Analysis of Workloads and ACWR in Sports Sessions

Analysis based on the 2019 season of the University of Michigan women's soccer team

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1. Introduction

This report presents an analysis of data collected through sports performance monitoring devices. The analysis focuses on evaluating the "acute to chronic workload ratio" (ACWR), a key indicator in training load management and injury prevention. This approach is applied both to monitor individual performance and to assess the overall state of a team or group, facilitating informed decision-making about physical well-being and sports performance. The data used in this report are just an example applicable to any similar sports performance data set.

2. Methodology

2.1. Data Collection:

- External sensors that record measures such as acceleration, speed, distance, body position, and GPS location were analyzed.
- Data from all sessions recorded by the devices during the season were used.
- Player positions are abbreviated in the data set: defensive players (D); forwards (F); midfielders (M); and the goalkeeper (GK).
- The data used in this tutorial come from the 2019 season of the University of Michigan women's soccer team, collected through Catapult Sports devices.

2.2. Analysis Parameters:

ACWR was evaluated using two sets of parameters:

- Classic: 7-day acute window, 28-day chronic window.
- Alternative: 3-day acute window, 21-day chronic window.
  It is also clarified that the standard parameters for ACWR are between 0.8 and 1.5:
- `ACWR > 1.5` means that the athlete is overloaded, which can lead to injury.
- `ACWR < 0.8` implies that the athlete has reduced their intensity and should be evaluated in more detail.

2.3. Exclusions:

The following were excluded from the team analysis:

- The player with the least participation.
- All goalkeepers.

3. Analysis Objectives

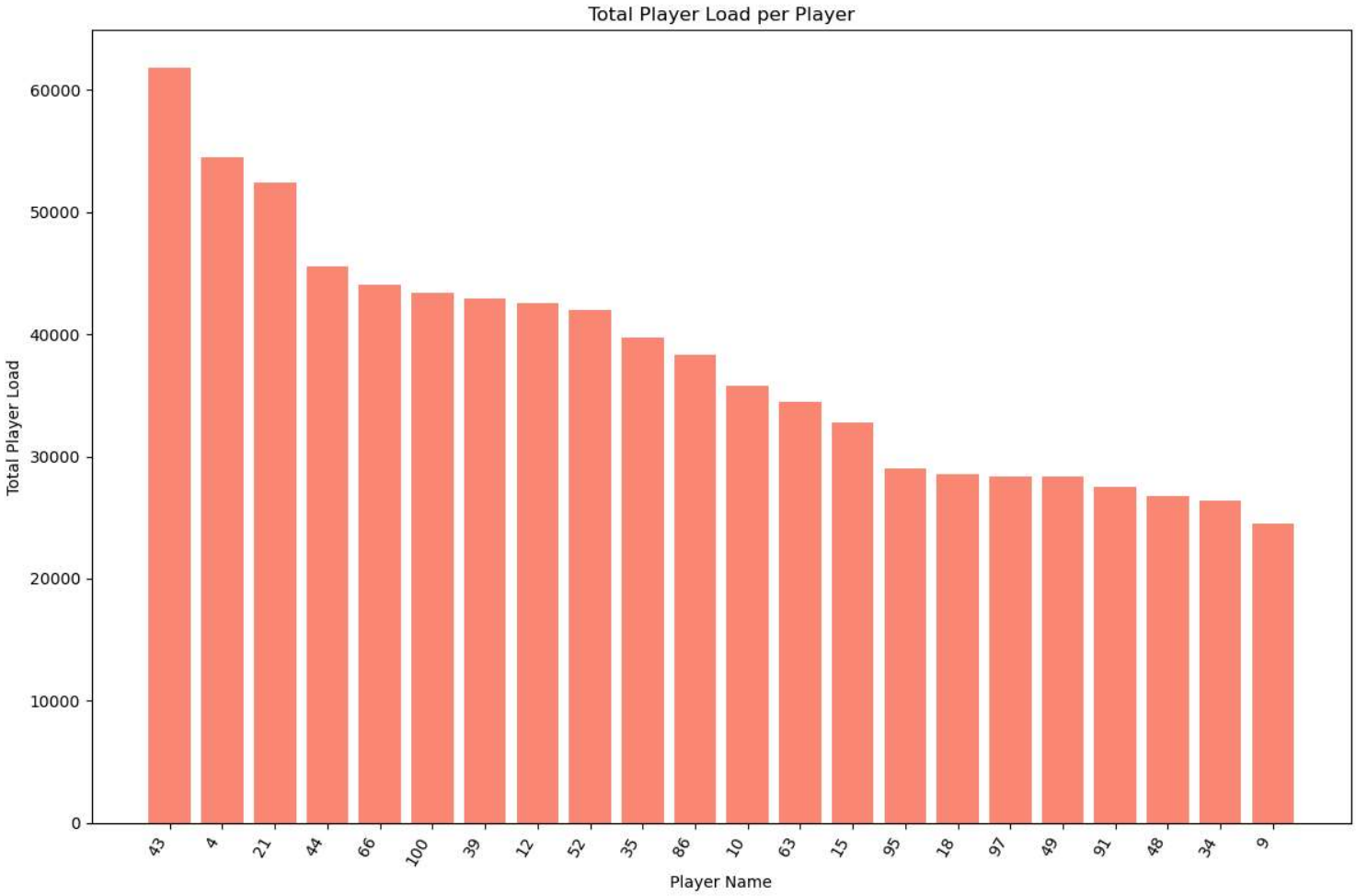
3.1. Identify the players with the highest total load throughout the season.

- Ideally, this study should be done daily to have an overview of the athlete's current performance.
- In this instance, we do it over a completed season to have a basis to work on in the future.

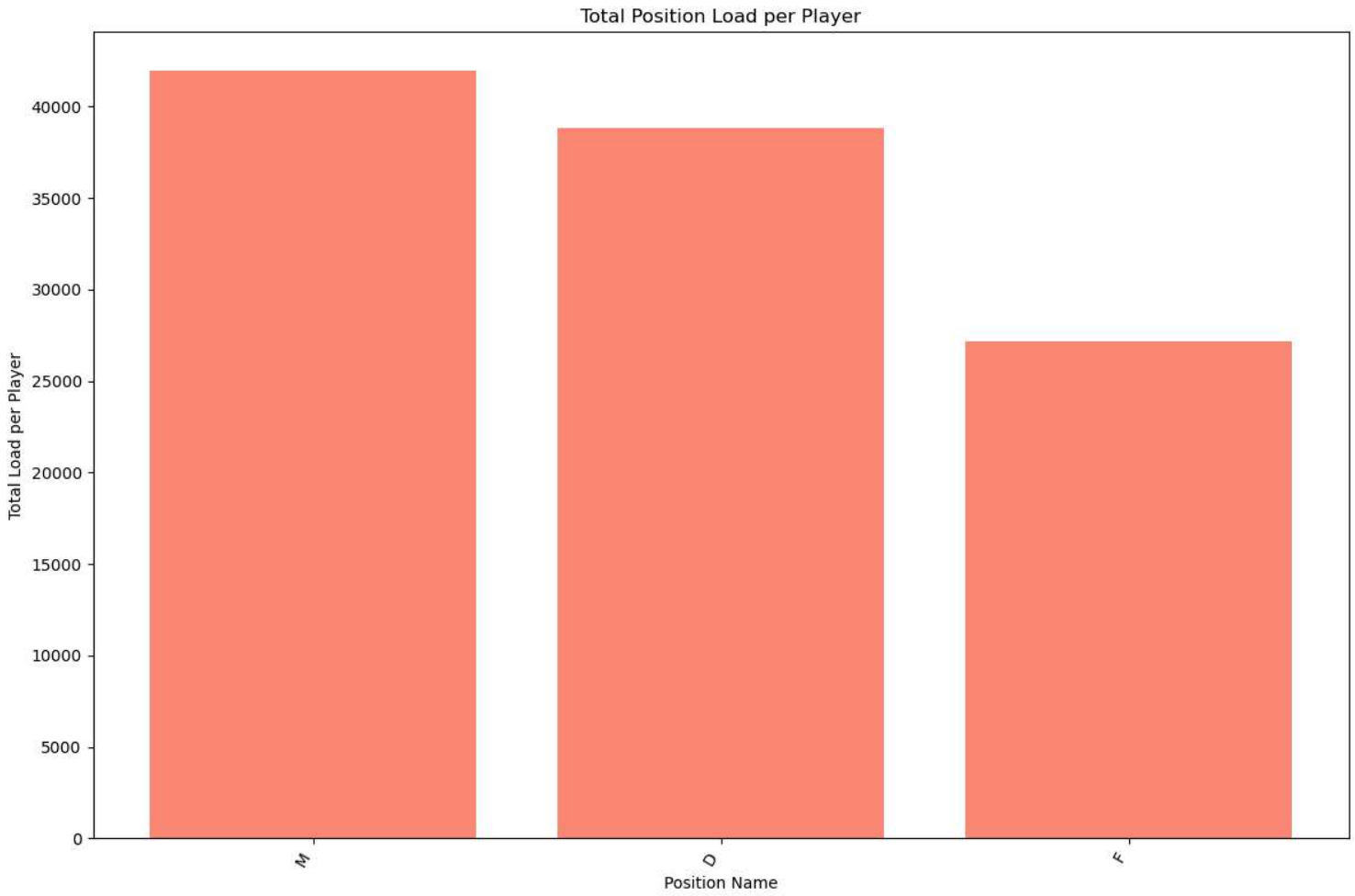
3.2. Compare the ACWR results using classic and alternative parameters, evaluating if there are significant differences throughout the season and deciding which one to emphasize.

4. Results and Discussion

4.1 Players with the Highest Total Load:



- We see that players with numbers `43` , `4` , and `21` accumulate the highest load and stand out significantly from the rest.
- This is mainly because they regularly start from the beginning in physically demanding positions such as midfielders (43 and 21) and the team's main defender (4).
- In the next graph, we see the distribution of workload by player, separated by field position, where it is clear that midfielders and defenders have the highest physical demand.



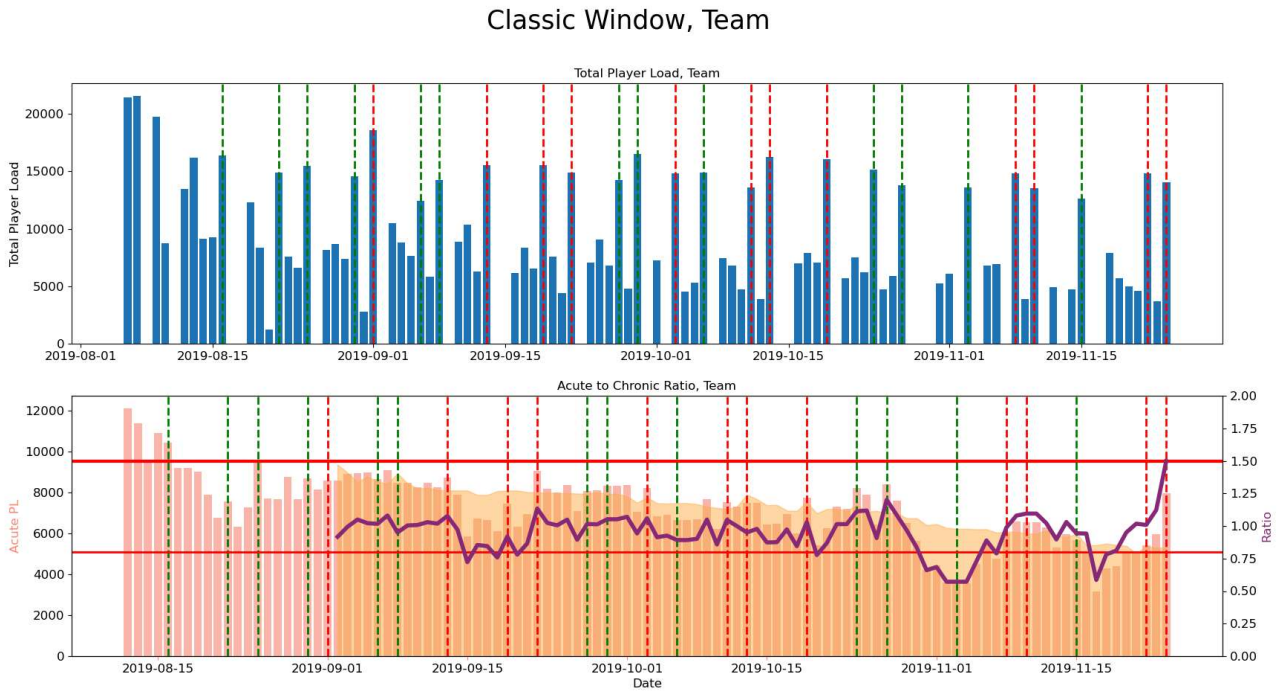
4.2 Comparison of ACWR - Classic vs. Alternative Parameters:

4.2.1 - First, let's explain the legends we will use in the following graphs:

- The top graph is a bar chart showing the average workload for each day.
- The bottom graph consists of:
  - Acute workload (light pink bars)
  - Chronic workload (shaded in orange)
  - Acute to chronic workload ratio (dark purple line)
  - "Normal" threshold (red lines)
- Dotted lines indicate game days:
  - Red dotted line is an away game
  - Green dotted line is a home game
- The acute to chronic workload ratio (and the value of the chronic workload) does not start until 28 days (this is because the calculation of moving averages requires a minimum of 28 observations). This also allows for clearer visualization.

Note: *For more information on acute and chronic workloads, go to the 7. Appendices section.*

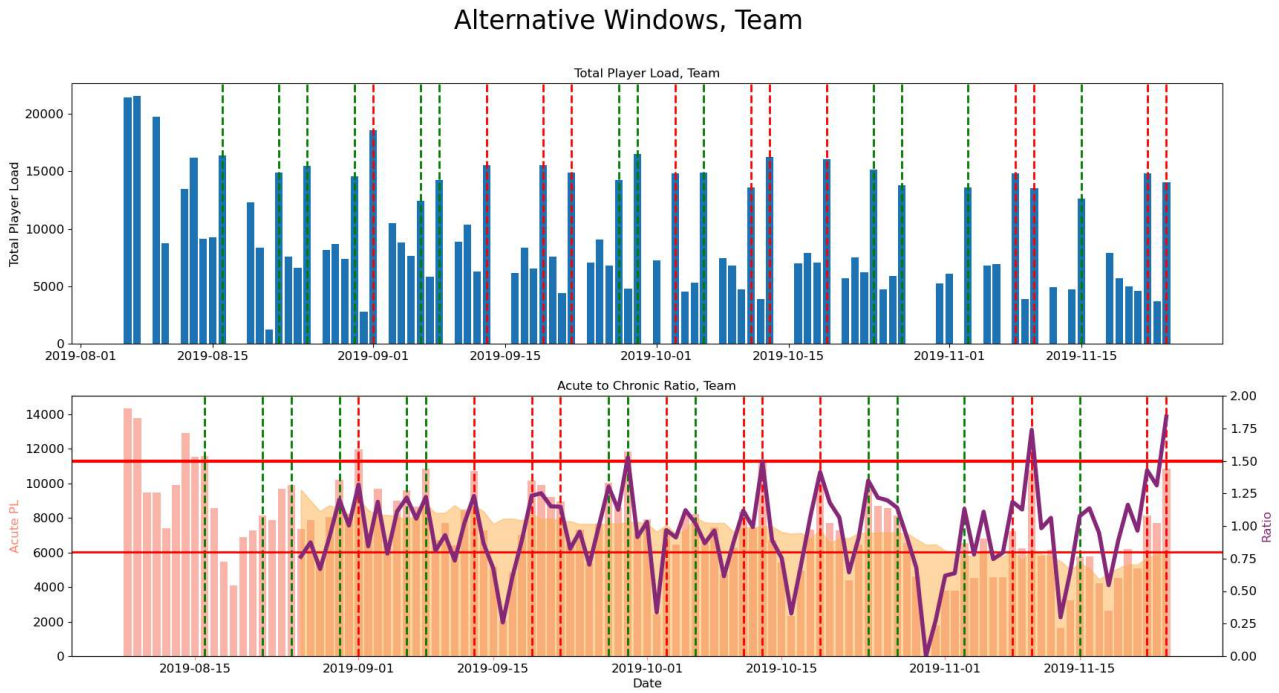
4.2.2 - Analysis of the Classic 7 and 28-day Window



We can see that the team's ACWR values (using the 7-day window for acute load and 28-day window for chronic load) never reached the value of 1.5. However, we see that the value was 1.49+ on the last day of the season (November 24), which is understandable as there is a lot at stake in the last game of the season.

- Presentation of results for both sets of parameters.
- Analysis of observed differences and their statistical significance.
- Discussion on the implications of these differences for managing players' workload.

4.2.3 Analysis of the Alternative 3 and 21-day Window:



We see that in the alternative window, we have three loads above 1.5 ACWR. This means that on those days, the players experienced much greater effort than they were used to.

To explain it more clearly, I'll give an example: Imagine you normally walk 5 km a day, but suddenly one day you have to run a marathon of 42 km. That sudden difference is what these peaks represent. In sports, these sudden jumps in effort can increase the risk of injury.

4.2.4 - Classic vs. Alternative Window:

We have analyzed our players' workload using two different 'lenses':

- One that looks at the last 3 days and
- Another that looks at the last 7 days.
  With the 3-day lens, we saw significant peaks on game days. However, when we used the 7-day lens, these peaks disappeared.

This is like looking at a roller coaster from different distances. Up close (3 days), we see the steep ups and downs. But when we step back (7 days), the ride looks smoother, and we don't notice those sharp changes.

This suggests that:

- Games cause a sudden and intense increase in players' effort.
- However, when we consider a full week, this extra effort is 'diluted' with the lower intensity days around the game.

Which window should we use then?

In reality, both give us valuable information:

- The 3-day window alerts us to the intense peaks that could increase the risk of short-term injuries.
- The 7-day window shows us that, overall, we are maintaining a more balanced workload throughout the week.

Therefore, we recommend using both windows:

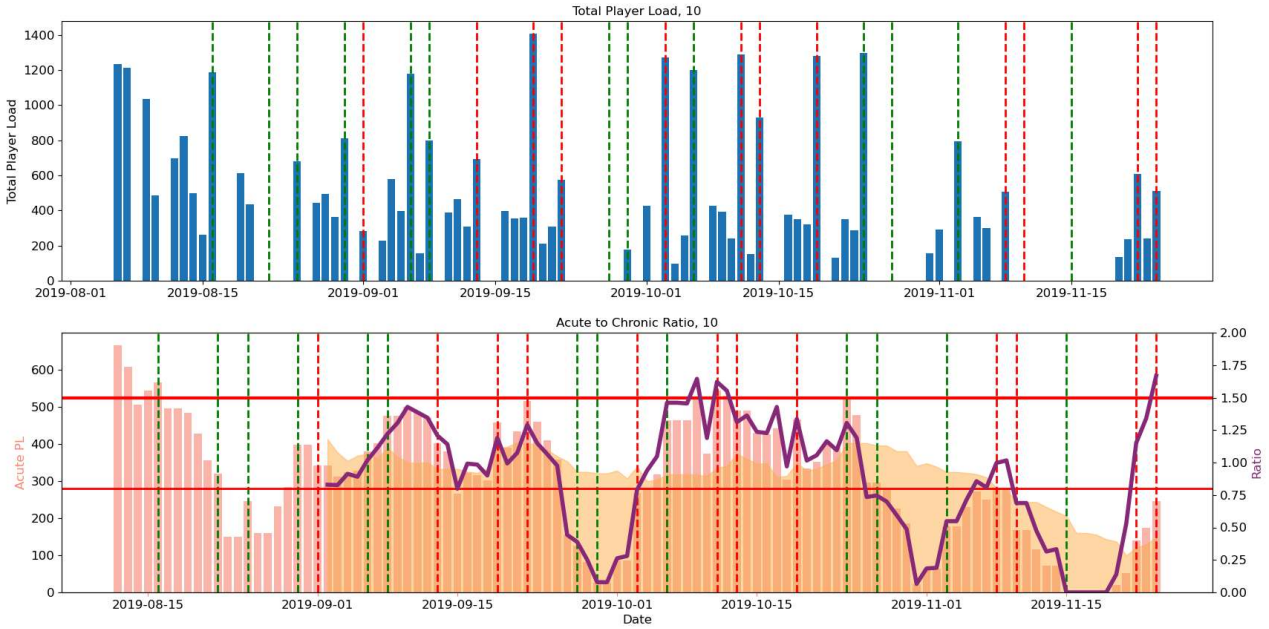
- We will use the 3-day window to fine-tune our immediate preparation before and after games, ensuring that players are ready for these intensity peaks.
- The 7-day window will help us plan weekly training, ensuring that the total load remains at appropriate levels.

This strategy will allow us to prepare players for the intense challenges of games while maintaining a healthy balance in their overall workload.

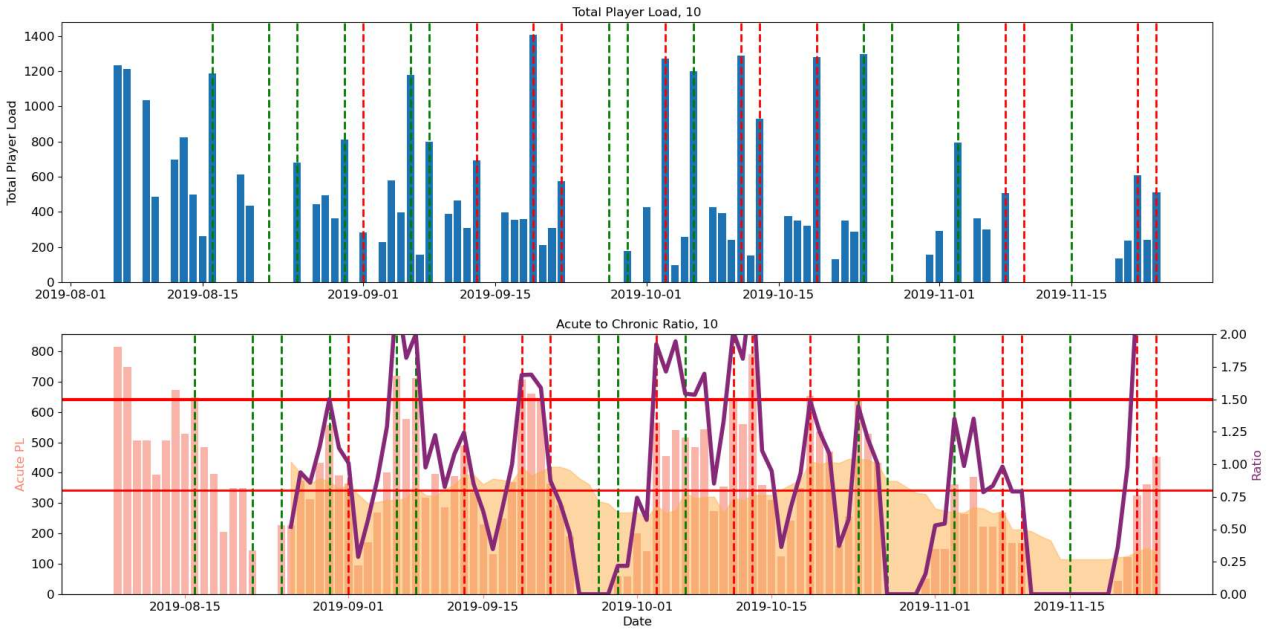
4.3 Individual ACWR Analysis

Note: *Here we will present the most relevant and specific information; for a complete report on each athlete, you can refer to the workbook that you can find Here.*

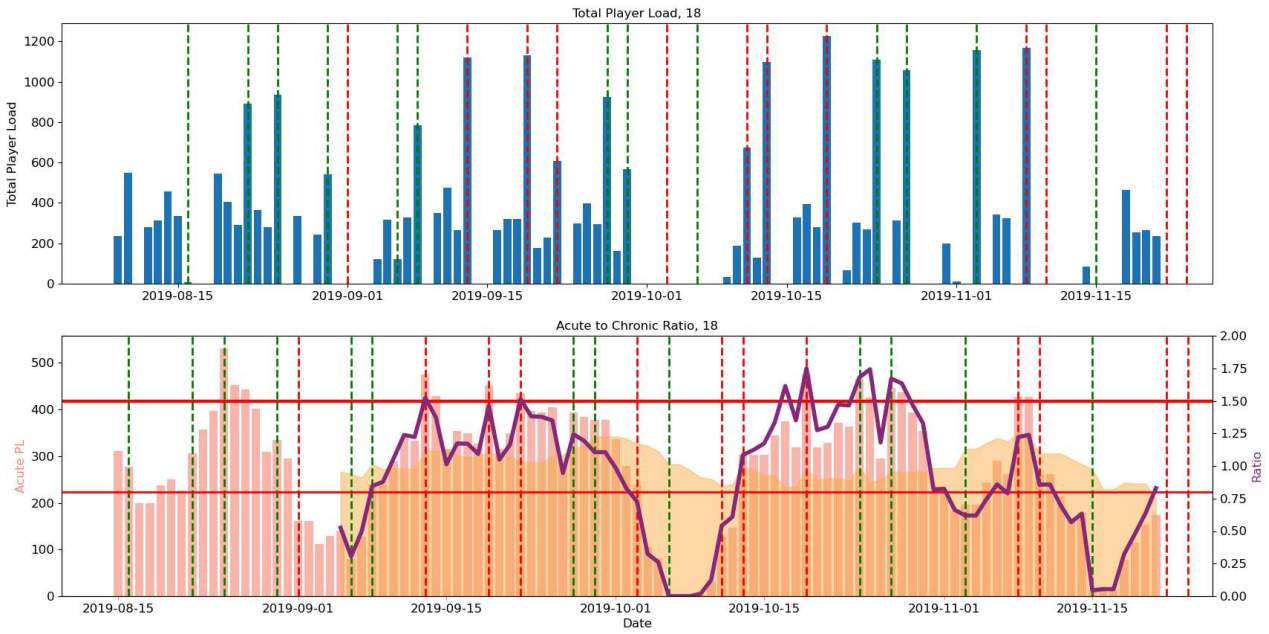
Classic Window, Player 10



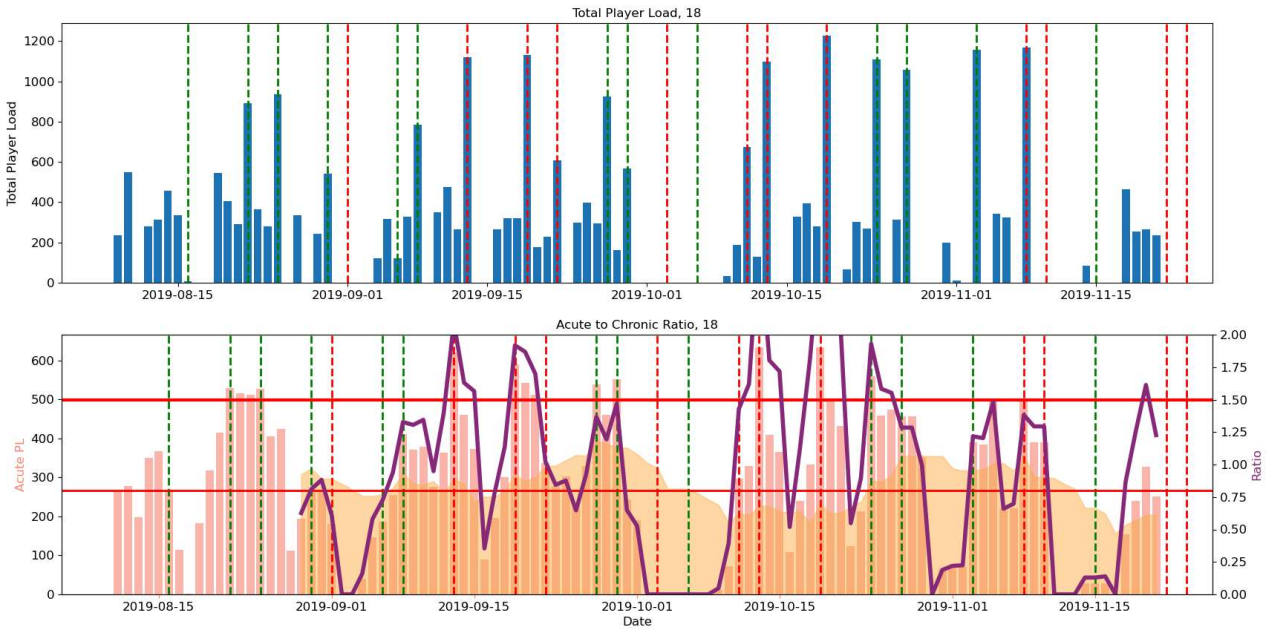
Alternative Window, Player 10



Classic Window, Player 18



Alternative Window, Player 18



These graphs show how the effort of our players number 10 and 18 has been throughout the season.

Let's interpret them in a simple way:

- The blue bars at the top of both graphs show the player's total workload day by day. We can see that there are days with high peaks, corresponding to game days.
- The purple line at the bottom represents the balance between recent effort and usual effort. When this line rises above the horizontal red line, it means the player is making more effort than usual.

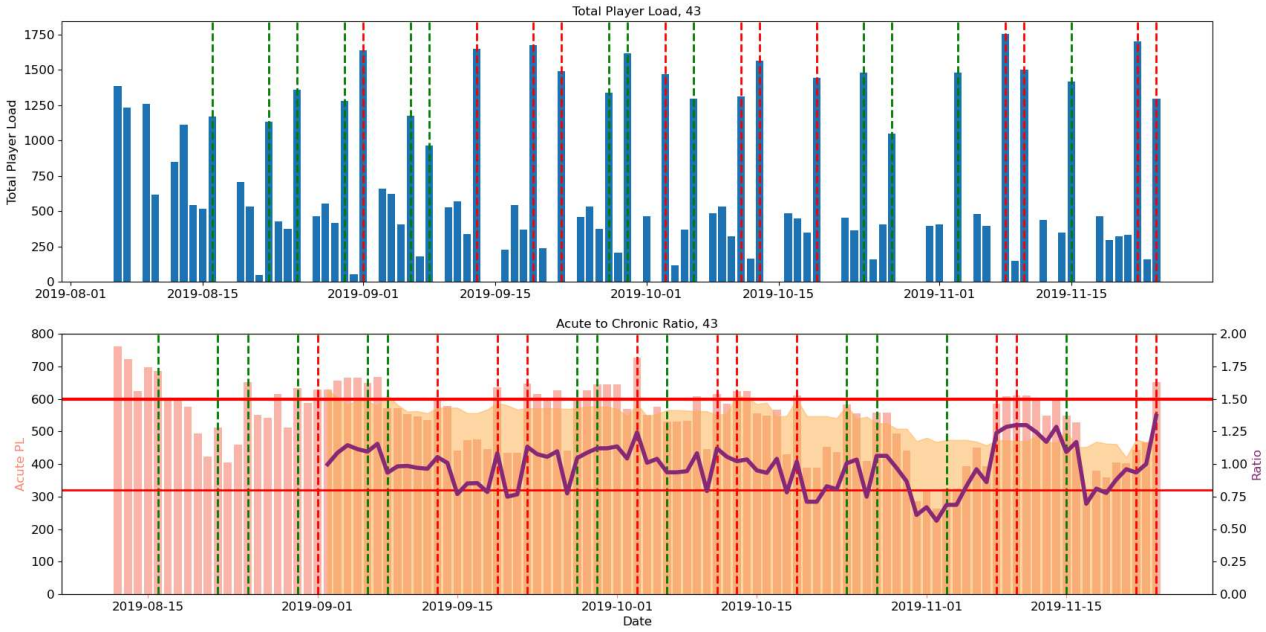
The key difference is in how we measure that 'recent effort':

- In the first image (classic 7-day window), the peaks are less pronounced and rarely exceed the red line.
- In the second image (alternative 3-day window), we see more peaks that exceed the red line.

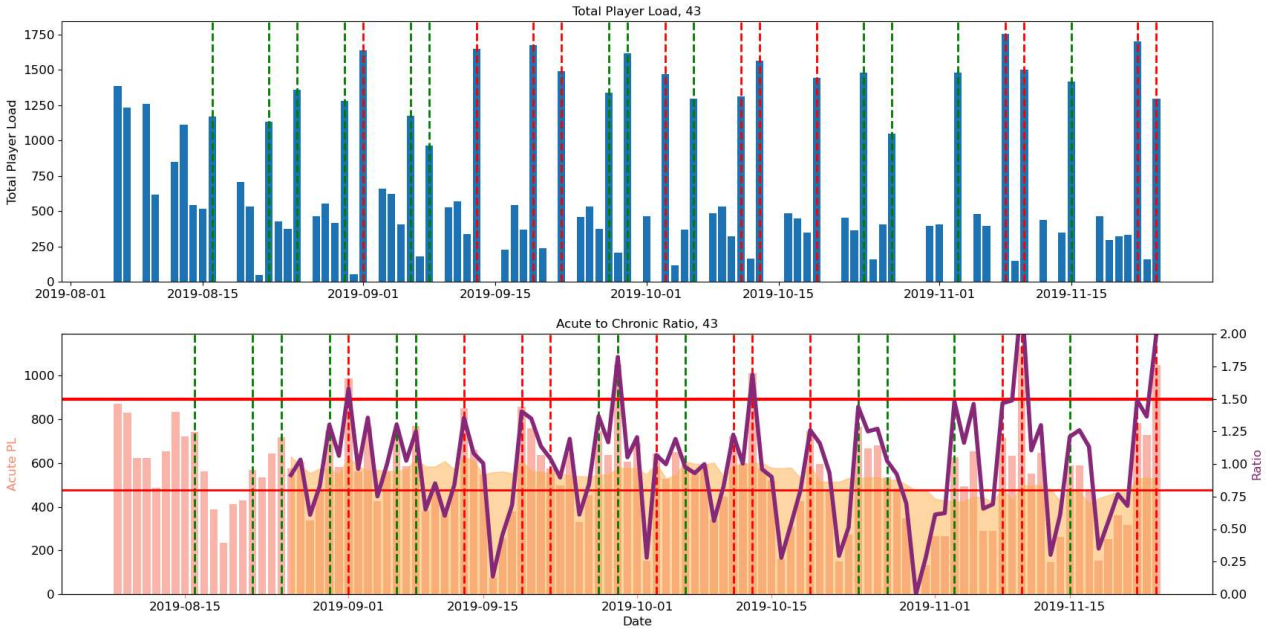
Conclusions we can draw:

- Sensitivity to rapid changes: The 3-day window shows us more 'alerts' (peaks above the red line). This indicates that the player experiences sudden changes in workload in the short term, probably due to the intensity of the games. This causes injuries that prevent the athletes from making physical efforts in the following days (purple line at zero), missing at least 3 games with the team.
- Importance of recovery: The peaks in the 3-day window remind us of the importance of allowing enough time for recovery after intense efforts, such as games.
- Training planning: This information helps us adjust training. We can work to smooth out those acute peaks we see in the 3-day window, better preparing players for the intense efforts of games.
- Injury prevention: By being attentive to both perspectives (3 and 7 days), we can better manage the risk of injuries, ensuring that players are not overloaded in the short or long term.

Classic Window, Player 43



Alternative Window, Player 43



Finally, let's look at the graphs for the player with the highest workload on the team, number 43:

- In the classic window, we see an almost perfect balance of workload throughout the season.
- In the alternative window, we see how the moments of overload are balanced with those of low intensity; this way, we can preserve the athlete's physical integrity by interspersing intense sessions with light ones in a staggered manner.

5. Study Limitations

Limitations of Workload Analysis and ACWR

Although workload analysis and ACWR provide valuable information, it is important to recognize the limitations of this approach:

1. **Partial view of performance**: ACWR focuses primarily on the amount of work done but does not fully capture the quality or efficiency of that work. A player could have an 'ideal' ACWR but not be performing at their maximum potential.
2. **Limited individualization**: Each athlete responds differently to workloads. ACWR uses general thresholds (such as 1.5) that may not be optimal for all players.
3. **Does not consider external factors**: Aspects such as personal stress, sleep quality, nutrition, or travel are not reflected in ACWR but can significantly affect performance and injury risk.
4. **Simplification of fatigue**: ACWR assumes that fatigue accumulates and dissipates linearly, which is not always the case in complex human physiology.
5. **Does not differentiate types of load**: ACWR treats all loads equally, without distinguishing between different types of stress (e.g., cardiovascular vs. neuromuscular).
6. **Fixed time window**: Although we use 3 and 7-day windows, these may not be optimal for all players or situations. Some load effects may manifest over longer or shorter periods.
7. **Does not consider relative intensity**: A high-intensity but short-duration session could have the same numerical value as a long low-intensity session, but their physiological effects would be very different.
8. **Absence of tactical context**: ACWR does not take into account the specific tactical demands of different positions or playing styles.
9. **Limitations in injury prediction**: Although ACWR can indicate periods of higher risk, it is not an infallible predictor of injuries. Many injuries occur due to acute factors that ACWR cannot capture.
10. **Does not consider injury history**: The current ACWR does not take into account previous injuries or rehabilitation periods, which can significantly affect a player's load tolerance.

6. Conclusions and Recommendations

The use of ACWR (Acute:Chronic Workload Ratio) with alternative 3 and 7-day windows has provided us with valuable insight into our players' workload. This technique allows us to identify both acute peaks of effort and longer-term trends, which is crucial for optimizing performance and preventing injuries.

However, to get a more complete picture of our players' status, we could incorporate the following improvements and additional variables:

1. Heart rate:

- Maximum, minimum, and average during training and games.
- This would give us a more accurate idea of the intensity of effort and recovery.

2. Heart rate variability (HRV):

- Measured upon waking, it would indicate the state of recovery and stress of the autonomic nervous system.

3. Subjective perception of effort (RPE):

- Ask players to rate their perceived effort after each session.
- This would add a valuable subjective component to our objective data.

4. Biochemical markers:

- Such as creatine kinase (CK) or cortisol, to measure muscle damage and physiological stress.
- These tests could be performed periodically, not necessarily daily.

5. Mood and psychological state:

- Brief questionnaires on mood and perceived stress level.
- Mental state significantly influences performance and susceptibility to injuries.

6. Injury history:

- Incorporate data on previous injuries to identify individual patterns and risk factors.

7. Nutritional analysis:

- Monitoring caloric and macronutrient intake.
- Proper nutrition is essential for performance and recovery.

8. External factors:

- Such as weather conditions or travel, which can affect fatigue and performance.

7. Appendices

7.1 Glossary

$$\text{Player Load} = \sum_{t=0}^{t=n} \sqrt{(\text{fwd}_{t+1} - \text{fwd}_t)^2 + (\text{side}_{t+1} - \text{side}_t)^2 + (\text{up}_{t+1} - \text{up}_t)^2}$$

- **Player Load**: metric that quantifies the physical load experienced by a player over a period of time.
- **t**: represents time in the sum, where t ranges from 0 to n in seconds.
- **fwd**: represents forward displacement at time t.
- **side**: represents lateral displacement at time t.
- **up**: represents vertical displacement at time t.

$$\text{Acute Chronic Workload Ratio (ACWR)} = \frac{\text{Acute Workload (7 days)}}{\text{Chronic Workload (28 days)}}$$

- **ACWR** > 1.5 indicates a high risk of injury due to a sudden increase in workload.
- **ACWR** [0.8 - 1.5] is generally considered a safe and optimal range for performance.
- **ACWR** < 0.8 It indicates undertraining or insufficient training..

7.2 Technical Analysis

See: Workbook.ipynb

7.3 References

- Catapult Sport ACWR
- University of Michigan