

Trends in Concussion Return-to-Play Timelines Among High School Athletes From 2007 Through 2009

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Context: Whereas guidelines about return-to-play (RTP) after concussion have been published, actual prognoses remain elusive.

Objective: To develop probability estimates for time until RTP after sport-related concussion.

Design: Descriptive epidemiology study.

Setting: High school.

Patients or Other Participants: Injured high school varsity, junior varsity, or freshman athletes who participated in 1 of 13 interscholastic sports at 7 area high schools during the 2007–2009 academic years.

Intervention(s): Athletic trainers employed at each school collected concussion data. The athletic trainer or physician on site determined the presence of a concussion. Athlete-exposures for practices and games also were captured.

Main Outcome Measure(s): Documented concussions were categorized by time missed from participation using severity outcome intervals (same-day return, 1- to 2-day return, 3- to 6-day return, 7- to 9-day return, 10- to 21-day return, >21-day return, no return [censored data]). We calculated Kaplan-

Meier time-to-event probabilities that included censored data to determine the probability of RTP at each of these time intervals.

Results: A total of 81 new concussions were documented in 478 775 athlete-exposures during the study period. After a new concussion, the probability of RTP (95% confidence interval) was 2.5% (95% confidence interval = 0.3, 6.9) for a 1- to 2-day return, 71.3% (95% confidence interval = 59.0, 82.9) for a 7- to 9-day return, and 88.8% (95% confidence interval = 72.0, 97.2) for a 10- to 21-day return.

Conclusions: For high school athletes, RTP within the first 2 days after concussion was unlikely. After 1 week, the probability of return rose substantially (approximately 71%). Prognostic indicators are used to educate patients about the likely course of disease. Whereas individual symptoms and recovery times vary, prognostic time-to-event probabilities allow clinicians to provide coaches, parents, and athletes with a prediction of the likelihood of RTP within certain timeframes after a concussion.

Key Words: injury incidence, time to event, survival probability

Key Points

- The return-to-play (RTP) probability estimates indicated a youth athlete with a sport-related concussion was unlikely to RTP within the first 2 days after concussion, but the probability increased substantially at 1 week.
- The RTP probability estimates suggested most athletes would RTP within 7 to 9 days after concussion, but RTP probability did not increase beyond a 21-day RTP.
- Current clinical practice and consensus guidelines should be followed closely for clinical decision making when considering RTP for any athlete with a concussion.
- The RTP probability estimates provide clinically relevant prognostic information about concussions that clinicians can give to athletes, coaches, and parents.

Return to play (RTP) after sport-related concussion remains a controversial topic and is largely based on empirical evidence and expert opinion.¹ Determining an accurate prognosis for RTP can be a challenge for the team physician or athletic trainer (AT) owing to the variability in presentation of concussion signs and symptoms and a lack of scientific data indicating when full recovery has occurred. Current guidelines for RTP after a concussion recommend full clinical and cognitive recovery before consideration for full resumption of sport participa-

tion.² However, actual clinical practice is demonstrably different from current concussion-management guidelines.³

Recovery after sport-related concussion has been described in reference to postconcussion signs and symptoms, neuropsychological test performance (ie, neurocognitive recovery), and balance or postural stability. Concussion symptoms typically resolve within 7 to 10 days after injury.^{4,5} Approximately 85% to 90% of athletes with concussion recover symptomatically within 1 to 2 weeks, and only a small percentage have symptoms lasting from

weeks to months.^{4,6,7} In a recent study⁷ involving 1056 high school athletes who had concussions and were assessed over 2 athletic seasons, 19.2% (n = 203) of the athletes had symptoms lasting longer than 1 week but less than 1 month, and only 2.8% (n = 30) of athletes had postconcussion symptoms for more than 1 month. Cognitive recovery largely overlaps with the time course of symptom recovery; however, the recovery of cognitive functions may precede or follow clinical symptom resolution.⁸ Among college football players with concussions, cognitive function, as measured by the Standardized Assessment of Concussion, demonstrated improvement to baseline levels within 5 to 7 days after injury.⁴ This finding is consistent with findings of other researchers^{1,4,8–10} who have reported that neurocognitive measures generally return to baseline within 5 to 7 days; however, some researchers have demonstrated slowed reaction time among participants with concussions ranging from 10 days^{11,12} to 14 days⁸ and 21 days¹³ after injury. High school athletes who have sustained sport-related concussions have demonstrated slower reaction times, impaired verbal memory, and decreased motor-processing speed on a computerized neuropsychological test battery for up to 14 days.¹³ Deficits in balance or postural stability may be observed as soon as 24 hours after injury and typically recover over a span ranging from 3 to 5 days⁴ or up to 5 to 10 days.^{14,15} Concussion-management guidelines for RTP are based on resolution of symptoms, recovery of neurocognitive function to baseline, and recovery of balance or postural stability, with a common assumption that the typical recovery period lasts from 7 to 10 days.^{2,16}

Whereas data on symptom resolution^{4,17,18} have been published, neurocognitive function (ie, neuropsychological test performance)^{12,19–22} and balance or postural stability^{14,23,24} data on actual RTP timelines after concussion in sports are insufficient. Time missed from participation after a sport-related concussion has been reported, but the statistical estimates of RTP probability have not been published. Among high school athletes participating in contact and collision sports, the time missed from participation ranges from less than 8 days (78.8%) to 8 to 21 days (1.7%) and greater than 21 days (0.45%).²⁵ These data indicate the actual time missed from participation relative to athlete-exposures (ie, opportunities to sustain an injury) and do not imply the probability for RTP subsequent to a concussion.

Time-to-event analysis is a method of generating evidence-based, objective estimates of when an athlete is likely to RTP after a given injury. Although these statistical methods commonly are used to determine survival probabilities for individuals with life-threatening conditions²⁶ or risk factors,²⁷ these methods essentially are unexploited in the athletic population for generating prognostic tools to predict RTP timelines. Further, time-to-event analyses do not replace RTP decisions that the sports medicine clinician makes and do not replace RTP decision making and management of specific signs and symptoms. These probabilities are designed to lend support to the decision of the sports medicine team by adding objective, evidence-based, predictive information to the RTP prognosis.

Using an epidemiologic approach, time until RTP and the probability of RTP are clinically important to team physicians, ATs, coaches, and athletes themselves for

estimating (or predicting) when an athlete is likely to RTP after concussion. Therefore, the purpose of our study was to develop RTP timeline probability estimates after sport-related concussion.

METHODS

Study Design

The design was a descriptive, epidemiologic study. Concussion injury data entered into an injury-surveillance system over 2 academic years were analyzed. This study was approved by the University of Kentucky Institutional Review Board and by each participating school's athletic director and principal.

Participants

Data were collected from 7 high schools of central Kentucky during the 2007–2008 and 2008–2009 academic years by the AT employed at each high school. Participants were injured high school athletes who participated in at least 1 of the 2 academic years at any level (varsity, junior varsity, or freshmen) in at least 1 of the following sports: baseball, basketball, cheerleading, cross country, football, golf, soccer, softball, swimming and diving, tennis, track and field, volleyball, or wrestling.

Instrumentation and Procedures

Each AT documented concussion data on a standardized injury-report form, which included sex, sport, history (new or recurrent injury), and severity based on time until RTP. The athletes were not baseline tested using protocols specific to concussion (eg, neurocognitive testing, symptom inventory, balance assessment). All athletes received a standard preparticipation physical examination and were cleared for full athletic participation by a physician before the commencement of each school year. All concussion data were entered into an injury-surveillance database from 2007 through 2009.

Operational Definitions

An *athlete-exposure* (AE) was defined as 1 athlete participating in 1 game or practice and also was documented by the ATs. A *concussion* was defined as a direct or indirect head injury with concurrent concussion-like signs or symptoms that occurred during a scheduled high school practice or game and that required the athlete to report to the AT or a physician for evaluation.^{28–34} Only new concussions were included in the analysis. A *new concussion* was defined as the first concussion the athlete had ever sustained.^{32,34–36}

A set of established guidelines³⁷ was used in determinations about diagnosis and management of a concussion. Regarding recognition of symptoms, the guidelines state

Any athlete who exhibits signs, symptoms, or behaviors consistent with a concussion (such as loss of consciousness, headache, dizziness, confusion, or balance problems) shall be immediately removed from the contest and shall not return to play until cleared by an appropriate health-care professional.³⁷

Table 1. New Concussion Incidence and Relative Incidence Rates per 100 000 High School Athlete-Exposures by Sport,^a 2007–2009

Sport	Players, n	Athlete-Exposures, n	Injuries, n	Relative Incidence Rate per 100 000 Athlete-Exposures
All sports	4768	442 123	81	16.9
Baseball ^b	473	41 624	2	4.8
Boys' basketball	310	20 460	5	24.4
Boys' soccer	483	42 504	7	16.5
Boys' track and field	360	31 680	1	3.2
Cheerleading ^c	330	25 410	1	3.9
Football ^b	1051	150 293	46	30.6
Girls' basketball	239	15 774	3	19.0
Girls' soccer	401	35 288	9	25.5
Girls' track and field	268	23 584	0	0.0
Softball ^c	317	27 896	1	3.6
Volleyball ^c	366	20 130	2	9.9
Wrestling ^b	170	7 480	4	53.5

^a Indicates no concussion injuries were reported for boys' or girls' cross-country, golf, swimming and diving, or tennis.

^b Indicates boys-only sport.

^c Indicates girls-only sport.

Regarding who may make the diagnosis of concussion, the policy states

An MD (medical doctor), DO (doctor of osteopathy), PA (physician's assistant), ARNP (advanced registered nurse practitioner), or ATC (certified athletic trainer) is empowered to make the on-site determination that an athlete has received a concussion.³⁷

Lastly, regarding who makes RTP decisions, this policy states "Once a concussion has been diagnosed by one of the above listed on site providers, only an MD or DO can authorize subsequent return to play."³⁷ The final RTP decision is based on the athlete's ability to progress through a stepwise protocol in the absence and without provocation or exacerbation of symptoms. Other clinical or neurocognitive tests were not used in making RTP decisions.

Concussion severity was defined in terms of days missed from participation reported in time intervals: same-day return, 1- to 2-day return, 3- to 6-day return, 7- to 9-day return, 10- to 21-day return, more than 21-day return, season ended before athlete returned, or medical disqualification. Although many researchers^{29,30,32,34,38–40} have considered athletes to be injured only if they missed at least 1 day of participation, others³ have considered athletes returning on the day of injury as injured, and this reflects current clinical practice. The ATs participating in our study followed the Kentucky High School Athletic Association and member schools guidelines³⁷ regarding RTP: (1) no athlete under any circumstances can return to play on the same day as he or she received a concussion, and (2) after a concussion has been diagnosed by one of the listed on-site providers, only a medical doctor or doctor of osteopathy can authorize subsequent RTP.³⁷ For this study, the event of interest was *time until RTP*, which was defined as full return to participation with no restrictions. At this point, the athlete was required to be asymptomatic of a concussion.

Data Reduction

Frequency counts of when an athlete returned to participation after a concussion were determined for each RTP interval. When the season ended before the athlete was

cleared to RTP or was medically disqualified, the time missed from participation was determined by subtracting the date of injury from the date the season ended. These cases were referred to as *censored*. Censored cases contributed to the overall probability estimates within the analyses, and we will further explain them. By using these censored cases, we accounted for athletes who did not sustain injury at exactly the same time during their seasons and were not followed for exactly the same length of time.

Statistical Analyses

Relative incidence rates (RIRs) were calculated for new concussions across all sports. These were presented as injuries per 100 000 A-Es. The calculation for RIR is provided in the following equation:

$$\text{RIR} = \frac{\text{Number of injuries per sport}}{\text{Number of A-Es per sport}} \times 100\,000.$$

We used Kaplan-Meier analyses that included censored data to determine the estimated time-to-event probabilities. *Censored cases* were those athletes who did not RTP before the season ended or were lost to medical disqualification but were entered into the probability calculations. Including censored cases was necessary because excluding them would have biased the probability estimates toward increased RTP probability in earlier timeframes. Estimated time-to-event probabilities are a predictive probability for when an athlete with the same injury will RTP (the "event"). We also generated a Kaplan-Meier time-to-event curve to visually depict the time-to-event (RTP) probability at each time point. A log-rank test was used to compare Kaplan-Meier time-to-event curves of time until RTP for male versus female athletes, with sex as the independent variable and time until RTP as the dependent variable.

Data were exported from the Central Kentucky Injury Surveillance System and exported to SPSS software package (version 17; IBM Corporation, Armonk, NY) and MATLAB (version R2008b; The MathWorks, Natick, MA) for analyses. The α level was set a priori at $<.05$ for all statistical analyses.

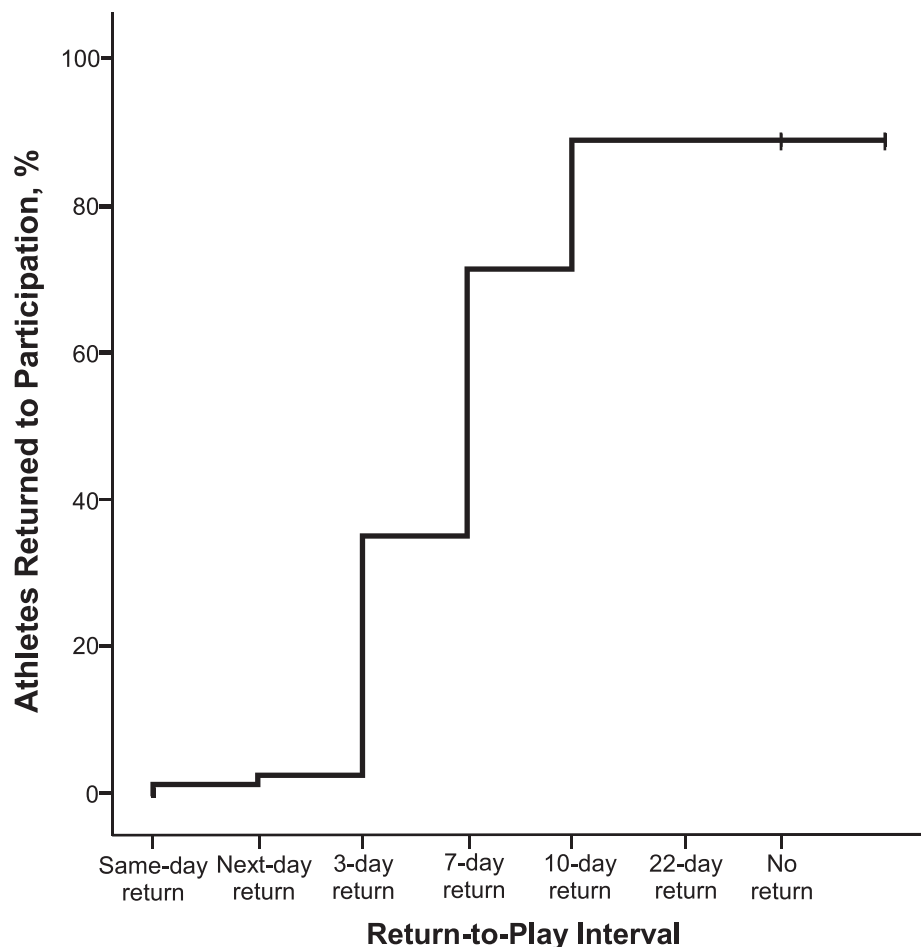


Figure. Time-to-event (return-to-play) probability curves for high school athletes after a new concussion, 2007–2009.

RESULTS

During the 2007–2009 academic years, a combined total of 1536 sport-related injuries occurred. Of those, 81 new concussions were documented for 478 775 A-Es during the study period. The RIRs were calculated for all 81 of these concussions. The RIRs for all sports in which concussions were reported are presented in Table 1.

Given that RTP data were missing for 1 concussion injury, 80 concussions were entered into the Kaplan-Meier time-to-event analyses. Of these 80 injuries, 9 cases were censored (medical disqualifications = 5 cases, season ended before RTP = 4 cases).

The log-rank test revealed no difference in RTP probabilities between males and females across all time points. Therefore, we collapsed the data into a single time-to-event curve depicting time-to-event analyses for all new concussions (Figure).

After a new concussion, the probability of RTP at 1 to 2 days was 2.5% (95% confidence interval = 0.3, 6.9). The probability increased to 35.0% (95% confidence interval = 25.3, 46.2) for a 3-day RTP, 71.3% (95% confidence interval = 59.0, 82.9) for a 7-day RTP, and 88.8% (95% confidence interval = 72.0, 97.2) for a 10-day RTP but did not increase again for a 22-day RTP. The full estimated time-to-event probabilities for new concussions are presented in Table 2.

DISCUSSION

The lack of epidemiologic information for high school athletes who sustain concussions is surprising. No universally accepted reporting system exists for concussion incidence rates, which may be reported as percentages of total sports injuries, percentages of athletes who sustain a concussion annually, concussions per 1000 or 100 000 AEs, and rates per contact exposures.⁴¹ Relative incidence rates and injury trends have been reported for athletes with concussions,^{3,42} but this information alone does not provide the clinician with sufficient information to make predictions on RTP timelines.

Our study provides predictive estimates of time until RTP for the adolescent athlete with a concussion, which is clinically relevant to clinicians, athletes, coaches, and parents. Using an epidemiologic approach, we applied time-to-event analyses to determine the probability of RTP within given timeframes. Time-to-event analysis is a method of generating evidence-based, objective estimates of when an athlete is likely to RTP. Specifically, they are prognostic and can be used to describe the likely course of sport-related concussions in high school athletes. Our results also highlight areas of agreement and areas of discrepancy between common clinical practice and current consensus statements.

Based on RTP probability estimates, our results suggest most concussions in this sample were generally mild, and

Table 2. Probability of Time for High School Athletes to Return to Play After a New Concussion, 2007–2009

Time Point of Return to Play	Time to Return to Play	Athletes Returned to Play, n	Athletes Not Returned to Play, n	Censored Cases, n	Probability of Return to Play, %	95% Confidence Interval
T ₁	Same day	1	79	0	1.3	0.03, 6.8
T ₂	1–2 d	1	78	0	2.5	0.3, 6.9
T ₃	3–6 d	26	52	0	35.0	25.3, 46.2
T ₄	7–9 d	29	23	0	71.3	59.0, 82.9
T ₅	10–21 d	14	6	3 ^a	88.8	72.0, 97.2
T ₆	> 21 d	0	6	0	88.8	54.1, 99.6
T ₇	Season ended before return or medical disqualification	0	0	6 ^a	Not applicable	Not applicable

^a Indicates 5 of these 9 censored cases were reported as medical disqualifications.

athletes recovered within 7 to 21 days. A high probability of RTP at 7 to 9 days corresponds with published reports on the resolution of postconcussion symptoms, return of neurocognitive functioning, and regaining normal balance or postural control within a relatively short timeframe. Recovery from a cerebral concussion is highly variable but typically occurs within this 7- to 10-day period. A neurometabolic cascade follows experimentally induced concussion, and these demonstrated neurometabolic changes persist for approximately 7 to 10 days before physiologic recovery is complete. Furthermore, researchers^{43–46} have found evidence suggesting the clinical signs and symptoms of concussion, as well as the typical neurocognitive deficits, may be attributed to this acute neurometabolic cascade. Although the precise timeframe for physiologic recovery from concussion in humans remains unknown, our data on time until RTP suggest most high school athletes recover and are cleared medically to resume sport participation within this same 7- to 9-day timeframe as described.

The need for evidence-based assessment and management strategies for sport-related concussions has resulted in the publication of several major international position and consensus statements since 2000.^{2,16,47–49} Our probability estimates regarding same-day RTP are in agreement with these current clinical practice and management guidelines. The probability of RTP within 24 hours of injury was very low (2.5%). The decision to return athletes to play within such a short recovery period most likely was based on published guidelines^{16,48} that have indicated same-day RTP may be considered as long as the athlete does not exhibit “significant, persistent, or worsening signs and symptoms,” including any loss of consciousness, posttraumatic amnesia, or retrograde amnesia.⁴⁸ The very low probability of RTP in less than 24 hours after injury indicates an adolescent athlete with a concussion returning to activity on the day of injury is extremely unlikely and, furthermore, not recommended. According to the Consensus Statement on Concussion in Sport,² athletes should not return to practice or competition on the same day. High school and collegiate athletes may demonstrate a delayed onset of symptoms or neuropsychological deficits that are not evident on the day of injury.^{3,5,41–43} As evidenced by the very low probability of RTP the same day or even the next day, clinicians in this specific study population appeared to be currently practicing within the Consensus Statement on Concussion in Sport guidelines.²

We observed a considerable increase in the number of athletes returning to play 3 days after concussion (35%). This abbreviated recovery period and rapid RTP (<3 days) may place the athlete at greater risk of subsequent concussion^{4,6,41,50,51} and the cumulative effects of repeated injury.^{5,6,52} Before the concept of graduated RTP protocols was introduced, clinicians followed the recommendation that athletes must be asymptomatic at rest before resuming any exertional activity and must be asymptomatic with exertion (ie, “progressive aerobic and resistance exercise challenge tests”) before full return to sport participation.⁴⁸ Under these guidelines, an athlete who is asymptomatic at rest within 48 to 72 hours after a concussion may proceed with exertional maneuver or provocative testing (sprinting, sit-ups, or push-ups) and potentially could be cleared medically to resume unrestricted activities if he or she has no symptom provocation.⁴⁹ Following current concussion-management guidelines, the clinician should not consider RTP for the athlete with a concussion unless the athlete has progressed through all stages of the stepwise protocol with no return of postconcussion symptoms. However, the evidence for this conservative management approach to concussion is limited, and additional investigation into the physical and cognitive factors influencing recovery is warranted.^{53,54}

After 1 week, the probability of RTP rose substantially, with a more than 70% probability of RTP at 7 days after injury. The considerable number of athletes who returned at 7 days provides evidence that most sport-related concussions are uncomplicated and that the current concussion-management practice guidelines are reasonable in indicating probable 7-day RTP.

Self-reported symptoms after sport-related concussion are an important component of the assessment and management of these athletes. Clinical decisions about the nature and extent of injury, as well as the ability of the athlete to resume sport participation, often are made on the basis of subjective symptom reporting only. While keeping in mind the individual nature and duration of an athlete’s clinical symptoms, clinicians can use time-to-event probabilities to provide athletes, parents, and coaches an estimate of the probability of RTP within a given timeframe. Our results indicated several key concepts of interest to the athlete, parent, and coach concerning recovery and management of concussion. First, the high school athlete who sustains 1 concussion has a high probability of RTP at 7 to 9 days after injury. Second, an

athlete with a concussion is unlikely to resume sport participation less than 7 days after injury. Third, if an athlete remains symptomatic for 10 days after a single-episode concussion, the probability for RTP by 22 days after injury does not increase. Most athletes with concussions recover fully within a short period, but a small percentage experience a period of protracted recovery known as the *postconcussion syndrome* (postconcussive symptoms lasting more than 3 months).^{55–57} Full recovery in these athletes can be confounded by many factors, including concussion history^{6,58–60}; developmental history (eg, learning disabilities, attention-deficit hyperactivity disorder, or other developmental disorders)⁶¹; headache history, including migraine headaches^{10,62,63}; and psychiatric history (anxiety, depression, sleep disorders).^{20,64–67}

Our results cannot be generalized to populations other than adolescent interscholastic athletes; therefore, the generalizability to a population less than age 14 or more than age 18 years is limited. We also acknowledge that, given the small number of female athletes who sustained injuries, we were not able to separate males from females within this time-to-event analysis. In addition, data were not collected for pediatric and youth athletes. The identification and assessment of pediatric concussions are complicated by several factors, including unique considerations for the still-developing brain.⁷ Only concussions reported to ATs were included for analysis, and the actual concussion incidence rates are unknown. Concussions may be unrecognized due to lack of knowledge, lack of awareness of concussion symptoms, or potential seriousness of injury or may be unreported due to desire to remain in the athletic practice or game or fear of being withheld from participation.^{25,68}

CONCLUSIONS

Time-to-event analysis is a method of generating evidence-based, objective estimates of when an athlete is likely to RTP. These methods commonly are used in other areas of health care research but are virtually nonexistent within sports-injury research. Of note, time-to-event analyses do not replace the individual RTP decisions of sports medicine clinicians and do not replace RTP decision making through the management of specific signs and symptoms. These probabilities are designed to lend support to the decision of the sports medicine team by improving on the RTP prognosis.

The RTP probability estimates after sport-related concussion in the young athlete (<18 years of age) indicated an athlete with a concussion is extremely unlikely to RTP the day after the injury; however, this probability of return increases substantially at 1 week. In addition, the RTP probability did not increase after 21 days. These RTP probability estimates suggested recovery after concussion occurs over a period of days after injury, and most athletes will resume sport participation within 7 to 9 days. Current clinical practice and consensus guidelines should be followed closely for clinical decision making when considering RTP for any athlete with a concussion. However, these RTP probability estimates provide clinically relevant prognostic information about concussions for clinicians to provide to athletes, coaches, and parents. In the future, time-to-event analyses may be used for sports

injuries to make RTP comparisons based on variables, such as age, sex, or injury history.

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DISCLAIMER

The views expressed in this paper are those of the authors and do not reflect the official policy or position of the United States Marine Corps, Department of Defense, or the US Government.

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