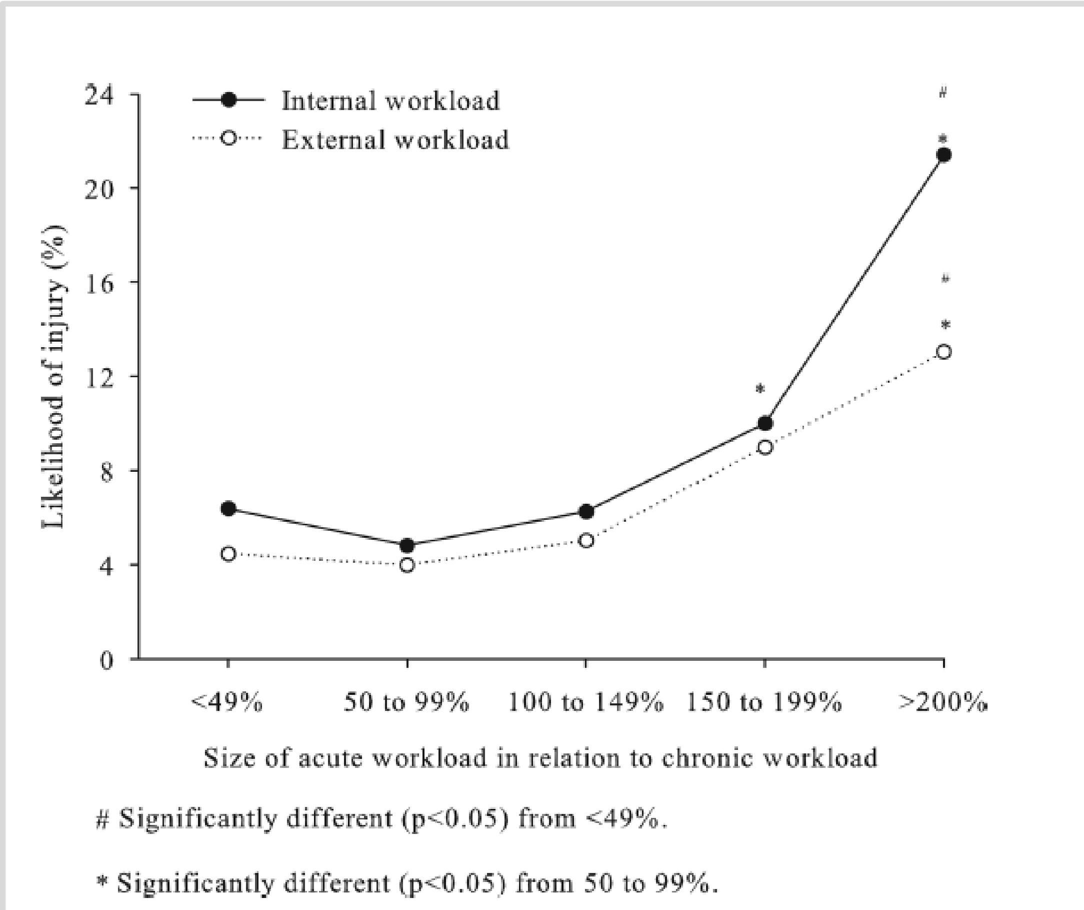
Module 3. Acute:chronic load ratio: applications and limitations

3.1 Acute:chronic load ratio and injury risk

3.1.1 Studies conducted in sports other than soccer

Numerous studies in the field of team sports have investigated the influence of training load on injury incidence and physio-athletic performance (Bowen, Gross, Gimpel & Li, 2017; Caparrós, Casals, Peña, Alentorn-Geli, Samuelson, Solana, Scholler & Gabbett, 2017; Hulin, Gabbett, Blanch, Chapman, Bailey & Orchard, 2014; Hulin, Gabbett, Lawson, Caputi & Sampson, 2016; Malone, Owen, Newton, Mendez, Collins & Gabbett, 2017). The first study tasked with analyzing the relationship between acute (1 week) and chronic (an average of 4 weeks) workloads and injury risk was conducted by Hulin et al. (2014) in elite cricket. Researchers recorded the total number of balls bowled per week, both in training sessions and competitions, in order to estimate the external workload. They then quantified players' internal load by multiplying athletes' rating of perceived exertion by the duration, in minutes, of the activities performed by the athletes. The authors observed that when the acute workload was similar to or lower than the chronic load (ratio ← 0.99), the probability of injury for the following 7 days was 4%. However, when the acute load was at least 1.5 times higher than the chronic load (ratio → 1.5), the injury risk during the following week increased between 2 and 4 times. Based on these results, the authors recommend that increases in chronic workloads should be carried out systematically, following a gradual progression appropriate to the values indicated, with the objective of reducing the probability of injury.

Figure 1: Probability of injury (%) in cricket players during the following week as a function of weekly load compared to the average (mean) of the 4 previous weeks



Source: Hulin et al., 2014, p. 4.

In the same vein, Hulin et al. (2016) used a methodological design similar to that described in the previous study but with elite rugby players, who were studied over the course of two league seasons. In this case, applying it to rugby players, they measured the total distance covered, or DT, to obtain the ratio between the acute load (DT in the "current" week) and chronic load (average DT over the past 4 weeks) both in training sessions and matches. The results showed that a very high A:C workload (ratio → 2.11) implied greater injury risk during the week corresponding to the value of the acute load (16.7%) and during the following week (11.8%). One of the novel findings of this study was that, in the microcycles following the establishment of chronic load, high workloads (20.117–24.503 m) in combination with moderate ratios (1.03–1.37) and high-moderate ratios (1.38–1.74) presented a lower injury risk than low chronic loads (6.956–11.343 m) combined with different A:C load ratios. Furthermore, the results revealed that a high chronic load value protects against injuries, as long as acute load totals are similar. However, the authors indicate that the A:C workload ratio predicts injury risk more consistently than the acute or chronic load ratios do in isolation.

In summary:

- High A:C load ratios were found to be associated with higher risk of injury.
- High chronic loads in combination with moderate ratios seem to have a certain protective effect against injury risk, which might support the idea that "being in shape" lowers the risk of injury, while being out of shape and overtraining (at both ends of the Gaussian curve) increase such risk.

Figure 2: Graphic representation of the probability of injury as a function of acute load in combination with the level of chronic load

		Chronic load	
		High	Low
Acute load	High		
	Low		

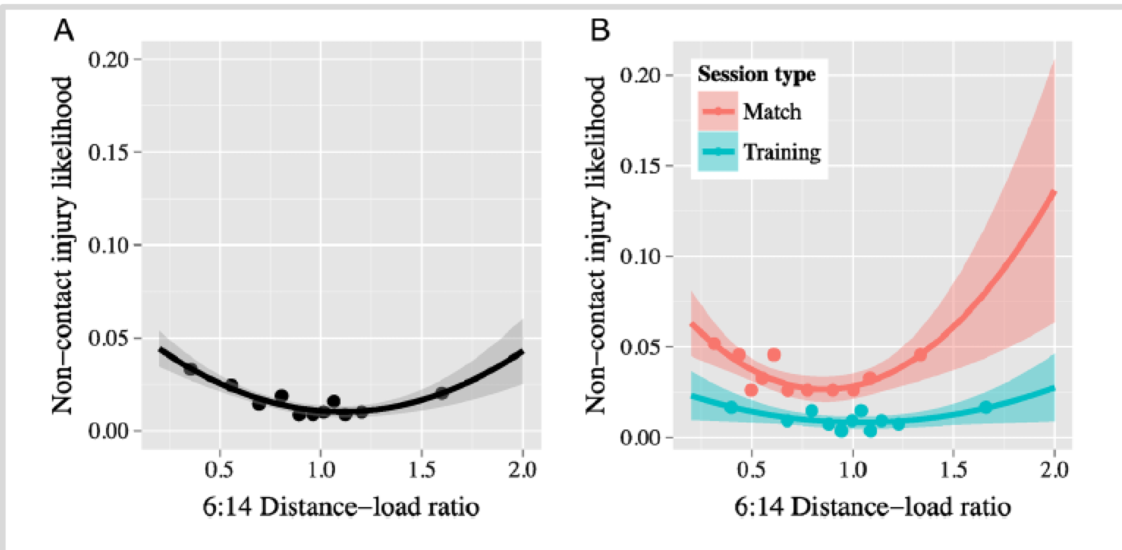
Source: Prepared by the author.

This shows that the situation of greatest injury risk occurs when a high acute load level is associated with a reduced chronic load level, while the opposite condition (reduced acute load with high chronic load) presents the lowest probability of injury.

As we commented previously, the A:C load ratio can be established for different periods of acute and chronic load and for each variable (of external or internal load). Accordingly, Carey, Blanch, Ong, Crossley, Crow and Morris (2017) studied which variable and period of acute and chronic load was most closely related with the probability of injury in Australian rules football players, utilizing periods of 2 to 9 days for acute load and periods of 14, 18, 21, 24, 28, 32 and

35 days for chronic load, which resulted in 56 different combinations of A:C load. Furthermore, 6 different dependent variables were chosen for the calculation, which produced a total of 336 A:C load ratios under study. When injuries from training sessions and matches were included in the model together, the distance-load variable, using a temporal relationship of 6:14 in the A:C load ratio, turned out to be the one that best accounted for the variation in the probability of injury. However, since the probability of injury is significantly higher during matches, the authors explain the need to study the models that best predict injuries in matches and in training sessions independently.

Figure 3: Relationship (with a 95% confidence interval) of the acute and chronic load ratios for the distance load variable utilizing a period of 6 days for the calculation of acute load and 14 days for the calculation of chronic load for the probability of a non-contact injury



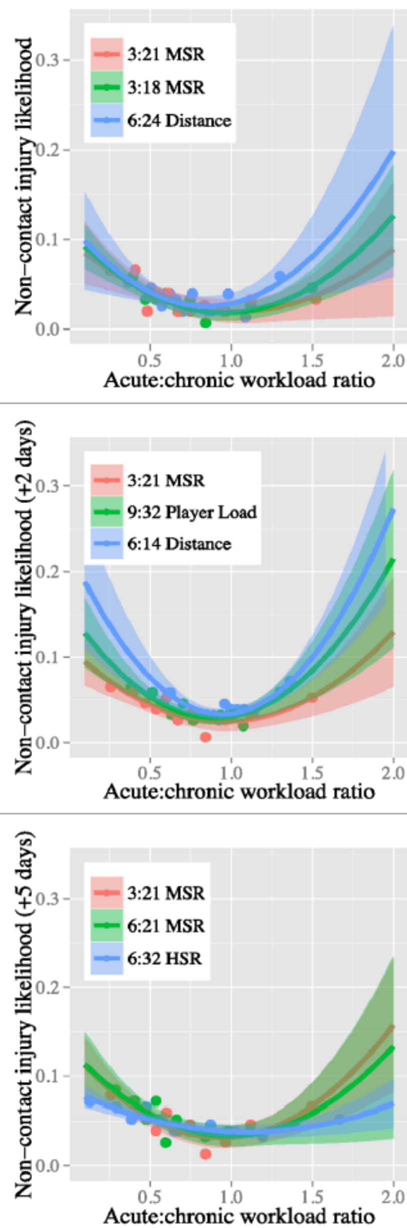
Source: Carey et al., 2017, p. 4.

With regard to the above figure: Figure A refers to both matches and training sessions in combination (R^2 = 0.91) and Figure B to matches (R^2 = 0.54) and training sessions separately (R^2 = 0.53).

An A:C load ratio of 3:21 days using the variable of distance covered at moderate velocity (18.0-24.0 km/h) is the best predictor of injury risk during matches, irrespective of the injury time window chosen. The ratio of the A:C load formula is similar to that described in previous studies, with lower probabilities of injury when the A:C load ratio is similar to the unit value, and higher probabilities when the ratio is either lower or higher.

Figure 4: Probability profiles for injury (with a 95% confidence interval) of the three combinations of parameters that illustrate: A = match injuries; B = match injuries and injuries sustained in the two following days; and C = match injuries and injuries sustained in the five following days.

	Injury lag	Rank	Workload ratio	Mean R^2
A	Non-contact injury (n=59)	1	3:21 MSR	0.79
		2	6:24 Distance	0.73
		3	3:18 MSR	0.71
B	Non-contact injury (+2 days) (n=69)	1	9:32 Player load	0.79
		2	6:14 Distance	0.78
		3	3:21 MSR	0.76
C	Non-contact injury (+5 days) (n=85)	1	3:21 MSR	0.82
		2	6:32 HSR	0.75
		3	6:21 MSR	0.75



Source: Carey et al., 2016, p. 4.

Note: HSR stands for distance covered at high speed (>24.0 km/h); MSR stands for distance covered at moderate speed (18.0-24.0 km/h).

Therefore, in this study, the A:C load ratio of 3 and 21 days for the variable of distance covered at moderate speed (18.0-24.0 km/h) is what best predicts the probabilities of non-contact injuries in Australian rules football. It would seem that these models should be adapted to each context – including, of course, different sports, their structures and competitive calendars (Carey et al, 2016) – and also, perhaps, to different styles of play and/or training, and even to different athletes.

Colby, Dawson, Peeling, Heasman, Rogalski, Drew, Stares, Zouhal & Lester (2017) have deduced how the A:C load ratio influences the probability of injury in Australian rules football players. If we examine the distance at sprint variable, A:C load ratios of <0.7 and of >1.4 increase the probability of injury significantly – by x 1.8 and x 1.9, respectively – for ratios between 0.93-1.13.

Recently, Caparrós et al. (2017) studied the possible injury risk factors in 26 professional basketball players in the NBA over 3 seasons. The variables recorded were minutes played, physiological load and intensity, mechanical load and intensity, total distance covered, speed in different ranges, accelerations and decelerations, the efficiency index and the percentage of use. The authors analyzed the influence of demographic characteristics, follow-up data, and performance factors for injury risk. The principal finding in this study was that fewer accelerations, less distance covered and a lower average defensive speed are significantly associated with injury during professional basketball games. Optimal levels of training could have a protective effect on athletes, and, together with proper load management, could be important factors in reducing the probability of injury, depending on individual profiles. However, more studies are needed to confirm these findings, with the objective of implementing appropriate prevention programs in order to diminish the number of injuries in professional basketball and other sports.

3.1.2 Studies conducted in soccer

In the context of soccer, a recent study (Ehrmann, Duncan, Sindhusake, Franzsen & Greene 2016) analyzed the relationship between various physical variables recorded during training sessions and matches and the injuries suffered by professional players (n = 19). The external load associated with the activity of these players was monitored using GPS devices, obtaining their total distance (m), distance at high speed (14.3-19.7 km·h-1, m), distance at sprint (>19.7 km·h-1, m), neuromuscular load (accelerations and decelerations, UA) and relative distance (m·min-1). All of these variables were averaged in blocks of 1 and 4 weeks, and it was noted that gradual increases in training load, but not necessarily high-load cycles, increase the risk of injury in soccer players. Furthermore, the authors noted that, among all the values recorded, the relative distance and neuromuscular load variables were the ones that showed the greatest predictive value in athletes.

For their part, Bowen et al. (2017) studied the relationship between physical workload and injury risk in 32 elite youth soccer players over the course of 2 seasons. The variables recorded were total distance covered (m), total distance covered at high speed (> 20 km·h-1, m), number of accelerations performed and neuromuscular load (accelerations and decelerations, UA). The results showed that accumulating a large number of accelerations (→ 9,254) over 3 consecutive microcycles was associated with a high risk of injury. When non-contact injuries were analyzed, an increase was observed when, for the distance covered at high speed variable, high acute load with was linked to low chronic load. At the same time, very high A:C loads relative to total distance covered and the number of accelerations performed increased contact injuries. The authors concluded that both high acute and chronic loads increase injury risk if the increase in these values is not carried out gradually. A managed increase in acute and chronic loads makes it possible to strengthen a player’s physical tolerance for high acute loads and increases his resilience to injury risk.

Malone et al. (2017) studied the relationship between workload, quantified through RPE x minute of practice, and physical condition, calculated by applying an intermittent endurance test (YYIR1), and the injury risk of elite soccer players. The results established that there was a positive linear relationship between a microcycle’s own load, its weekly modifications, and the injury risk associated with it. Players that recorded A:C load ratios of between 1 and 1.25 were at less risk of injury, and players with the best results in the YYIR1 test tolerated the load alterations in each microcycle better.

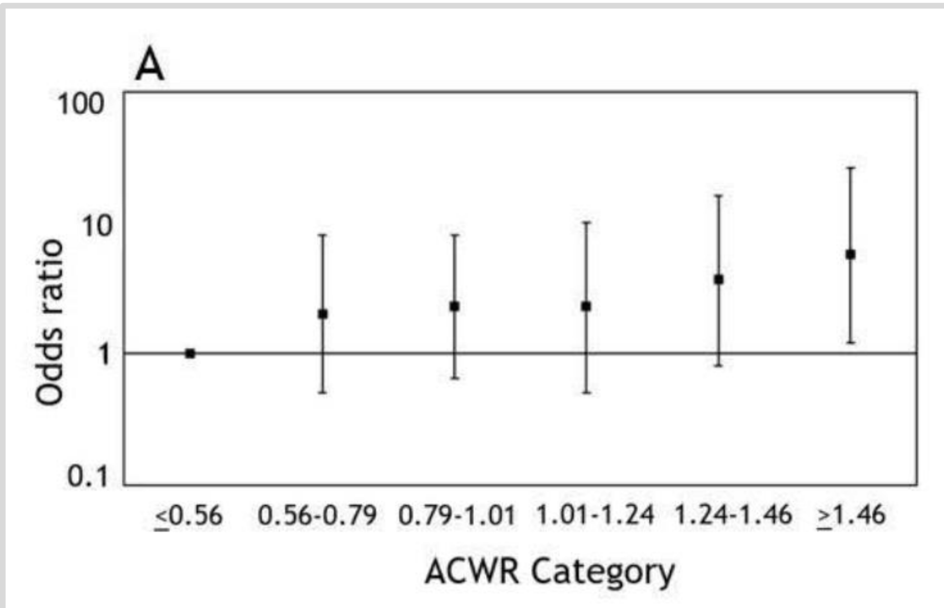
Table 1: Injury risk as a function of the phases of a season (pre-season and competitive season) for different acute:chronic load ratios of professional soccer players. The data is presented as OR (95% CI).

	Training load Component	Pre-Season (July-Aug)	In-Season (Sept-May)
Cumulative Load (Sum)		**OR EXP B (95% CI)**	**OR EXP B (95% CI)**
	Acute: Chronic Workload Ratio		
	← 0.85 (Reference)	1.00	1.00
	Between 0.85 AU to ← 1.00 AU	0.95 (0.98 – 3.95)	1.05 (0.98 – 3.95)
	Between → 1.00 AU to ← 1.25 AU	0.68 (0.08 – 1.66)	0.28 (0.08 – 1.26)
	→ 1.50 AU	2.33 (1.69 – 4.75)	3.03 (1.69 – 3.75)

Source: Malone et al., 2017, p. 4.

Øyen (2017) utilized the A:C load ratio, calculated using minutes spent training, as reported by athletes. Despite the fact that the study in question exhibits a variety of significant limitations, it finds a link between the acute:chronic workload ratios (ACWR) and the appearance of new hip injuries during the week recorded.

Figure 5: Probability of a hip injury at different acute:chronic load ratios.



Source: Øyen, 2017, p. 61.

In this graph we can see how the probability of a new hip complaint increases as the acute:chronic load ratio increases. To define a hip complaint, the criterion that states that this should necessarily involve lost playing time was not utilized. Rather, complaints that did not impede the completion of a training session and/or match were recorded. Specifically, the probability is 5.69 times greater with a ratio of >1.46 than when the ratio is very low (<0.56); 2.83 times greater than when the ratio is low (0.56-0.79); 2.49 times greater in comparison to a moderately low ratio (0.79-1.01); 2.46 times greater than a moderately high ratio (1.01-1.24); and 1.53 times greater than a high ratio (1.24-1.46).

However, no link was demonstrated between the A:C load ratio and significant new hip complaints. Accordingly, we should emphasize that for an complaint to be categorized as significant, there must be a moderate or severe reduction in training volume or competitive performance or a complete inability to train (Clarsen, Myklebust & Bahr, 2013).

Malone et al. (2017) calculated the acute:chronic load ratio using 3 and 21 days as time frames for distance covered at high speed (>14.4 km/h) and distance covered at sprint (> km/h).

Table 2: Probability of injury for different acute:chronic load ratios for the distance covered at high speed and distance covered at sprint variables.

External Load Calculation	In-Season	90% Confidence Interval		*p*- Value
	Odds Risk (OR) of Lower Limb Injury	Lower	Upper	
High-speed distance acute:chronic workload ratio (AU)				
≤ 0.85	1.00			
Between 0.86 to 1.00	1.20	1.10	2.03	0.021
Between 1.00 to 1.25	2.27	2.13	3.04	0.001
→ 1.25	3.02	2.53	4.98	0.001
Sprint distance acute:chronic workload ratio (AU)				
≤ 0.70	1.00			
Between 0.71 to 0.85	0.85	0.33	0.95	0.035
Between 0.86 to 1.35	1.15	1.11	2.14	0.012
→ 1.35	5.00	3.01	7.38	0.021

Source: Malone et al., 2017, p. 4.

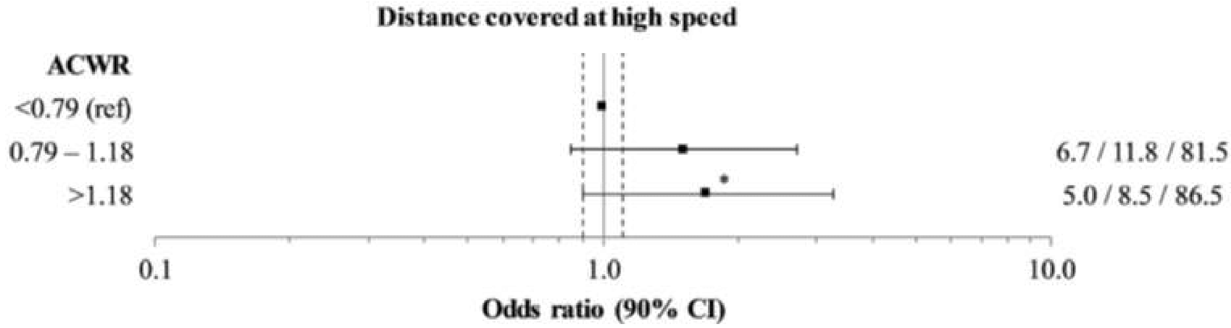
As we can see, the probability of injury is between 3 and 5 times greater when the A:C load ratio is greater than 1.25 for distance covered at high speed and greater than 1.35 for distance covered at sprint.

In professional soccer players (Jaspers, Kuyvenhoven, Staes, Frencken, Helsen and Brink, 2017) it has been found that moderate A:C load ratios provide a protective effect in relation to the lowest load levels for the following variables:

- Number of accelerations performed (load ratio 0.87-1.12 OR: 0.49, 90% CI: 0.24-1.02).
- Number of decelerations performed (load ratio 0.86-1.12 OR: 0.38, 90% CI: 0.20-0.72).
- Internal load (RPE*duration, load ratio 0.85-1.12, OR 0.39, 90% CI: 0.23-0.65).

At the same time, A:C load ratios for distance covered at high speed show an increase in the probability of injury (A:C load ratio >1.18, OR: 1.71, 90% CI: 0.90-3.26).

Figure 6: Probability of a substantial increase in the probability of injury for different acute:chronic load ratios for the distance covered at high speed variable.



Source: Jaspers et al., 2017, p. 3.

3.2 The utilization of the acute:chronic load ratio in the rehabilitation process

As we mentioned earlier, an elevated A:C load ratio is a factor in injury risk, particularly if it is associated with low chronic load levels. This indicator also takes on heightened importance during an athlete's rehabilitation process. Thus, it seems that this indicator can be used as a guide in the rehabilitation process, and particularly for decisions about the return to play, should we want to make such decisions in a progressive and safe manner.

As we can see in Figure 7, injuries often occur after an elevated A:C load ratio. In this case, the distance covered at high speed variable has been utilized. In week 15, the athlete experiences an increase in his load level that is 60% greater than the previous month's average (mean) load, increasing the probability of injury, as has been previously described. However, this indicator is also very interesting for its use in the rehabilitation process, since injuries cause a decrease in activity and, therefore, in chronic load. If, once functionality has been regained by the athlete, this parameter is not taken into account and the usual weekly activities are performed (acute load), and the A:C load ratio will increase due to the decrease in activity implied by a period of injury. In other words, we subject the athlete to an workload amount that they are not prepared for, or, at least, are not accustomed to bearing.

Figure 7: Acute:chronic load ratio for the distance covered at high speed variable over a period of time during which the athlete suffers two injuries. We can see elevated acute:chronic load ratios in the weeks prior to the injuries (1.6 and 1.9)

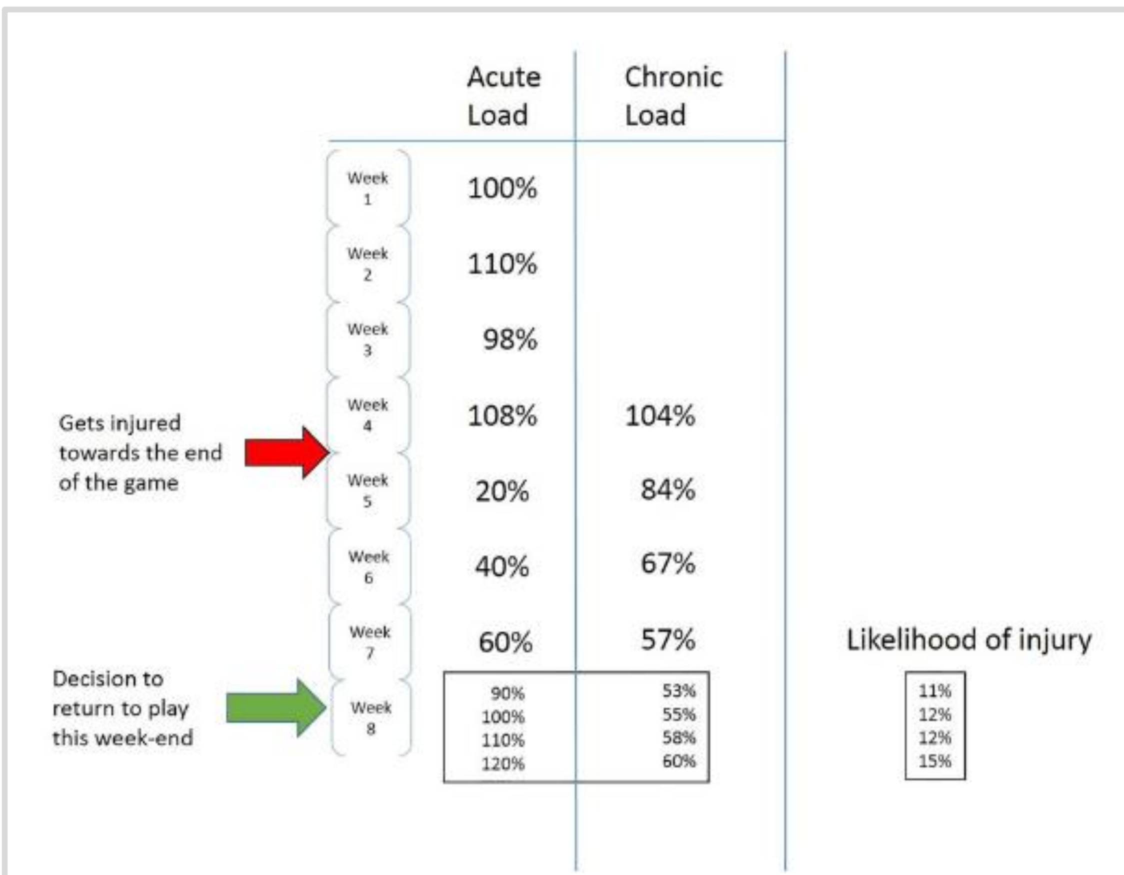
Source: Blanch & Gabbett, 2016, p. 2.

Figure 8 shows a typical example of load management during an injury. During the first 4 weeks, a healthy athlete accumulates a weekly load of 104% of his habitual load (slightly above his average). At the end of week 4, the athlete suffers an injury, which causes a decrease in activity during the following weeks. So, in the week immediately following the injury, the athlete accumulates only 20% of his habitual load (the week with least load), while, as weeks pass following the injury, the percentage of load borne by the athlete increases. At the same time, his chronic load decreases. We should remember that chronic load refers to the average value of the past 4 weeks, and, since the athlete has recorded a lower acute load in the period following the injury, this lowers the chronic load value. In week 8, the player makes a return to play and, when evaluating the load value for that week, we should keep in mind that:

- An increased level of acute load in this week could lead to an increase in the athlete's level of fatigue.
- An increased level of acute load in this week increases an athlete's chronic load level, since week 8 is taken into account during the analysis of chronic load (the average of weeks 5, 6, 7 and 8).
- However, the increase in weekly load alters the acute load value more than the chronic load value, so a rise in the acute load value increases the acute:chronic load ratio.
- An increase in the acute:chronic load ratio above the "sweet spot" can increase the likelihood of an injury.

In the example shown in Figure 8, we can see that, if in week 8 the athlete records a load level of 120%, his chronic load registers a value of 60%. Consequently, the acute:chronic load ratio would be 2.0 and a probability of injury 15%. However, if in week 8 the player bears an acute load of just 90%, the chronic load would be 53%, which results in an acute:chronic load ratio of 1.69 with a 12% probability of injury. As we can see in the example given, the acute:chronic load ratios are very high and increase the probability of injury for the athlete. Accordingly, coaches should ensure that a high level of chronic load is maintained, and, to do this, it is necessary to accumulate weeks of high acute load values before subjecting athletes to high acute load levels and/or returning them to play. In the example given, if in week 8 the athlete attains an acute load of 70%, of 80% in week 9, and 90% in week 10, his chronic loads would be 47.5%, 62.5%, and 75% in weeks 8, 9 and 10, respectively. These values would result in A:C load ratios of 1.47, 1.28 and 1.2 during these same weeks, progressively diminishing the likelihood of injury.

Figure 8: Graphic representation of an injured athlete and his decision to return to play



Source: Blanch & Gabbet, 2016, p. 4.

Note: Figure 8 is based on different hypothetical acute loads that alter both the chronic load and the likelihood of injury. The graph indicates that as the athlete goes through the

rehabilitation phase (from weeks 4 to 7), their chronic load begins to decline until it reaches 57% at the end of week 7.

Table 3 shows the likelihood of injury as a function of acute load (% of normal load) and of chronic load (% of normal load). We can see that the probability of injury is greatest when acute load is high and chronic load very low. This is sometimes the case during an athlete's rehabilitation process. Let's consider a couple of examples that illustrate this situation.

An athlete injures himself and thus his acute load declines abruptly and gradually increases as he recovers. This decline in his level of acute load causes his chronic load to diminish. He returns to competitive play "quickly" during a week with a high competitive density. The athlete participates in both of the week's matches, which leads to an elevated acute load, with reduced levels of chronic load. His ratio, in this case, is also very high, as is his likelihood of injury.

Another example might be an athlete that, along with rejoining the group, performs extra work to boost the improvement in his condition, which results in an elevated level of acute load (team load plus individual load) and represents a major change from previous weeks, during which his injury resulted in a decline in his chronic load. We find ourselves with the same scenario: a high A:C load ratio and a high likelihood of injury.

Table 3: Probability of injury, utilizing an equation derived from the studies of 3 different sports to compare different acute and chronic load scenarios.

Chronic workload (% of normal average)		Acute workload (% of normal average)						
		60	70	80	90	100	110	120
	110	4.7	4.1	3.6	3.4	3.2	3.3	3.5
	100	4.3	3.7	3.4	3.3	3.3	3.6	4.0
	90	3.9	3.5	3.3	3.3	3.6	4.2	4.9
	80	3.5	3.3	3.3	3.7	4.3	5.3	6.6
	70	3.3	3.3	3.7	4.6	5.8	7.5	9.5
	60	3.3	3.8	4.9	6.6	8.8	11.6	14.9
	50	4.0	5.5	7.9	11.0	14.9	19.6	25.1
	40	6.6	10.1	14.9	20.9	28.2	36.7	46.5
	30	14.9	23.2	33.7	46.5	61.4	78.6	98.0

Source: Blanch & Gabbett, 2016, p. 4.

3.3 Limitations on the practical use of the acute:chronic load ratio

In soccer, it has been shown that the recording of acute and chronic training loads and the A:C workload ratio enable coaches and physical trainers to determine which athletes are in a state of fitness or fatigue, along with their corresponding likelihood of injury (Gabbett, 2016). However, the application of this concept reveals a number of limitations: it is difficult to define an individual locomotor profile for every player that has the same injury; it is impossible to integrate the various systems of data collection using a common predictive variable; and it is extremely complicated to record every soccer player's sessions and competitions to obtain consistent A:C load ratios (Buchheit, 2017). Furthermore, the concept of A:C load deserves to be the subject of further consideration. It is possible that different sports have different load-injury relationships, so, until more data is available, the recommendations offered in the literature should be implemented with caution (Gabbett, 2016). There are, therefore, some practical limitations which may affect their usefulness in soccer, which we will proceed to detail in the following sections (Buchheit, 2017).

3.3.1 The need to individualize the load imposed on each athlete

Given that the speed at which effort is expended has an influence on an athlete's likelihood of injury (Malone et al., 2016), it is essential to relativize such efforts, keeping an athlete's best performances in mind. It seems that athletes who attain > 95% of their peak speed during the week have a lower probability of injury than those who attain just 85% of it. Consequently, knowing these maximum capacities is believed to be very important. However, to determine this capacity it is necessary to know the athlete's maximum speed, which is rarely evaluated by professional football coaches (Buchheit, 2017).

Many coaches choose to use the highest value attained by a player in a training session or match as their maximum speed. However, we should know that, depending on the methodology applied in training, the player will perform actions that are closer to or farther from their maximum potential. Djaoui, Chamari, Owen & Dellal (2016) explain that in none of the match tasks studied did players attain values above 90% of their maximum speed. During ball possession exercises, they attained lower peak speeds (22.1 ± 2.3 $km \cdot h^{-1}$) than during tasks involving goalkeepers or small goals (24.1 ± 3.6 $km \cdot h^{-1}$). The average values obtained during matches reached 92% of a player's maximum speed, values obtained by monitoring 6 competitive matches.

Due to the high variability than exists within a team, even between players that play the same position, the use of absolute speed thresholds to define actions as “high velocity” can limit the sensitivity of the A:C load ratio when predicting an athlete’s probability of injury.

It has also recently been reported that the fastest athletes are those that are most susceptible to injury when submitted to elevated A:C load ratios. Consequently, it is essential to properly detect and manage the load that is imposed, especially on this group of athletes (Murray, Gabbett, Townshend & Blanch, 2017).

Furthermore, fitness levels, as will be discussed in the section on load moderators and modulators, have a protective effect, since it is players with higher levels of fitness and who have elevated A:C load ratios who are more resilient when facing injury. However, fitness tests (maximum aerobic speed) are rare in professional soccer (Buchheit, 2017), so coaches do not know the A:C load ratio that each player would be able to tolerate without excessively increasing their likelihood of injury.

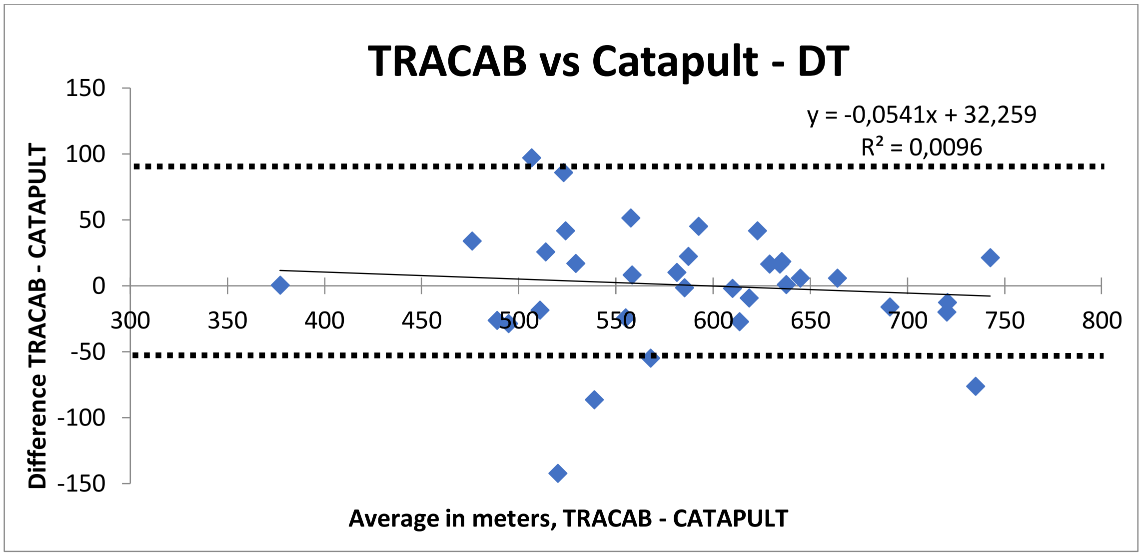
In summary, to increase the sensitivity of the A:C load ratio we should consider athletes’ individual characteristics, and this is something that is not always done in professional soccer.

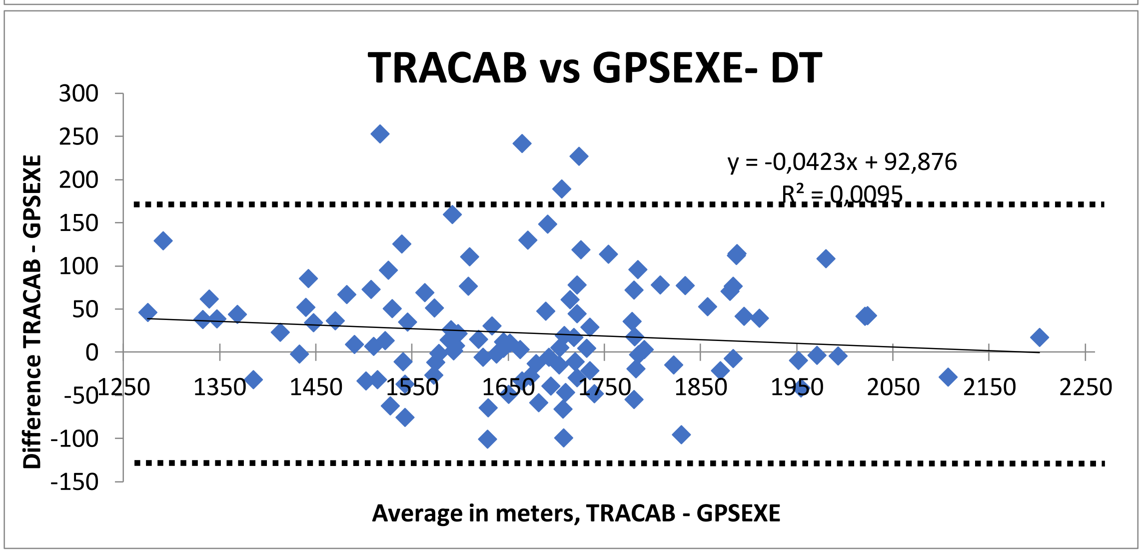
3.3.2 Challenges in monitoring the entire workload of an athlete over the course of the year

Many teams monitor their athletes’ activities through the use of different technologies during training and competition. It is most common to use GPS systems in training and semi-automatic video tracking during matches. The integration of this information should be carried out using calibration equations, which are not always available (Buchheit, Allen, Poon, Modonutti, Gregson & Di Salvo, 2014). Furthermore, compatibility between systems is never perfect, especially for variables related to high-speed and high-acceleration actions. If the relevant adjustments cannot be made, the sensitivity of the A:C load ratio could diminish, thus reducing its applicability.

Figure 9: The relationship between values obtained by different systems and their calibration equations

TRACAB is a semi-automatic player tracking system and Catapult and GPSEXE are two types of GPS device.





Source: Castellano et al. [unpublished]

In elite soccer, many teams have a large number of international players who travel with their national squads during different international windows for periods of 8-10 days, 4-5 times per season (Buchheit, 2017). During these periods, international players accumulate workloads that are not always known to their clubs, since, on many occasions, national teams do not monitor training loads (50% of cases, in the specific case of PSG in France). Communication with these national teams is non-existent or infrequent for a number of reasons (11% of cases). In addition, the monitoring systems they use differ from those of their home clubs and, as a consequence, there are problems integrating the information resulting from the use of different brands, different variables, or different ranges of intensity by the club and the national team (33% of cases). In only 5% of cases do national teams use monitoring systems similar to those of the club, which makes integrating data easier.

At best, the external load can be estimated and thus the A:C load ratio calculated. In the majority of cases there is a net loss of information of approximately 10 days during each international event involving national teams, which compromises the use of the A:C load ratio.

In order to avoid artificial peaks or drops in the A:C load ratio, it was proposed that lost values be predicted by using historical data recorded in training sessions and games. However, we must be mindful of the fact that we are imposing load values that will not always correspond to activities actually performed by the player, which may diminish the usefulness of the A:C load ratio (Buchheit, 2017).

3.3.3 Lack of monitoring during the off-season

The impossibility of monitoring load during this period of the season, prior to the beginning of the pre-season, renders the A:C load ratio unrealistic during the first few weeks of the pre-season. We need to record 28 days of training (if that is the time frame that has been chosen for establishing chronic load) in order to be able to have a realistic A:C load value. During this period of the pre-season or during the start of training sessions, reducing the period utilized when establishing chronic load (to 2 or 3 weeks) might be an alternative, although the ideal period remains undefined (Buchheit, 2017).

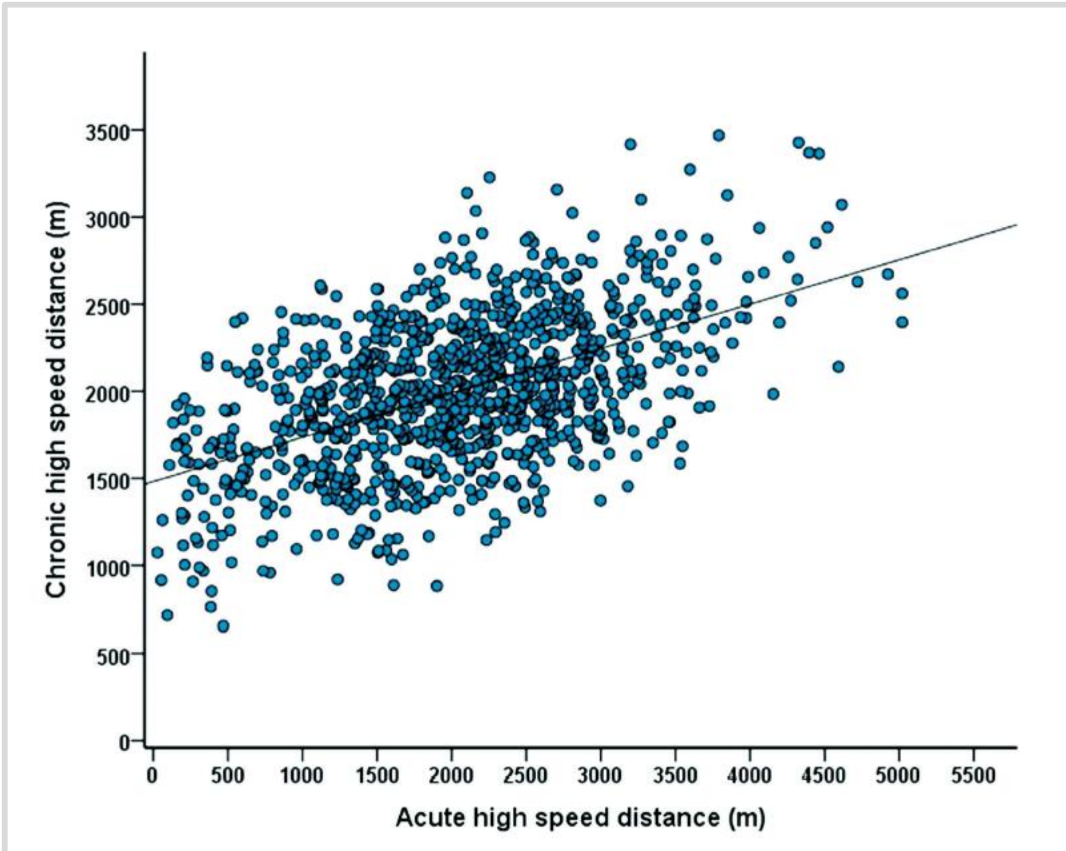
Accordingly, the utilization of session-RPE provides a solution, or at least an alternative. Monitoring exercise intensity through the rating of perceived exertion and then, once recorded, multiplying that value by the duration allows us to obtain the training load value. This method is commented upon in depth in its own section. There are several reasons that justify its utilization during those times of the season when, for various reasons, other types of information are not available. On one hand, this measure is connected with the probability of injury and can be obtained independently of the external load monitoring systems that are utilized by all athletes throughout the season (clubs and/or national teams, and also during the off-season). However, it should be taken into account that it does not have a significant bearing on actions that the athlete performs at high speed or at sprint. Due to its low sensitivity for these types of actions, the confidence that coaches have when determining the probability of injury diminishes. Some national teams do not collect RPE values from athletes, so if this value is asked for *a posteriori*, the A:C load ratio would be of uncertain validity and utility. Furthermore, we should make an effort to increase the rate of adherence to this practice, since, in professional soccer, athletes' availability for and attitude toward the monitoring of their training load during their vacation period is low.

3.3.4 False mathematical correlations during calculation

False correlations in the calculation of the A:C load ratio occur mainly when the most recent week's load – if it is the selected duration (acute load) – appears both as the numerator and the denominator in the calculation equation. In order to study this hypothesis, the authors estimated 4 weeks of training (week 1, week 2, week 3 and week 4) in 1,000 players without finding significant correlations between the different weeks of training. Consequently, the acute load (week 4) revealed no relationship with the loads of the previous weeks. However, when the relationship between the level of acute load (week 4) and chronic load (the average of weeks 1, 2, 3 and 4) is studied, the relationship is significant (r=0.52, 95% CI: 0.47 to 0.56). Likewise, when the load of week 4 is not included in the calculation of chronic load, the relationship between acute and chronic load is nearly zero (r=0.01, 95% CI: 0.05 to 0.07).

This insertion of the acute load into the numerator and the denominator of the calculation equation for the A:C load ratio affects the standard deviation of the measurements and modifies the value of the ratio. In the databases created by Lolli, Batterham, A.M., Hawkins, R., Kelly, D.M., Strudwick, A.J., Thorpe, Gregson & Atkinson (2017), the acute load was 2,375 m which, in the traditional calculation, would imply a chronic load of 1,639 m and an A:C load ratio of 1.45. On the other hand, when this calculation of chronic load is carried out without including the acute load in the period studied, the former shows a value of 1,393 m and an A:C load ratio of 1.71. Therefore, based on these findings, it seems that the mathematical definition of chronic load limits the validity of the A:C load ratio obtained and may result in interpretive errors.

Figure 10: Relationship between distance covered at high speed movement in the past week (acute load) and on average during the past four weeks (chronic load).



Source: Lolli et al., 2017.

However, we still have a long way to go in refining these types of metrics, and, consequently, in making accurate predictions about the conditions relating to injury risk. These aspects, which remain unresolved and whose resolution would be useful, have to do, for example, with:

a) knowing which of the variables or indicators are the ones that must be used in formulas, intensity indicators or load indicators, and of these, which to use;

b) deciding if, instead of choosing 4 weeks to calculate chronic fatigue, this could be calculated in 2, 3 or 5 weeks, or if this period should vary throughout the season (4 weeks at the start of the season, 3 in the middle, and 2 at the season's end);

c) if, instead of taking the load of the most recent week into account when calculating acute fatigue, another unit - of 1 to 7 days' duration, for example - or other options might be used.

d) how to individualize acute:chronic load ratios for each player and their variability over the course of a season;

e) how to include elements of training that were performed when beyond the reach of tracking systems in this type of evaluation. For example: gym workouts, stretching, prevention, and, of course, the invisible dimensions of training such as nutrition, the recovery process, lifestyle etc., and, most importantly;

f) having a metric available that, rather than determining injury risk through the retrospective study of acute load accumulated during the current microcycle, could be used to make the information available before or during sessions in order to avoid undesirable injury risk scenarios. In all, a genuinely interesting route to take.

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