The Acute: Chronic Workload Ratio is Associated with Injury in Junior Tennis Players

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Abstract

Purpose: Session rate of perceived exertion (sRPE) is used to track internal training/competition load in athletes using a metric known as the acute to chronic workload ratio (ACWR). Research reported on team sports have determined that if the acute load is higher than the chronic load athletes are likely to sustain injury. No studies, however, have attempted to investigate internal load and injury in a tennis population despite the rigorous training loads. Therefore, the purpose of this study was to investigate if sRPE ACWR is associated with injury in junior tennis players over a 7-month time period. **Methods**: Forty-two junior tennis players were recruited to participate, 26 were included in the final analysis. Players provided a rating of RPE as an estimate of training intensity every day after training/match sessions. Session RPE, a measure of internal and external training load was calculated by multiplying the training/match session RPE by the session duration in minutes. Players self-reported all injuries. The ACWR was the primary independent variable. Acute load was determined as the total sRPE for one week, while a 4-week rolling average sRPE represented chronic load. **Results**: Seventeen players sustained injuries. The model indicated that ACWR from the previous week ($p<0.001$) and previous injury history ($p=0.003$) were significant predictors of injury the following week. In the week preceding injury, the average ACWR was 1.57 (SD 0.90). **Conclusion**: Injured players had on average 1.5 times more training load in the past week compared to the previous 4 weeks. Majority of players that went on to sustain an injury were not prepared for the load endured. These results were similar to previous studies investigating ACWR where an acute increase in load was associated with increased injury risk.

Key Words: session rate of perceived exertion, internal and external load, training load, and relative load

Introduction

It is not uncommon for intermediate and advanced junior tennis players (Universal Tennis Rating:5-11) to compete and practice year-round. These players often train, practice, and compete 5-6 days a week. Aside from practice and conditioning, tournament schedules may lend themselves to players participating in up to 10 matches, depending on the player's progress throughout the tournament (1). Therefore, a junior tennis player's schedule can lead to rigorous training and competition loads that stress the body. This stress may be detrimental to the health of the athlete and lead to injury if adequate monitoring, management, recovery, and rest are not implemented (2). Epidemiology studies have reported that lower extremity injuries (31-67%) are the most common in tennis followed by upper extremity injuries (20-49%). The ankle and thigh and the elbow and shoulder are the most frequently injury parts of the lower and upper extremity, respectively. (3)

In the sports medicine literature, two different types of training and competition load are commonly discussed: external and internal load. It is important to note that these load definitions are different from the Standard International (SI) System of Units meaning of "load" used in physics and engineering. External workload describes any external training stimulus applied to an athlete that is independent of a physiological response (4). Examples of external load include, but are not limited to, distance covered, frequency of training/competition (days, week, month), and duration of training/competition (second, minutes, hours) (2). Frequency and duration have been investigated as potential risk factors for injury within a tennis population. Athletes are 3 times more likely to medically withdraw if players participate in greater than or equal to 5 matches during a tournament (1). One prospective study identified that injured junior players participate in 5 more hours of singles per week than non-injured players (5). In addition to these external load risk factors, sports medicine researchers have also been investigating how internal load plays a role in injury.

Internal load describes a player's physiological or psychological response to an external training or competition stimulus (4). Examples of internal load often include perception of effort, heart rate, and sleep inventories (2). Perception of effort is often quantified with a rating of perceived exertion (RPE) and is a commonly used metric due to ease of application (6). During competitive tennis, advanced players have reported RPE ranging between 5 and 8 on a 0-10 scale (7). A common variation of RPE investigated in the literature is session rate of perceived exertion ((sRPE), sRPE = duration*RPE) (8). Session RPE has been validated against heart rate during a variety of types of exercise training in a variety of physical active populations(8,9). This metric has been used in many training load studies; (10-13) however, no study has determined the relationship between sRPE and injury within a tennis population.

Training load can be assessed two different ways: absolute and relative. Absolute training loads are the sum of a particular domain of training over a specified time period while relative loads assess the rate or history of load application (6). Banister and colleagues (14) introduced relative loads by addressing an athletes state of fatigue (acute load) to his or her state of fitness, operationalized as the chronic load. To help quantify this concept the acute:chronic workload ratio (ACWR) has been investigated (15). The ACWR is a method that can be used to quantify and monitor patterns in load to help assess an athlete's level of readiness to train and compete in sports.(16) The ratio examines acute (most recent week) training load to the chronic (2-6 week) training load (16). Research conducted on various sports, such as rugby players and

European football players, have determined if the acute load is higher than the chronic load (ACWR >1.3) athletes are almost twice more likely to sustain injury than athletes with lower ACWRs (12,15).

Previous research has examined descriptive data on external loads in elite level tennis players (17-19). However, incorporating a measure of internal load should be investigated, as sRPE has been shown to be twice as predictive of injury compared to external load in cricket bowlers (10). Therefore, the purpose of this research is to investigate if sRPE ACWR is associated with injury in junior tennis players over a 7-month time period. It was hypothesized that high sRPE ACWR from the previous training week would be associated with injury the following week.

Methods

Participants

Forty-two junior advanced tennis players were recruited from one tennis academy in Austin, Texas. Players provided written informed consent (or assent with guardian consent, where applicable) to participate in this study, which was approved by Texas State University's Institutional Review Board. Thirty-one athletes (21 males & 10 females; 14 (2) years, height 170 (115) cm, and 59 (12) kg.) successfully completed all aspects of the study, and were prospectively followed for 31 consecutive weeks. Athlete sex and demographic data are presented in Table 1. All data were collected between May and December 2018. Players were included in this study if: (1) participated in tennis at least three times a week; (2) ranged in age between 9 and 18; (3) participated in sectional, regional, or national tournaments; and (4) had no injuries at the time of enrollment that influenced tennis participation. Players were excluded if did not have access to a tablet or smartphone or suffered from a contact injury. These devices were used to document load and injury throughout the study.

Quantifying Internal Training load

Internal load was measured using sRPE. Researchers often refer to sRPE as a measure of internal load, (2) the authors of this research believe it is better described as internal plus load as session duration (a measure of external load) is used to quantify sRPE. Players were asked to provide a subjective rating of RPE using a 0-10 point scale as an estimate of self-perceived training intensity (8,10). Players also documented practice duration. RPE and duration were documented within 30 minutes after every training/match session. Internal plus load was defined by multiplying the training/match session RPE by the session duration in minutes to get sRPE (10).

Definition of Injury

At the commencement of data collection, all players reported a previous history of musculoskeletal injuries sustained within the last 3 years. Injuries during the study were self-reported by the players. One member of the research team (medical professional) followed up with every documented injury to ensure the injury was a result of training and met the injury definition. Common post-practice pain or soreness that were reported by the players were excluded from analysis. All injuries were categorized using standard tennis injury surveillance procedures as suggested by Pluim and colleagues (20). An injury was defined as any non-contact injury that resulted in 1 or more missed training sessions, or a loss of match-time (10).

Procedures

Self-reported RPE, duration of training/match, and injury were recorded using AthleteMonitoring Software (FITSTATS Technologies) after every tennis session. The software is accompanied with the AthleteMonitoring Application which is compatible with any smartphone or tablet. Each player was given a username and password. Players received daily notifications from the software alerting them to document self-perceived data and training duration times.

Data Reduction

The sRPE ACWR was the primary independent variable within this study. Data were categorized into weekly blocks running from Monday to Sunday. One-week data, in conjunction with 4-week rolling mean sRPE data were calculated using the traditional coupled method for ACWR (21). The 1-week data represented sRPE acute load, while the 4-week rolling average represented sRPE chronic load. Weekly loads that were below 1 standard deviation of the player's chronic loads were removed from the analysis. These methods were in accordance with Hulin et al (10) so the final analysis would not consider small absolute increases of acute load at low chronic loads. The sRPE was left blank for players who participated in tennis practice/competition but forgot to record RPE and duration data; however, players included in the final analysis had a 90% or higher compliance rate throughout study.

Statistical Analysis

A Cox proportional hazard regression model analysis was used to determine if sRPE ACWR from the previous week was a significant predictor of injury the following week (22). The ACWR requires a minimum of four weeks to calculate; therefore, the data from this analysis were left centered at 5 weeks and right centered at 31 weeks (i.e. the end of the observational period). A non-repeating single event model was applied to determine hazard ratios; where time to injury was measured in weeks. More specifically, a player was followed only until the initial injury and was then censored. Injury was coded as either zero (no injury) or one (injury). Following injury players were excluded from subsequent analyses. Beginning with the 5th week 26 participants were available for model analysis.

The primary predictor of interest was sRPE ACWR a time-varying covariate. Other predictor variables included age, sex, height, weight, years of experience, and previous injury history. Backwards elimination was used to identify and remove non-significant predictors, manually, based upon the size of *p*-values. To control for violations of independent observations, that are unavoidable with longitudinal data, the SPSS complex sampling procedures were used. Sample weights were set at one. Significance of predictor variables were determined using Wald F statistics with an a priori alpha level of 0.05. Follow up analysis was conducted creating a categorical variable of sRPE ACWR using 1.5 as the threshold. This threshold was used as this value has been significant in other studies (10,15,23). All data were analyzed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, N.Y. USA).

Results

Of the 42 players, 2 athletes sustained injuries within the first two weeks of data collection limiting the ability to calculate sRPE ACWR data, and 14 athletes were considered dropouts due to <90% data reporting compliance rate, leaving a total of 26 athletes. The average weekly compliance for documenting training load data was 92%. Of the 26 athletes 6 had a previous injury history, and 100% (6/6) of these players went on to sustain an injury during the study. A summary of acute and chronic workload data for all athletes are shown in Table 2. Seventeen injuries were reported over the 31 weeks. The median time loss for these injuries were 5 (IQR 0-11) days. Eleven athletes reported a lower extremity injury (65%), 4 reported an upper extremity injury (23%) and 2 reported a trunk injury (12%). All seventeen injuries are presented in table 3 by week.

Results from the Cox proportional hazard regression model analysis suggests that sRPE ACWR from the previous week (Wald $F_{1,25} = 14.11$; $p<0.001$) and previous injury history (Wald $F_{1,25} = 10.78$; $p=0.003$) were both significant predictors of injury and increased injury risk. The overall test of proportional hazard was not significant (Wald $F_{2,24} = 2.76$; $p=0.08$) indicating the proportional hazard assumption was met (i.e., the ratio of hazard is constant over time). Hazard ratios and 95% confidence intervals are provided in table 4 for all significant predictors. Average sRPE ACWR across all injured participants in the week preceding injury was 1.57 (0.87).

Secondary analyses using an sRPE ACWR of 1.5 was used to categorize individuals into high and low risk categories. Changes in injury risk for high and low risk players and those with and without a previous history of injury are provided in figures 1 and 2, respectively. Players categorized as high risk (sRPE ACWR ≥ 1.5) were seven times more likely (hazard ratio = 7.51; 95% confidence interval = 2.09 – 27.00) to get injured compared to those with sRPE ACWR < 1.5 (Wald $F_{1,25} = 10.54$; $p=0.003$) in the week preceding injury.

Discussion

This is the first study to investigate the sRPE ACWR in relation to injury in junior tennis players. Our hypothesis was supported as high sRPE ACWR from the previous training week was associated with injury the following week. More specifically, injury risk in these junior tennis players increased by a factor of 2.76 (hazard ratio, table 4) for every increase of 1 in the sRPE ACWR. Players whose acute workload exceeded the chronic load had a higher probability of sustaining an injury the subsequent week. This is a finding that is consistent with a systematic review on training load and injury in athletes (24). The average sRPE ACWR of 1.57 suggests that injury risk increases when acute loads are 50% greater than typical chronic workloads. It is important to note that some players in our study had a balanced sRPE ACWR and still sustained an injury the following week. Why a player sustains an injury is multifactorial and health care professionals and coaches should not rely on one single variable (25). For example, in this study previous history of injury was also related to those who went on to sustain an injury (Figure 2).

The results of this study are consistent with previously published research observing a relationship between acute and chronic perceptions of internal load and subsequent injury risk. In cricket bowlers (10) acute loads that were similar to, or lower than the chronic load had a lower injury risk. The ACWRs that were ≥ 1.5 in the current week increased injury risk to 2-4 times greater in the subsequent 7 days (10) In agreement with the aforementioned study, Malone et al. demonstrated that increased weekly workloads resulted in an increased injury risk in professional soccer players (26). Researchers investigating elite rugby players determined that a very high ACWR of ≥ 2 demonstrated a 17% injury risk in the current week, and a 12% injury risk in the subsequent week (15). Acute:chronic workload ratios that were ≥1.54 were associated with the greatest risk of injury at 29% (15). In the present study, the percentage of individuals who sustained an injury with sRPE ACWR ≥ 1.5 was 11% compared to 2% for those who sustained an injury with ACWR < 1.5.

The ACWR is a user-friendly metric that health care professionals and coaches working with tennis athletes can use to monitor sRPE training load. While the risk of injury has been shown to increase in team sports and now individual sports with a ratio of approximately 1.5; this does not mean a player cannot train at a higher ACWR (27). Training and competition load should be individualized to the athlete as some players will be able to sustain higher workloads and some will not. An editorial in the *British Journal of Sports Medicine* discussed the importance of applying load principles to tennis and proposing six guidelines to manage training loads and reduce injury prevalence in tennis players (28). The guidelines consisted of: establishing fitness levels, minimizing week-to-week training changes, avoiding peaks in load, maintaining a correct work-rest balance ratio, establishing a minimum training load during "rest" periods, and lastly to not over do it (28). This article is a testament to the fact that many factors may contribute to diminishing injury risk in tennis players.

The current study has implications for coaches and players as well as health care professionals. Use of the ACWR can emphasize both positive and negative effects of training loads (29). Utilizing this metric can help coaches and other personnel compare the training load an athlete has actually performed relative to the amount of training they are prepared for (29). In sports like tennis where juniors can play multiple matches a day, it is important to ensure athletes are training at an adequate load up to 4 weeks in advance to help prepare for those rigorous tournament schedules. Given that the ACWR ≥ 1.5 was associated with injury in these tennis players and other sports (16) , the ratio may also be helpful in determining return to play for athletes rebounding from injury. While injury risk factors are likely multifactorial future research should aim to investigate multiple variables over time to determine any relationships with injury and even performance. Lastly, future research should aim to investigate if perception of exertion or intensity of duration is the most influential component of sRPE.

This study has limitations that should be considered in interpreting the results. The athletes monitored were typical advanced junior tennis players; however, the convenience sampling from a warm region of the United States likely influence the application to other tennis players. Both sRPE and injuries were self-reported by players; however, sRPE is a common metric used to measure internal load and has been validated in previous research (6,8,10,15,26). While injury was self-reported, a certified athletic trainer was on-site every day during training to follow up with participants when injuries were documented within the AthleteMonitoring software. While the compliance rate for reporting sRPE was high (>90%), there were days in which some players missed a reporting session. Previous injury history was documented as a categorical variable (yes/no), so previous injury location was not documented. Session RPE was the main independent variable within this model. Other workload parameters were not collected; however, concurrent research on some of these participants is being conducted on other external load measures specific to tennis. Lastly, athletes were removed from analysis following the initial injury, reintroducing the athletes after the recovery period would have added more power to the data set as more injuries could have been accrued.

Conclusion

Monitoring and managing internal loads may be important for adolescent tennis players and may play a meaningful role in the injury prevention paradigm. The outcomes of this study investigated the relationship between sRPE ACWR and injury in adolescent athletes, and further help to substantialize the impact of avoiding large spikes in acute workload relative to chronic workloads. Our study indicates that injured players perceived on average 1.5 times more internal plus load in the week prior to injury compared to the previous 4 weeks. Over half of the players that went on to sustain an injury were not prepared for the workload endured as the sRPE ACWR was greater than 1. To the author's knowledge this study is the first of its kind in tennis players and provides evidence on the importance of consistently and progressively monitoring and managing training loads in tennis players and their association with injury.

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Conflicts of Interest:

No conflicts of interest, financial or otherwise, are declared by the authors. The results of this study do not constitute endorsement by the American College of Sports Medicine. The results of this study are presented clearly, honestly, and without fabrication, falsification or inappropriate data manipulation.

References

1. Jayanthi NA, O'Boyle J, Durazo-Arvizu RA. Risk factors for medical withdrawals in United States tennis association junior national tennis tournaments: a descriptive epidemiologic study. *Sports Health.* 2009;1(3):231-235.

2. Soligard T, Schwellnus M, Alonso JM, Bahr R, Clarsen B, Diikstra PH, Gabbett T, Gleeson M, Hagglund M, Hutchinson MR. How much is too much?(Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *Br J Sports Med.* 2016;50(17):1030-1041.

3. Abrams GD, Renstrom PA, Safran MR. Epidemiology of musculoskeletal injury in the tennis player. *Br J Sports Med.* 2012;46(7):492-498.

4. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med.* 2014;44 Suppl 2:S139-147.

5. Hjelm N, Werner S, Renstrom P. Injury risk factors in junior tennis players: a prospective 2-year study. *Scand J Med Sci Sports.* 2012;22(1):40-48.

6. Drew M, Finch C. The Relationship Between Training Load and Injury, Illness and Soreness: A Systematic and Literature Review. *Sports Med.* 2016;46(6):861-883.

7. Gomes RV, Moreira A, Lodo L, Capitani C, Aoki MS, Foster C, Jenkins D. Ecological validity of session RPE method for quantifying internal training load in tennis. *Int J Sports Sci Coach.* 2015;10(4):729-737.

8. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, Doleshal P, Dodge C. A new approach to monitoring exercise training. *J Strength Cond Res.* 2001;15(1):109-115.

9. Haddad M, Stylianides G, Djaoui L, Dellal A, Chamari K. Session-RPE method for training load monitoring: validity, ecological usefulness, and influencing factors. *Front Neurosci.* 2017;11:612.

10. Hulin BT, Gabbett TJ, Blanch P, Chapman P, Bailey D, Orchard JW. Spikes in acute workload are associated with increased injury risk in elite cricket fast bowlers. *Br J Sports Med.* 2014;48:708-712.

11. Colby MJ, Dawson B, Peeling P, Heasman J, Rogalski B, Drew MK, Stares J, Zouhal H, Lester L. Multivariate modelling of subjective and objective monitoring data improve the detection of non-contact injury risk in elite Australian footballers. *J Sci Med Sport.* 2017;20(12):1068-1074.

12. McCall A, Dupont G, Ekstrand J. Internal workload and non-contact injury: a one-season study of five teams from the UEFA Elite Club Injury Study. *Br J Sports Med.* 2018;52:1517-1522.

13. Coutts AJ, Gomes RV, Viveiros L, Aoki MS. Monitoring training loads in elite tennis. *Rev Bras Cineantropo Desempenho Hum. 2010;12(3):217-220.*

14. Banister EW, Calvert TW. Planning for future performance: implications for long term training. *Can J Appl Sport Sci.* 1980;5(3):170-176.

15. Hulin BT, Gabbett TJ, Lawson DW, Caputi P, Sampson JA. The acute: chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. *Br J Sports Med.* 2016;50(4):231-236.

16. Gabbett TJ, Hulin BT, Blanch P, Whiteley R. High training workloads alone do not cause sports injuries: how you get there is the real issue. *Br J Sports Med.* 2016;50:444-445.

17. Myers NL, Sciascia AD, Kibler WB, Uhl TL. Volume-based interval training program for elite tennis players. *Sports Health.* 2016;8(6):536-540.

18. Whiteside D, Cant O, Connolly M, Reid M. Monitoring hitting load in tennis using inertial sensors and machine learning. *Int J Sports Physiol Perform.* 2017;12(9):1212-1217.

19. Myers N, Kibler WB, Axtell AH, Uhl TL. The Sony Smart Tennis Sensor accurately measures external workload in junior tennis players. *Int J Sports Sci Coach.* 2019;14(1):24-31.

20. Pluim BM, Fuller CW, Batt ME, Chase L, Hainline B, Miller S, Montalvan B, Renstrom P, Stroia KA, Weber K, Wood TO. Consensus statement on epidemiological studies of medical conditions in tennis. *Br J Sports Med.* 2009;43(12):893-897.

21. Windt J GT. Is it all for naught? What does mathematical coupling mean for acute:chronic workload ratios? *Br J Sports Med.* 2018. doi: 10.1136/bjsports-2017-098925.

22. Windt J AC, Gabbett T. Khan K, Cook C, Sporer B, Zumbo B. Getting the most out of intensive longitudinal data: a methodological review of workload–injury studies. *BMJ Open.* 2018;8:e022626.doi:10.1136/bmjopen-2018-022626.

23. Blanch P, Gabbett TJ. Has the athlete trained enough to return to play safely? The acute: chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. *Br J Sports Med.* 2015;50(8):471-475.

24. Eckard TG, Padua DA, Hearn DW, Pexa BS, Frank BS. The Relationship Between Training Load and Injury in Athletes: A Systematic Review. *Sports Med.* 2018;48(8):1929-1961.

25. Gabbett TJ. Debunking the myths about training load, injury and performance: empirical evidence, hot topics and recommendations for practitioners. *Br J Sports Med.* 2018. doi:10.1136/bjsports-2018-099784.

26. Malone S, Owen A, Newton M, Mendes B, Collins KD, Gabbett TJ. The acute: chonic workload ratio in relation to injury risk in professional soccer. *J Sci Med Sport.* 2017;20(6):561-565.

27. Bourdon PC, Cardinale M, Murray A, Gastin P, Kellmann M, Varley MC, Gabbett TJ, Coutts AJ, Burgess DJ, Gregson W, Cable NT. Monitoring athlete training loads: Consensus Statement. *Int J SPorts Physiol Perfom.* 2017;12(Suppl 2):S2161-S2170.

28. Pluim BM, Drew MK. It's not the destination, it's the ‘road to load’that matters: a tennis injury prevention perspective. *Br J Sports Med*. 2016;50:641-642.

29. Gabbett TJ. The training—injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med.* 2016;50(5):273-280.

Table 1. Descriptive data reported as mean (standard deviation) for all 26 athletes.

	N	Age (years)	Previous injury history (N)	Years of tennis experience	Height (cm)	Weight (kgs)
Males	18	15(2)	4	5(3)	171(3)	61(3)
Females	8	16(2)	2	6(2)	167(2)	55(3)

Table 2. Descriptive load data reported as mean (standard deviation) for all athletes over the duration of the study.

Time Frame	*RPE (SD)	Duration (SD) minutes	sRPE (SD) arbitrary units	sRPE Minimum - Maximum
Acute (1-week total)	-	-	2,880 (2,126)	0 – 9,090
Chronic (4-week average)	-	-	3,373 (1,621)	0 – 7,626
All weeks	7 (2)	117 (43)	-	-

sRPE = Session rate of perceived exertion

*Represents average RPE of all players during training/competition

Table 3. Injury and sRPE ACWR descriptive data in the week preceding injury.

Week of Injury	Injury Location	Injury Grouping	sRPE ACWR in week prior to injury
5	Ankle	Muscle/tendon	1.34*
7	Calf	Muscle/tendon	0.72
7	Knee	Muscle/tendon	1.67*
7	Knee	Muscle/tendon	0.86
8	Trunk	Muscle/tendon	1.40*
11	Shoulder	Muscle/tendon	2.35*
12	Forearm	Muscle/tendon	1.97*
16	Hip	Muscle/tendon	1.55*
16	Back	Muscle/tendon	2.49*
18	Hamstring	Muscle/tendon	4.0*
20	Wrist	Muscle/tendon	0.79
20	Heel	Bone	0.84
20	Shoulder	Muscle/tendon	1.31*
21	Hamstring	Muscle/tendon	1.15*
21	Heel	Bone	0.54
21	Hamstring	Muscle/tendon	2.39*
21	Back	Muscle/tendon	1.24*

*represents sRPE acute workload > sRPE chronic workload

Table 4. Hazard Ratios

Risk Factor	Parameter Estimate	*p*-value	Hazard Ratio (95% CI for Hazard Ratio)
sRPE ACWR	1.02	0.001	2.76 (1.58 – 4.82)
Previous Injury History	1.45	0.003	4.25 (1.71 – 10.51)

Note: Parameter estimates, and hazard ratios are calculated using no previous history of injury as the reference category; those with a history of injury are more likely to become injured compared to those with no history of injuries.

Figure 1. Represents the probability of injury in the subsequent week using 1.5 sRPE ACWR cutoff

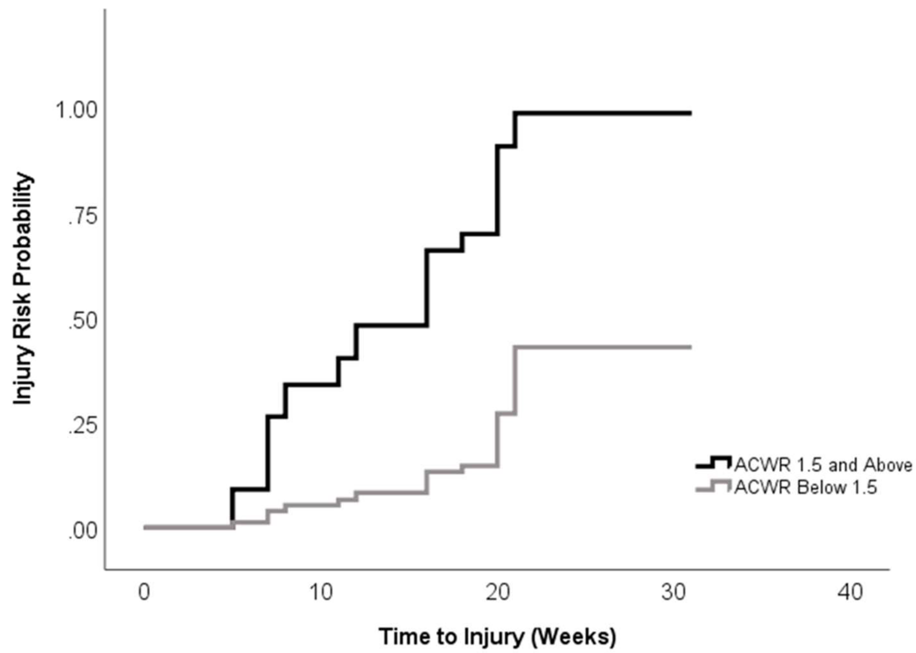

Figure 2. Represents injury risk probability in those with and without a previous history of injury.