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Recovery duration and concussion severity in sport- and non-sport-related concussion among Pac-12 collegiate athletes: a retrospective cohort study

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ABSTRACT

Objectives To examine non-sport- and sport-related concussion severity, clinical care frequency and delayed reporting in relation to recovery duration among collegiate athletes.

Design Retrospective cohort study.

Setting Pac-12 varsity collegiate athletes.

Participants 461 collegiate male and female athletes

Primary and secondary outcome measures The incidence of sport-related concussion (SRC) and non-sport-related concussion (NRC) were collected as well as times to recovery and return-to-play (RTP), symptom score and symptom severity and reported a loss of consciousness (LOC), retrograde amnesia (RGA) and post-traumatic amnesia (PTA) following concussion incidence.

Results Among 461 concussions, 388 (84%) occurred within sport and 73 (16%) occurred outside of sport. NRC, on average, required 3.5 more days to become asymptomatic (HR: 0.73, 95%confidence interval: 0.56 to 0.96, p=0.02) and 7 more days to RTP (HR: 0.64, 95% confidence interval: 0.49 to 0.85, p<0.01) compared with SRC. NRC were associated with an increase of 1.83 (p=0.07) symptoms reported at the time of diagnosis, an increase of 6.95 (p=0.06) in symptom severity and a higher prevalence of reported LOC (22% NRC vs. 3% SRC, p<0.001), PTA (15% NRC vs. 5% SRC, p<*0*.01) and RGA (10% NRC vs. 4% SRC, p=0.06), compared with SRC. There was no significant difference in clinical care (p=0.28) or immediate reporting (p=0.35) between NRC and SRC.

Conclusion NRC were associated with greater severity and longer recovery duration when compared with SRC in a cohort of collegiate athletes.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is the first study to investigate differences in sport-related concussion (SRC) and non-sport-related concussion (NRC) in Pac-12 athletes.
⇒ NRC and SRC may have been underreported during the study period.
⇒ The mechanism of injury for NRC was not collected and could not be controlled for during analysis.

INTRODUCTION

Sport-related concussion (SRC) has been a subject of interest to both the public and scientific communities, but the contribution of non-sport-related concussion (NRC) is often underappreciated. Epidemiological studies of concussion in athletes often look only at SRC, but NRC occur in this age group as well. Studies in youth aged 8–19 years showed only 21% of concussions were related to organised sports and over half (54%) of all concussions were NRC.[1] Likewise, in a study of collegiate students, within the general population, 35.6% of concussions were SRC, whereas in varsity athletes, the figure was 82.5%.[2] However, NRC in varsity athletes still represented an important proportion of concussions (17.5%).[2] In data collected from varsity collegiate athletes across the NCAA, of 2049 concussions, 83.4% were SRC while 16.6% were NRC.[3] Thus, while the focus of concussion study has often been SRC, NRC represent an important subset of concussion occurrences among athletes.

NRC often requires greater time for symptom resolution and time to return-to-play (RTP) as compared with SRC.[4–6] Two studies analysing differences between non-intercollegiate and intercollegiate athletes[4] and non-varsity and varsity cadets[5] found that concussions occurring outside of sport required ~9 more days to symptom resolution than concussions occurring within sport. In a study comparing SRC and NRC within one cohort of collegiate athletes similarly found that NRC required three more days to symptom resolution and four more days to RTP completion than SRC.[6] These differences between NRC and SRC may be due to greater symptom severity reported after NRC[5] or due to inherent characteristics of concussion.

NRC may require greater time for symptom resolution and RTP due to traits associated with severe injury. For example, prolonged recovery after concussion has been associated with loss of consciousness (LOC), posttraumatic amnesia (PTA), retrograde amnesia (RGA) and significantly greater symptom severity within 24 hours of injury.[7] In contrast, other studies have concluded greater acute and subacute symptom burden was the most consistent factor associated with longer recovery duration after SRC, but the evidence was weak for measures of severity such as LOC, PTA and RGA.[8–11] Results from the NCAA-DoD CARE Consortium examining the natural history of SRC in 1751 concussed athletes showed RTP was lengthened in those with greater initial post-injury symptom severity.[3] This study did not analyse LOC, PTA or RGA or examine NRC.

Differences in clinical care between NRC and SRC may also contribute to prolonged recovery after NRC. This was supported by data from the NCAA-DoD CARE Consortium which demonstrated RTP was lengthened by less frequent post-injury assessments.[3] In high school athletes, the decreased availability of athletic trainers increased the duration of concussion recovery after SRC.[12] While less frequent care is unlikely to alter the duration of symptom recovery, it could delay the start of the RTP protocol. Finally, it is also possible that NRC recovery trajectories may be longer than SRC recoveries because of delayed reporting in NRC. In a systematic review of 12 studies investigating the effects of delayed reporting on concussion recovery, patients who delayed reporting of their concussion symptoms took significantly longer to recover than those who reported immediately.[13]

Due to the still few studies investigating NRC recovery, our understanding of what factors influence time to symptom resolution and return-to-play is limited. The purpose of this study was to identify and compare frequency, initial injury severity, injury characteristics, recovery time, frequency of clinical care and timing of report of initial symptoms after injury from both SRC and NRC among a cohort of varsity athletes in the Pac-12 Conference (Pac-12). It was hypothesised that NRC would show longer RTP times and time to symptom resolution and report higher initial concussion severity within 48 hours of injury. Furthermore, we hypothesised NRC and SRC would have no significant difference in time to initial reporting of symptoms or clinical care frequency throughout injury recovery.

METHODS AND ANALYSIS

Data for this investigation were obtained from an ongoing prospective cohort study, the Pac-12 CARE Affiliated Programme (CAP). The structure and standard procedures of CAP have been previously published.[6] Briefly, student-athletes were enrolled in this study after providing informed consent during the period between July 1, 2018, and June 30, 2021. Consented athletes remained in the study, and incident concussions were tracked while the student-athlete was enrolled at their university. Concussion diagnoses for SRC and NRC were made by team physicians at each institution using the Concussion in Sport Group definition.[14] Only the first concussion sustained by the participant was included in the analyses, and incomplete data were excluded from the final analyses.

If an athlete sustained a concussion, they first completed the symptom evaluation form within 48 hours of injury and then daily until asymptomatic. After reaching asymptomatic status, the athlete then began a RTP protocol. This progression back to sport involves a gradual, stepwise increase in physical exercise and sport-specific drills without a return of concussion symptoms before a student athlete may return to full-contact sport. Stages of this progression typically include symptom-limited activity, light-aerobic exercise, sport-specific exercise, non-contact training drills, full contact practice and finally, return to sports.

Patient and public involvement

In this study, patient and public involvement (PPI) was not incorporated during the study design phase. However, despite this, ethical considerations were upheld according to established guidelines.[15]

Measures

Following a concussion, an incident form was completed describing various elements of injury. This included injury situations, defined as ‘practice’, ‘competition’, or ‘outside of sport’. Injuries occurring during ‘competition’ and ‘practice’ were grouped and defined as SRC, and those occurring ‘outside of sport’ were defined as NRC. Additionally, occurrences of LOC, PTA and RGA after concussion were self-reported and identified in the incident form. Finally, whether or not concussion symptoms were immediately reported was also recorded in the incident form.

The Sport Concussion Assessment Tool (SCAT) Post Concussion Symptoms Score (PCSS)[16] was administered at baseline before the start of the season, within 48 hours of injury, daily until return to baseline (which was defined as ‘asymptomatic’) and within 24 hours of the athlete being cleared to begin the RTP protocol. Days to asymptomatic and days to complete the RTP protocol were used to assess overall recovery duration. Days to asymptomatic was determined by the athlete’s physician by comparing their post-injury SCAT scores to baseline. Days to RTP completion was the number of days it took the athlete to complete the entire RTP protocol and to be fully cleared for athletic participation by their team physician.

Sex, self-reported concussion history and sport played at the time of injury were obtained from baseline demographics and health history questionnaires completed by the athletes. The number of days between SCAT exams was used as a measure of frequency of clinical care.

Data analysis

The prevalence of LOC, RGA and PTA was compared between injury situations (sport vs. non-sport) using Fisher's exact test. Multiple linear regression models were used to test the association between injury situation and PCSS. Cox-proportional hazard models were used to test the association between days to asymptomatic and RTP and injury situation. Logistic regression was used to test the association between injury situation and immediate reporting of an injury. A multiple linear regression model was used to test the association between our proxy for clinical care frequency, the average number of days between SCAT exams and injury situation. This was completed by generating a difference score, which was calculated by comparing each survey exam date to the previous survey. Self-reported sex (female vs. male), sport (football vs. others) and concussion history (none vs. one or more) were controlled for in the Cox models and all linear regression models, as they are known variables which may impact total symptoms, symptom severity and recovery after concussion.[6 17–19] All statistical analyses were performed using R statistical software version 1.1.447.[20]

RESULTS

Data refinement

During the study period, 468 concussions were recorded. To analyse the prevalence of LOC, PTA and RGA, only injuries which reported injury situations were included (n=461). To determine the initial symptom score and total symptom severity, only concussions reported within 48 hours of injury and recorded injury situations were included (n=381). To determine the time to asymptomatic and time to RTP, injuries which recorded injury situation, a valid asymptomatic date (n=414) or a valid RTP date (n=424) were included.

Descriptive characteristics

A majority of injuries occurred during sports (84.16%) compared with non-sport-related injuries (15.84%). Males had a slight majority (50.54%) of concussions compared with females (46.20%). Football contributed 31.89% of concussions. Of the concussions reported, 71.80% reported never having a concussion before. The mechanism of injury was only reported for SRC (table 1).

There was a significant difference in the prevalence of LOC and PTA in NRC as compared with SRC. There was a larger prevalence of LOC and PTA in NRC as compared with SRC by 17% and 10%, respectively. Furthermore, there was a 6% greater prevalence of RGA in NRC as compared with SRC, but the difference was not significant (table 2).

Concussion severity characteristics

PCSS scores within 48 hours of injury were used to determine the severity of concussion, following standard post-injury assessment protocol (NRC=46, SRC=335). With all

Table 1 Descriptive characteristics of injury situation, sex, concussion history and sport participated in during the incidence of concussion. Severity characteristics for concussions reported within 48 hours of injury, including mean Post Concussion Symptoms Score severity and symptoms scores and 95% CIs are reported. Recovery characteristics, including mean difference score of non-sport- and sport-related concussions, as well as median and IQR for days to symptom resolution and RTP are also reported.

	Non-sport concussion (n=73)	Sport-related concussion (n=388)
Sex	N (%)	N (%)
Male	31 (42.5)	202 (52.1)
Female	39 (53.4)	174 (44.9)
Unspecified	1 (1.4)	1 (0.3)
Concussion History		
None	60 (82.2)	271 (70)
One or more	13 (17.8)	117 (30.2)
Sport		
Football	16 (21.9)	131 (33.9)
Soccer	8 (11)	46 (11.9)
Basketball	6 (8.2)	33 (8.5)
Volleyball	2 (2.7)	33 (8.5)
Lacrosse	6 (8.2)	28 (7.2)
Softball	1 (1.4)	22 (5.7)
Water Polo	6 (8.2)	12 (3.1)
Swim and Dive	8 (11)	14 (3.6)
Baseball	1 (1.4)	12 (3.1)
Track and Cross Country	7 (9.6)	5 (1.3)
Gymnastics	1 (1.4)	11 (2.9)
Cheer	0 (0)	9 (2.3)
Skiing	2 (2.7)	7 (1.8)
Wrestling	0 (0)	8 (2.1)
Rugby	0 (0)	7 (1.8)
Rowing	3 (4.1)	1 (0.3)
Tennis	3 (4.1)	2 (0.5)
Beach Volleyball	0 (0)	3 (0.8)
Unspecified	1 (1.4)	1 (0.3)
Golf	1 (1.4)	1 (0.3)
Triathlon	1 (1.4)	1 (0.3)
Sailing	0 (0)	1 (0.3)
Severity Characteristics		
Concussions reported within 48 hours of injury (%)	46 (63)	335 (86.3)
Mean PCSS Severity Score (95% CI)	35.6 (28.5 to 42.8)	28.7 (25.6 to 31.8)

Continued

Table 1 Continued

	Non-sport concussion (n=73)	Sport-related concussion (n=388)
Mean PCSS Symptom Score (95% CI)	12.8 (10.9 to 14.7)	10.9 (10.1 to 11.8)
Recovery Characteristics		
Mean Diff Score (95% CI)	2.3 (-0.2 to 4.7)	3.6 (2.4 to 4.8)
Median Days to Asymptomatic (IQR)	10.5 (6.0–16.25)	7 (4.0–12.0)
Median Days to RTP (IQR)	20 (13.0–28.0)	12 (8.0–19.0)

PCSS, Post Concussion Symptoms Score; RTP, return-to-play.

variables controlled for, there was a non-significant trend ($\beta_{\text{Injury situation}}$= 1.83, 95% CI=-0.11–3.78, p=0.07) of higher total PCSS Symptom Score in NRC (12.8, 95% CI=10.9–14.7) compared with SRC (10.9, 95% CI=10.1–11.8). Similarly, there was a non-significant trend ($\beta_{\text{Injury situation}}$ = 6.96, 95% CI=-0.33–14.24, p=0.06) of higher initial PCSS Symptom Severity in NRC (35.6, 95% CI=28.5–42.8) compared with SRC (28.7, 95% CI=25.6–31.8) (table 1).

Recovery characteristics

Four hundred fourteen concussions (SRC=350, NRC=64) met the criteria to determine days to asymptomatic and 424 (SRC=361, NRC=61) concussions met inclusion criteria to determine time to RTP (online supplemental file 1). Reasons for failing to complete the RTP protocol included participant graduation or transferring schools before completion, as well as COVID shutdowns during the protocol. Adjusted for sex, sport and concussion history, NRC were associated with a lower likelihood of recovery on each day and required greater days to asymptomatic (HR=0.73, p=0.02) and days to RTP completion (HR=0.64, p<0.01), as compared with SRC.

Means, medians and IQR ranges of days to symptom resolution and days to RTP completion stratified by injury situation are presented in table 1. NRC had greater median days to asymptomatic (10.5) than SRC (7) and greater median days to RTP (20) as compared with SRC (12). Survival curves were generated comparing days to asymptomatic and days to RTP completion for SRC versus NRC (figure 1). NRC had significantly longer median days to symptom resolution (figure 1A) and significantly longer time to RTP completion (figure 1B) as compared with SRC.

Clinical care frequency

Across NRC, the average days between administration of each SCAT5 symptom evaluation form were 2.3 days, whereas for SRC, the average difference score was 3.6 days. There was no significant difference between clinical care frequency when controlling for sex, sport and concussion history, between injury situation (p=0.28) or in immediate reporting of SRC or NRC (p=0.35).

DISCUSSION

This study demonstrated that athletes sustain both SRC and NRC and that NRC are more often associated with LOC, PTA and RGA as well as a longer time to becoming asymptomatic and returning to play. The increased time to RTP does not appear to be related to the frequency of clinical care or delayed reporting in NRC. Although both the number of symptoms and symptom severity were greater in NRC compared with SRC, this did not reach statistical significance (p=0.06). When comparing concussions which reported LOC, PTA and RGA, NRC required greater time to asymptomatic and time to RTP. While SRC represent most concussions varsity collegiate athletes sustain, NRC are prevalent and occur about a fifth of the time. Most recent research on athletes has focused on SRC but understanding differences between SRC and NRC is important in the care of athletes.

Although SRC are more common in athletes, NRC also occur and are often associated with greater severity.[4–6] Consistent with the results of this study, in a population of varsity and non-varsity cadets with concussion, non-varsity cadets reported greater average symptom severity as compared with varsity cadets.[5] Although in this study, the causes of NRC were not reported, differences in symptom severity between NRC and SRC may be due to the mechanism of injury. CDC statistics show the most common cause of NRC in young adults aged 15–24 years

Table 2 Fischer's exact test was individually run to determine the prevalence of loss of consciousness (LOC), post-traumatic amnesia (PTA) and retrograde amnesia (RGA) in non-sport-related concussion (NRC) (73) versus sport-related concussion (SRC) (388). There is a significant increase in the prevalence of LOC (p<0.01) and PTA (<0.01) in NRC as compared with SRC, and no significant difference in the prevalence of RGA, although trending (p<0.1).

	Non-sport-related concussion (n=73)	Sport-related concussion (n=388)	Fisher's exact p-value	OR
Loss of consciousness (LOC)	16 (22%)	10 (3%)	<0.01	0.095
Post-traumatic amnesia (PTA)	11 (15%)	20 (5%)	<0.01	0.307
Retrograde amnesia (RGA)	7 (10%)	15 (4%)	0.06	0.374
LOC, PTA or RGA	18 (25%)	24 (6%)	<0.01	0.202

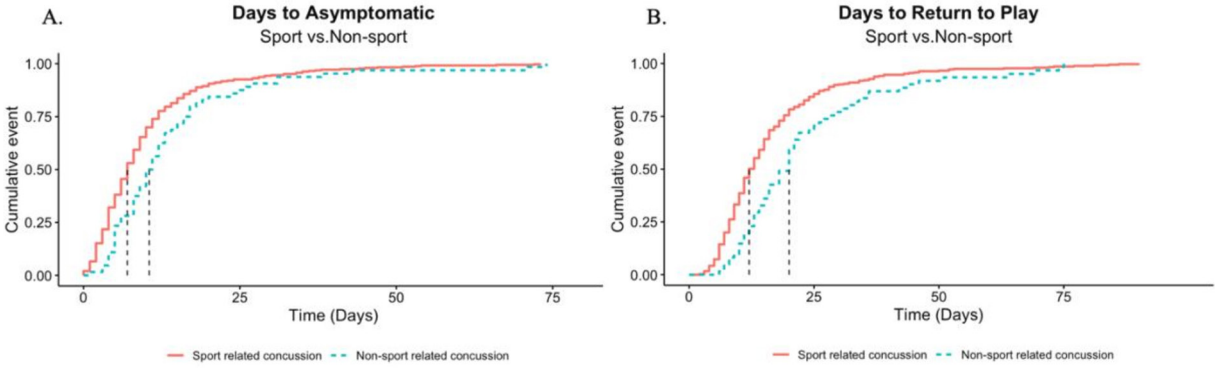

Figure 1 Comparison of days to asymptomatic and days to return-to-play (RTP) protocol completion by injury situation (non-sport vs. sport). Cumulative event, the probability of having reached recovery at a given time, is listed on the y-axis, and time (days) is listed on the x-axis. At 25 days, n=55 NRC, n=323 SRC; at 50 days, n=7 NRC, n=20 SRC; and at 75 days, n=2 NRC, n=6 SRC were asymptomatic. At 25 days, n=42 NRC, n=299 SRC; at 50 days, n=14 NRC, n=43 SRC; and at 75 days, n=4 NRC, n=8 SRC had returned to play. NRC, non-sport-related concussion; SRC, sport-related concussion.

is motor vehicle accidents.[21] In another study, non-sport-related TBI was more likely to result in hospitalisation and death as compared with sport-related TBI with the most common causes firearm injuries (64%), motor pedestrian crash (56%), motor vehicle crash (37%) and bicycle crash (28%).[22] Among all causes of TBI, SRC had the lowest severity at admission and shortest duration of stay,[22] and in a college-aged undergraduate population incidence of NRC (64.02%) was higher than that of SRC (36.98%).[2] Causes of NRC included falls (59.6%), hits to the head (13.5%), motor vehicle accidents (10.22%) and 'others' (16.72%).[2] Differences in mechanisms of injury may support findings from this study and others[4–6] which have determined that NRC often results in greater and more severe symptoms and prolonged time to symptom resolution and RTP as compared with SRC.

When examining concussion characteristics associated with concussion recovery, we determined that NRC was associated with a higher prevalence of LOC, PTA and RGA and prolonged recovery after injury than SRC. Similarly, initial results from the Pac-12 CARE-Affiliated Programme found that NRC not only contributed significantly to the burden of injury in this student-) from athlathlete population but also required greater time to symptom resolution and RTP as compared with SRC.[6] Previous research has also found that NRC are more likely to present with worse acute clinical outcomes (presence of LOC, RGA, higher symptom burden and prolonged recovery), compared with SRC.[23] Multiple studies have also reported an association between these characteristics of concussion and prolonged recovery in SRC.[7 11 24] When investigating post-concussion characteristics of cadets, researchers found SRC had significantly shorter symptom duration than free-time-related concussions although no differences in the prevalence of reported LOC, PTA or RGA between SRC and NRC were reported.[5] The higher prevalence of LOC, PTA and RGA after NRC may explain why NRC required longer time to symptom resolution and RTP as compared with SRC.

Delayed reporting of concussion has been shown to result in prolonged time to RTP.[13] Although in a previous study of collegiate athletes NRC were less likely to report immediately as compared with SRC,[23] we found no such difference. Differences in clinical care and time to injury reporting between NRC and SRC may explain extended recovery in NRC, as athletes can only begin their RTP protocol once a clinician determines them to be asymptomatic. However, there was no significant difference in the frequency of clinical care during concussion recovery or immediate injury reporting between SRC and NRC. These findings suggest that NRC require longer time to recover not because of external factors but because of intrinsic differences in injury between SRC and NRC.

LIMITATIONS

Our study had limitations. First, less severe concussions which took place out of a season or off-campus may have been under-reported. Under-reporting of concussion is also reported in the athletic setting, and SRC may have been under-reported as well. In order to account for these possible limitations, we compared NRC and SRC which took place within 48 hours after injury, theorising that concussions reported within the same time frame are most likely of similar initial severity although occurring both in and out of sports. Reporting of injury characteristics (LOC, RGA and PTA) from athletes with concussions occurring outside of sport relied on athlete self-reports and may be subject to recall bias. Athletes may have under-reported the number and severity of their symptoms and injury characteristics to RTP quicker. However, the symptom evaluation form used for this study is just one of many tools used for concussion diagnosis and recovery.[6] Therefore, recovery and RTP times do accurately describe when an athlete no longer exhibited symptoms of concussion throughout multiple forms of testing. In addition, our study would have been strengthened with a more contextual aetiology of the observed NRC.

However, a majority of NRC observed did not include how the injury occurred (ie, motor vehicle accident, fall, etc.). As such, we were not able to control for the exact mechanism of NRC or perform any subgroup analysis on those concussions. Lastly, we failed to control for previous neurological or psychiatric problems, which have been associated with prolonged recoveries.[11]

CONCLUSION

These findings support that NRC require longer recovery times compared with SRC and are an important cause of time loss in the athletic population. NRC are more severe with an increase in reported symptoms, symptom severity and injury with LOC, PTA and RGA. This is also the first study investigating differences between NRC and SRC to use daily symptom evaluation forms to verify the time between clinical visits, as well as time to symptom resolution and time to RTP. NRC not only required greater time to RTP but also time to symptom resolution as compared with SRC. Although prolonged recovery time may be explained by differences in clinical care frequency or time to reporting between NRC and SRC, no such findings were made in this study. These findings are also not due to differences in concussion management and therefore are likely due to extrinsic factors (ie, mechanism of injury) and warrant further investigation. Ultimately, it is important to recognise that athletes sustain concussions outside of sport and clinicians should anticipate that recovery with NRC may be prolonged.

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Contributors NAK and ADB conceived and planned the study aims and analyses. NAK, ADB and EG performed data analysis. KGH, BMW and SKP contributed to the interpretation of the results. NAK lead the writing of the manuscript. All authors provided critical feedback and helped shape the research, analysis and conclusions of this manuscript. ADB, as guarantor, accepts full responsibility for the work of the study, had access to the data, and controlled the decision to publish.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the institutional review boards. All research was conducted with the appropriate institutional review board (IRB) approval (IRB Protocol 21-0521). Data security and dissemination are managed by the Presagia Sports Athlete Electronic Health Record software (Montreal, Quebec, Canada) and QuesGen Systems (San Francisco, California, USA). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data security and dissemination are managed by the Presagia Sports Athlete Electronic Health Record software (Montreat, Quebec, Canada) and QuesGen Systems (San Francisco, California, USA).

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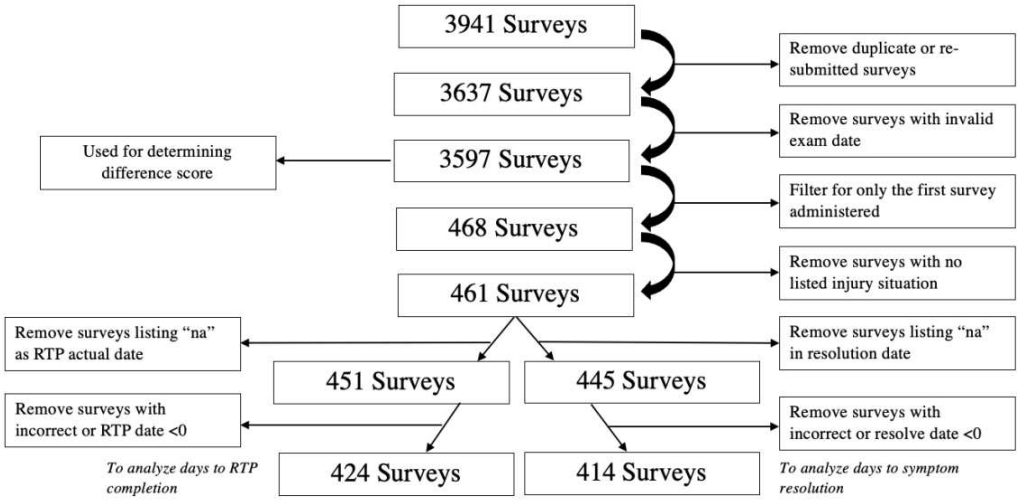

Supplemental Figure 1: Method for cleaning original data set containing 4458 surveys. The data set of 3597 surveys, containing all surveys throughout recovery of each concussion was used when determining difference in clinical care during recovery. When analyzing difference in days to symptom resolution and days to RTP completion, two different subsets of this data set were used, with 414 and 424 surveys used respectively for survival analysis and cox proportional hazards models.