College football players less likely to report concussions and other injuries with increased injury accumulation

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Abstract

Athletes sometimes choose not to report suspected concussions, risking delays in treatment and health consequences. How and why do athletes make these reporting decisions? Using original survey data from a cohort of college football players, we evaluate two assumptions of the current literature on injury reporting. First, that the probability of reporting a concussion or injury is constant over time. Second, that athletes make reasoned deliberative decisions about whether to report their concussion or other injury. We find that athletes are much less likely to report a concussion to a medical professional than they are to report another injury (47% vs. 80%), but no association between reporting and a measure of athletes' ability to switch from fast, reactive thinking to reasoned, deliberative thinking. The likelihood of reporting decreases as the number of injuries and concussions increases, and no athlete reported more than four concussions. Sports medicine clinicians sometimes use four concussions as a time to discuss possibly curtailing sports participation, which may influence athletes' subsequent reporting behavior. Sports medicine clinicians may want to consider athlete injury history as a risk factor for concussion and injury under-reporting.

Keywords: concussion, injury reporting, football, decision-making, sports medicine

Introduction

The risk of injury is present in nearly all sports, but it is elevated in sports involving contact or collision such as American football.[1] Many injuries present with visible somatic manifestations that allow medical personnel to identify injured athletes and remove them from play, without requiring athletes to report the harm. Brain injuries like concussions, however, are not always evident to outside observers. In contrast to injuries diagnosed using objective biomarkers such as brain imaging, concussions are diagnosed with clinical evaluation, which relies heavily on an athlete's report of symptoms.[2, 3] Furthermore, timely removal from play may reduce the risk of catastrophic injury and shorten recovery time.[4, 5] Together, these factors amplify the importance of an athlete's timely report of a possible concussion to enable appropriate removal from play, diagnosis, and management.[6, 7]

A number of studies have evaluated athletes' concussion-reporting behaviors in sports including American football (hereafter, simply "football").[8-17] One main finding is that many concussions, perhaps as many as half in some populations, go unreported or there is a delay in reporting. Athletes' self-described reasons for not reporting a possible concussion include: not wanting to leave the game, not wanting to let their teammates down, not thinking the injury was serious enough to warrant reporting, or uncertainty about whether the injury was a concussion.[8-14] Rates of concussion reporting are particularly low among college football players when compared to athletes competing in other sports.[10]

Health-related risk-taking, including bodily sacrifice and playing while injured, is a normative and often rewarded behavior in sport settings.[18-25] This is frequently described as part of the "sport ethic" and may be integral to an individual's identity as an athlete.[18, 21, 25] Risk-taking behaviors may be reinforced as an athlete gains more experience in a sport and with playing through injuries, including concussion. Coaches may also normalize pain and playing through injury,[19, 21] which may influence an athlete's perceptions of the severity of the risk of concussion and the utility of reporting. In one cohort study of college football players, athletes who perceived their coach to be supportive of their decision to report a possible concussion were less likely to continue to play while experiencing concussion symptoms.[26]

Two assumptions are implicit in much of the empirical work on injury reporting to date. First, researchers tend to treat the probability of reporting a possible concussion as a static characteristic of the athlete, implying that an athlete is as likely to report the third (or fourth, or fifth) possible concussion as the first. Second, cognitive factors are interpreted within a deliberative decision-making framework. That is, it is assumed that an athlete weighs the benefits and costs of reporting an injury when deciding whether to report an injury ("I will get the medical attention I need" versus "I will have to stop playing"). This paper investigates both assumptions. Specifically, it examines whether the probability of reporting a concussion is a static characteristic of an athlete and whether the decision to report can be viewed as the outcome of a deliberative process.

Reporting behavior may vary with consecutive injuries for several reasons. These include varying experience in football and exposure to prior concussions. Additionally, athletes may learn from their own experiences of reporting versus "playing through" a concussion and from observing the experiences of their teammates.[27] Furthermore, the perceived risk of continuing to play may change as the number of concussions sustained increases.[28] Previous studies support the possibility that athletes' experiences after reporting (or not reporting) an injury may influence whether they choose to do so in the future.[15, 27, 29, 30] Athletes' willingness to report may also depend on whether they believe doing so would compromise their ability to continue participating in sports. A recent study of college sports medicine clinicians found that clinicians would initiate discussions about sport retirement after 3 or 4 concussions (mean=3.16, SD=1.15).[31] A study of clinicians and parents of youth soccer athletes found similar thresholds for considering athlete sport retirement (clinicians 4.6 concussions, parents 3.7 concussions).[32]

Athletes may not make deliberative decisions about reporting possible injuries, particularly during the heat of competition. Behavioral economics describes two modes of decision-making.[33] Fast and reactive decision-making is more often employed, and is frequently advantageous, in the physiologically arousing and emotional conditions of sport. By contrast, reasoned deliberative decision making may be required for an athlete to assess whether an injury warrants reporting to medical personnel. The ability to switch between these two modes of thinking, called cognitive reflection, varies from person to person.[34] Athletes likely vary in their ability to "switch gears" and make a reasoned reflective decision to report (or not report) an injury during the heat of competition. Reactive decision-making has been previously suggested as an explanation for concussion under-reporting among athletes, but it has not yet been assessed empirically.[17] In line with existing literature on cognitive reflection and decision-making,[34] we hypothesized that to the extent that athletes anticipate the benefits of reporting an injury to outweigh the drawbacks, athletes with better cognitive reflection would report an increased number of concussions and other injuries. Developing more nuanced models of concussion reporting behavior can guide interventions targeted at decreasing the prevalent and potentially dangerous behavior of concussion under-reporting.

We conducted a survey of college football players in highly competitive football programs to investigate athlete injury reporting behaviors. First, we describe athletes' injury histories and reporting behaviors. Next, we evaluate whether the probability of concussion reporting varies across the sequence of suspected concussions. We compare this to the variation in athletes' probability of reporting other (non-concussion) injuries. Finally, we examine whether a measure of athletes' cognitive reflection is associated with their concussion and injury reporting behaviors.

Methods

Athletes from the most competitive level of college football (National Collegiate Athletic Association (NCAA) Division I Power 5) were recruited to participate in this study. The Director of Sports Medicine, Head Football Athletic Trainer, or equivalent position at each school within this subdivision was contacted regarding possible participation in the study. Of the 65 teams contacted, four teams agreed to participate.

After the team representative agreed to allow athlete participation, a date and time for an on-site research visit was coordinated. During this visit to the participating institution, one author [CMB] provided athletes with a description of the study and invited them to ask questions. This typically occurred in a group setting following a team meeting or off-season training session. Interested athletes then provided informed consent and filled out the questionnaire. Questionnaires were administered to athletes on their home campuses, using paper and pen, and took approximately 15 minutes to complete. Surveys were administered between February and May 2017. Athletes were provided with a $10 Amazon gift card as a thank you for participating. The research protocol was approved by the Institutional Review Board at Harvard's T.H. Chan School of Public Health. The study was funded by the Football Players' Health Study at Harvard.

Measures

Demographics: Participants indicated their race, ethnicity, year in school, and highest level of maternal and paternal educational attainment.

Athletic Information: Athletes indicated their primary playing position (e.g., offensive lineman, running back), total years of participation in full-contact football, and whether they received an athletic scholarship from their school (none, partial, full).

Injury History and Injury Reporting: Athletes were asked to write-in their answer to the question: "During your entire football career, how many times did you think you had a concussion?" Then they were asked to write-in their answer to the following "Of all the times you thought you had a concussion, how many times did you tell a medical professional (doctor, athletic trainer)?" They were also asked the same questions about non-concussion injuries. Ranges, when given, were converted to their mid-points and then rounded down to the nearest integer for use in the model fitting (e.g., the integer 7 would be used if an athlete provided the range 5-10).

Cognitive Reflection: A three-item cognitive reflection test, previously validated in a general college population, was scored 0, 1, 2, or 3, based on the number of questions answered correctly.[34] Questions were relatively simple math-based word problems with an answer that seems intuitive (but is incorrect), thus requiring the participant to engage in reasoned, deliberative decision-making to answer correctly.

Subjective Norms: About coaches, teammates, parents, and students at their school, athletes were asked to rate their agreement with the following statement, "[Referent] thinks I should report an injury" on a seven-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (7).

Analysis

A coder hand-entered data from pen and paper questionnaires into a database. A second coder checked a random 10% of the questionnaires for data entry errors. Inter-coder discrepancy was <0.1%. Athletes were not required to answer all questions; complete case analysis was used to handle missing data (approximately 1%).

To test whether an athlete's likelihood of reporting a concussion varies over the sequence of concussions sustained, we compared a binomial model (with a constant reporting probability) to a generalization of the binomial that allows the reporting probability to vary across the sequence of suspected injuries. For an athlete's number of suspected concussions n and reported concussions $r \in \{0, \ldots, n\}$, the binomial likelihood contribution for an individual is a function of the constant reporting probability p:

$$\Pr(r = k|n, p) = \binom{n}{k} p^k (1-p)^{n-k} \tag{1}$$

In the generalization of the binomial model, the reporting probability depends on the order of the concussion in the sequence. Thus, the likelihood is a function of a set of probabilities $\boldsymbol{p} = (p_1, \ldots, p_n)$:

$$\Pr(r = k|n, \boldsymbol{p}) = \sum\nolimits_{j,j' \in \mathcal{K}_k} \prod\nolimits_j p_j \prod\nolimits_{j'} 1 - p_{j'} \tag{2}$$

where $\mathcal{K}_k$is the set of permutations of reported and non-reported concussions that produce k total reported concussions.

For example, for $n = 3$ total concussions, there are 3 ways to yield $r = 2$ reported concussions: the first two are reported (and not the third), the second and third are reported (and not the first), or the first and third are reported (and not the second). Then

$\mathcal{K}_2 = \{\{j = (1,2), j' = 3\}; \{j = (2,3), j' = 1\};\ \{j = (1,3), j' = 2\}\}$
and the likelihood is

$$\Pr(r = 2|3, \boldsymbol{p}) = p_1 p_2 (1 - p_3) + p_2 p_3 (1 - p_1) + p_1 p_3 (1 - p_2).$$

We estimated the parameters $\boldsymbol{p}$ by maximizing this likelihood over all the observed counts of reported concussions among suspected concussions. Although we did not observe any individual's sequence of reports of individual concussions, we had data on people with 0 or 1 reported out of 1; 0, 1, or 2 reported out of 2; etc. Thus, we could estimate the reporting probability parameters.

We repeated the above analysis for reporting of non-concussion injuries. We limited the analysis to individuals with no more than 5 suspected concussions or 10 suspected non-concussion injuries to avoid problems with data sparsity at higher injury and concussion counts. We used likelihood ratio tests to assess whether the full model (2) fit the data sufficiently better than the single-parameter model (1) to justify the additional parameters.

To evaluate whether cognitive reflection was significantly associated with concussion reporting, we used zero-inflated Poisson regression. Our outcome of interest (number of reported concussions) is a count, but it is more meaningfully thought of as a rate (number of reported concussions divided by the number of suspected concussions); thus, we used number of suspected concussions as an offset. Because we used zero-inflated models to account for the distribution of the data and not because we suspected a separate mechanism to account for the zero values, an intercept-only model was used for the zero-inflation component of the regression.

We built seven regression models. The full model included all measured variables that have been found to be associated with concussion reporting in the literature plus the athletes' scores from the cognitive reflection test. Model variables were standardized for ease of interpretation. The variables could be grouped into psychosocial factors, demographic characteristics, and head impact exposure modifiers

(Table 1). The remaining models represented all permutations of these three predictor categories. After the models were fit, five-fold cross validation was performed, and the final model was selected based on having the lowest average cross-validated error. One advantage of cross validation is that it helps guard against overfitting.[35] The same procedure was followed for non-concussion injuries.

Results

Study Population

The four participating teams represented three of the Power 5 conferences. Three schools were public, one was private. Two teams had a win-loss record over 50% in 2017 and were among the top schools in their conference. Two teams had a win loss-record under 50% and were among the bottom schools in their conference.

The four participating teams yielded a total of 296 participating male athletes (team 1 n=80, team 2 n=54, team 3 n=80, team 4 n=82). Athletes had played organized full-contact football for over 10 years on average and represented a range of primary playing positions (Table 2). About half (48%) of participants identified as white and 35% identified as black or African American. Most reported that their mother (64%) and father (61%) had attained a bachelor's degree or higher. Nearly all athletes (>99%) received some form of athletic scholarship from their school, with the majority receiving a full scholarship (Table 2).

Injury and Reporting Characteristics

Athletes indicated that, on average, they had sustained about two concussions and four or five other injuries during their football careers. The distributions of the counts of injury and concussion as well as both reporting variables were skewed, so Figure 1 presents the distributions of injury and concussion reporting percentages. 104 athletes (35%) had no suspected concussions and 60 (20%) had no suspected non-concussion injuries. Athletes reported their concussions to medical personnel less than half of the time (47%), whereas they reported their non-concussion injuries over three-quarters of the time (80%), on average. While the maximum number of suspected career concussions was 17, no athlete indicated reporting more than four concussions to medical personnel.

Modeling Concussion and Injury Reporting

Among 192 athletes with any suspected concussions in their career, we excluded 22 (11%) who had more than 5 suspected concussions. Fitting the single-parameter model for concussion reporting to the remaining data, the estimated probability of reporting a concussion was 0.48. Fitting the full model fit to the same data, the estimated probabilities for reporting the first through fifth concussions were 0.53, 0.53, 0.48, 0, and 0.32, indicating that participants were less likely to report a concussion as the number of concussions they sustained increased. The likelihood ratio test statistic was 10.3 and the 95% quantile of the χ^2_4 distribution is 9.49, so we rejected the single-parameter model in favor of the full model.

Among the 216 athletes with any suspected non-concussion injuries in their career, we excluded 20 (9%) who had more than 10 suspected injuries. Fitting the single-parameter model for injury reporting to the remaining data, the estimated reporting probability of reporting a non-concussion injury was 0.78. Fitting the full model to the same data, the estimated reporting probabilities for the first through tenth injuries were 0.85, 0.83, 0.83, 0.77, 0.74, 0.66, 0.74, 0.54, 0.46, and 0.34, indicating that participants tended to be less likely to report a non-concussion injury as the number of injuries they sustained increased. The likelihood ratio test statistic was 27.71 and the 95% quantile of the χ^2_9 distribution is 16.92, so we rejected the single-parameter model in favor of the full model.

The difference in the reporting tendencies over the sequence of suspected concussion and non-concussion injuries is apparent in Figure 2, which shows the estimated parameters from the full models fit to each of the two types of injury data.

Cognitive Reflection and Concussion and Injury Reporting

About half of participants (n=150, 51%) scored 0 on the cognitive reflection test, 62 (21%) scored 1, 56 (19%) scored 2, and 28 (9%) scored 3.

Athletes tended to report their non-concussion injuries more than their concussions. Over half of athletes (n=165, 56%) reported none of their concussions, 68 (23%) reported some, and 60 (20%) reported all. In contrast, about half of athletes reported all their non-concussion injuries (n=147, 51%), 75 (26%) reported some, and 66 (23%) reported none.

The regression models fitted to predict concussion reporting and (separately) injury reporting, selected based on the results of cross validation, included only exposure modifiers (Table 3).

Cognitive reflection score was not significantly associated with either concussion or non-concussion injury reporting (Table 4). In the exposure-only concussion reporting model, there was a significant association between total career injuries and concussion reporting such that athletes who had one standard deviation more career injuries reported 17% fewer concussions to medical personnel (Table 5). In the injury reporting model, athletes with one standard deviation more career concussions than average reported 10% fewer injuries.

Discussion

Understanding athletes' injury reporting behaviors could lead to improvements in communication between athletes and health care providers and the timely provision of health care to injured athletes. This is particularly important for concussion, where sustaining an additional impact while symptomatic may have catastrophic or long-lasting neurological consequences.[5] In this study, we find that college football players' tendencies to report injuries varies across the sequence of injuries sustained. Thus, injury reporting is not a static feature of the athlete or their environment, but an evolving process in which the athlete learns from his experience and environment. This finding reinforces previous studies that showed that features of the athletic environment, such as pressure or support from a coach, can influence an athlete's concussion reporting behaviors.[9, 17] The estimated reporting probabilities for non-concussion injuries decrease relatively linearly as more injuries are sustained. For concussions, in contrast, we see a dramatic decline at the fourth concussion. It is our interpretation that both the exact zero estimation for the probability of reporting the fourth concussion and the uptick in probability of reporting the fifth concussion are, in part, a function of data sparsity at higher concussion counts. More specifically, the modeled values for reporting concussions four and five rely on the small number of people who had at least four (n=12) or five (n=14) concussions and reported one or more of their concussions to medical personnel (n=20).

No athlete in this study reported more than four total concussions to medical personnel, despite suspected concussion totals as high as 17. This hard cutoff in the number of concussions reported is remarkable. The reporting pattern may result from environmental factors. For example, in a recent survey of college sports medicine clinicians, clinicians indicated that they would discuss retirement from sport after a mean of 3.2 concussions.[31] In a separate study, parents of youth athletes reported a similar threshold.[32] Athletes may be aware of how concussions are managed and alter their concussion reporting behaviors to avoid being medically disqualified. Additional research in this area is warranted.

The overall rate of concussion reporting in this population is in line with some previous estimates of concussion reporting in football players.[10, 11, 14, 36] The present study included athletes in the most competitive conferences of college football. Factors specific to this subgroup, such as increased competitive pressures and possibility of advancing to the professional level, may influence rates of reporting. Within this population, the rate of reporting non-concussion injuries is notably higher than the rate of reporting concussion. One possible reason for the difference is the stigma that athletes who are removed from play for concussions lack “toughness”, which is valued in football and other sports.[37] Alternatively, the difference may be driven by the fact that concussions are easier to conceal than other injuries that present with overt somatic manifestations. A third possibility is that this is an unintended consequence of the NCAA’s concussion management protocol. This protocol specifies that if a concussion is diagnosed, no matter the severity, athletes are required to proceed through a series of steps before returning to sport; in practice, this means that even if an athlete feels back to normal one day post-injury they will likely still require 4-6 days to return to full sport participation. As a result, reporting a suspected concussion results in being removed from play for a longer minimal time than reporting other kinds of injuries.

We did not find an association between athletes’ cognitive reflection test scores and their reporting of either concussion or non-concussion injuries. While the cognitive reflection test is a validated measure,[34] it has not been used in this population, which may have unique numeracy considerations. It may also be the case that athletes are disclosing injuries off the field, once they are in a more contemplative state, thus reducing the relevance of cognitive reflection to injury reporting behavior. Another possibility is that testing athletes’ cognitive reflection while they are in a contemplative state, taking a survey, does not appropriately capture the change in cognition that occurs during the heightened physical and emotional state of athletic competition. Future studies should include measures of how immediately concussions were reported and consider whether there are other means of measuring an athlete's likelihood of making deliberative decisions while in situations of high physiologic arousal. For example, it is possible that factors, such as trait impulsivity, are related to such behavior. Finally, it is possible that we did not observe an association between cognitive reflection test score and concussion or injury reporting because even in a contemplative state, athletes did not see the benefits of reporting as outweighing the risks of doing so.

Injury history was associated with athlete reporting behaviors. For concussion, athletes with a greater history of non-concussion injuries were less likely to report a concussion. For other non-concussion injuries, athletes with a greater history of concussion were less likely to report a non-concussion. Our results suggest that athletes learn from their experiences in reporting (or not reporting) injuries to medical personnel for both concussion and non-concussion injuries. Decreased reporting with more experience could indicate negative experience with sports medicine staff (e.g., feeling like they were removed from play longer than warranted), that their previous experiences suggested that the injury did not warrant medical attention, or that they had negative experiences from others in the athletic environment when they reported an injury (e.g., coaches or teammates were displeased). Additional research is needed to investigate the mechanism behind this association.

Limitations

Our findings should be considered in light of the study's limitations. The sample size was modest, and the data were sparse at higher counts of career concussions and injuries. That said, while we expect that a larger sample would produce better model fit, we do not anticipate that it would change the fact that the full model outperforms the single-parameter model in estimating concussion and injury reporting probabilities. The findings may not generalize to other sports, other levels of football, or to non-participating schools.

Conclusion

Athletes' concussion and non-concussion injury reporting varies across the sequence of sustained injuries. Across both concussion and non-concussion injuries there is a downward trend in the probability of reporting as more injuries are sustained; for concussion, there is a significant inflection point around four concussions. Concussions are less likely to be reported than non-concussion injuries, and no athlete in this study reported more than four concussions to medical personnel during his career, despite many suspecting more than four concussions. Sports medicine professionals may want to incorporate athlete injury and concussion history as a risk factor for underreporting.

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Figure 1. Distributions of Injury and Injury Reporting Characteristics Overall and by Cognitive Reflection Test Score

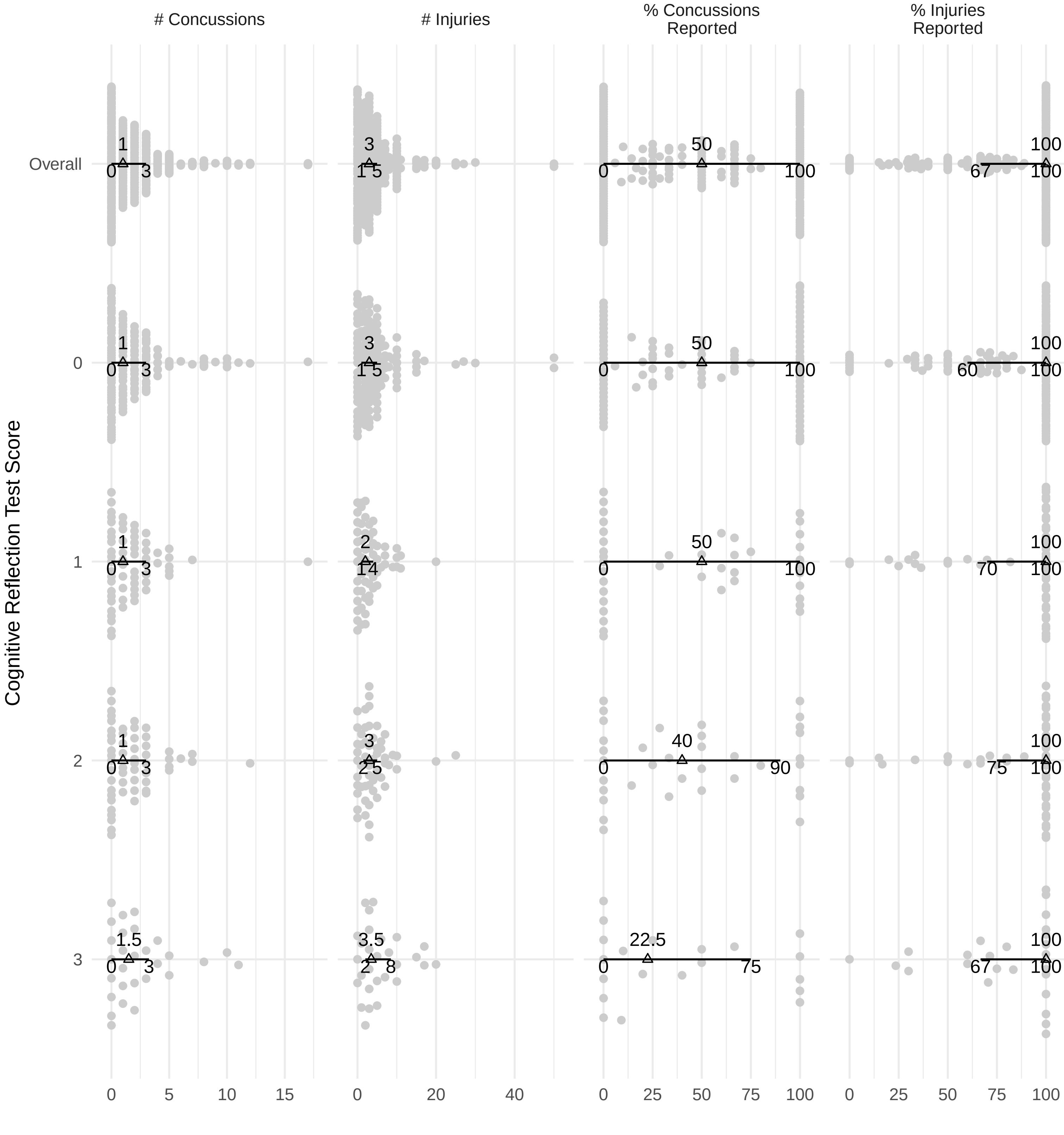

Figure 1 Legend. This figure depicts the distributions of the number of concussions, number of injuries, percent of concussions reported, and percent of injuries reported. Each of these features is presented for the overall study population and by score on the cognitive reflection test (0, 1, 2, or 3). Medians, 25^{th} percentiles, and 75^{th} percentiles are noted for each distribution.

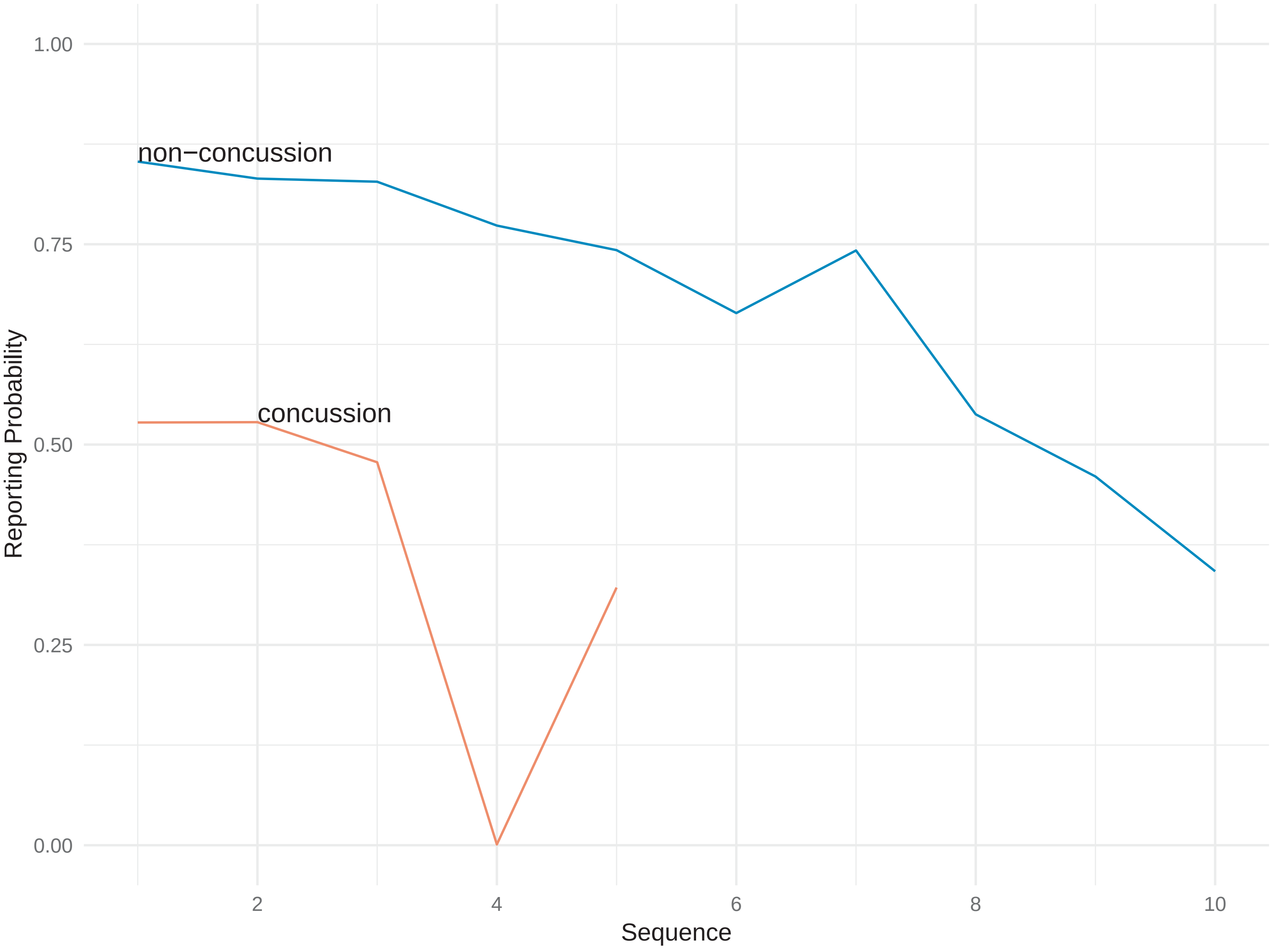
non−concussion
concussion
1.00
0.75
0.50
0.25
0.00
Reporting Probability
2
4
6
8
10
Sequence

Figure 2 Legend. This figure depicts the modelled trends in concussion and non-concussion injury reporting over the sequence of experienced concussions and non-concussion injuries.

Table 1. Conceptual Categories of Model Variables

Category	Specific Variables
Psychosocial Factors	Subjective Reporting Norms (Coach, Teammates, Parents, Students)
Demographic Characteristics	Highest Level of Parental Educational Attainment (Mother, Father); Race/Ethnicity; Scholarship Status
Exposure Modifiers	Primary Playing Position (Line v. Skill); Year on Team; Total Years of Full-Contact Football; Total Career Concussions (used in injury model only); Total Career Non-Concussion Injuries (used in concussion model only)

Table 2. Sample Characteristics

Variables	Mean (SD) or %* (n)
Years of Contact Football	10.58 (2.97)
Parental Educational Attainment	
Mother College Graduate or Higher	64% (185)
Father College Graduate or Higher	61% (171)
Race / Ethnicity	
White	48% (140)
Black or African American	35% (102)
Hispanic or Latino	3% (10)
Mixed race or other	13% (38)
Primary Playing Position	
Defensive Backs	18% (54)
Defensive Line	12% (36)
Linebackers	14% (42)
Offensive Line	15% (46)
Quarterbacks	6% (17)
Running Backs	9% (26)
Special Teams	5% (15)
Tight Ends	5% (16)
Wide Receivers	15% (44)
Athletic Scholarship Status	
Full Athletic Scholarship	72% (211)
Partial Athletic Scholarship	<1% (1)
No Athletic Scholarship	28% (83)

*Totals may not sum to 100% due to rounding.

Table 3. Cross-Validated Errors for Models of Concussion- and Injury-Reporting

Variables Included	Concussion Reporting CV-Error	Injury Reporting CV-Error
Full Model	1.59	2.91
Psychosocial + Demographics	1.46	3.65
Psychosocial + Exposure	1.53	3.29
Demographics + Exposure	1.51	3.12
Exposure Only	**1.40**	**2.68**
Demographics Only	1.52	3.60
Psychosocial Only	1.73	3.31

Table 4. Factors Associated with Concussion and Injury Reporting in College Football Players

Variables	Concussion Reporting	Injury Reporting
	Beta (p-value)	
Cognitive Reflection Score	-0.03 (0.67)	-0.03 (0.51)
Exposure Modifiers		
Year on team	0.06 (0.33)	0.02 (0.64)
Years of football*	-0.15 (013)	0.03 (0.54)
Position Skill (v. Line)	0.28 (0.07)	-0.12 (0.17)
Injuries over career*	**-0.19 (0.01)**	
Concussions over career*		**-0.10 (0.003)**

*Variable was standardized.