Comparison of recovery time from uncomplicated sports-related mild traumatic brain injury (mTBI) in intercollegiate athletes: A baseline study for quality assessment and improvement of an intercollegiate athletic program

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Abstract

Sports-related mild traumatic brain injuries (mTBIs) have become an increasingly popular topic. Cognitive and physical rest are the mainstays of management, but effective evidence-based therapies do not exist. Very few studies report mean recovery times from mTBI and even less for intercollegiate athletes. The primary aim is to retrospectively compare the recovery time in athletes from a large Division I University that suffered a sports-related mTBI during 2010 - 2012 to published data for quality assessment and improvement. Since the institution's concussion management follows current guidelines, no significant difference was expected. Secondary aims included comparing recovery times between gender, sport, and league. As reported in current literature, no significant gender differences were expected. 53 athletes with sports-related mTBI (27 male and 26 female) showed a mean recovery time of 10.11 days (95 % confidence interval [CI] = 8.58 - 11.65 days), statistically different than the time reported in 1 study of 7 days, but not in another of 7 - 10 days. Mean recovery time in males and females was 9.74 days (95 % CI = 7.38 - 12.1 days) and 10.5 days (95 % CI = 8.4 - 12.6 days), respectively. Mean recovery time in National Collegiate Athletic Association (NCAA) and non-NCAA (club) athletes was 9.91 days (95 % CI = 8.27 - 11.55) and 11.25 days (95 % CI = 5.87 - 16.63), respectively. A nonparametric Wilcoxon rank-sum test showed no significant variation between genders and between NCAA and non-NCAA athletes. Subgroup statistics of 13 sports were inconclusive due to inadequate power. However, the subgroup of male football athletes showed a mean recovery time of 6.5 days (95 % CI = 4.86 - 8.14 days), which was not significantly different than published rates. Multiple confounding variables were not well controlled for including: sport, gender, concussion severity, multiple concussions, etc. However, this study did highlight areas for quality improvement in the institution's concussion management plan. Further investigation with increased power and confounding variable control is indicated for a more definitive mean time to recovery. This study is the first to detail the mean time to recovery from sports-related mTBI in an intercollegiate athletic program. Similar studies should be done at other institutions for quality assessment and improvement of

concussion management. Such data will be useful in establishing a baseline for measure of efficacy in future investigations of therapeutic interventions.

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Introduction

A concussion is defined by the Consensus Statement on Concussion in Sport as a "complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces"[1]. It can be characterized by the following:

1. Concussion may be caused by a direct blow to the head, face, neck, or elsewhere on the body with an "impulsive" force transmitted to the head;
2. Concussion typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously;
3. Concussion may result in neuropathologic changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury;
4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical cognitive symptoms typically follows a sequential course; however, it is important to note that in a small percentage of cases, postconcussive symptoms may be prolonged;
5. No abnormality on standard structural neuroimaging studies is seen in concussion.

There is disagreement in the literature over the exact definition and whether a concussion is the same as a mild traumatic brain injury (mTBI). For the purposes of this study the terms "sports-related mTBI" and "concussion" will be used interchangeably.

Sports-related mTBI is a common condition suffered by athletes. There are an estimated 1.6 to 3.8 million sports-related mTBIs each year in the United States[2]. According to the Injury Surveillance System (ISS) of the National Collegiate Athletic Association (NCAA), among collegiate athletes there was an average of 0.28 concussions per 1000 athlete-exposures (A-E; defined as one athlete participating in one practice or competition) from the 1989 - 1999 season to the 2003 - 2004 season[3]. Approximately 20 guidelines exist for the evaluation and management of concussions[4]. However, they are all based on expert opinion rather than

scientific data and there is no agreement on which guideline is the most appropriate[5]. The literature clearly demonstrates the lack of sound evidence based guidelines for the management of sports concussion[6-10]. Furthermore, there is a lack of effective evidence-based pharmacological management options for athletes who suffer from concussion[6-10]. Much of the literature reflects this and expresses the need for more evidence for effective management options, particularly pharmacological therapy.

The most consistent and established recommendation for the management of athletes with concussion is physical and cognitive rest[1,7]. They are considered the cornerstones of concussion management. Over the past decade, guidelines for return to play in athletes have become increasingly stringent, especially in children and adolescents[1]. In addition to strict physical rest, students are removed from class in order to achieve complete cognitive rest. The reasoning behind this is the thought that attending classes leads to increased cognitive demand resulting in impaired recovery. Additionally students are asked to abstain from other activities that would lead to increased cognitive work including texting, playing video games, computer use, and watching television. Before further interventions can be identified and investigated, the mean rate of recovery must first be determined.

With the increased concern over the detrimental sequelae of sports concussions, the majority of intercollegiate programs institute a step-wise return to play protocol to help determine concussion resolution[1]. The time to resolution of the majority (80 - 90 %) of concussions is about 7 - 10 days. Very few studies have reported the mean time to recovery of intercollegiate athletes suffering from sports-related mTBI[11,12]. Lack of empirical data on concussion recovery time impairs an already difficult clinical decision on the appropriate and safe time for return to play. In male collegiate football players, the NCAA concussion study demonstrated an average of 7 days until the athletes were fully recovered from their sports-related concussion and subsequently returned to play[12]. Unfortunately, at this time, colleges and universities do not routinely publish records of the mean time to recovery of their athletes from concussions.

Therefore, universities are still left with very little data with which to reference an athletes recovery from an mTBI.

The immediate post-concussion assessment and cognitive testing (ImPACT) battery is a widely used neurocognitive testing battery for evaluation of individuals suffering from concussion. It should be noted that ImPACT is not universally accepted as a valid cognitive tool. However, studies demonstrate that combined clinical assessment and computerized neurocognitive testing, specifically ImPACT, has been validated and shown to have the highest sensitivity, specificity, positive predictive value, and negative predictive value in predicting recovery after sports-related concussion[13-15]. Every contact sport athlete at this institution receives a baseline ImPACT battery at the beginning of their first season. In addition, concussed athletes receive testing 24 - 48 hours post concussion, when asymptomatic with exertion, and until the time at which the athlete's neurocognitive testing is near or at their pre-injury baseline. An athlete is generally cleared to return to play when the athlete is asymptomatic at rest, asymptomatic with exertion, and the ImPACT testing is at or near baseline. Because this institution's return to play protocol follows the same step-wise progression as other intercollegiate athletic programs across the country, recovery rates at this institution are expected to be comparable to estimates nationally and among other intercollegiate programs.

The primary goal of the study is to determine how the recovery rate of intercollegiate athletes who suffer from a sports-related concussive head injury at this university compares to recovery rates currently published in the literature. This will allow a preliminary assessment of whether the current concussion management guidelines being used are producing comparable outcomes in regards to time to recovery. This information will be used for quality assessment and improvement of the sports concussion management at the study's university. In light of the dearth of data published on recovery rates of intercollegiate athletes suffering from sports concussion and the dearth of options available for pharmacologic treatment, this study will provide baseline data for future therapeutic interventions.

A secondary goal of this study is to determine whether there is a significant difference in the time to recovery between gender in our study population. Based on current published data, it is expected that there should be no significant difference in the time to recovery from sports-related mTBI between male and female intercollegiate athletes[1]. However, the most recent consensus statement on concussion does indicate that gender is a possible modifying factor[1]. Although the expert panel at the Zurich Conference found no definitive evidence among the currently published literature that female gender is a modifier in the management of concussion, it was accepted that gender can be a risk factor for injury and/or influence the severity of injury[16].

Other secondary goals include comparing recovery times between sport subgroups and between National Collegiate Athletic Association (NCAA) and non-NCAA (club) athletes. It is unlikely that recovery times at the sport subgroup level will obtain adequate power to show statistical significance in this study. Although NCAA and non-NCAA athletes are treated by separate teams of healthcare professionals, it is expected that recovery times will be comparable as concussion management guidelines and recommendations are standardized across healthcare teams at this study's institution.

The following study analyzes the mean recovery time of a large Division I University's intercollegiate athletes who have suffered an uncomplicated sports-related mTBI during the 2010 - 2012 seasons. It is meant to serve only as a baseline study for quality assessment, quality improvement, and future investigation of therapeutic interventions. Over the last 10 years, there has been an annual average of 35 concussions among the study institution's intercollegiate athletes. However, the mean rate of recovery from concussions has never been assessed. With a known mean rate of recovery, future studies investigating therapeutic interventions will have a baseline from which efficacy can be adequately assessed.

Research Materials & Methods

Participant selection

All intercollegiate athletes including athletes participating in National Collegiate Athletic Association (NCAA) and non-NCAA sports (e.g. club athletes) who attended a large Division I University and suffered a sports-related mild traumatic brain injury (mTBI) from the beginning of the 2010 academic year through mid-November 2012 were eligible for participation in this study. All participants received care through the sports medicine department at this study's institution. NextGen, the electronic medical record (EMR) at the institution, contains health records of all previously concussed athletes. This system was data-mined for all NCAA and club athletes that suffered an mTBI during the study time frame. In addition, immediate post-concussion assessment and cognitive testing (ImPACT), which the institution has a license for, was also data mined for all individuals that took a post-concussive ImPACT test during the same time frame and cross-referenced with the EMR data. At the study's institution, all NCAA intercollegiate athletes and non-NCAA intercollegiate club athletes are required to undergo a thorough pre-participation evaluation including baseline ImPACT testing if they participate in a high risk sport for head injury. These high risk sports include football, basketball, soccer, hockey, equestrian, gymnastics, wrestling, water polo, rugby, cheerleading, baseball, softball, field hockey, lacrosse, waterskiing, tae kwon do, and diving.

A chart review was done of all sports-related mTBI cases from August 2010 to mid-November 2012. Individuals who were diagnosed with head injuries other than a sports-related mTBI were not included for review. These diagnoses include but are not limited to: subdural hematomas, epidural hematoma, anxiety disorder, conversion disorder, tension headaches, migraine headaches, and occipital neuralgia. Patients who obtained a non-sport related concussion (e.g. via fight, car accident, etc.) or were under the influence of alcohol at the time of the injury were not eligible for the study. Other patients who were also not eligible for the study included:

patients not participating in an intercollegiate sport and patients without medical records. A total of 55 records were identified as eligible for this study.

Exclusion Criteria

A number of exclusion criteria were applied to exclude athletes initially identified as eligible for the study. These included, athletes who had injuries complicated by post-concussive syndrome, records without definitive dates of clearance for return to play, athletes who were referred to a neurological specialist for refractory or complicated injuries, patients with abnormal imaging, and athletes requiring medical treatment of symptoms. Post-concussion syndrome occurs in about 10 % of concussed patients and the diagnosis is currently poorly defined[17]. At 4 - 6 weeks post-concussion, the diagnosis of post-concussive syndrome generally comes into consideration. Of the 55 records identified initially as eligible for this study, a total of 2 records were excluded from this study. One female water polo athlete was excluded due to referral to a neurological specialist for refractory symptoms and likely post-concussion syndrome. One male football athlete was excluded because of a lack of definitive dates as his injury occurred over winter break of the academic year and there was no follow up during that time. 53 cases were included for final analysis of this study including 27 males and 26 females.

Determination of time to recovery

All concussed athletes are evaluated as indicated by the institution's guidelines for athletes diagnosed with concussion. Baseline ImPACT testing is obtained for all athletes from high risk sports. The management of concussions and return to play guidelines are in accordance with recommendations from the Consensus statement on concussion in sport[1]. The guidelines follow a stepwise progression listed below:

1. Asymptomatic at rest
2. Asymptomatic with exertion
3. Neurocognitive testing that is at or above baseline
4. Normal CT/MRI if done

Concussed inter-collegiate athletes are monitored closely by their respective team athletic trainers, who act as physician extenders and aid in obtaining symptom scores during recovery. Team physicians are notified by the athletic trainers when a concussed athlete becomes asymptomatic at rest or asymptomatic with exertion. In order to objectively document cognitive recovery, computerized neurocognitive testing, ImPACT, is used to assess cognitive status. The clinical utility and importance of neurocognitive testing in the management of athletes with acute sports-related concussion has been emphasized[1]. ImPACT is not universally accepted as a valid cognitive tool. However, studies demonstrate that combined clinical assessment and computerized neurocognitive testing, specifically ImPACT, has been validated and shown to have the highest sensitivity, specificity, positive predictive value, and negative predictive value in predicting recovery after sports-related concussion[13-15].

Resolution of concussion is defined as an athlete who is asymptomatic at rest, asymptomatic with exertion, and with an ImPACT at or above baseline. When all three of these criteria are met, the athlete is cleared for return to play with full concussion resolution.

It should be noted that, the team physicians for NCAA intercollegiate athletes and non-NCAA athletes are not the same group of physicians. Non-NCAA athletes are still seen at the same sports-medicine clinic, have neurocognitive testing done under the same license, and records kept in the same EMR, but are followed up by separate, equally qualified, and credentialed primary care sports medicine physicians.

All ImPACT records were cross referenced with each patient's record in NextGen EMR to determine recovery time. Each patient's sex, sport, and sport league (e.g. NCAA vs. non-NCAA) were recorded, patient information was de-identified and each record was assigned a numerical code. The date of concussion and date of clearance for return to play were recorded and the time from injury to return to play was defined as the time to recovery. As mentioned previously, athletes were not considered recovered until all the return to play guidelines were

met. Records meeting eligibility requirements were evaluated and those meeting exclusion criteria listed previously were excluded from the study.

Statistical Analysis

The following study is a retrospective chart review of intercollegiate athletes diagnosed with a sports concussion. The time to recovery from concussion will be recorded for each athlete. There are no controls in this study. There is no randomization of patients to an intervention or placebo controlled group. Time to recovery results published in the literature serve as comparison groups to the results of this study.

For the primary objective, a mean rate of recovery was determined from this data and rates were further delineated by gender, sport, and league. Results were compared for statistical significance with other reported mean recovery times found in the literature. This data was organized into a histogram showing the frequency of cases for each length of days to recovery. Superimposed on this data is a graph of the cumulative percentage of subjects who have recovered by that particular number of days. A set of descriptive statistics were also calculated for the data delineated by gender, sport, and league. A 95 % confidence interval for mean recovery times was determined assuming a non-normal distribution for the sample population. Using an upper tail probability, p, of 0.025 and the sample group size, a t distribution critical value was found to calculate the 95 % confidence interval[18].

For the secondary objectives, a nonparametric Wilcoxon rank-sum test was performed to test the hypothesis that each time to resolution measure as delineated by gender is drawn from the same underlying probability distribution against the alternative hypothesis that the underlying probability distributions are not the same for them. A Z value was determined for the observed values. A critical Z value of greater than 1.96 was used as the threshold for statistical significance. The standard p value of less than 0.05 was used as the threshold for statistical significance. This same statistical method was used to test the hypothesis that each time to resolution as delineated by sport league (e.g. NCAA vs. non-NCAA) is drawn from the same

underlying probability distribution against the alternative hypothesis that the underlying probability distributions are not the same for them.

Results

A total of 55 cases were identified as eligible for the study. Two cases met exclusion criteria and were excluded from the study. These cases are not represented in the results. 53 cases of sports-related mild traumatic brain injury (mTBI) were analyzed as shown in **Table 1**.

As shown in **Table 1**, the mean time to recovery in the study population was 10.11 days (95 % confidence interval [CI] = 8.58 - 11.65 days) for 53 cases from August 2010 to mid-November 2012. The mean time to recovery was greater than the published average of 7 days from the National Collegiate Athletic Association (NCAA) Concussion study, which did not fall within the 95 % confidence interval of this study[12]. As noted in **Table 1**, it is important to mention that the patient population in the NCAA study consisted only of concussed NCAA male football athletes. A 95 % confidence interval was not given in this study, which did not allow for in-depth evaluation of the significance of this difference. However, the 95 % confidence interval of 8.58 - 11.65 days overlapped with the mean time to recovery given in the Zurich Consensus Statement of 7 - 10 days[1]. However nothing further can be concluded from this overlap.

Figure 1 allows for further comparison of the time to recovery in this study with the time to recovery in the NCAA concussion study. The histogram in **Figure 1** shows the frequency of concussion cases for each length of days to resolution. As shown in this histogram, the most frequent number of days to resolution was 6 days, followed by 7 days, which is the shorter than or the same as the NCAA concussion study, respectively. Superimposed on the histogram in **Figure 1** is a graph of the cumulative percent of concussion cases in this study that have resolved by a particular number of days. The graph shows that 23 subjects or 43.4 % of the cases in this study were resolved within 7 days. Half or 50 % of the cases were resolved by 8 days post-concussion. The mean time to recovery in this study of 10.11 days is 44.47 % longer than the NCAA, which is statistically different. Without knowing the standard deviation, probability distribution, and specifics of the NCAA study, it is impossible to do a complete comparison with this study's data outside of the tables and figures presented. **Figure 1** also

Table 1: Comparison of time to recovery from sports-related mTBI

Source	Recovery Time (95 % CI) [days]	N
Current Study's Results	10.11 (8.58 - 11.65)	53
NCAA Concussion Study[12]	7[a]	79[b]
Zurich Consensus Statement[1]	7 - 10[c]	N/A[c]

[a]confidence intervals for this study were not given; [b]all athletes in this study were male NCAA football players; [c]a relative range was given without a confidence interval or mention of sample size

demonstrates that at the small sample size of this population, there is a non-normal distribution of recovery times from sports-related mTBI.

Table 2 compares the mean time to recovery from mTBI between males and females in this study. A total of 27 males and 26 females were included in this study. As shown in the table, male and female athletes in this study had a mean time to recovery of 9.74 days (95 % CI = 7.38 - 12.1 days) and 10.5 days (95 % CI = 8.4 - 12.6 days), respectively.

A nonparametric Wilcoxon rank-sum test was performed to test the null hypothesis that each time to resolution measure as delineated by gender is drawn from the same underlying probability distribution against the alternative hypothesis that the underlying probability distributions are not the same for them. Because the observed Z value of 0.72, is less than the critical Z value of 1.96, the null hypothesis is not rejected.

Table 3 compares the mean time to recovery from mTBI between NCAA and non-NCAA athletes in this study. A total of 45 NCAA and 8 non-NCAA athletes were included in this study. As shown in **Table 3**, NCAA and non-NCAA athletes in this study had a mean time to recovery of 9.91 days (95 % CI = 8.27 - 11.55) and 11.25 days (95 % CI = 5.87 - 16.63), respectively.

A nonparametric Wilcoxon rank-sum test was performed to test the null hypothesis that each time to resolution measure as delineated by league is drawn from the same underlying probability distribution against the alternative hypothesis that the underlying probability distributions are not the same for them. Because the observed Z value of 0.52, is less than the critical Z value of 1.96, the null hypothesis is not rejected.

Table 4 shows the mean time to recovery in the study population delineated by sport. A total of 13 different sports are represented in this study with 6 and 9 men's and women's sports, respectively. Confidence intervals were only calculated for sports with more than one case.

Figure 1: Histogram of frequency of concussion cases resolved by time to resolution with superimposed graph of cumulative percent of concussion cases resolved by post-concussive day

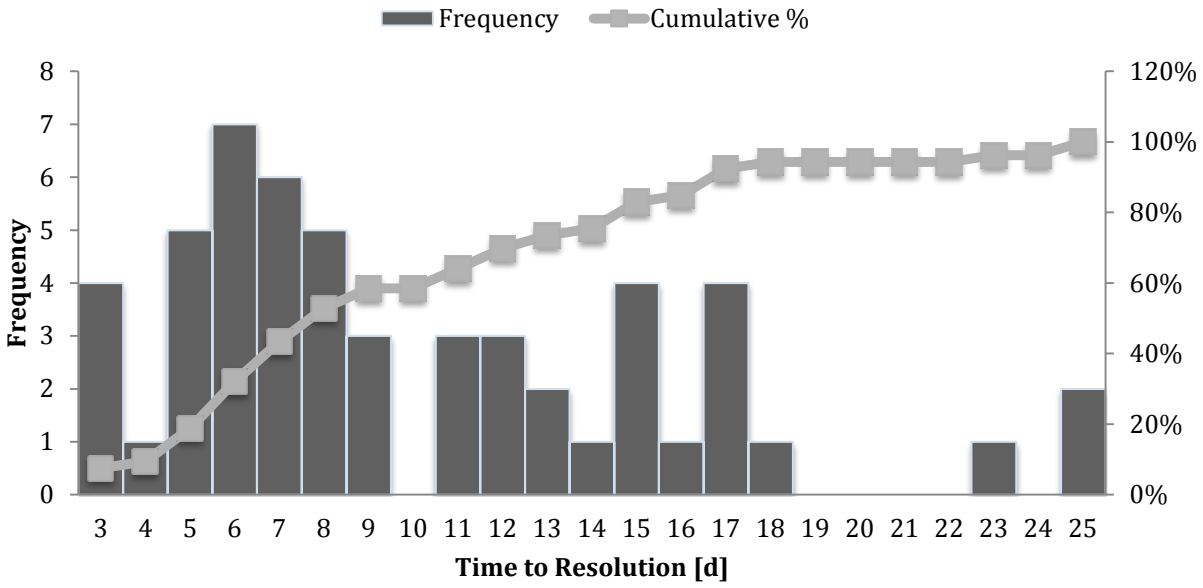

Table 2: Mean time to recovery from sports-related mTBI delineated by gender

Sex	Recovery Time (95 % CI) [days]	N
Male	9.74 (7.38 - 12.1)	27
Female	10.5 (8.4 - 12.6)	26

Nonparametric Wilcoxon rank-sum test: Z value = 0.72 ($Z_{critical}$ = 1.96)

Table 3: Mean time to recovery from sports-related mTBI delineated by sport league

Sport Group	Recovery Time (95 % CI) [days]	N
NCAA	9.91 (8.27 - 11.55)	45
Non-NCAA (Club)	11.25 (5.87 - 16.63)	8

Nonparametric Wilcoxon rank-sum test: Z value = 0.52 ($Z_{critical}$ = 1.96); NCAA - National Collegiate Athletic Association

Due to the low power of the study, the confidence intervals and standard deviations of the majority of the represented sports was large.

The sport with the most number of cases in this study was men's football with a total of 12 cases or 22.6 % of this study's 53 cases. The mean time to recovery for concussed football athletes in this study was 6.5 days (95 % CI = 4.86 - 8.14). This value is shorter than the value given in the NCAA concussion study shown in **Table 1** and the mean time to recovery in that study lies within the confidence interval for time to recovery of concussed football athletes in this study. Again, this subgroup, most closely matches the patient population in the NCAA comparison study. Note also, that the confidence interval for time to recovery in this specific subpopulation overlaps with the average values presented in the literature shown in **Table 1**.

Table 4: Mean time to recovery from sports-related mTBI delineated by sport

Sport	Recovery Time (95 % CI) [days]	N
Basketball	10.4 (3.57 - 17.23)	5
Basketball: Men	14[a]	1
Basketball: Women	9.5 (0.09 - 18.91)	4
Cheerleading: Women	12[a]	1
Football: Men	6.5 (4.86 - 8.14)	12
Gymnastics: Women	13[a]	1
Lacrosse: Men	8[a]	1
Rugby	12 (-1.12 - 25.12)	4
Rugby: Men	8.33 (-3.14 - 19.81)	3
Rugby: Women	23[a]	1
Soccer: Women	10.38 (6.05 - 14.71)	8
Surfing: Women	5[a]	1
Tennis: Women	17[a]	1
Track & Field: Male	17[a]	1
Volleyball: Women	7.5 (1.15 - 13.86)	2
Water Polo: Women	9.57 (5.48 - 13.67)	7
Wrestling: Men	13.44 (7.49 - 19.4)	9

[a]sports with a single case did not have confidence intervals

Discussion

The results shown in **Table 1** address the primary objective of this study of comparing the time to recovery in concussed intercollegiate athletes at this institution with rates currently presented in the literature. The study population consisted of 53 athletes (27 male and 26 female) from 13 different National Collegiate Athletic Association (NCAA) and non-NCAA sports. The mean time to recovery in the study population was 10.11 days (95 % confidence interval [CI] = 8.58 - 11.65 days). This value was significantly longer than the average time to recovery from the NCAA concussion study, but not from estimates from the Zurich consensus statement[1,12]. At a mean time to recovery of 10.11 days, this was 44.47 % longer than the time to recovery published in the NCAA concussion study, which is statistically significant. This significance would indicate that the original hypothesis that the time to recovery at this Division I University is similar to published rates can be rejected. However, the NCAA study did not publish information of their study population's standard deviation, probability distribution, and other specifics for the mean time to recovery. Without knowing this information, it is impossible to do a complete comparison with this study's data outside of the tables and figures presented in the results section and the results should be interpreted cautiously.

The power of this current study of 53 cases did not reach the power of the NCAA study of 79 cases[12]. As such, this study's population of cases may not have been representative of the general collegiate population.

Despite the statistically significant difference between this study's results and the NCAA concussion study, a statistically significant difference could not be determined when compared with the average time to recovery published in the Zurich Consensus Statement of 7 - 10 days[1]. The confidence interval of this study for mean time to recovery overlaps with the range presented in the Zurich Consensus Statement, but nothing further can be definitely concluded about the significance of this overlap.

This discrepancy between a statistically significant difference with one study and not the other indicates that no definitive conclusions can be drawn between the two comparisons. It is important to note that the NCAA concussion study evaluated only concussed male football players[12]. Our study included 12 cases of concussed male football players (22.6 % of this study's caseload), but also 41 cases of male or female athletes from 12 other sports. When comparing the time to recovery for this study's subgroup of male football players shown in **Table 4**, of 6.5 days (95 % CI = 4.86 - 8.14 days) to the published values in the literature shown in **Table 1**, there is no statistically significant difference between either study. The 95 % confidence interval for this subgroup overlaps with the average time to recovery presented in both of the studies in **Table 1**.

While the increased length of time to recovery in this paper might indicate the need for further quality improvement investigation in the concussion management, there are several important factors that need to be taken into consideration. Since other institutions do not routinely publish data on time to recovery from sports-related mTBI, it is difficult to assess how our institution compares to other similar institutions who manage similar patient populations.

Athletes with multiple or repeat concussions within the same year were included in this study. There is some evidence that suggests that individuals with recurrent concussions or multiple concussions exhibit a higher incidence of complicated injuries and long-term sequelae[19]. The effects of multiple concussions is an uncontrolled confounding variable that may alter the results. Five of the cases in this study were repeat concussions within the same year.

Conversely, the increased time to recovery in this study group may also be an indication that this institution's management of concussions lies more on the conservative side of treatment. Graduated return to play guidelines have become increasingly stringent over the past decade and time to return to play has only increased, especially in adolescent athletes[1]. The results may simply indicate that this institution’s concussion management is merely following a trend of increasingly stringent conservative management.

Since there currently are no effective evidence based therapeutic interventions for concussion management, cognitive and physical rest remain the cornerstones of concussion management[1,6-10]. Physical rest is usually achieved by keeping concussed athletes out of practice and games. However, as young adult student athletes, achieving optimal cognitive rest can be difficult. There is not only pressure on the field, but in the classroom. Not only are athletes encouraged to abstain from practice and games, but they are held out of class and instructed to avoid any activities which would increase cognitive demand including texting, playing video games, doing school work, using a computer, and similar activities[1]. This optimal cognitive rest is difficult to achieve in collegiate athletes and may not be consistent between individual cases. There is no way to ensure that patients fully comply with cognitive rest recommendations and it would be unreasonable to monitor them to ensure compliance.

Coordination between academic faculty and the intercollegiate athletic department may help improve compliance with cognitive rest, at least in regards to the classroom. Universities and colleges may consider establishing rules and policies that would allow student athletes to sit out of class without any adverse repercussions or punishment for compliant students.

There is also increased pressure to get athletes to return to the field of play for numerous reasons. These include the desire from the player to play and help his or her team; and the desire of the coaching staff to have all their players available and their team at full strength. From an institution's perspective, there is pressure to have star or starting players on the field to improve the product that they put on the field. This pressure is especially strong in high profile and high profit sports (e.g. football), which bring in significant revenue as high as tens of millions of dollars, to a university[20]. The average time to recovery for football players in this study and the NCAA study was 6.5 and 7 days, respectively. For the other sports represented in this study, nearly all had recovery times of greater than 7 days. The fact that there are typically 7 days between football games and an average time to recovery of 7 days or less for the football athlete subpopulation may not be much of a coincidence.

Although no definitive conclusions can be made in regards to the primary objective from the results of this study, the multiple confounding factors identified are beneficial to the quality assessment of this institution's concussion management. Although it was initially thought that many of the confounding factors in this study were due to the discrepancy in care between NCAA and non-NCAA athletes at this institution and that standardization of care across these groups was the most useful start for quality improvement, the results of a secondary analysis mentioned later on argued against this.

The results in **Table 2** support the hypothesis of the secondary aim of this study that there is no significant difference in time to recovery between genders. The Z value of 0.72 for the time to recovery between male and female cases is less than the critical Z value of 1.96, demonstrating that the time to recovery between the two groups was not statistically significant. These results are consistent with current published data[1]. However, the most recent consensus statement on concussion does indicate that gender is a possible modifying factor. Although the expert panel at the Zurich Conference found no definitive evidence among the currently published literature that female gender is a modifier in the management of concussion, it was accepted that gender can be a risk factor for injury and/or influence the severity of injury[1,16]. There was no evidence that this was the case in this study. The near equal incidence of concussions in both genders in this study show no indication of increased risk of injury due to gender. However, as mentioned previously, the low power of this study could have led to a beta-type error.

At this institution, the team physicians for NCAA intercollegiate athletes and non-NCAA athletes are not the same groups of physicians, although they do carry the same credentials. Non-NCAA athletes are still seen at the same sports-medicine clinic, have neurocognitive testing done under the same license, and records kept in the same EMR, but are followed up by separate club athlete physicians. Non-NCAA athletes or club athletes do not have their own athletic trainers and are not followed up as closely as NCAA athletes in regards to the graduated return to play leading to another source of uncontrolled variability. Two of the club sports included in

this study that are not typically considered NCAA sports and not typically included in NCAA data are rugby and surfing. The addition of these cases changes the study population and makes comparisons with NCAA data unequal. It was initially hypothesized that concussion management between the two groups of NCAA and non-NCAA athletes and physicians were not equal and were likely leading to additional confounding variability in this study.

An additional secondary aim was added to the study, comparing the recovery times between NCAA and non-NCAA athletes. The results of this secondary aim are shown in **Table 3**. As shown in the table, NCAA and non-NCAA athletes had a mean time to recovery of 9.91 days (95 % CI = 8.27 - 11.55) and 11.25 days (95 % CI = 5.87 - 16.63), respectively. A nonparametric Wilcoxon rank-sum test showed no statistically significant difference between these two groups. However, it is important to note that the power of the non-NCAA subgroup was much lower with an n = 8 compared to an n = 45 for the NCAA subgroup. A difference may not have been identified in this study secondary to a beta-type error.

The results of this study were further delineated by sport and gender presented in **Table 4**. A total of 13 different sports were represented in this study with 6 and 9 men's and women's sports, respectively. Confidence intervals were only calculated for sports with more than one case. The low power of this study becomes increasingly magnified at the sport and gender subgroup level. The majority of these subgroups have large 95 % confidence intervals due to the low power within each subgroup.

The sport subgroup with the most number of cases in this study was men's football with a total of 12 cases or 22.6 % of this study's total cases. The mean time to recovery for concussed football athletes in this study was 6.5 days (95 % CI = 4.86 - 8.14). This value is shorter than the value given in the NCAA concussion study shown in **Table 1.** The mean time to recovery in the NCAA study lies within the confidence interval for time to recovery of concussed football athletes in this study. The confidence interval for the mean time to recovery in this specific subpopulation also overlaps with the average values presented in the literature shown in **Table**

1. As mentioned previously, this subgroup is most similar to the study group in the NCAA concussion study and may be more appropriately used for comparison[12].

It is clear from this study that more data is needed for sports-related mTBIs regarding time to recovery. Very few studies have reported the mean time to recovery of intercollegiate athletes suffering from sports-related mTBI[11,12]. Lack of empirical data on concussion recovery time impairs an already difficult clinical decision on the appropriate and safe time for return to play. Higher powered data across larger subgroups and different intercollegiate athletic programs will allow for establishing a more reliable baseline mean time to recovery.

With this information, professionals in this field can begin to look beyond statistics to possible therapeutic interventions for improving the management of sports-related mTBI. As mentioned previously, there is a dearth of evidence-based effective medical therapeutic interventions for concussions. With this baseline data for time to recovery in this intercollegiate athletic program, studies on clinical interventions can be performed and the efficacy of interventions can be assessed based on change from baseline in time to recovery.

Future Directions

One of the most significant weaknesses of this study is its low power, especially regarding the sport subgroups. Further investigation is required with sufficient power before establishing a definitive mean time to recovery from sports-related mTBI at both this institution and in the general collegiate athlete population. Future studies should better control for other confounding variables. These include gender, sport, mechanism of injury, repeat concussions, co-morbid conditions, post-concussive syndrome, and standard of care. Similar studies from other collegiate athletic institutions should be done to allow for a more thorough comparison of time to recovery. Without more published data on time to recovery, adequate comparisons for statistical significance cannot be performed as was the problem in this study.

Further work is necessary in investigating certain subpopulations of athletes experiencing sports concussions. Specifically included in these subpopulations are cases of multiple concussions and post-concussive syndrome. Evidence of whether cases of multiple concussions can be categorized as a typical sports-related mTBI will be useful in improving data analysis. The effect of sport and mechanism of injury on time to recovery should also be further delineated. The extremely low power of this study at the sport subgroup level did not allow for any definitive conclusions. Future studies should match cases to both gender and sport to allow for more accurate comparisons.

More specifically to this institution, this study has provided a helpful quality assessment of the program's management of concussions and has led to identification of future areas for quality improvement. Although the results of this study did not indicate a statistically significant difference in the recovery times between NCAA and non-NCAA athletes, it did bring to light the question of whether these two groups receive the same post-concussion management. This study had an extremely low power of non-NCAA cases and a difference may have been missed secondary to this. The question of whether there may still be a need to standardize care across NCAA and non-NCAA athletic programs at this institution is not definitively answered.

Comparison of recovery rates from these two groups should be further evaluated and the same should be done at other similar institutions. Regardless of the results, care between both groups of physicians should be standardized in regards to initial cognitive testing and adherence to the institution's stepwise graduated return to play protocol. This improvement will make the data more robust and reliable.

As the field continues to see an increase in stringency of concussion management towards more conservative measures, more needs to be done to ensure adherence to physical and cognitive rest recommendations. Since this is the only effective means for managing concussions, it is imperative that all institutions optimize this intervention. Athletic departments must partner with academic departments to reduce pressures of having athletes return to play or to the classroom too early.

Once a reliable baseline mean time to recovery is established, investigation into clinical interventions for improving concussion management can be initiated. Having this baseline time to recovery allows for comparison from which the efficacy of a therapeutic intervention can be assessed. An example of such an investigation is detailed below.

Among individuals who suffer from traumatic brain injury (TBI; this includes mild, moderate and severe TBIs), the prevalence of sleep disturbances is 30 % - 70 %[21]. Among TBIs, sleep disturbances are more frequently found in mTBI than severe TBI[21]. One possible investigation for therapeutic intervention could be using a sleep aid, such as cyclobenzaprine (Flexeril) to aid in the recovery from sports-related mTBI. Cyclobenzaprine is a commonly used drug for people with sleep disturbance and because many people with concussions exhibit sleep disturbances, it may be reasonable to hypothesize that intervention with cyclobenzaprine will improve time to recovery[22]. With reliable baseline data of time to recovery recommended in this study, a control group comparison can exist from which the efficacy of a therapeutic intervention can be measured.

Conclusions

Concussion management and sequelae have become an increasingly popular subject over the past decade. There continues to be a lack of evidence based therapeutic options and data on time to recovery in the literature. This retrospective analysis of concussion cases showed a mean time to recovery of 10.11 days (95 % confidence interval [CI] = 8.58 - 11.65 days) from sports-related mild traumatic brain (mTBI) injuries. This value had a statistically significant difference than one of the two studies used for comparison. However, the data for the comparison study was incomplete to allow for a robust comparison. A comparison of a more closely matched subgroup of male football athletes showed no statistically significant difference between this study's population and the published data. Similar studies should be done, but with a larger study group and improved control of the confounding variables before a reliable baseline time to recovery can be established among this study's population.

This study did serve one of its primary goals of providing a quality assessment and a measure for quality improvement. This study helped to identify a potential source of variability in the standard of care regarding concussion management between National Collegiate Athletic Association (NCAA) and non-NCAA athletes. Although initial results from this study did not show significant differences in recovery times between NCAA and non-NCAA athletes, further investigation is needed in determine whether this is truly an area of need for quality improvement. Cooperation between multiple collegiate departments is also recommended to improve adherence to concussion management recommendations.

This study demonstrates the utility of such an investigation. Similar studies with better control for confounding variables should be performed by other institutions for a more reliable determination of mean time to recovery. These studies should further delineate time to recovery by sport. Such studies can provide other institutions with assistance in quality assessment and improvement of concussion management as in this study's case.

With baseline data for mean time to recovery from sports-related mTBI, possible therapeutic interventions can be investigated for improvement in concussion management. This study and future similar studies will provide a baseline mean time to recovery from which efficacy of a therapeutic intervention can be adequately assessed.

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