The association between training load indices and injuries in elite soccer players

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ABSTRACT

To investigate the association between contact injuries, non-contact injuries and training load indices, across different lag periods in elite soccer players. Internal load (session rate of perceived exertion) was collected from 15 elite soccer players over one-season (40-weeks). Acute (7-days), chronic (28-days), Acute:Chronic Workload Ratio (ACWR) (uncoupled), Exponentially Weighted Moving Averages (EWMA) ACWR and 2-, 3-and 4-week cumulative load were calculated on a rolling weekly basis. Multilevel logistic regression was used to analyze the associations between contact, non-contact injuries and training load indices, across different lag periods (5-and 7-days). A player was at a significantly higher risk of a non-contact injury 5-days' later, if week-to-week acute load changes increased (Odds Ratio, OR=1.97). An increase in EWMA ACWR was associated with an increased risk of both a contact (OR=1.30) and non-contact injury (OR=1.35), 5-days' later. An increase in 2-week cumulative load (OR=1.77) was associated with an increased risk of a contact injury 7-days' later and 3-week cumulative load (OR=1.55) 5-days' later. These findings suggest that in order to reduce the potential risk of a non-contact injury, training load should be gradually increased avoiding an increase in week-to-week acute load change (≥9%) or EWMA ACWR (>1.20). Findings indicated that EWMA ACWR may be a more sensitive measure for detecting a player at a higher risk of an injury than ACWR. Furthermore, a high 2- and 3-week cumulative load was associated with an increased risk of a contact injury, which may indicate accumulated fatigue. Practitioners must note this study investigated associations with injury risk and not injury prediction.

Keywords: Contact injuries; Non-contact injuries; Acute:chronic workload ratio; Injury prevention; Load monitoring; Team sports.

INTRODUCTION

Injuries are the most common reason for player unavailability from training and competitions in soccer (32), which can have a considerable impact on a team's performance. Training load is widely used to manage fatigue, reduce the risk of injuries and optimize training adaptations (9). Training load data can be quantified from internal and/or external measures. Internal load is a player's physiological and/or psychological response to an external load and can be measured by Rating of Perceived Exertion (RPE) (14), which is a valid and reliable internal measure of a player's exercise intensity (25). External load is the objective physical load applied to the athlete, which can be measured through Global Position System (GPS) metrics (e.g. maximum speed or total distance covered during training or a match) (14).

Session RPE (sRPE; RPE x session duration) is widely used in team sports, due to its relative ease of implementation (21). A number of derivative measures can be calculated from sRPE (37), such as acute load (sum of 7-days training load) and chronic load (average of the previous 28-days training load) (24). These training load indices (acute and chronic) can subsequently be used to calculate the Acute:Chronic Workload Ratio (ACWR), which indicates whether the acute load is greater, less or equal to the preceding chronic load (18). To examine ACWR accurately, the uncoupled calculation should be used, this means the current week of training (acute) is not included in the chronic load (Table 1) (24). More recent research has explored Exponentially Weighted Moving Averages (EWMA) ACWR, which puts a greater emphasis on the most recent training load by giving it more weighting, and a decreased weighting to the older training load (31, 38), whereas, the ACWR calculates all training loads as equal (31). A recent study by Murray et al. (31) suggested that EWMA ACWR may be a more sensitive measure for identifying the likelihood of a non-contact injury than ACWR in Australian football players.

Previous research has found that a rise in acute load increased the risk of injury (8, 27, 33), and a high ACWR was also found to associate with an increased risk of injury in the subsequent week in cricket (17), Australian football (10), and soccer players (5, 11). Furthermore, a high EWMA ACWR and a low chronic load was found to associate with an increased injury risk in Australian football (34), while a 2- and 3-week cumulative load were found to associate with an increased risk of injury in soccer players (20, 27). A limitation in a number of these previous studies (5, 20, 27), was training load data were analyzed in weekly blocks (e.g. Monday-Sunday), instead of training load as rolling weekly data. Rolling weekly means data can be analyzed from the exact injury day rather than a specific week; where an injury may have occurred at the beginning or end of the training week and thus, omitting training load data. Another limitation of previous research was only sRPE for outdoor sessions (i.e. field sessions and matches) combined with GPS data were collected (5). Additionally, in the Sampson et al. (34) and Murray et al. (31) studies, only GPS data were collected, no internal load (sRPE) or indoor training load data were collected. This is problematic as the load data should encompass all training sessions to ensure a player’s total training load is collected and accounted for in the analyses (7, 17). The load should also include all non-training load days, i.e. training load= 0 (10).

Lag period has been defined as the time between the dose (training load) and response (onset of injury) (9). This is important for coaches, as it may provide them with an early window of opportunity to adjust training load in order to help reduce the risk of injury (21), i.e. the lag period provides an opportunity for a coach to periodize training to prospectively avoid training loads that may place a player at a higher risk of injury post-lag period. There is a dearth of research investigating the lag time between training load indices and contact and non-contact injuries (9, 21). To the authors’ knowledge, no study has conducted lag analysis with rolling weekly training load data in soccer players for contact or non-contact injuries, which consequently is a reason for the current study exploring the association between training load indices and injuries. Previous research has analyzed non-contact injuries association with rolling weekly training load data at 3- and 7-day lag periods, with American college football players, over a 17-week season (34). Additionally, Carey et al. (6) also analyzed rolling weekly training load data with Australian football players, over 2 seasons. The study was investigating the likelihood of a non-contact injury and the possible delayed effects in injury occurrence (i.e. lag period) following a match at 2- and 5-days. However, these studies did not include all training load data, instead only outdoor sessions were included. Therefore, the total training load completed during a week was not analyzed. Additionally, other studies analyzed weekly blocks (7, 8, 17, 27), rather than rolling weekly training load data, could only analyze the lag period as the subsequent week (7-days) (7, 8, 17, 27). These limitations may mean important injury or training load data were excluded, due to lag period not being analyzed with rolling weekly data. Therefore, further research is required to investigate lag period at set days prior to a potential injury (contact and non-contact) in soccer players.

Currently, there is a lack of research analyzing the association between contact injuries and training load indices (5, 15). Previous research has found that acute training load was associated with a higher risk of contact injuries in Rugby league (15), and in soccer players, if acute load was ≥ 648 AU (5). Acute load was calculated as the sum of the week’s total training load (Monday-Sunday) during outdoor sessions and classified as the total forces on the player over the entire session based on GPS accelerometer data alone (5). However, Bowen et al. (5) study only collected GPS data, which means indoor training sessions were excluded from the calculations. Lag period was not explored in either study (5, 15). Due to the limited research investigating the association between rolling weekly training load indices and contact and non-contact injuries in soccer (5, 20, 27) further research is required. Therefore, the aim of this study was to investigate the association between contact and non-contact injuries and rolling weekly training load indices, across different lag periods, in elite soccer players.

METHODS

Experimental Approach to the Problem

Testing took place over a full soccer season (January- November 2018, 43-weeks). The playing season comprised of 47 matches, including a 1-week break in-season. Each player completed a 1-week familiarization and attended verbal anchoring workshops (23) at the beginning of pre-season. Data (i.e. training and injury information) were recorded daily for each player. The first 3 weeks of pre-season were not included in the injury analysis due to training load calculations (e.g. cumulative load), thus over the 40-week period, there were 280 data points per player.

Subjects

Fifteen male elite soccer players volunteered to take part in the study (age 23.4 ± 4.8 years, height 180.8 ± 5.8 cm, body mass 77.1 ± 5.1 kg). All players were contracted and played for the senior first team, competing in the Premier League of Ireland. A typical training week consisted of 4 team training days and a match. Sessions included fitness conditioning, gym/resistance, skills and conditioned games. All players were informed of the study requirements and provided written informed consent. The study was approved by the University Research Ethics Committee.

Procedures

The familiarization period, during the first week of pre-season, included 3 separate education sessions by the lead researcher (C.T.) on the RPE scale. The players also completed a yo-yo intermittent test, as this is a maximal test, to help anchor the top end of the RPE scale. Additionally, during this pre-season period, after each player inputted their RPE scores post training session, the lead researcher (C.T.), would privately check with the athletes that they fully understood why they gave that session a specific score on the RPE scale. The purpose was to ensure players were able to accurately provide RPE values.

Training load

sRPE was calculated by RPE x session duration (minutes), using the modified Borg's 0-10 scale (12), and was collected after every individual or team training session and match. sRPE was recorded on a specifically designed mobile phone app, installed on the players' phone, to avoid external influences (35). For the team sessions, each player's session duration and the type of session was recorded by the coach. If players completed individual sessions, they recorded the type of session and session duration through the app. If multiple sessions were completed in a day, the sRPE loads were summed at the end of the day to give a daily load (Arbitrary Unit, AU) (37) (Table 1). Recovery days were noted as 0 (10). All training load indices were derived from sRPE and can be seen in Table 1. RPE has been found to be a reliable (25) and valid method to subjectively measure the player's exercise intensity in soccer (19).

Due to the calculation of a number of training load indices (i.e. cumulative load/chronic load), the first 3 weeks of pre-season were not included in the injury analysis. Furthermore, no injuries occurred during this period.

Insert Table 1 here

Injuries

An injury was defined as a 'time loss' injury, where a player was unable to fully participate in training or a match (13). All injuries were recorded by the teams' qualified physiotherapist or physical therapist under the soccer injury consensus statement (13). These headings included, date of incident, where it occurred (e.g. training or match), type of surface, contact or non-contact, overuse or sudden, body part, type of injury, injury duration and return to play date.

For further clarification, a contact injury was classified as an injury that occurred as a result of physical contact with another player, object and/or equipment (13, 15). This included, collision with another player, tackle, moving object (ball), static object (goal post) and violation of rules (tackle) (13). A non-contact injury was classified as an injury that was sustained without any extrinsic contact with another player or object on the field (13).

Statistical analysis

All statistical analyses were conducted using MLwin software (version 3.01) and descriptive statistics were calculated for all variables, and assumptions for parametric analysis were explored. Odds Ratio (OR) and Confidence Intervals (CI) and probability of an injury were calculated (34). All training load indices were scaled by the units shown in Table 1. Where an OR was > 1, an increased odds of injury was reported and where an OR was < 1 a decreased odds of injury was reported (33). To examine the probability of an injury, the following criteria was used to provide descriptive figures (Figure 1 and 2) using a quadratic polynomial analysis from MLwin, <0.005 most unlikely; 0.005–0.05 very unlikely; 0.5–0.25 unlikely; 0.25–0.75 possible; 0.75–0.95 likely; 0.95–0.99.5 very likely; >0.99.5 most likely (3). The unit increase values presented in the current study, were the arbitrary mean values of all players training load indices, whether they were injured or not injured. The arbitrary values indicated a point where a player was at higher risk of an injury in relation to the OR. This was important as the analysis conducted was to explore associations with injury risk and not injury prediction. Significance levels were set at $p \leq 0.05$.

Multilevel binary logistic regression was used to analyze the data, where days (level 1) were nested within players (level 2). ~~Multilevel binary logistic regression was used to analyze the~~

~~data, level 1 (within) and level 2 (between).~~ A player was coded as 1 = injured (contact or non-contact) or 0= no injury. All data were included in the analyses, whether a player was injured or not. Both contact and non-contact injuries were analyzed as the dependent variables, and the training load indices were independent variables. All the independent variables were analyzed in separate models.

Lag period was analyzed as a sequential assessment (1 to 7-days). For clarification, in the current study lag period was classified as at least 24-hours preceding an injury. For example, if an injury occurred on the Sunday, 1-day lag would be the preceding Friday. This was to ensure there was a 1-day (24-hour) lag period before the potential injury, as daily training load data was summed at the end of each day. Lag period was calculated for every training load variable by moving each variable back day by day (1 to 7-days). Each training load day data were moved up to align with the following day's injury status. For example, 1-day lag = training load data on day 9 compared to injury status on day 10 (injury status= injured or not), 2-day lag = training load data on day 8 compared to injury status on day 10. However, for the purposes of this study and consistent with previous research (6, 34), lag period is presented at 5-days (6) and 7-days (34) prior to an injury (contact or non-contact), using rolling weekly training load data. A 7-day lag represents a period of training including a match, while a 5-day lag period represents a typical training week, thus providing enough time for a coach to alter training if required. For further clarification, only the training load data prior to the 'initial injury' were analyzed. Training load data on the day of the injury or post injury were not included. When an injured player was fully recovered (i.e. they could take part in all training sessions and matches), any subsequent injury was classified again as a new injury.

Multilevel logistic regression was used as it allowed within subject analysis for each player across 40-weeks. Due to the repeated measures this resulted in 280 observations per player. This analytical (multi-level) approach reduced the independent observation assumption, thus allowing within subject comparisons. This provides the opportunity to analyze within player changes over time, which is fundamentally important in the context of this research, as each player is individual and will react/respond differently to the same training.

RESULTS

Over the 40-week period (280 observations per player), 35 injuries were recorded from the 15 players included in the study, 21 were non-contact and 14 were contact injuries, indicating a player would typically have 1.4 non-contact injuries and 0.6 contact injuries over the course of the season. Of these 35 injuries, 26 occurred during a match (14 non-contact and 12 contact injuries), and 9 occurred during training (7 non-contact and 2 contact injuries). The match injury incidence rates were 34 injuries per 1000 playing hours, approximately one injury per player every 20 matches. The time-loss of a non-contact injury ranged from 1- to 70-days (average of 14-days) and for contact injuries ranging from 1- to 35-days (average of 8-days).

Non-contact injuries

The logistic regression found a significant association 5-days prior to a non-contact injury with week-to-week acute load change (OR=1.97, OR 95% CI=1.088-3.582, p=0.025) (Table 2). Additionally, a significant association was found 5-days prior to a non-contact injury with ACWR (uncoupled, Table 1) (OR=1.14, OR 95% CI= 1.047-1.234, p=0.003) (Table 2). Where week-to-week acute load change increased by 1-unit (1000AU), 5-days' later a player was at a 68% increased risk of a non-contact injury. Where ACWR increased by 0.1, over 1.0 (e.g. ACWR increased from 1.1 to 1.2), a player was at a 13% increased risk of a non-contact injury, 5-days' later.

No association was found for any of the training load indices 7-days prior to a non-contact injury (Table 2).

** Insert Table 2 here**

Contact injuries

For contact injuries, if 2-week cumulative load increased by 1-unit (1000 AU), over 3134 AU (e.g. increased from 3134 to 4134) a player was at a 57% increased risk (OR=1.77, OR 95% CI=1.018-3.088, p=0.043) of a contact injury 7-days' later (Table 3). Additionally, where 3-week cumulative load increased by 1-unit (1000 AU), over 4700 AU (e.g. increased from 4700 to 5700), this significantly increased the risk (OR=1.55, OR 95% CI=1.045-2.307, p=0.030) of sustaining a contact injury 5-days' later by 44%.

** Insert Table 3 here**

Furthermore, an increases (1-unit (0.1) over 0.97) in EWMA ACWR was associated with both an increased risk (26%) (OR=1.30, OR 95% CI=1.058-1.590, p=0.013) of sustaining a contact injury (Table 3) and a 30% increased risk of a non-contact injury (OR=1.35, OR 95% CI= 1.140-1.591, p<0.001), 5 days' later (Table 2).

Figure 1 shows the probability of sustaining a non-contact injury for week-to-week acute load change, EWMA ACWR and ACWR (5-day lag). Figure 2 shows the probability of sustaining a contact injury at 2-week cumulative load (7-day lag) and 3-week cumulative load (5-day lag).

** Insert Figure 1 here**

** Insert Figure 2 here**

DISCUSSION

The purpose of this study was to investigate the association between contact injuries, non-contact injuries, and training load indices, across different lag periods in elite soccer players. The results found if week-to-week acute load change increased by 1000 AU, 5-days' later a player was at a higher risk (OR=1.97, 68%) of a non-contact injury. Previous research with Australian football rules players, also found that an increase >1750 AU in acute load (current week-previous week) meant a player was 2.58 times more likely to be injured (33), and Cross et al. (8) found if acute load increased by 1069 AU, from the previous week, a Rugby player was at an increased risk (60%) of an injury within the subsequent week. A reason for the current study finding a specific 5-day lag period rather than just the subsequent week, may be due to rolling weekly training load analysis being conducted instead of weekly block analysis (5, 17). The rolling weekly data includes all training load data from 1-day prior to the injury, which means it may provide a more sensitive measure of training load to try to reduce the risk of injury, which is a key finding from the current study. The more detailed analysis from the current study found that 62% of non-contact injuries occurred if week-to-week acute load change increased by 9% or more. These findings are similar to previous research where it was found a player was at an increased risk of an injury, if there was an increase in 10% or more in acute load (14). These results may help a coach to appropriately plan training load to reduce the risk of a non-contact injury.

An increase in ACWR (uncoupled, 7:28) of 0.1, over 1.0, increased the risk of a non-contact injury 5-days' later, with 62% of injuries occurring if ACWR >1.20. These findings are similar to previous research, where it was found that a high ACWR increased the risk of injury (5, 6, 10, 27, 31), in the subsequent week (17). Fanchini et al. (11) also found if ACWR was >1.20, there was an increased risk of non-contact injuries in soccer players. These results mean acute load was greater than chronic load (17) and further supports the finding that an increase in week-to-week acute load change increases the risk of a non-contact injury. However, the week-to-week acute load change had a higher OR (OR=1.97) compared to ACWR (OR=1.14), indicating it may be a more useful training load variable to help reduce the risk of a non-contact injury. In practical terms, this means a coach must avoid a sudden increase in acute training load (week-to-week acute load change ≥ 9%), to decrease the likelihood of a non-contact injury, 5-days' later.

The current study also found that 5-days prior to an injury (contact or non-contact), if EWMA ACWR increased by 0.1, over 0.97, a player was at a 30% increased risk of a non-contact injury and a 26% increased risk of a contact injury. Previous research has also found a high EWMA ACWR was associated with an increased risk of non-contact injuries (10, 31, 34). Sampson et al. (34) study analyzed data using rolling weekly training load with a 3- and 7-day lag period. The results found that EWMA ACWR (7:21) associated most closely with a non-contact injury within a 3-day lag period. However, training load data was only collected for outdoor session using GPS, whereas the current study collected all training and match load data (indoor and outdoor training sessions). The current study found EWMA ACWR associated with both contact and non-contact injuries 5-days prior, which may provide a coach with an earlier opportunity to alter training load to help reduce the risk of both a contact or non-contact injury. The OR in the current study were found to be higher in EWMA ACWR (OR=1.35) compared to ACWR (OR=1.14) for non-contact injuries, indicating EWMA ACWR may be more sensitive in identifying the likelihood of a non-contact injury (31). This sensitivity of EWMA ACWR, can also be seen in Figure 1, where EWMA ACWR shows a greater probability of sustaining a non-contact injury compared to ACWR. This may be due to EWMA ACWR taking into account the timeframe in which the stimulus occurred and the decaying nature of fitness and fatigue effects, giving more weighting to the most recent training (31). In contrast, ACWR calculates all training load sessions as equal, whether it was completed 3-days’ prior or 28-days’ prior. These findings highlight that EWMA ACWR may be a useful measure to alter training load to try and reduce the risk of both contact and non-contact injuries. Further investigation is required to explore the association between EWMA ACWR and contact and non-contact injuries, due to limited research in this area. It should be highlighted that the most appropriate acute and chronic time periods, and training load variables, may be dependent on the specific sport, the sporting structure and training plan (6, 16). Therefore, future researchers, coaches, and practitioners should ensure their own analysis is conducted for their team and each individual player.

Previous research has found that high sustained workloads increased the risk of non-contact injuries in soccer (26) and a 2-week cumulative load (>4000 AU) increased the risk of injury in Australian football (33). Interestingly, the detailed data analysis for the current study found that for 2-week cumulative load 57% of contact injuries occurred at >4000 AU, and 71% of contact injuries occurred if 3-week cumulative load >5200 AU. The limited research investigating the association between contact injuries and training load indices, found that an increase in acute load, ≥ 648 AU, increased the risk of a contact injury in soccer (5) and Rugby union players (15). Bowen et al. (5) also found no association between cumulated loads and contact injuries, which contradicts the findings in the current study. A limitation to the study by Bowen et al. (5) and the potential reason for the lack of association between contact injuries and cumulative load, may be due to the fact that all training sessions were not included in their analyses. Thus, a lower cumulative load would have been calculated. A potential reason for the increased risk of a contact injury due to cumulative load, may be the accumulated effect of fatigue (37), which can reduce the stress-bearing capacity of the tissue (22) and thus, increase the risk of injury (37). Additionally, it has been found that the cumulative loads may alter neuromuscular control meaning hazardous movement strategies may be employed, increasing the risk of injury (1, 29). Fatigue may also reduce a players reaction time and increase injury risk (4, 36). Further research is required however, to explore the relationship between contact injuries, training load indices and cumulative fatigue (37).

The current investigation was the first study to analyze the association between both contact and non-contact injuries with rolling weekly data, across different lag periods in soccer. A limitation of the study was no external training load data were collected (e.g. GPS), which may provide further insight into the external load a player is exposed to. Additionally, while data were analyzed sequentially (1 to 7-day lag periods), only 5-day and 7-day data were presented, to provide a coach with an earlier time point in which to alter training load. A 7-day lag represented a period of training including a match, while a 5-day lag period represented a typical training week, thus providing enough time for a coach to alter training if required. However, it must be highlighted that care must be taken when interpreting the results as lag period assumes that the lag operates independent of the training load. This means it does not account for the fact training load during the interim period may affect the injury. Therefore, future research should investigate the cumulated training load within these lag periods and the various periodization strategies, aimed at controlling the load. Data from the current study was collected from one soccer team over a season, even with 280 data points per player, caution must be taken when interpreting these results due to the low number of injuries and the fact training was planned and adjusted according to the player's needs. Therefore, further research is required to explore the association between rolling weekly training load indices and contact and non-contact injuries across different lag periods, with multiple teams.

It should also be highlighted that injuries are unlikely to be caused by a single event; it is a result of a complex interaction between internal and external factors (2, 30). Internal factors such as history of injury and conditioning (7, 10, 28), have been noted as predisposing individuals to an injury (2, 30). External factors such as equipment, weather conditions, playing surface (30), and shoe traction (2), are also enabling factors (30). The multifactorial nature of injuries further highlights a single monitoring marker (e.g. training load) may not provide sufficient information to identify a player's injury risk (2, 30). A limitation of this current study was the nature and severity of a previous injury, which may have influenced a subsequent injury, were not included in the analysis. Future studies, therefore, should ensure that they explore the multifactorial nature of injuries (internal and external), which may include training load, injury history, injury severity, and playing surface. Furthermore, coaches, practitioners, and players should be aware that while training load was found to associate with injury risk in the current study, it is part of a more complex interaction between a number of internal and external factors. These were not all included in the current study, and so the results and findings need to be interpreted with this in mind.

In conclusion, the findings of this study revealed that a player was at a higher risk of a non-contact injury, 5-days' later, if week-to-week acute load change increased by 9% or more. For contact injuries, an increase in 2-week (>4000 AU) and 3-week (>5200 AU) cumulative load increased the risk of a contact injury. Additionally, a player was at a higher risk of a contact or non-contact injury 5-days' later if EWMA ACWR >1.20.

PRACTICAL APPLICATIONS

These results highlight the different training load indices required to help try to reduce the risk of a contact and non-contact injury in soccer. A player was at a higher risk of a non-contact injury with an increase in week-to-week acute load change, EWMA ACWR and ACWR. This reinforces the importance of a gradual increase in acute load, to reduce the risk of a non-contact injury. Where there was a high 2- and 3-week cumulative load a player was at a higher risk of a contact injury, which may be potentially due to accumulated fatigue. EWMA ACWR was found to associate with both contact and non-contact injuries, suggesting that EWMA ACWR may be a more sensitive measure than ACWR to detect a player at a higher risk of a contact or non-contact injury. However, it should be noted that the values presented in this study, may only relate to this team. Therefore, future research and coaches should calculate their own values specific to their team and individual players, as each player will react and respond to training differently. Rolling weekly training load data may be used to provide a more sensitive measure of training load than weekly blocks, as all training load data, from 1-day prior to an injury, are included in the calculations.

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Figure Captions

Table 1. Training load indices, calculation and scaled units.

Table 2. Logistic regression, CI (95%) and OR for non-contact injuries, 5- and 7-day lag period for all training load indices. * p<0.05- significant, ** p<0.001- highly significant.

Table 3. Logistic regression, CI (95%) and OR for contact injuries, 5- and 7-day lag period for all training load indices. * p<0.05- significant.

Figure 1. Probability of injury risk and CI (95%) associated training load indices with non-contact injuries (5-day lag period).

Figure 2. Probability of injury risk and CI (95%) associated training load indices with contact injuries (5- and 7-day lag period).

Figure 1. Probability of injury risk and CI (95%) associated training load indices with non-contact injuries (5-day lag period).

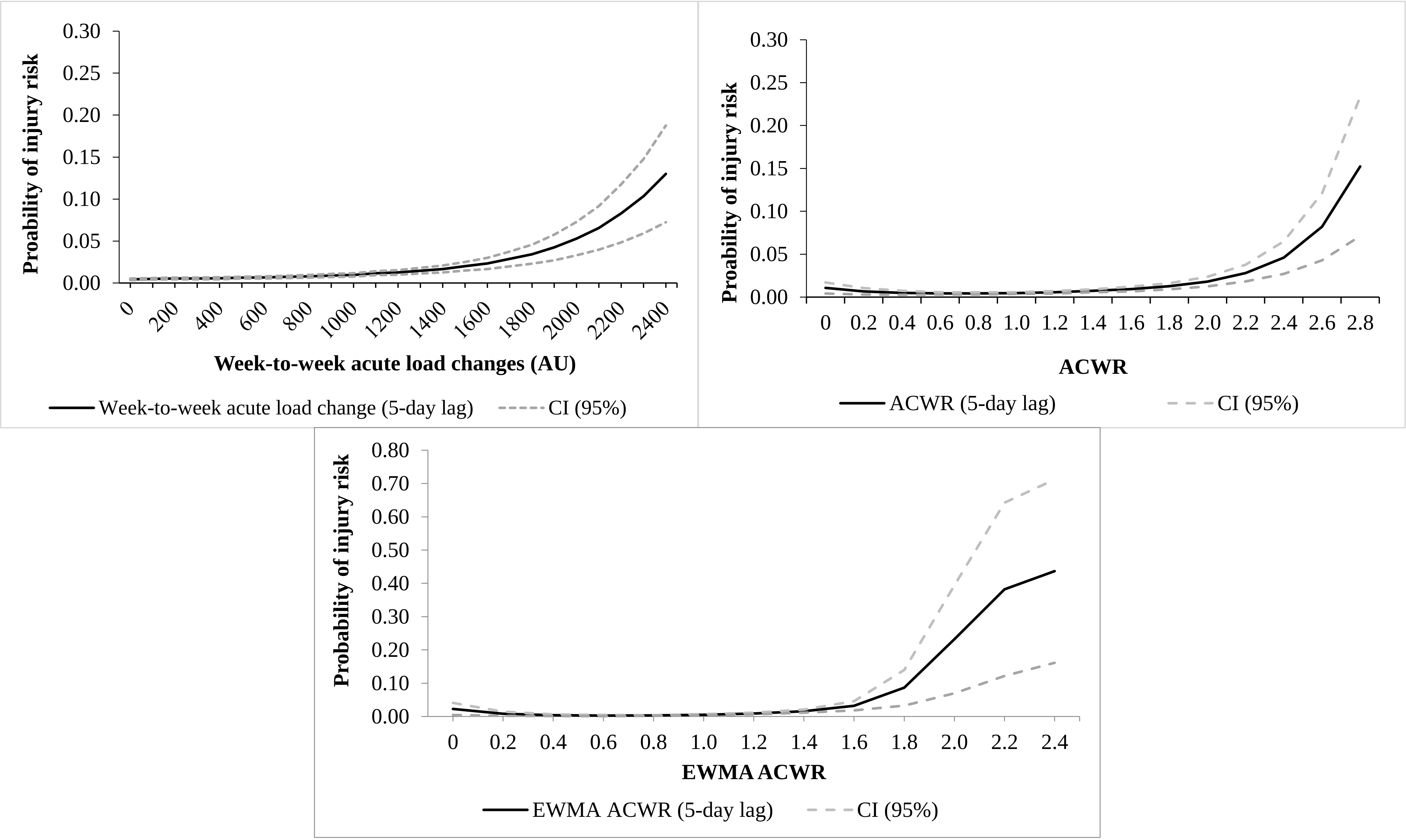

Figure 2. Probability of injury risk and CI (95%) associated training load indices with contact injuries (5- and 7-day lag period).

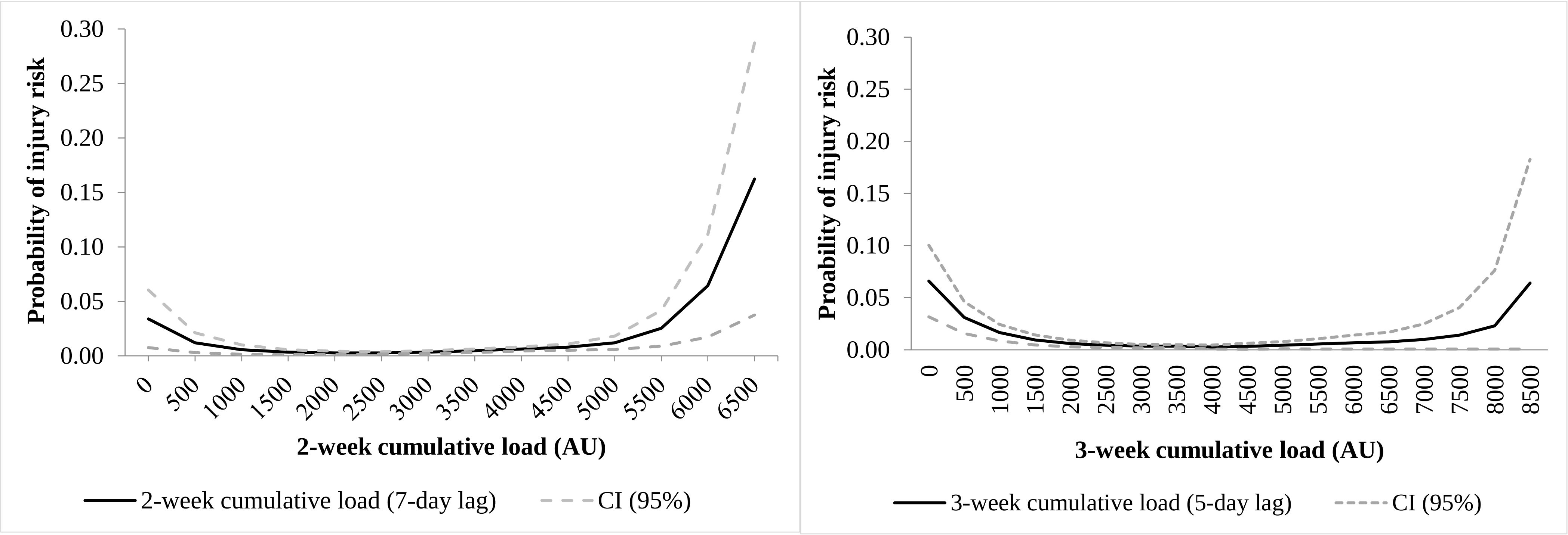

Table 1. Training load indices, calculation and scaled units.

Training load Indices	**Calculations**	**Scaled units**
Daily training load	RPE x session duration (minutes)= sRPE. All training sessions or matches completed in one day (24-hours) were added together to generate daily training load (10).	100 AU
Acute load (7-days)	Sum of daily training load over 7-days (10).	100 AU
Chronic load (28-days)	Average of the previous 28-days (21).	1000 AU
Acute:Chronic Workload Ratio (ACWR) (7:28, uncoupled)	Acute workload (sum 7-days) / chronic workload (average of 28-days, uncoupled). Uncoupled means the current week the player was training, was not included in the chronic load calculation, e.g. if the current training week was 5, chronic load would be the average of week 4, 3, 2 and 1 (4, 21).	0.1 AU
Exponentially Weighted Moving Averages (EWMA) ACWR	$\mathrm{EWMA}_{\mathrm{today}}=\mathrm{Load}_{\mathrm{today}}$ x fx + ((1 - fx) x $\mathrm{EWMA}_{\mathrm{yesterday)}}$ (31) Note- $fx = 2/ (N + 1)$, N is the decaying constant, 7-days (acute) and 28-days (chronic) (31). fx (previous day's training load) + $(1 – f)$ x (cumulative load up to that point), where f is a decay factor with value between 0 and 1 (32).	0.1 AU
2-,3- and 4-week cumulative load	Sum of daily training load for the previous 14-, 21- and 28-days (28).	1000 AU
Week-to-week acute load change	Absolute difference between the current week and previous weeks acute training load (7-days). Thus meaning, the current week minus the previous week (6, 28, 31).	1000 AU

Table 2. Logistic regression, CI (95%) and OR for non-contact injuries, 5- and 7-day lag period for all training load indices.

Lag period		**Constant**	**Daily Load**	**Acute load**	**Chronic load**	**Week-to-week acute load change**	**ACWR (7:28, uncoupled)**	**EWMA ACWR**	**2-week cumulative load**	**3-week cumulative load**	**4-week cumulative load**
5-day lag period	**Beta**	-5.248	0.032	0.020	**-0.965**	**0.680**	**0.128**	**0.298**	-0.179	-0.137	-0.135
	SE	0.219	0.085	0.035	**0.487**	**0.304**	**0.042**	**0.085**	0.207	0.154	0.122
	Low 95% CI	-5.678	-0.135	-0.050	**-1.920**	**0.085**	**0.045**	**0.131**	-0.585	-0.438	-0.373
	High 95% CI	-4.818	0.199	0.089	**-0.011**	**1.276**	**0.211**	**0.464**	0.227	0.164	0.104
	z-score	-23.916	0.376	0.559	**-1.982**	**2.237**	**3.015**	**3.494**	-0.865	-0.890	-1.107
	P-value	<0.05	0.708	0.577	**0.047***	**0.025***	**0.003***	**<0.001****	0.388	0.372	0.269
	OR Exp(B)		1.033	1.020	**0.381**	**1.974**	**1.136**	**1.347**	0.836	0.872	0.874
	OR 95% CI- Low	0.003	0.874	0.953	**0.147**	**1.088**	**1.047**	**1.140**	0.557	0.645	0.688
	OR 95% CI-High	0.008	1.220	1.093	**0.990**	**3.582**	**1.234**	**1.591**	1.254	1.179	1.110
7-day lag period	**Beta**	-5.242	-0.028	-0.018	0.345	-0.919	0.068	0.061	-0.294	-0.178	-0.213
	SE	0.220	0.091	0.034	0.306	0.489	0.046	0.081	0.206	0.154	0.122
	Low 95% CI	-5.672	-0.206	-0.086	-0.255	-1.879	-0.023	-0.098	-0.697	-0.479	-0.452
	High 95% CI	-4.812	0.150	0.049	0.946	0.040	0.159	0.221	0.109	0.124	0.026
	z-score	-23.880	-0.307	-0.535	1.127	-1.879	1.467	0.755	-1.427	-1.156	-1.746
	P-value	<0.05	0.759	0.592	0.260	0.060	0.142	0.451	0.153	0.248	0.080
	OR Exp(B)		0.972	0.982	1.412	0.399	1.070	1.063	0.745	0.837	0.808
	OR 95% CI- Low		0.814	0.919	0.775	0.153	0.978	0.907	0.498	0.619	0.636
	OR 95% CI-High		1.162	1.050	2.572	1.040	1.171	1.246	1.116	1.132	1.026

* p<0.05- significant, ** p<0.001- highly significant.

Table 3. Logistic regression, CI (95%) and OR for contact injuries, 5- and 7-day lag period for all training load indices.

Lag period		**Constant**	**Daily Load**	**Acute load**	**Chronic load**	**Week-to-week acute load change**	**ACWR (7:28, uncoupled)**	**EWMA ACWR**	**2-week cumulative load**	**3-week cumulative load**	**4-week cumulative load**
5-day lag period	**Beta**	-5.655	-0.022	0.075	0.687	-0.017	0.057	**0.260**	**0.567**	**0.440**	0.252
	SE	0.267	0.110	0.046	0.624	0.374	0.058	**0.104**	**0.282**	**0.202**	0.157
	Low 95% CI	-6.179	-0.239	-0.015	-0.535	-0.751	-0.056	**0.056**	**0.014**	**0.044**	-0.055
	High 95% CI	-5.131	0.194	0.165	1.910	0.717	0.170	**0.464**	**1.120**	**0.836**	0.558
	z-score	-21.143	-0.202	1.637	1.101	-0.045	0.991	**2.497**	**2.011**	**2.178**	1.605
	P-value	<0.05	0.840	0.102	0.271	0.964	0.322	**0.013***	**0.045***	**0.030***	0.108
	OR Exp(B)	-	0.978	1.078	1.988	0.983	1.059	**1.297**	**1.763**	**1.553**	1.287
	OR 95% CI- Low	-	0.789	0.985	0.585	0.472	0.945	**1.058**	**1.014**	**1.045**	0.946
	OR 95% CI-High	-	1.214	1.180	6.753	2.046	1.186	**1.590**	**3.064**	**2.307**	1.750
7-day lag period	**Beta**	-5.649	-0.027	0.058	-0.260	0.712	0.049	0.015	**0.573**	0.332	0.181
	SE	0.267	0.111	0.045	0.371	0.628	0.058	0.098	**0.283**	0.199	0.155
	Low 95% CI	-6.174	-0.245	-0.031	-0.988	-0.518	-0.065	-0.177	**0.019**	-0.059	-0.123
	High 95% CI	-5.125	0.191	0.146	0.468	1.942	0.163	0.207	**1.127**	0.723	0.485
	z-score	-21.121	-0.243	1.279	-0.701	1.134	0.836	0.152	**2.025**	1.668	1.168
	P-value	<0.05	0.808	0.201	0.484	0.256	0.403	0.879	**0.043***	0.096	0.243
	OR Exp(B)	-	0.973	1.059	0.771	2.038	1.050	1.015	**1.774**	1.394	1.198
	OR 95% CI- Low	-	0.783	0.970	0.373	0.595	0.937	0.838	**1.018**	0.944	0.884
	OR 95% CI-High	-	1.210	1.157	1.595	6.979	1.177	1.230	**3.088**	2.059	1.624

* p<0.05- significant.