggested a nearly four times greater risk for a musculoskeletal lower extremity injury within ninety days of suffering a concussion, propelling this topic into consideration.\textsuperscript{23}
Though studies have suggested this connection between concussions and lower extremity injury, no data has yet been published on a direct link.

This is a follow-up study, with preliminary data collected between 2011 and 2012. The previous study involved 161 participants, involving seventeen different sports from ten different institutions over a span of four collegiate athletic divisions. The main outcome measures of this study were a reported concussion rate of 33.5%, an unreported rate of 11.8%, and a potentially unrecognized rate of 18.8%. Overall, 49.7% of respondents acknowledged at least one of these concussive variables. This study is repeating these previous measures to expand upon previous numbers, and additionally determine any potential relationship between lower extremity injury and concussive injury.

The majority of sports-related concussions remain unreported primarily due to a lack of knowledge and recognition or social pressures to play. By examining athletes at the end of their career, the pressure to compete has been removed, so we anticipate data collected would be more honest. The purpose of this study is to assess the underreporting of concussions in athletes at the end of their collegiate careers. Research questions for this study included 1) how many concussions were reported throughout an athlete’s career, 2) how many concussions were unreported and the reasoning behind failure to report, and 3) how many concussions go potentially unrecognized as an injury requiring medical attention during a collegiate career? The secondary purpose is to look at any existing relationships between concussions and acute lower extremity injury.
CHAPTER 2

METHODS

Participants

We recruited 133 student-athletes who recently completed their intercollegiate athletic career as participants for our study. (Appendix D, Table 1) Individuals were recruited from thirteen colleges and universities of various athletic division levels. Inclusion criteria included having completed an intercollegiate athletic career within six months, either by resignation from the team or exhausting eligibility, and indicating no intention of playing at a professional level. The six month time frame allowed data collection to include athletes that decided to finish their careers while on a school or athletic break. Exclusion criteria was any athlete who had not completed their athletic careers, or intended to play at a higher level. All participants provided written informed consent as approved by each institution’s Institutional Review Board (IRB).

Instrumentation

We used a twenty-one item questionnaire regarding collegiate athletic injuries, created by Llewellyn in an initial study involving 161 subjects. These questions asked for a variety of experiences involving many types of athletic injuries that may have occurred throughout a collegiate athletic career. Of these questions, six pertain to concussions that helped to identify concussion reporting rates, unreported rates, unrecognized concussion rates, and the reasoning behind why an athlete may fail to report a concussive injury. Other additional orthopedic questions acted as distractor questions, however, only those involving concussions and lower extremity injuries were analyzed at this time. The questionnaire will be available in hard copy paper format, as well as online through Qualtrics (Provo, Utah, USA.). Test-retest reliability for this instrument was excellent (0.92), and face validity was established with experts in the field.
Procedures

Recruitment for participating schools occurred between spring 2013 and spring 2014 with a designated contact person at each location. Once an institution had committed to participation, they were contacted to determine the most convenient format of questionnaire for their program. Additionally, permission to conduct this research was acquired through each institution’s Institutional Review Board (IRB). Participants were to be recruited verbally at the end of their career on a voluntarily basis by their team athletic trainers. The questionnaire were administered during medical exit screening or appointment set by the athletic trainer, and completed on pen and paper or through the Qualtrics internet survey website. The pen and paper copy began with the administering athletic trainer reading a script including directions for the questionnaire, followed by an informed consent form per the institution’s IRB. (Appendix C) If the participant agreed to participate, they completed the questionnaire in privacy, preferably in a secluded office or classroom. Once completed, the participant placed the questionnaire in an envelope, sealed the envelope, and wrote “complete” across the seal. Once questionnaires for an institution were completed, they were mailed or returned to the primary investigator. At no point was a sealed questionnaire opened until it was in the possession of the primary investigator. If an institution chose the Qualtrics version of the questionnaire, a link to the questionnaire was emailed to the contact person to distribute to their athletic training staff as needed. When administering the online version, a script was to be read prior to opening the link, again describing and providing direction for the questionnaire. The initial screen provided informed consent, and if agreed, progressed into the twenty-one items. Once the questionnaire was completed and submitted,
answers were recorded into Qualtrics. The survey took approximately five minutes to complete in either format.

Data Analysis

This study was retrospective and cross-sectional in nature. Independent variables for this study were gender, age, sport, years of experience in collegiate athletics, and athletic division level, as well as lower extremity injury. Dependent variables were concussion reporting rates, unreported rates, and unrecognized rates. Reporting rates were assessed by using only the concussion related questions found in the questionnaire. (Appendix C) Concussions reported were assessed by question #4, unreported concussions were evaluated by question #5, and unrecognized rates were examined through questions #10, 12, 20. Question # 18, asked if following a blow to the head, would the athlete report potential concussive symptoms to his or her athletic trainer, and was evaluated with descriptive analysis to determine intent to report. Lower extremity injury rate was determined from dichotomous responses to question #1 concerning ankle sprains, question #2 regarding acute knee injury, and question #11 about muscle strains during career.

Statistical Analysis

A descriptive analysis was used to analyze the dependent variables of reported concussion rates, unreported concussion rates, and potentially unrecognized concussion rates. Chi-square analyses were used to explore associations between the dependent variables and independent variables. Specifically, chi-square analyses were used with gender and all dependent variables, as well as between acute lower extremity injury and reported concussive rate, and acute lower extremity injury and overall potential concussive injury. The alpha level was set at .05.
CHAPTER 3

RESULTS

Demographics

The respondents represented twelve different sports, over three athletic divisions. (Appendix D, Figure 1 and Figure 2) Responses were 64.7% female, with an average age of 20.9 ±1.4, and mean years of participation being 3.0 ± 1.4. (Appendix D; Table 1 and Figure 1) The response type was comprised of 72.9% (97/133) pen and paper.

Self-Reported Concussion Rate

The overall collegiate self-reported concussion rate was 34.1% (45/132). From the 45 participants reporting a concussion, 62.2% (28/45) were female, 66.7% (30/45) were from NCAA Division I, and were represented primarily by soccer (35.6%, 16/45) and football (22.2%, 10/45). Of those reporting a previous concussion, 60.0% (27/45) reported only having had one concussion, while 28.9% (13/45) reported two concussive injuries, and 11.1% reporting three or more. There was no statistical difference for reported rate based on gender (χ² (1)= .140; p=.708).

Unreported Concussion Rate

The acknowledged unreported concussion rate during a collegiate career was 12.8% (17/133). Of the seventeen participants acknowledging an unreported concussion, 58.8% (10/17) were female, and 64.7% (11/17) were NCAA Division I. Soccer was the largest response group, encompassing 41.2% (7/17) of unreported concussions, followed by football at 23.5% (4/17). The most common reasons for not reporting a concussion were 1) not wanting to be pulled from a game or practice (76.5%, 13/17), 2) not wanting to be pulled from future games or practices (76.5%, 13/17), 3) they did not think it was serious (52.9%, 9/17), and 4) they did not want to let their teammates down (52.9%, 9/17). These responses were not mutually exclusive and
respondents could select all answers that applied. There was no statistical difference for unreported rate based on gender ($\chi^2 (1) = .291; p=.590$).

**Potentially Unrecognized Concussion Rates**

The potentially unrecognized concussive injury rate was 18.8% (25/133), indicating twenty-five participants noted having one or more of the potential concussive symptoms (Question #10 knocked out, Question #12 knocked silly/seen stars, or Question #20 lost memory while playing sports) without diagnosis of a concussion. Female and males reported potentially unrecognized concussions fairly evenly, with females only slightly higher (52.0%, 13/25), with the most common sports being soccer (36.0%, 9/25) and cheerleading (28.0%, 7/25). Being “knocked silly/seeing stars” was the most common potentially unrecognized concussive symptom of the three responses, reported by 92.0% (23/25) of those recalling a potentially unrecognized symptom. There was no statistical difference for potentially unrecognized concussion rate based on gender ($\chi^2 (1) = 2.160; p=.142$).

**Combined Rates**

Participants that selected “yes” to at least one of the questions regarding reported rate, unreported rate, and any potentially unrecognized concussion, were calculated and labeled as a combined potential concussive injury rate. It was determined that 42.9% (57/133) of respondents suffered a potential concussive injury, with the majority being female 61.4% (35/57). There was no statistical difference for the combined potential concussive injury rate based on gender ($\chi^2 (1) = .463; p=.496$).

**Intention to Report**

When respondents were asked if they would report potential concussion symptoms including a headache, dizziness, or confusion to their athletic trainer after a blow to the head,
57.3% (75/131) indicated they would report the injury. Of those who would report it, 65.3% (49/75) were female. Those who indicated they would not report the symptoms, were offered a space for text response for their reasoning. Though there were limited responses (16/49), reasons included “I would want to keep playing” and “did not want to make a big deal”. (Appendix D, Table 2) There was no statistical difference for intention to report based on gender ($\chi^2 (1) = .015; p=.901$).

Lower Extremity Injury with Concussions

Acute lower extremity injury occurred in 73.7% (98/133) of the respondents. Individually, ankle sprains impacted 58.6% (78/133) of respondents, while knee injuries and acute lower extremity muscular injury accounted for 34.1% (45/132) of respondents each. The lower extremity injury variable and self-reported concussive injury variables were evaluated with a chi-square, and though 80.0% (36/45) of those with self-reported concussions also reported a lower extremity injury, there was no statistical significance suggesting any association ($\chi^2 (1) = 1.487; p=.223$). When lower extremity injury was evaluated with overall potential concussive injury (the combined rate) by chi-square, 82.5% (47/57) reported “yes” to both variables with statistical significance ($\chi^2 (1) = 3.958; p=.047$). Athletes who had a lower extremity injury were 2.0 times more likely to have a potential concussive injury.

Pen and Paper and Online Comparison

We compared the pen and paper response data against the online data for any significant differences in the responses. Three variables were determined to be significantly different. Acute lower extremity musculoskeletal injury as determined by question #11 was significantly different between the two response types ($\chi^2 (1) = 7.220; p=.007$). Our combined potentially unrecognized concussion rate, comprised of Questions #10, 12, and 20 was also significantly
different based on response type ($\chi^2 (1) = 5.670; p=.017$). Additionally, our combined overall potential concussive injury rate, made up of Questions #4, 5, 10, 12, and 20, was significantly different between the two response types ($\chi^2 (1) = 4.583; p=.032$).
CHAPTER 4
DISCUSSION

Concussions can be challenging to diagnose in collegiate student-athletes due to the lack of visible signs and symptoms to athletic trainers thus relying on an individual athlete’s willingness to report.\textsuperscript{3, 14, 20, 45} Results of this study suggest that slightly less than half of all respondents suffered at least one potential concussive injury, whether it was reported, unreported, or potentially unrecognized. (Appendix D; Figure 3) The self-reported concussion rate was 34.1\%, of which 11.1\% acknowledged having three or more concussions. The unreported concussion rate was 12.8\%, while 18.8\% of respondents had a potentially unrecognized concussive injury. These findings advocate for continued athlete education and awareness to improve the unreported and potentially unrecognized concussion rates, in addition to continued active involvement by athletic trainers in suspecting and assessing concussive injuries.

Each variable gave insight into the current concussion issue, with reported rates emphasizing the impact of concussions upon collegiate student-athletes. Our study found that 34.1\% of athletes reported suffering a concussion, similar to the previous number of 33.5\% found with the initial data collection.\textsuperscript{43} Other collegiate studies found athlete concussion incidence rates to be approximately 5-6\% per year, which if calculated for about three years (the mean years of participation in our study), could be estimated to include about 15-18\% of athletes.\textsuperscript{9, 32}

Unreported concussions may be one of the sports medicine community’s greatest concerns, due to the inability to care for and safely return the athlete to his or her sport participation. It is estimated from previous studies that 50-80\% of concussions may go
Another study collecting data in the late 1990’s to early 2000’s noted an unreported rate of 20% of total athletes. The end of career inclusion criteria, in addition to complete anonymity, may encourage honesty and willingness to report injuries that may have precluded the athlete’s participation during his or her season. We anticipated the security with this study would allow athletes to respond honestly about why they may not have reported concussive incidents, despite the NCAA requirement of signing a statement of intent to report. Our unreported rate of 12.8% was consistent with our preliminary study’s findings of 11.8%. Though the rate of unreported concussions appears to have declined, across the board we see consistent reasons why they were not reported. Our current data suggests the most common reasons for not reporting are the athletes “did not want to be pulled from practice or the game” (13/17, 76.5%) or “future practices or games,” (13/17, 76.5%) followed by the athletes “did not think it was serious” (9/17, 52.9%) and “did not want to let [their] teammates down” (9/17, 52.9%). Earlier data suggests that athletes’ primary reasoning was that they “did not think it was serious,” however the preliminary data collection for this study determined the primary reasons were that athletes “did not know it was a concussion” and that they “did not want to be pulled from future practices or games.” Another concern that we saw was that soccer alone encompassed 41.2% of these unreported concussions, while football had the second most unreported, with 23.5%. The difference here may be due to societal differences in each sport. The NFL stays regularly in the media with concerns about concussions, lawsuits, rule changes, and injuries, shedding light on the potential dangers and long term effects of injury. However, FIFA has been more recently criticized in the media for allowing players to continue playing after severe head impacts, which through the eyes of fans and viewers may be seen as a courageous, tough, and heroic act. Additionally, education efforts may play a role in unreported
rates, for as many as 83% of athletes would have reported an injury if they had known the potential consequences.\textsuperscript{17,34} While some of these concussions go unreported for a variety of pressures to continue to play, the area athletic trainers may be able to address is the understanding and recognition of concussions.

Potentially unrecognized concussions pose a unique threat in that the athlete would not even attempt to disguise signs and symptoms, but they still may evade diagnosis and proper care. Our current data suggested that nearly 20\% of respondents had a potentially unrecognized concussion, just under the 26.1\% seen with previous data.\textsuperscript{43} Other earlier studies determined potentially unrecognized rates of 33.7\% in 2005 and 30.5\% in 2013, suggesting a slight decline over the recent years.\textsuperscript{38,49} Possible theories for the decline in potentially unrecognized concussions include an increase in education and knowledge for athletes as well as increased media attention. In 2010, the NCAA began mandating concussion education in all institutions, including signing a statement of intention to report, taking baseline measurements, and athletes with suspected concussion had to be removed for at least one day, as well as be cleared by a physician.\textsuperscript{47} One study looked at the incidence rate for the year prior to these mandates, and the year following their enforcement, noting the incidence rate to be increased two-fold after the policy was implemented.\textsuperscript{47} Overall, others suggest the heavy media attention regarding concussions may play a large role in reporting and recognition. One theory, “agenda setting,” suggests that the heavy promotion of concussions cause the public to perceive it as an important topic, reinforcing heavy media viewers to categorize harder hits as concussive injuries.\textsuperscript{50} “Social cognitive theory,” in which viewers gain knowledge through observation, suggests that reporting rates would naturally increase due to increased education.\textsuperscript{51} Additionally, the “cultivation theory” also proposes that heavy media viewers would adopt the media’s viewpoint on
concussions, and that those who have higher rates of report would most likely be heavy media viewers.\textsuperscript{29, 52} This may offer a prospective reasoning for why potentially unrecognized rates have been seemingly improving over the last decade.

Our lower extremity data provided some interesting results, despite the substantial limitations that reside with this data. We found a two times greater risk for potential concussion with self-reported acute lower extremity injury. Only one other abstract appears to have analyzed this, determining a 3.79 increased risk for lower extremity injury within ninety days of a concussion.\textsuperscript{23} However, if this relationship does exist, there is potential to expand upon theories regarding general motor control and concussions. Previous studies have noted those athletes with poorer performance on balance tests, processing speeds, and reaction times are at an increased risk for non-contact lower extremity injury.\textsuperscript{22, 42} The question to consider becomes whether decreased motor control potentially leads to an increased risk for both concussions and lower extremity injuries, or whether concussions actually create or add to the problem.

Gender has often been debated as to its role in concussive injuries, providing potential for either biomechanical or societal influences.\textsuperscript{53} Our results showed no statistical difference in gender with respect to any of our variables. The NCAA recently released a self-reported concussion summary that collected over 20,000 responses from 600 schools, and in nine different gender matched sports, they too saw no significant risk factor for concussion based on gender.\textsuperscript{54} However, many previous studies have noted increased female reporting rates, in which they believe that females may be more honest, and more likely to report injuries with less societal pressures than make counterparts.\textsuperscript{55} With the more recent data from the NCAA suggesting a higher reporting rate of males, it may also add support to the “agenda setting theory”, if men are primary viewers of sports media.\textsuperscript{29}
We examined athletes’ intention to report potential concussive symptoms after a blow to the head. We found that 57.3% of our respondents indicated they would report, which is lower than the preliminary data of 73.9%. It could be argued that our rate is positive, indicating that the majority of athletes would report; however, alarmingly more than 40% suggested they would not report, which presents a continued problem for athletic trainers in the recognition and diagnosis. 65.3% (49/75) of those that indicated they would report potential concussive symptoms were female. Typically, when an individual intends to perform a health behavior, he or she is more likely to actually follow through and perform the behavior, and intent can actually predict exercise behaviors. According to a previous study, however, it appears that an increased intent to report does not actually reflect in reporting rates. Intention to report concussive symptoms was only moderate in the aforementioned study, but could be associated to a decreased likelihood of continuing to play with concussive symptoms. Though we had minimal responses to our text answer requesting why athletes would not report, we found similar reasons as those that were unreported. (Appendix D; Table 5) Variation between different colleges and universities in their concussion education and return-to-participation protocols may also have influenced athletes’ responses. In earlier research, fewer than half of respondents reported having any head injury knowledge, yet in another study 90% of athletes reporting a history of concussion had received formal education. Additionally, as many as 83% of athletes noted that they would have reported a concussive injury if they had known the potential consequences. Previous research has noted that better understanding of concussive injuries may improve the positive reporting attitude, therefore those schools who have a more in depth and effective concussion education may have an improved intention to report. Potentially, for those athletes who do not want to miss playing time, schools who have a more conservative
return-to-participation, consistent with the 4th CIS recommendations, may actually deter the reporting of concussive injuries. Further, some athletes perceive coach approachability to a substantial consideration when deciding if they will report a suspected concussion.\textsuperscript{36,40} Athletes are most likely to report concussive signs and symptoms to an athletic trainer, and with 94.0% of our athletes having a good relationship with their athletic trainer, we would anticipate a better intent to report, thus encouraging the likelihood of other barriers.\textsuperscript{3} Psychosocial factors for reporting have also been evaluated with Theory of Planned Behavior models, and suggest that specifically targeting knowledge, attitudes, and adjustments of reporting environments may increase concussion self-report.\textsuperscript{60} All of these become considerations for future research and improving concussion reporting rates. Continued education and knowledge for athletes and coaches, involving re-emphasizing signs and symptoms, as well as potential consequences, should be a part of each institution’s preseason concussion education program. With the potential for institution variability in concussion management protocols, perhaps more detailed guidelines or mandates by the NCAA for return-to-play could reinforce the education provided. Additionally, athletic trainers should have a continued awareness and actively suspect those who suffered may have suffered a potential injury to help improve reporting rates.

Our study was not without its own limitations. First, this questionnaire was self-reported data (0.92 test-retest reliability) which is the common form of collecting concussion reporting data.\textsuperscript{29,30} The questionnaire was also only available in English, recognizing that though some student-athletes are international, they have previously passed an assessment recognizing their comprehension of the English language. Additionally, no assistance could be provided to the athlete if they did not understand a question in order to maintain the privacy integrity. We had a relatively small sample size with only 133 participants. When comparing our pen and paper
version to our online Qualtrics, we found several variables (Question #11: acute lower extremity musculoskeletal injury; Combined potentially unrecognized concussion rates of Questions #10, 12, and 20; Combined overall potential concussive injury of Questions #4, 5, 10, 12, and 20) in which there were a significant differences. With lower extremity question #11, we saw a greater percentage of “yes” responses from our online participants. Alternately, we saw a greater percentage of “yes” responses from our pen and paper respondents with our combined potentially unrecognized rates and combined overall potential concussive injury rate. Our preliminary study with the same instrument saw no significant differences, and literature regularly supports the notion that there are no differences between pen and paper and internet-based self-report instruments.\textsuperscript{44, 61} We also have large limitations in our lower extremity data as it is self-reported information, and is set on no timeline, meaning that either injury could have preceded the other, and the injuries could have been days or years apart.

For future research considerations, it would be ideal to increase sample size overall. More institutions, over a wider variety of athletic divisions, could provide greater detail into variations by division. A greater number of participants would improve the overall detail based on sport, gender, division, in addition to added data on the reported, unreported and potentially unrecognized rates overall. Future research should also consider participant randomization to remove any potential bias. Alternative designs for future research should include comparisons of self-report to medical records to look at accountability of reporting. An added question could also account for demographics or an assessment of concussion education knowledge and where they received it, to evaluate the effect of retained knowledge upon reporting rates. Additionally, future research should include more specifics in comparing concussion and acute lower extremity injury, such as looking at injury timelines, or comparing them in real time as opposed
to self-report, to provide more detail into the potential motor control effects involved with concussive injuries.

In conclusion, just under half of all athletes may experience a concussion during their collegiate athletic career. While one-third of all respondents endorsed having suffered a concussion, we have more concern for the 12.8% who did not report a concussive injury and the 18.8% with a potentially unrecognized concussion who may continue play without proper assessment and treatment. Fortunately the unreported and potentially unrecognized rates have shown a decline over the last decade, potentially due to the education efforts by institutions and the overall effect of the media on the public, but we must maintain advocacy for these recommendations and mandates. Our data and responses continue to reinforce the necessity of athlete concussion education, and maintained awareness and suspicion by athletic trainers in the assessment and diagnosis of concussions, as well as promote continued research on concussions and general motor control.
REFERENCES

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APPENDIX A
LIMITATIONS, DELIMITATIONS, AND ASSUMPTIONS

Research Questions

1) **How many concussions were reported throughout an athlete’s collegiate career?** We hypothesize that concussions are vastly underreported in a collegiate athletic career.

2) **How many concussions are not reported during an athlete’s collegiate career, and why?**
We hypothesize that the gross underreporting of concussions will be primarily related to social pressures to play and lack of knowledge and ability to recognize concussions and consequences.

3) **How many concussions go unrecognized during a collegiate career?** We hypothesize that collegiate athletes will not recognize more subtle signs and symptoms following a head injury.

Limitations

Limitations will include that study is self-reported and that it is limited only to those athletes that have completed their athletic careers. There is currently no determined reliability and validity for the study, and there is no assistance if a question is not fully understood.

Delimitations

Delimitations for this study include selecting only collegiate athletes who have completed their athletic career, only at voluntarily participating institutions.

Assumptions

Assumptions for this study are that participants will answer questions honestly, to their best knowledge, and will have privacy while completing the survey.
Definitions

Concussion: a head injury caused by a direct or indirect blow to the head, initiating a complex pathophysiological process that affects the brain.
APPENDIX B

REVIEW OF LITERATURE

Concussion is a high profile injury topic in sports today, as the most common sports-related head injury, with 1.6-3.8 million sport-related traumatic brain injuries (TBI) occurring each year.\(^2\) This number however, only accounts for those that are recognized. With the existence of variability in assessment and diagnosis of concussion, many rely on the ability of an injured athlete to self-report and recognize signs and symptoms of injury. To encourage recognition and reporting of sport-related concussion, an understanding of symptoms, biomechanics, effects and recovery must be acknowledged.

DEFINITION OF A CONCUSSION

A concussion has been defined as “a complex pathophysiological process affecting the brain, induced by biomechanical forces” by the 4th International Conference on Concussion in Sport (CIS). Though there is no single universally accepted definition, experts agree upon the features of concussion.\(^6\) Concussion may result from direct or indirect forces that transmit to the head, causing a diffuse injury, which often results in transient neurologic impairment. Impairment is noted through graded clinical symptoms, cognitive and postural stability assessments, and may or may not involve loss of consciousness. Symptoms typically resolve sequentially over a short period of time, though a percentage of incidents are noted to have prolonged post-concussive symptoms. Standard structural neuroimaging returns unremarkable with concussion, presenting a case for concussion as a more functional injury than structural injury.\(^6\), \(^3\)

Concussive injury does, however, create pathophysiologic changes that can account for neuronal dysfunction, and in turn, various concussive symptoms and post-concussive
vulnerability. This neurometabolic cascade of events occurs immediately following
biomechanical injury, and lasts about seven to ten days. Beginning with nonspecific
depolarization and initiation of action potentials, a disturbance in the neuronal membranes leads
to an early release of the neurotransmitter and excitatory amino acid, glutamate. The release of
glutamate initiates an excessive efflux of potassium, which cannot be controlled by surrounding
glial cells. In order to restore homeostasis, the sodium-potassium pumps increase activity, which
requires the use of adenosine triphosphate (ATP.) In order to generate more ATP for this
process, hyperglycolysis is initiated, which in turn increases lactate production, leading to an
accumulation of excess lactate. In combination with hyperglycolysis, cerebral blood flow may be
reduced as much as 50% after injury, resulting in an energy crisis due to unbalanced supply and
demand of glucose. Oxidative metabolism becomes impaired after calcium influx and
sequestration occurs in mitochondria, which then leads to decreased ATP production. The brain
begins to protect itself by activating enzymes and initiating apoptosis, or self-initiated cell death.

There may also be diffuse axonal injury, which begins with axolemmal disruption, allowing
calcium influx, and is then followed by neurofilament compaction from five minutes to six hours
after injury. The increased calcium levels allow microtubule breakdown between six and twenty-
four hours post-injury, while organelles are continually carried in, thus collecting at the site of
damage. This leads to axonal swelling, and, eventually, secondary axotomy. The
accumulation of these internal damages leads to the signs and symptoms seen in clinical
examination after concussive injury.

**EPIDEMIOLOGY**

Many studies have been performed to collect data relating to the occurrence of
concussion in high school, college, and professional athletes. The Center for Disease Control
(CDC) released in 1998 that an estimated 300,000 sports-related TBI occurs each year, but that only accounted for those cases that were hospital visits and involved loss of consciousness. Loss of consciousness has been noted by multiple studies to only occur in 6.4% to 8.9%\textsuperscript{19,20,45} of concussions, providing support for Langlois’ updated estimation of 1.6 to 3.8 million annual sport-related TBIs.\textsuperscript{2}

Defining concussion and its severity has been a large task to determine and evaluate the number of concussions in sport. Many concussion grading scale guidelines, aside from Cantu’s revised guidelines, focus primarily on the occurrence of loss of consciousness and post-traumatic amnesia. The data, however, notes a relatively small number of concussions actually include either of these signs. Loss of consciousness only occurs in approximately 5-8% of concussions, with post-traumatic amnesia apparent in 8.8% to 27.2%.\textsuperscript{19,20,45} In 2000, following with LOC and PTA grading scales, Guskiewicz found Grade I concussions to be most common, accounting for 88.9% of all incidents, with 10.6% being Grade II, and only a small .4% noted as Grade III.\textsuperscript{19}

Though football accounts for the highest percentage of concussions, high school athletics report an overall concussion rate of 5.5%.\textsuperscript{64} For high school and collegiate football, concussions are reported to occur in 5.1% of all athletes.\textsuperscript{19} According to Shankar, head and face injuries accounted for 11.5% of all of high school football injuries, with 96.1% of those being concussions, for a total of approximately 60,000 concussions per year.\textsuperscript{64,65} Concussions were calculated as 7% of all football injuries at the collegiate level.\textsuperscript{65} In high school athletics, concussion accounts for 8.9%-13.2% of athletic injuries, while making up only 5.8% of all collegiate athletic injuries.\textsuperscript{32,33} Multiple studies also suggest that females have a higher incidence of concussion rate; females had greater incidence rates in sports both genders played, however several factors may contribute to this data. Females may be predisposed
biomechanically due to weaker neck musculature, or smaller head to body ratios, such as a smaller head compared to soccer ball size. Additionally, cultural reasoning may lead to improved reporting, due to females increased likelihood to be honest, less of a pressure to play injured as it is socially permissible to play through pain, and the societal thought that parents and coaches may be more protective over female athletes. Ultimately, to understand the occurrence of concussions, a full appreciation of the signs and symptoms is necessary.

SYMPTOMATOLOGY

The two primary indicators for nearly all grading scales is loss of consciousness (LOC) and posttraumatic amnesia (PTA), despite much research calling for a multifaceted grading approach, involving symptom, cognition, and postural stability assessments. As previously noted, LOC and PTA only occur in a small portion of traumatic brain injuries, but are still important on-field markers when they do occur.

Many other symptoms associated with concussion are seen during the initial evaluation and follow up evaluations. The most common symptoms associated with concussion are headache, dizziness and confusion, but those injured may also present with vomiting, impaired concentration, light and noise sensitivity, fatigue, drowsiness and memory impairment at time of injury. During follow up evaluations, an individual may still present with some or all of these symptoms, and may note differences in severity or the addition of other symptoms such as weakness, irritability, impaired vision, depression or difficulty sleeping. Symptoms may be grouped together based on common characteristics, known as symptom clusters. Each symptom is classified into migraine, cognitive, sleep, or neuropsychiatric clusters. The migraine cluster consists of headaches, visual problems, dizziness, sensitivity to noise and light, nausea or vomiting, balance discrepancies, and any numbness or tingling. The cognitive symptom cluster
includes fatigue, fogginess, drowsiness, concentration difficulties, memory dysfunction, and
cognitive slowing. The third cluster involves difficulty or altered sleeping, either an increase or
decrease in regular habits. The final cluster revolves around neuropsychiatric symptoms,
specifically, increased emotions, sadness, nervousness, and irritability. The migraine and
cognitive clusters, if present, appear to be statistically significant in being able to predict cases
that may have prolonged recovery.\textsuperscript{70} According to NFL injury data, a concussed athlete, on
average, presents with 3.6 signs or symptoms.\textsuperscript{71}

Several other physical signs are also becoming more valuable in assessment with
increased research and available testing. Impaired cognition is an important sign accompanying
concussion that can be evaluated to determine presence and duration. Those sustaining a
concussion have been shown to have a deficit in cognitive function\textsuperscript{20}, though approximately half
of that deficit may be attributed to the general effects of injury, as some cognitive deficit is also
noted in those with musculoskeletal injury.\textsuperscript{72} Postural stability in concussed athletes can be
noted in balance and gait deficits.\textsuperscript{72,73} Guskiewicz states that balance deficits may occur due to a
decrease in communication between three sensory systems in the brain following TBI, causing
instability with anterior-posterior balance, medial-lateral balance, or both. This alteration could
be transient or permanent, based on the extent of damage.\textsuperscript{73} Some data also suggests instability
may be seen in gait for up to a month after concussion, which further shows the need to evaluate
all symptoms involved with concussive injury.\textsuperscript{74}

\textbf{BIOMECHANICS}

Understanding the biomechanics involved with concussive blows is crucial to piecing
together how and why concussions occur, and providing implications for injury prevention. The
National Football League (NFL) reconstructed impacts, based on two separate video views to
determine biomechanical influences. Pellman determined the average impact velocity for NFL hits was 9.3 m/s, which is comparable to an impact at 20.8 miles per hour, with an average head velocity change of 7.2m/s. Results also noted an average head linear acceleration of 98g, with the average duration of impact lasting about fifteen milliseconds. Peak rotational acceleration was measured at 6432 rad/s² for NFL impacts, but a stronger correlation was seen between TBIs and translational acceleration.\textsuperscript{75} While the frequency of this linear acceleration was highest in front impacts to the helmet, it has been seen to produce the greatest force at the top of the head.\textsuperscript{76-78} Guskiewicz noted that collegiate football athletes are 6.5 times more like to sustain an impact over 80g at the top of the head, providing data to support implementation of spearing and helmet-to-helmet contact rules in football leagues. Concussions, however, can occur at varying locations and force magnitudes, and the acute symptoms associated to concussion seem to be unrelated to either linear or rotational magnitudes, as well as impact locations.\textsuperscript{77}

Multiple studies have identified average linear acceleration forces in football at various levels. Mihalik found an average force of 21 to 23g in nonconcussive hits in NCAA Division I football.\textsuperscript{78} Interestingly, another study noted that high school football had greater average linear acceleration than reported in at the collegiate level, with average forces of 23-24g.\textsuperscript{76} Even more alarming is the data from Daniel’s study in youth football, where a median linear force of 18g was noted, a comparable force to high school and collegiate level athletes. Daniel’s data also reports that six in 748 recorded impacts were recorded at 80g or greater, in a demographic of seven players, ranging from seven to eight years old.\textsuperscript{79} Guskiewicz found a range of linear accelerations in thirteen collegiate football concussive injuries of 60g to 169g. When the concussion assessment battery was administered to each of the impacts, the 169g impact had better scores than many of the lower level impacts.\textsuperscript{77} While an injury threshold of approximately
70 to 75g was initially considered, after multiple studies, and noting concussions at lower and higher forces, with no change in severity of some signs and symptoms, there is currently no defined threshold for concussion.\textsuperscript{77,80}

Certain positions have been seen to take harder hits, while others take more, less forceful hits. Overall, offensive backs, offensive linemen, and defensive linemen took the most hits on average, but not by a significant number. Offensive backs and wide receivers were the most likely to sustain high magnitude impacts, however, they had the lowest injury rates.\textsuperscript{78} At the high school level, the highest injury incidence occurred at quarterback and running back positions, with wide receivers accounting for the most severe injuries. These findings are thought to be related to the low impact speed of the linemen taking hits at every play, against the full speed and open field contact with high impact accelerations that other position players would incur.\textsuperscript{76}

**EFFECTS OF CONCUSSION**

The effects of concussion can be widespread, involving all aspects of life, and may be short term, long term, career or even life ending. It is estimated that one in ten of the 54 million Americans with disabilities has a disability related to a TBI, including moderate to severe brain injuries. Within three years of injury, a person who suffered a TBI is 1.8 times more likely to report binge drinking, 11 times more likely to develop epilepsy, and 7.5 times more likely to die than the general population.\textsuperscript{2,81,82} While 6.7\% of all adults will suffer depression, those who have experienced one or two concussions are 1.5 times more likely to suffer, and those with three or more have increased their risk by three-fold.\textsuperscript{25,83} Additionally, an individual with three or more concussions have a two to five time’s greater risk of developing Alzheimer’s disease when
compared to those who have suffered one to two concussions, or those with no history, respectively.\textsuperscript{24,84}

Having a medical history of concussion increases the risks for future concussive injuries, which is known as a dose response. Guskiewicz noted that 35.1\% of concussive injuries in one season had a history of at least one concussive injury in the last seven years.\textsuperscript{9} He also found athletes with three or more concussions were three times as likely to sustain another concussion, while Zemper found individuals with past medical history of concussion were 5.8 times more likely to sustain subsequent concussions than those with no concussive history.\textsuperscript{10} Collins found high school athletes with concussion history to be more susceptible in many areas. First, those with three or more concussions are 9.3 times more likely to present with three or four on field severity markers (LOC, PTA, confusion, or five or more minutes of mental status change.) Additionally, those with three or more concussions also had an increased likelihood of having loss of consciousness by 6.7 times, anterograde amnesia by 3.8 times, confusion likelihood was 4.1 times greater, and five minutes or more of mental status change was 4.4 times more likely.\textsuperscript{8} While in-season, 11 of 12 repeat concussions occurred within ten days of initial injury, and 9 of 12 occurred within seven days, suggesting a seven to ten day period of increased vulnerability following concussion. This may be attributed to the neurometabolic processes occurring alongside decreased cerebral blood flow during this period. Subsequent concussions also appear to be related to slower neurological recovery\textsuperscript{9}; one study found that prolonged post-injury mental status occurred in 31.6\% of athletes with a prior history, as compared to 9.4\% of those with no history of concussion.\textsuperscript{8}

Other considerations include post-concussion syndrome, second impact syndrome, long term effects, and chronic traumatic encephalopathy (CTE). Post-concussion syndrome (PCS) is
not currently well-defined, but the World Health Organization recommends clinical diagnostic
criteria. Though conservative, PCS is clinically diagnosed based on “(1) cognitive deficits in
attention or memory and (2) at least 3 or more of the following symptoms: fatigue, sleep
disturbance, headache, dizziness, irritability, affective disturbance, apathy, or personality
change,\textsuperscript{12,13}\textsuperscript{12} and is often considered with persistence of these symptoms past the normally
accepted 7 to 10 day recovery period. An estimated 10% of athletes have persistent symptoms
for longer than two weeks.\textsuperscript{11,12} Second impact syndrome (SIS), while rare, occurring in only one
or two cases each year, is a serious effect from concussion. SIS is seen when a second
concussive impact occurs, typically within the window of vulnerability following an initial
injury.\textsuperscript{26} It manifests itself as diffuse cerebral swelling and brain herniation\textsuperscript{28}, typically within
five minutes. SIS is fatal in approximately 9% of cases, while 50% are typically left with severe
neurologic impairments, often rendering survivors unable to care for themselves.\textsuperscript{27,85} Long term
effects of recurrent concussions can include depression\textsuperscript{25}, increased risk for Alzheimer’s disease,
mild cognitive impairment, and late-life memory impairment.\textsuperscript{24} Similar symptoms are also noted
with CTE, though there is no proven link between this and concussions. CTE can only be
diagnosed post-mortem with an autopsy, but can be viewed clinically in patients with “memory
disturbances, behavioral and personality changes, parkinsonism, and speech and gait
abnormalities\textsuperscript{86}, and may be associated with depression, early dementia, motor neuron disease,
erratic behavior, and often suicide.\textsuperscript{27} The implications are clear as to why it is important to
reduce the number of recurrent concussive impacts, and why honest reporting of a concussion
can prevent long term sequelae.

**PREVENTION OF CONCUSSION**
Prevention is a large area of concern for sport-related concussions, to ensure elimination of as much of the problem as possible. Unfortunately, preventing concussions has proven to be difficult, with no biomechanical threshold, and the uniqueness of each individual injury. Some studies have focused on helmet technology, with a lack of evidence to show they would even have potential to prevent concussive head injury.\textsuperscript{87} In addition to helmets, no other personal protective equipment, including mouthguards, has any evidence supporting its use for concussion prevention, although the improper fitting and use of any protective equipment may actually increase the risk of concussion.\textsuperscript{88} Another suggestion involves looking at possible genetic predisposition for preventing long term consequence to concussion. However, the feasibility of even determining the efficacy of genotyping is difficult, due to the current separation between genotype indices and general medical information, potential controversy in adolescent genotyping, and the excessive methods required to determine a significant relationship.\textsuperscript{89} One focal point for prevention, however, involves the implementation of rules and appropriate techniques in all levels of athletics. In football, with the greatest forces related to the impacts on the top of the helmet, rules banning spearing and head-to-head contact, in addition to teaching proper tackling technique, should be incorporated with even the youngest players.\textsuperscript{71, 76, 88} Furthermore, limited hitting in athletics, particularly with younger age groups, has been recommended to limit exposures and opportunities to sustain concussive injuries.\textsuperscript{90} Some say that due to body size and biomechanical factors at younger ages, tackling should even be eliminated for those under the age of fourteen. Though that may be difficult to adopt within society, reduction in practice times and implementation of hit counts, similar to Little League pitch counts, may be effective means by which to achieve some level of prevention.\textsuperscript{27}

\textbf{ASSESSMENT OF CONCUSSION}
Until 2001, all concussion grading scales were based solely on the occurrence of LOC and/or PTA of each case. It had been found repetitively though, that while LOC and PTA are important and helpful in making a diagnosis, they occur so infrequently with sports-related TBIs that it is nearly impossible to identify those signs as primary indicators of severity.\textsuperscript{20, 66, 91} Cantu then released a new grading system, involving symptoms in a retrospective grading scale. He stated, “While not diminishing the importance of being rendered unconscious, I find it illogical to grade a concussion that produces postconcussion symptoms lasting months or years without loss of consciousness as less severe than a concussion resulting in brief unconsciousness and resolution of all postconcussion symptoms within a few minutes or hours.” With this, Cantu led concussion evaluations into identifying symptoms as the most important grading criterion.\textsuperscript{66} With symptom checklists, Broglio found a greater sensitivity with a nine-item inventory than large scales due to a greater standard deviation of questions.\textsuperscript{92} Collins also identified several on-field injury severity markers including positive LOC, retrograde amnesia, posttraumatic amnesia, any disorientation, five or more minutes of disorientation, and any three to four abnormal markers. All but LOC and any disorientation led to an increased risk of poorer presentation post-concussion.\textsuperscript{68} Balance assessment tests, such as Balance Error Scoring System (BESS) and Sensory Organization Test (SOT), become more sensitive to gait and balance deficits when cognitive tasks are added in, creating a dual task assessment.\textsuperscript{93} Regarding orientation assessment, Maddock’s found that recent memory questions were more sensitive to concussed subjects, leading to the inclusion of “Maddocks’ Questions” in the Sport Concussion Assessment Tool 2 (SCAT2).\textsuperscript{91} A battery of exams has been shown to be much more effective in the assessment of concussive injuries. When looking at symptom severity scores, Automated Neuropsychological
Assessment Metrics (ANAM), and Sensory Organization Test (SOT), they all have poor sensitivities, both combined and separately, however, they have a combined specificity of .940 at a 95% confidence interval. The author cautions that while the assessment tests and tools are valuable measurements for concussive injuries, particularly combined, nothing can replace a thorough clinical evaluation for decision. Broglio found that when combining symptom checklists, postural assessment (SOT) and a neurocognitive test (ImPACT, Headminder CRI, or paper and pencil tests), the sensitivity for the battery ranged between 89-96%, which fared far better than individual sensitivities between 43-79%. The sensitivity of a concussion assessment increases with the addition of more tests, calling for a multifaceted assessment for better overall clinical evaluations.

**CONCUSSION RECOVERY**

As previously discussed, a seven to ten day vulnerability period is present after a concussive impact, but it has been questioned as to if that time period is even enough for full recovery. One study noted different recovery periods found within different tests. Collegiate football players were able to, on average, return to baseline on postural stability tests within three to five days, though symptoms and cognitive deficits typically normalized around day seven. Ten percent did not become asymptomatic by day seven, emphasizing the individuality of each injury, and further implicating that not all concussions can be fully recovered in one week. Acute injury severity can increase the risk of prolonged recovery, identified through LOC, amnesia, and an elevated symptom score of twenty or more points over an individual’s baseline score during the first 24 hours. Additionally, increased scores for migraine and cognitive symptom clusters appear to predict prolonged recovery for concussed individuals. Motor stability, especially when assessed with dual task, has shown impairments up to a month after
concussive injury, suggesting some areas may take even longer than just ten days for full recovery. Guskiewicz cautions that baseline may not actually be enough to deem a concussed athlete recovered. Practice effects involved with neurocognitive tests and postural stability assessments may allow a symptomatic athlete to appear recovered, and could allow premature return to play.

CONCUSSION AWARENESS

Concussion awareness is an important aspect for every individual involved in an athlete’s participation, including athletes, their guardians, coaches, and healthcare providers to ensure best care in the event of a TBI. Studies have reported coaches and coaching students to be able to recognize signs and symptoms of concussion, with increased formal coaching education improving the ability to do so. However, not all signs and symptoms are as easily recognizable to coaches. Unfortunately, many misconceptions about concussions also still run rampant amongst coaches, including the ideas that athletes may return to play while symptomatic, or even that a second blow to the head can help restore memory lost after an initial concussion.

Physician concussion knowledge was evaluated using the Centers for Disease Control “Heads Up” concussion awareness toolkit, and while the use of the toolkit did not affect physicians’ overall knowledge, it did reduce the likelihood of recommending next day return to play. More alarming measures came from underlying numbers in the study; 40% of physicians were not comfortable diagnosing a concussion, and two-thirds were not comfortable with concussion management. Also, while the majority of physicians answered correctly, approximately 15% of all physicians surveyed thought it was safe for a player to return immediately to play if his or her symptoms had resolved within fifteen minutes, and one in eleven believed LOC was required for diagnosis of concussion. Additionally, team related bias
could play a role, in which case hiring medical staff through a league would potentially help reduce this risky issue. In 2005, only 3% of certified athletic trainers were found to be following the National Athletic Trainers’ Association position statement, using symptom checklists, neurocognitive and postural stability assessments as a full battery of tests during evaluation. During the data collection, there was still no consensus amongst athletic trainers concerning grading scales and return to play guidelines.

In 2003, only 43% of athletes indicated having any knowledge concerning head injuries, and more than 50% did not realize the consequences associated with a head injury. For all persons involved with sport, from athlete to physician, appropriate education is important to understanding concussions and the associated consequences from each action. Although recent attention and education to concussion has helped improve the overall awareness of signs and symptoms and management, it is still recommended that an appropriately credentialed healthcare provider be available at all levels to ensure a safe playing environment.

REPORTING ISSUES

It has been generally accepted that concussions are largely underreported, for a multitude of reasons. The difficulty of diagnosis of concussion, with a wide array of symptoms that vary between each case, make it easy for some athletes to hide problems, or even not realize the severity of an injury. Since blatant concussive signs, such as loss of consciousness, are relatively uncommon, the primary means for diagnosis involves self-reported symptoms. During a high school football season, 15.3% of athletes reported sustaining a concussion during the season, however, only 47.3% of those athletes reported the concussion. This provides data that over half of high school football players with symptoms did not report sustaining a concussive injury. This data leads researchers to believe that the previous numbers of three to six percent incidence
rates of high school concussion may be extremely low, and that the actual number may be closer to 15%. Additionally, by this data, an average of 5% of these athletes will enter college with three or more concussions.\(^3\) Another study found approximately 75% of high school football players failed to report concussion symptoms during the season.\(^4\) Researchers also found that in 320 concussions and/or “bell ringers” that were sustained during a game setting, only 73, a mere 23%, reported their symptoms to appropriate professionals. In that same group, 348 other concussions or “bell ringers” were sustained during practices, and an even fewer 40 events were reported, only 12% of all practice concussive injuries.\(^3\) Data involving collegiate athletes also reports a lack of knowledge and understanding, since only about 20% of athletes reported previous concussive history, while more than 30% claimed to have had dizziness following a direct blow to the head. This leaves one-third of concussive blows unaccounted for and undiagnosed.\(^1\)

Another pertinent question involves the reasoning behind this lack of reporting of concussions in athletes. McCrea found with high school football players, 66.4% of athletes did not think their injury was serious enough. Another 41% did not want to leave the game, and 36.1% did not know it was a concussion. 22.1% of the responding athletes did not want to let their teammates down, and 9.8% had other reasons.\(^3\) Other studies primarily reported that athletes failed to report concussion symptoms because “it wasn’t a big deal” and “‘playing hurt’ goes along with football.”\(^4\) Only one percent of these high school athletes thought a “bell ring” and a concussion were the same thing, however, 83% stated that if they had been aware of the potential dangers of these symptoms, they would have reported them to medical personnel.\(^4\) This further calls for the insistence of education among athletes, in order that they understand potential consequences of concussions, and can recognize common signs and symptoms in
themselves and teammates. In collegiate athletes, approximately 20% failed to report dizziness while playing, which may be due to pressures to continue playing, or a lack of injury knowledge and the ability to recognize signs and symptoms involved with concussion. Only 43% of the athletes surveyed indicated they had any knowledge regarding head injury, and over 50% noted they did not know consequences involved with concussion.\textsuperscript{17} Concussion knowledge was found to have a positive relationship with reporting amongst high school athletes. A higher level of concussion knowledge was found to be associated with an increased likelihood to report concussions or “bell ringers” during practices, and reporting any “bell ringer” events overall. They did not find any significant relationships, however, with reporting events during games which may involve social pressures to play.\textsuperscript{35}

The lack of knowledge that clearly exists may also roll over into how we collect previous concussion history data. It seems that though professionals are trying to move away from the terms “ding” and “bell rung” concerning concussions, it may be more sensitive in collecting past medical history. While 86.4% of athletes reported no history of concussion on their pre-participation screening, Valovich-McLeod found that 55% reported having at least one concussion-related symptom following a head injury on a concussion symptom survey. At least two-thirds of those who reported having had their “bell rung” did not report having a concussion. This data suggests that in pre-participation screening of athletes, previous symptoms, and even colloquial terms should be included to better determine actual concussive history.

The lack of recognition and reporting of concussive injuries is at an alarming rate, particularly in young athletes, who do not have a full understanding of the symptoms and possible effects and consequences. This suggests a need for education and preventative techniques that can be offered to spare a future generation from long term trauma. By providing
a solid foundation in education, research suggests we could increase self-reporting of symptoms, which would allow a more thorough medical intervention to provide for appropriate recovery.


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APPENDIX C

QUESTIONNAIRES

Hard Copy Informed Consent

Hard Copy Questionnaire

Qualtrics Informed Consent

Qualtrics Questionnaire

IRB Approval
CONSENT TO ACT AS A SUBJECT IN AN EXPERIMENTAL STUDY

1. Title of Project: Accuracy of Injury Reporting upon completion of a Collegiate Athletic Career.

   Investigator’s Name: Frances Gilbert, ATC, LAT       Phone: (817) 343 - 9046
   Participant’s Name _______________________________ Date: ___________________
   Data Collection Location: Athletic Training Room, Georgia Southern University Campus

2. The purpose of this study is to determine how accurately student-athletes report their injuries after completing their collegiate athletic career. There will be approximately 500 subjects in this study. The results of this study may benefit health care professionals in the recognition and treatment of sports-related injuries.

3. You are being asked to participate in this study because you are a student-athlete at Georgia Southern University, who has completed your collegiate athletic career.

   If you agree to participate in this study, you will be asked to complete a brief questionnaire regarding your injury history.

4. There is minimal risk associated with participating in this study. If there are any questions that make you uncomfortable or that you do not wish to answer, you may skip those questions. You understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. You also understand that you are not waiving any rights that you may have against the University for injury resulting from negligence of the University or investigators. Should medical care be required, you may contact Health Services at (912) 478 – 5641.

5. You will likely receive no direct benefit for participating in this study, however you will be provided your results, if you so request. The results of this study may be used to assist health care professionals in the recognition and treatment of sports-related injuries.

6. The questionnaire will take approximately 5 minutes to complete in its entirety.
7. All data concerning you will be kept confidential and be made available only upon your written request to Frances Gilbert. All information about your records will be handled in a confidential (private) manner consistent with medical records. The questionnaires will remain secure and confidential with Frances Gilbert as allowable by Georgia state law.

8. If you have any questions about this research project, you may call Frances Gilbert at (817) 343-9046 or her advisor, Thomas Buckley, Ed.D. at (912) 478-5268. If you have any questions or concerns about your rights as a research participant in this study it should be directed to the IRB Coordinator at the Office of Research Services and Sponsored Programs at (912) 478-0843. This research has been reviewed and approved by the GSU IRB under protocol number H11375.

9. You will not receive compensation for your participation in this project. You will not be responsible for any additional costs for your participation in this project.

10. It is understood that you do not have to participate in this project, and your decision to participate is purely voluntary. At any time you can choose to end your participation by telling the primary investigator, Frances Gilbert, by telling any of the other investigators, or by simply not completing all of the questions.

11. It is understood that you may terminate your participation in this study at anytime without prejudice to future care or any possible reimbursement of expenses, compensation, employment status, or course grade except provided herein, and that owing to the scientific nature of the study, the investigator may in his/her absolute discretion terminate the procedures and/or investigation at any time.

12. It is understood that there is no deception involved in this project.

13. By signing this document, you certify that you are 18 years of age or older and you have read the preceding information, or it has been read to you, and you understand its contents. Any questions you have pertaining to the research have been, and will continue to be, answered by the investigators listed at the beginning of this consent form or at the phone numbers given: (817) 343-9046 or (912) 478 – 5268.

14. By signing this document, you acknowledge that you have been provided a copy of this form.

Title of Project: Accuracy of Injury Reporting upon completion of a Collegiate Athletic Career.

Principal Investigator
Frances Gilbert, ATC, LAT
(817) 343-9046
fg00244@georgiasouthern.edu

Other Investigator
Thomas Buckley, Ed.D., ATC
0107-C Hollis Building
(912) 478 – 5268
tbuckley@Georgiasouthern.edu
Participant Signature   Date

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

Investigator Signature   Date
**Injury History Questionnaire**

Directions: Please answer the following questions regarding your *collegiate athletic career* to the best of your knowledge. Your answers will remain confidential and will NOT be shared with your coaches or athletic training staff.

**Demographics**
Gender: M / F    Age: _______    Academic year in school: FR SO JR SR 5th Other_____    Position in sport: ___________________________

How many years did you participate in your sport at the collegiate level? _______

Which Division? NCAA I NCAA II NCAA III NJCAA Other_______________________________

**Injury History**

1. Have you ever sprained your ankle? YES NO  
   a. Was the ankle sprain reported to a healthcare provider? YES NO  
   b. Did you complete a rehabilitation program, either on your own or with a healthcare provider? YES NO  
      1. If no, why not? ____________________________________________________________________

2. Have you ever injured a ligament or cartilage in your knee? YES NO  
   a. If yes, which one(s)? Meniscus Cartilage MCL ACL LCL PCL

3. Have you ever sprained any other joints (shoulder, wrist, etc.) while playing sports? YES NO  
   a. If yes, what body part(s)? ____________________________________________________________________

4. Have you ever suffered a concussion? YES NO  
   a. If yes, how many? _____  
   b. If yes, approximately when were they? (Month and year to the best of your memory) ____________________________________________________________________  
   c. If yes, when was your last concussion? ____________________________________________________________________

5. Did you ever suffer a concussion and not tell anyone? YES NO  
   a. If yes, why? (check all that apply)  
      ____ 1. Did not think it was serious  
      ____ 2. Did not know it was a concussion  
      ____ 3. Did not want to be pulled out of the game/practice  
      ____ 4. Did not want to be pulled from future games/practices  
      ____ 5. Did not want to let your teammates down  
      ____ 6. Would have if it was a less important game/practice  
      ____ 7. Other:________________________________________________________________________

6. Have you ever hurt your back? YES NO
a. If yes, please explain:__________________________________________________________

7. Have you ever broken a bone?     YES     NO
   a. If yes, which bone(s)?________________________________________________________

8. Have you ever dislocated your shoulder?     YES     NO

9. Have you ever pulled, strained, or torn your rotator cuff or any other structure in your shoulder?     YES     NO
   a. If yes, briefly explain:________________________________________________________

10. Have you ever been knocked out while playing sports?     YES     NO
    a. If yes, how many times?_______________________________________________________
    b. If yes, how many were diagnosed as concussions?_______________________________

11. Have you ever pulled, badly strained, or torn a muscle?     YES     NO
    a. If yes, which muscle(s)?_____________________________________________________

12. Have you ever been “knocked silly/seen stars” (confused/disoriented) while playing sports?     YES     NO
    a. If yes, how many times?_______________________________________________________
    b. If yes, did you tell your coach, athletic trainer, or parent? Which one?_____________
    c. If yes, how many were diagnosed as a concussion?________________________________

13. Have you had multiple ankle sprains?     YES     NO
    a. If yes, how many?__________

14. Have you had any episodes of your ankle giving way?     YES     NO
    a. If yes, how many times?__________

15. Do you have any current residual (lingering) symptoms regarding your ankle sprains?     YES     NO
    a. If yes, what are they?_________________________________________________________

16. Have you ever experienced any season ending injuries?     YES     NO
    a. If yes, what was/were your injury/injuries?______________________________________
    b. If yes, did you have surgery on any of these injuries? Which ones?

17. During your collegiate athletic career, did you ever have any orthopedic surgeries?     YES     NO
18. Following a blow to the head, if you had experienced a headache, dizziness, or confusion, would you report it to your athletic trainer?  YES  NO 
   a. If no, why not?__________________________________________________________

19. Have you ever had injuries that you did not tell your athletic trainer about?  YES  NO 
   a. If yes, what injuries?_____________________________________________________ 

20. Have you ever been hit so hard you lost your memory while playing sports?  YES  NO 
   a. If yes, how many times?_______________________________________________
   b. If yes, did you tell your coach, athletic trainer, or parent? Which one?________
   c. If yes, how many were diagnosed as a concussion?_______________________

21. During your collegiate athletic career, do you feel like you had a good relationship with your athletic trainer?  YES  NO
Dear Student-Athlete,

The athletic training program at Georgia Southern University invites you to participate in a research study entitled, "Accuracy of Injury Reporting upon Completion of a Collegiate Athletic Career" after you have completed your collegiate athletic career.

Participation in this research will include completing a questionnaire which should take approximately five minutes to complete. This survey is intended for any collegiate student-athlete who has completed their athletic career. The purpose of this study is to determine how accurately student-athletes report their injuries upon completing their athletic career.

There is no compensation or reward for participating in this questionnaire. There is minimal risk associated with participating in this study and no service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose to not participate in the study. If, for any reason, there are any questions that make you feel uncomfortable or that you do not wish to answer, you may skip those questions. Although the results of this study may be published, no information that could identify you will be collected or included. We will ask you to identify the division, sport, and primary position you participated in, but no information which could identify either you or your institution will be collected.

Your consent is being given voluntarily by completing this questionnaire. You may refuse to participate in the entire study or any part you do not choose, as you have the right to not answer any questions you do not wish. The completion of the survey implies that you agree to
participate in the study, and your data may be used in this research. If you decide to participate in the study, you are free to withdraw at any time without negative ramifications. You must be 18 years of age or older to consent to participate in this research study.

Questions and comments about this research may be addressed to the primary investigator, Frances Gilbert (817) 343-9046 or fg00244@georgiasouthern.edu or her faculty advisor Dr. Thomas Buckley (912) 478-5268 or tbuckley@georgiasouthern.edu. For questions concerning your rights as a research participant, contact Georgia Southern University Office of Research Services and Sponsored Programs at (912) 478-0843. This research has been reviewed and approved by the GSU IRB under protocol number H11375.

Thank you for completing this questionnaire, your assistance in this research is greatly appreciated.

Yes, I agree to participate. Please take me to the questionnaire.

No, I do not agree to participate.

Directions: Answer the following questions regarding your COLLEGIATE ATHLETIC CAREER to the best of your knowledge. Your answers will remain confidential and will NOT be shared with your coaches or athletic training staff.

What is your gender?

Male
Female

How old are you?
18
19
20
21
22
23
24
Other

What is your academic year in school?
Freshman
Sophomore
Junior
Senior
5th Year
Other

Which collegiate sport(s) did you participate in? Check all that apply
Baseball
Basketball
Cheerleading
Cross Country
Equestrian
Fencing
Field Hockey
Football
Golf
Gymnastics
Ice Hockey
Lacrosse
Rifle
Rowing
Skiing
Soccer
Softball
Swimming and Diving
Tennis
Track and Field
Volleyball
Water Polo
Wrestling
Other

What was your primary position in your sport?

Which division did your school compete in? (Select all that apply)

NCAA I
NCAA II
NCAA III
NJCAA
Other

How many years did you participate in your sport at the collegiate level?

1
2
3
4
5
Other

Directions: Please answer the following questions about your collegiate athletic career as honestly as possible. Your answers will remain confidential and will not be shared with your coaches or athletic training staff.
Have you ever sprained your ankle?
Yes
No

Have you ever injured a ligament or cartilage in your knee?
Yes
No

Have you ever sprained any other joints (shoulder, wrist, etc.) while playing sports?
Yes
No

Have you ever suffered a concussion?
Yes
No

Did you ever suffer a concussion and not tell anyone?
Yes
No

Have you ever hurt your back?
Have you ever broken a bone?
Yes
No

Have you ever dislocated your shoulder?
Yes
No

Have you ever pulled, strained, or torn your rotator cuff or any other structure in your shoulder?
Yes
No

Have you ever been knocked out while playing sports?
Yes
No

Have you ever pulled, badly strained, or torn a muscle?
Yes
No
Have you ever been "knocked silly/seen stars" (confused/disoriented) while playing sports?
Yes
No

Have you had multiple ankle sprains?
Yes
No

Have you had any episodes of your ankle giving way?
Yes
No

Do you have any current residual (lingering) symptoms regarding your ankle sprains?
Yes
No

Have you ever experienced any season ending injuries?
Yes
No

During your collegiate athletic career, did you ever have any orthopedic surgeries?
Following a blow to the head, if you had experienced a headache, dizziness, or confusion, would you report it to your athletic trainer?

Yes

No

Have you ever had injuries that you did not tell your athletic trainer about?

Yes

No

Have you ever been hit so hard you lost your memory while playing sports?

Yes

No

During your collegiate athletic career, do you feel like you had a good relationship with your athletic trainer?

Yes

No

Survey Powered By Qualtrics
After a review of your proposed research project numbered H11375 (H14359) and titled "Accuracy of Injury Reporting Upon Completion of a Collegiate Athletic Career" it appears that (1) the research subjects are at minimal risk, (2) appropriate safeguards are planned, and (3) the research activities involve only procedures which are allowable. You are authorized to enroll up to a maximum of ___ subjects.

Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that the Institutional Review Board has approved your proposed research. – Description: The purpose of this study is to assess the underreporting of concussions in athletes at the end their collegiate careers through an injury history questionnaire.

If at the end of this approval period there have been no changes to the research protocol; you may request an extension of the approval period. Total project approval on this application may not exceed 36 months. If additional time is required, a new application may be submitted for continuing work. In the interim, please provide the IRB with any information concerning any significant adverse event, whether or not it is believed to be related to the study, within five working days of the event. In addition, if a change or modification of the approved methodology becomes necessary, you must notify the IRB Coordinator prior to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, you are required to complete a Research Study Termination form to notify the IRB Coordinator, so your file may be closed.

Sincerely,

Eleanor Haynes
Compliance Officer
APPENDIX D

TABLES AND FIGURES
Table 1: Demographics

An overall representation of our response demographics, with primary responses from NCAA division I, females, and soccer athletes. The majority of responses were collected via pen & paper.

<table>
<thead>
<tr>
<th>Participants</th>
<th>n=133</th>
</tr>
</thead>
<tbody>
<tr>
<td>Division</td>
<td>NCAA I 69.6% (87/125)</td>
</tr>
<tr>
<td>Gender</td>
<td>Female 64.7% (86/133)</td>
</tr>
<tr>
<td>Age</td>
<td>20.91±1.41</td>
</tr>
<tr>
<td>Academic Year</td>
<td>Senior 51.1% (≥Senior 62.4%)</td>
</tr>
<tr>
<td>Years Participated</td>
<td>3.04±1.39</td>
</tr>
<tr>
<td>Sports</td>
<td>Soccer 21.7%, Basketball 20.3%, Football 13.8%</td>
</tr>
<tr>
<td>Response Type</td>
<td>Pen &amp; Paper 72.9%</td>
</tr>
</tbody>
</table>
Figure 1: Sport Demographics
A representation of the responses by individual sport, with the most responses from soccer, basketball and cheerleading.
Figure 2: Division demographics of our responses. “Other” primarily consisted of cheerleaders, who do not compete in an NCAA division and student-athletes who reported playing at more than one level.
Table 2: Text Responses to why respondents would not report.
Though we received minimal responses on the open ended question regarding why an athlete would not report, they were similar answers to why some individuals’ concussions go unreported.

<table>
<thead>
<tr>
<th>Reason</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Because I came to play not sit on the bench</td>
<td>i didn't think it was serious enough</td>
</tr>
<tr>
<td>Fear of being pulled</td>
<td>See 5a) If I didn't think it was serious, I wouldn't have said anything</td>
</tr>
<tr>
<td>Can handle a little headache</td>
<td>I would want to keep playing</td>
</tr>
<tr>
<td>make me sit for too long</td>
<td>knew it would go away</td>
</tr>
<tr>
<td>depends on how severe</td>
<td>may get pulled from a game</td>
</tr>
<tr>
<td>playing is too important to me</td>
<td>did not want to make a big deal</td>
</tr>
<tr>
<td>didn't want to sit out</td>
<td>Because I would want to play and the future and eventually the symptoms should go away,</td>
</tr>
<tr>
<td>I was always fine after</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall Rate</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Reported Rate</td>
<td>34.1% (45/132)</td>
</tr>
<tr>
<td>Unreported Rate</td>
<td>12.8% (17/133)</td>
</tr>
<tr>
<td>Potentially Unrecognized</td>
<td>18.8% (25/133)</td>
</tr>
<tr>
<td>-Knocked Out</td>
<td>.8% (1/133)</td>
</tr>
<tr>
<td>-Knocked Silly</td>
<td>17.6% (23/131)</td>
</tr>
<tr>
<td>-Lost Memory</td>
<td>3.0% (4/133)</td>
</tr>
<tr>
<td>Pot. Conc Injury</td>
<td>42.9% (57/133)</td>
</tr>
<tr>
<td>Would Report</td>
<td>57.3% (75/131)</td>
</tr>
</tbody>
</table>

Table 3: Overall Results per Variable

A comprehensive view of results of overall rates, gender and sport responses per variable.
Figure 3: Overview of Primary Variable Rates

A side-by-side view of our three primary variables and the overall potential concussive injury rate.
Figure 4: Reported Rates by Sport

A view of the sports with greatest reported rate based on overall responses, with soccer, football, and cheerleading having the highest reported concussion rate.
Table 4: Number of Reported Concussions

<table>
<thead>
<tr>
<th># of concussions</th>
<th># of athletes</th>
<th>Percentage of athletes</th>
<th>Percentage of athletes w/ Concussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27</td>
<td>20.3%</td>
<td>60.0% (27/45)</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>9.8%</td>
<td>28.9% (13/45)</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>2.3%</td>
<td>6.7% (3/45)</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>.8%</td>
<td>2.2% (1/45)</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>.8%</td>
<td>2.2% (1/45)</td>
</tr>
</tbody>
</table>

*3+ Concussions: 11.1% of individuals with concussions

A comprehensive table of the number of reported concussions, and what percentage of overall respondents it was comprised of, as well as what percentage of the self-reported concussions each number represented.
Figure 5: Unreported Rates by Sport

A view of the sports with greatest unreported rate based on overall responses. Soccer had the majority of unreported cases, encompassing 41.2% of all unreported responses.
<table>
<thead>
<tr>
<th>Reasoning for Not Reporting</th>
<th>McCrea 2004</th>
<th>Broglio 2010</th>
<th>Llewellyn 2014</th>
<th>Current Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not think it was serious?</td>
<td>66.4%</td>
<td>94.4%</td>
<td>42.1%</td>
<td>52.9%</td>
</tr>
<tr>
<td>Did not know it was a concussion?</td>
<td>36.1%</td>
<td>66.7%</td>
<td>52.6%</td>
<td>23.5%</td>
</tr>
<tr>
<td>Did not want to be pulled from practice/game?</td>
<td>41.0%</td>
<td>66.7%</td>
<td>42.1%</td>
<td>76.5%</td>
</tr>
<tr>
<td>Did not want to be pulled from future practices/games?</td>
<td>N/A</td>
<td>N/A</td>
<td>52.6%</td>
<td>76.5%</td>
</tr>
<tr>
<td>Did not want to let your teammates down?</td>
<td>22.1%</td>
<td>38.9%</td>
<td>42.1%</td>
<td>52.9%</td>
</tr>
<tr>
<td>Would have if it was a less important practice/game?</td>
<td>N/A</td>
<td>N/A</td>
<td>21.1%</td>
<td>17.6%</td>
</tr>
<tr>
<td>Concussions are a part of the game?</td>
<td>N/A</td>
<td>88.9%</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Other?</td>
<td>9.8%</td>
<td>N/A</td>
<td>5.3%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

A comparison to previous literature on the reasoning behind unreported concussions.
Figure 6: Potentially Unrecognized Concussion Rates

A view of the sports with greatest potentially unrecognized rate based on responses.
Figure 7: Potentially Unrecognized Concussions- “Knocked Out”

A view of the sports with greatest “knocked out” rate based on responses. Only one incidence was potentially unrecognized and was acknowledged by a soccer athlete.
Figure 8: Potentially Unrecognized- “Knocked Silly”

A view of the sports with greatest “knocked silly” rate based on responses.
Figure 9: Potentially Unrecognized- “Lost Memory”

A view of the sports with greatest reported “lost memory” rate based on responses.
Figure 10: Combined Rates of Overall Potential Concussive Injuries

A view of the sports with greatest combined rates based on responses.
Figure 11: Overall Potential Concussive Injury Rate by Sport

Of the total responses for each sport, the calculated overall potential concussive injury rate included if they had a positive response for reported concussion, unreported concussion, or any of the potentially unrecognized questions.
Figure 12: Would Report Concussive Symptoms

A view of the sports with greatest rate of those who would report symptoms based on responses.
Table 6: Response Rates Divided by Division
A comparison between divisions based on responses for each of the variable.

<table>
<thead>
<tr>
<th>Division/Total:</th>
<th>NCAA I</th>
<th>NCAA II</th>
<th>NJCAA</th>
<th>Other</th>
<th>No Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported Rate</td>
<td>66.7% (30/45)</td>
<td>13.3% (6/45)</td>
<td>8.9% (4/45)</td>
<td>4.4% (2/45)</td>
<td>4.4% (2/45)</td>
</tr>
<tr>
<td>Unreported Rate</td>
<td>64.7% (11/17)</td>
<td>11.8% (2/17)</td>
<td>5.9% (1/17)</td>
<td>17.6% (3/17)</td>
<td>0.0% (0/17)</td>
</tr>
<tr>
<td>Pot. Unrecognized</td>
<td>60.0% (15/25)</td>
<td>16.0% (4/25)</td>
<td>4.0% (1/25)</td>
<td>16.0% (4/25)</td>
<td>0.0% (0/25)</td>
</tr>
<tr>
<td>-Knocked Out</td>
<td>100.0% (1/1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-Knocked Silly</td>
<td>60.9% (14/23)</td>
<td>13.0% (3/23)</td>
<td>4.3% (1/23)</td>
<td>17.4% (4/23)</td>
<td>0.0% (0/23)</td>
</tr>
<tr>
<td>-Lost Memory</td>
<td>50.0% (2/4)</td>
<td>25.0% (1/4)</td>
<td>0.0% (0/4)</td>
<td>25.0% (1/4)</td>
<td>0.0% (0/4)</td>
</tr>
<tr>
<td>Would Report</td>
<td>69.3% (52/75)</td>
<td>10.7% (8/75)</td>
<td>9.3% (7/75)</td>
<td>4.0% (3/75)</td>
<td>5.3% (4/75)</td>
</tr>
</tbody>
</table>
Table 7: Number of Concussions Based on Division

A comparison of responses involving number of concussions reported divided by each division.

<table>
<thead>
<tr>
<th></th>
<th>NCAA I</th>
<th>NCAA II</th>
<th>NJCAA</th>
<th>Other</th>
<th>No Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 8: Lower Extremity Injury Chi-Square

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Lower Extremity N</th>
<th>Lower Extremity Y</th>
<th>$\chi^2$</th>
<th>P</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Reported Rate</td>
<td>45</td>
<td>9</td>
<td>36</td>
<td>1.487</td>
<td>.223</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Overall Potential Concussive Injury</td>
<td>57</td>
<td>10</td>
<td>47</td>
<td>3.958</td>
<td>.047</td>
<td>2.034</td>
<td>1.0-5.3</td>
</tr>
</tbody>
</table>

Chi-square results for the comparison of lower extremity injuries and concussive variables.