

Research Analysis

Explanation of ACWR

- Acute Workload: This is typically calculated as the average workload over a shorter period, such as the last 7 days.
- Chronic Workload: This is usually calculated as the average workload over a longer period, such as the last 28 days.
- ACWR Formula used:
 - $ACWR = (\text{Acute Workload (7-day average)}) / (\text{Chronic Workload (28-day average)})$
- Guidelines:
 - Ratios above 1.5 may indicate an increased risk of injury (excessive acute workload relative to chronic workload).
 - Ratios below 0.8 may indicate inadequate workload to maintain fitness.
 - We get this from past studies:
 - (Schumann et al., 2023)
 - (Bowen et al., 2019)

Player Focuses:

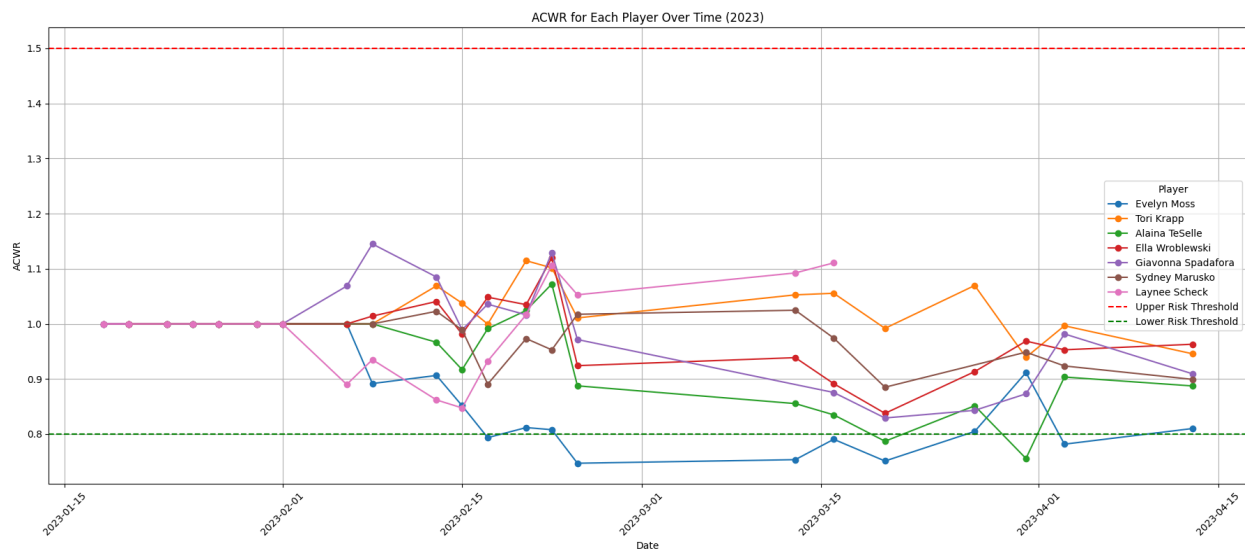
- The injuries that we have of note are:
 - Tori Krapp: Achilles Tendonitis 4/15, 4/8, 3/25; Right Quad 1/13
 - Evelyn Moss: Bilateral Shin Splints 3/25, 3/17
 - Alaina TeSelle : 3/25 and 3/17

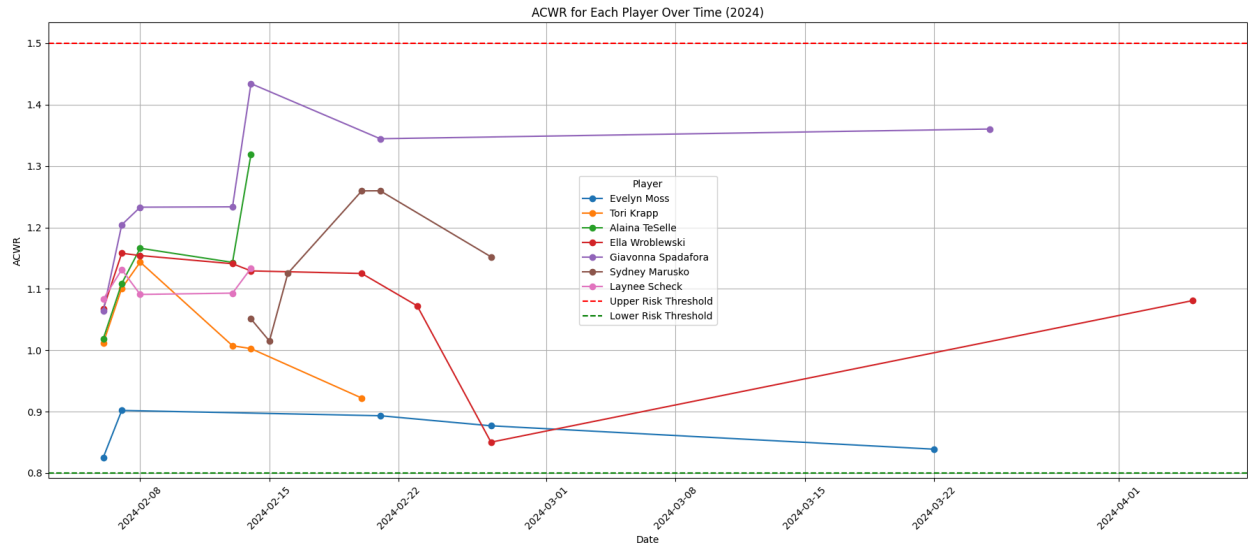
- The non injured we are comparing:

- Ella Wroblewski
- Giavonna Spadafora
- Sydney Marusko
- Laynee Scheck

ACWR and Training Load:

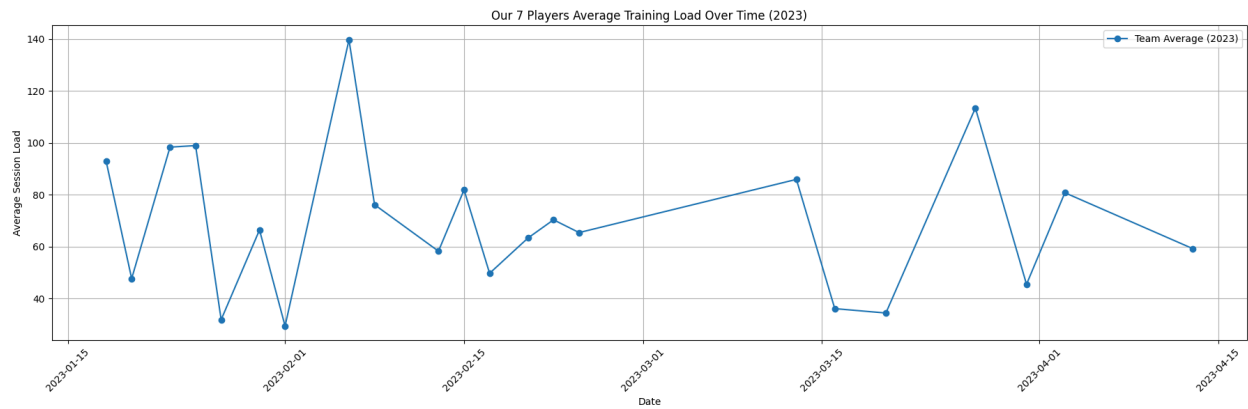
Complete ACWR:

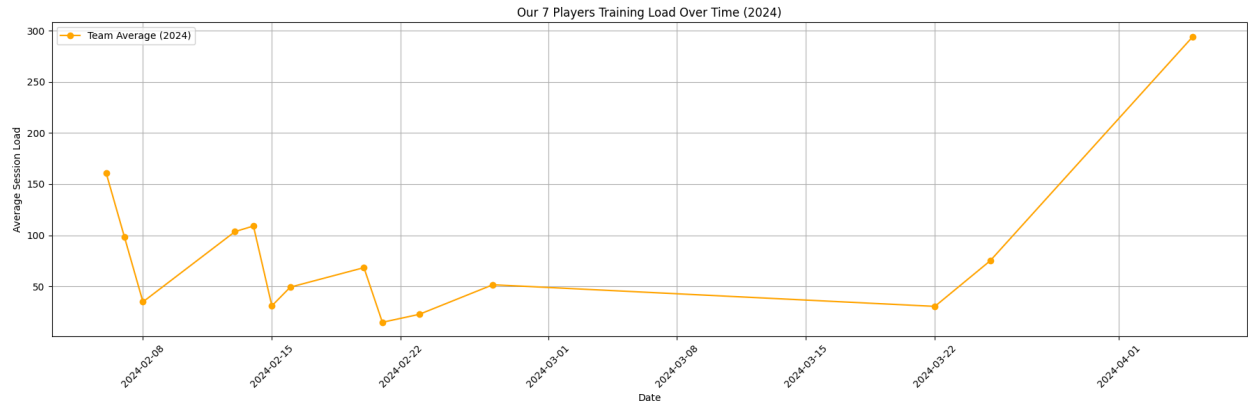




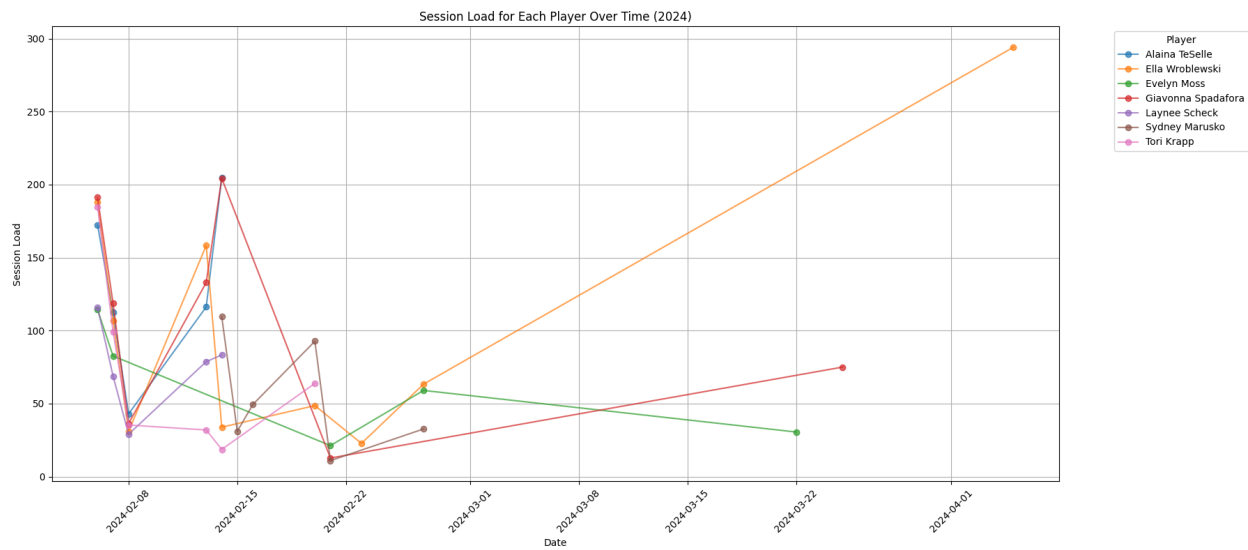
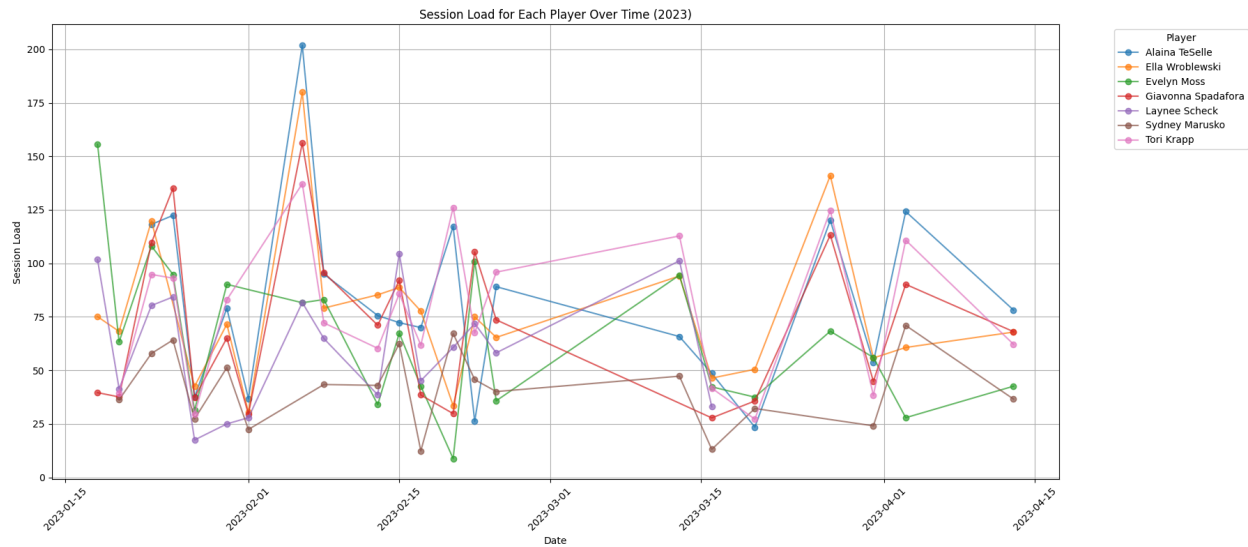
- Look at the ACWR over time for these individuals. We see some are closer to going outside of the comfortable range of 0.8 to 1.5.

Average Training Load:



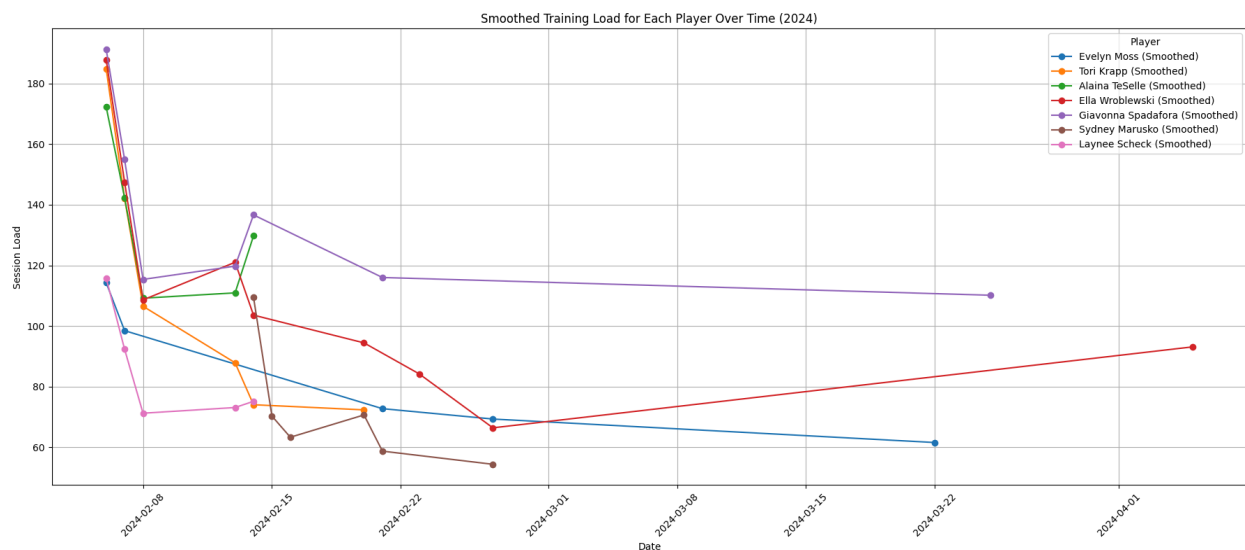
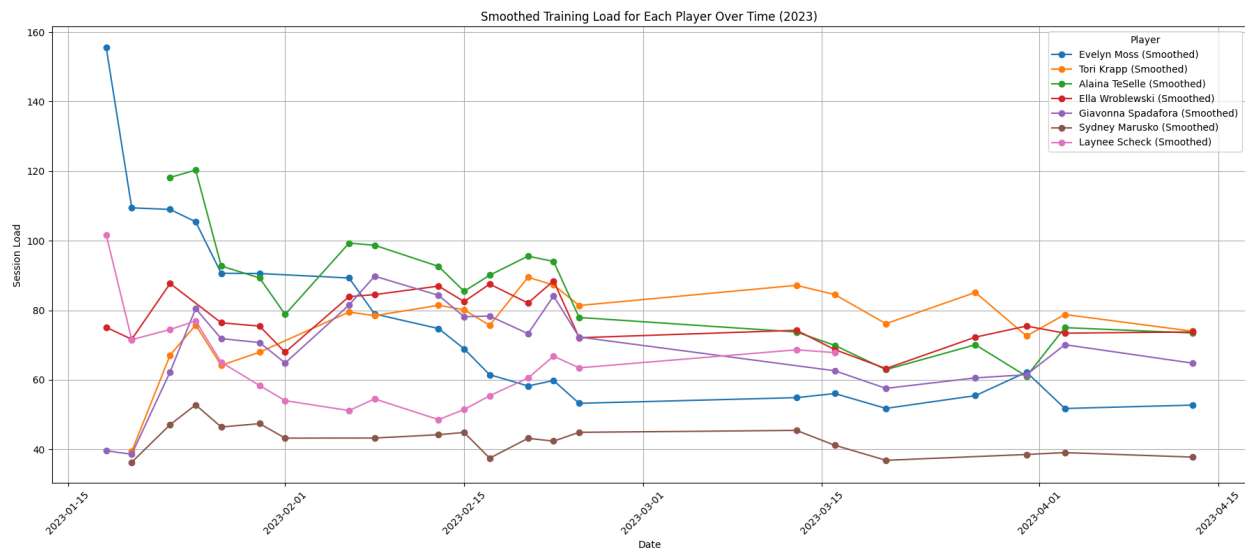


Complete Training Load



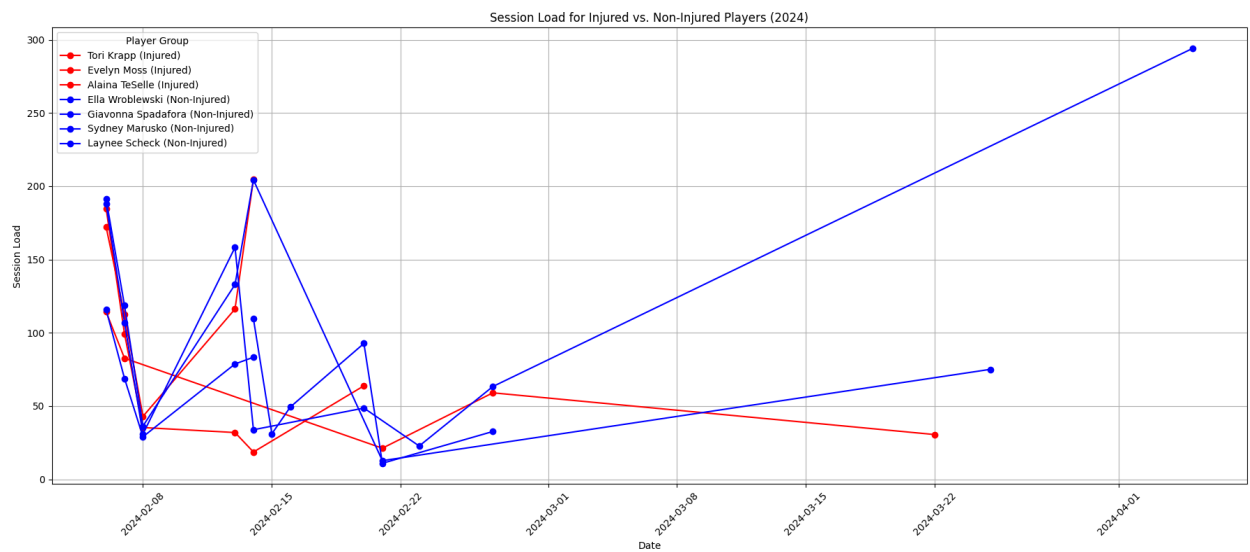
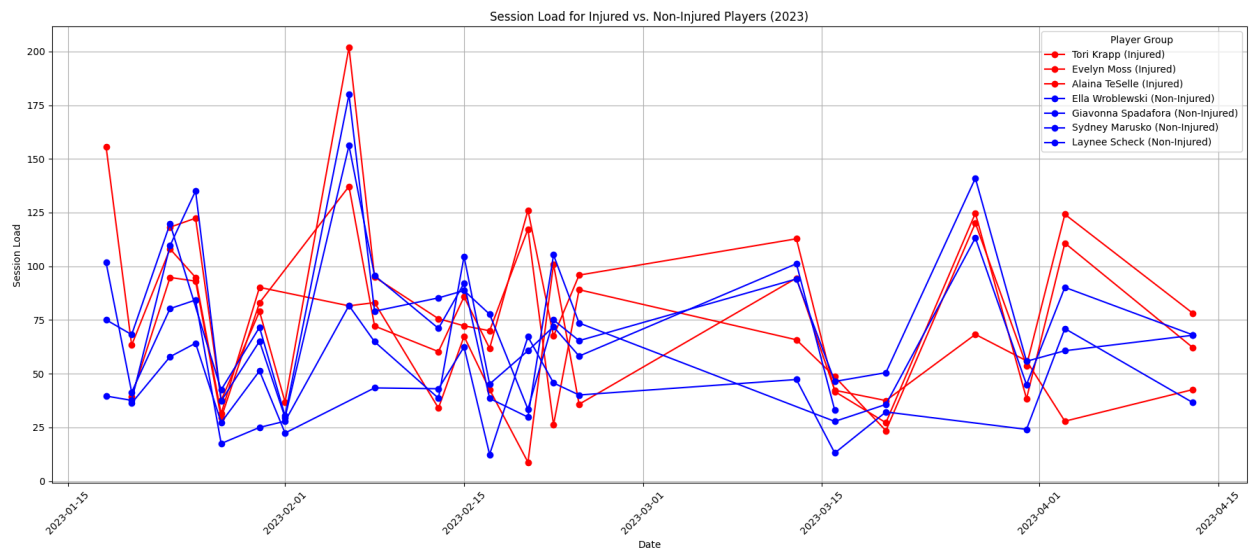
- Here are the following training loads for the players focused on. This gives us an idea of where their training loads were throughout the data collection period. There appears to be a lot of variance in data collection, which should be a part of the limitations to the study.

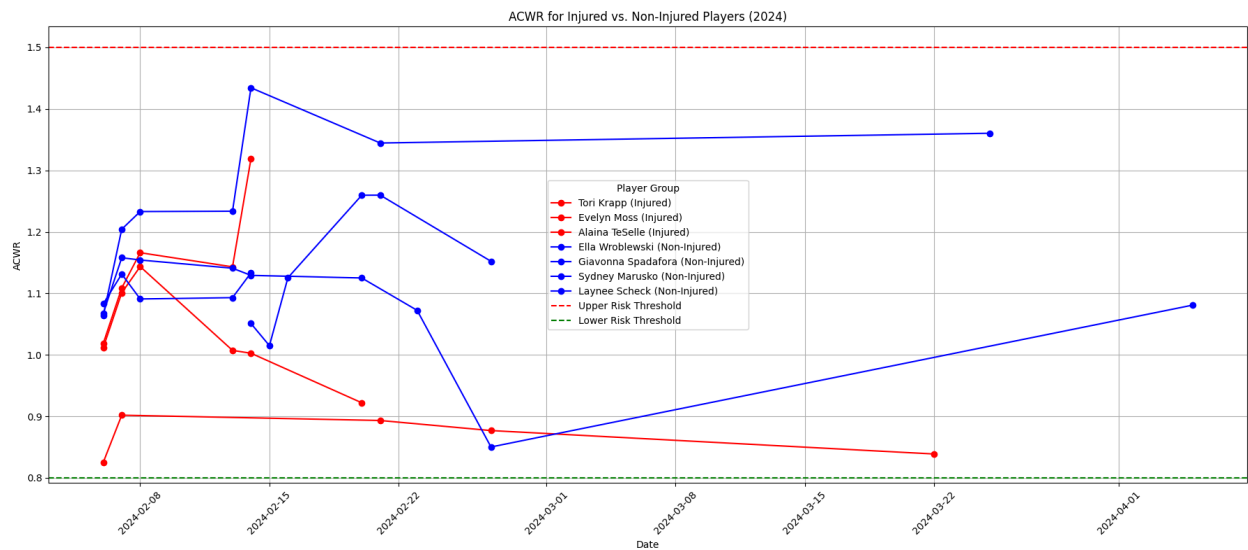
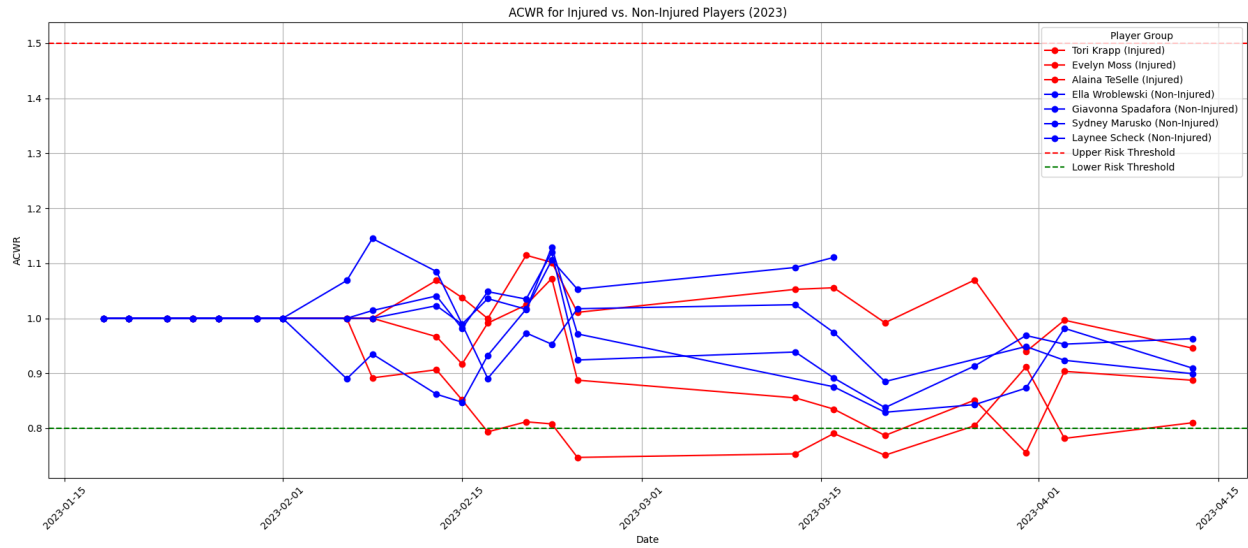
Doing a Rolling Average of the Players' Session Load:



- This was done to find a general trend line in the session loads for everyone.
- I used a rolling average over 7 data points to calculate weekly trends.
- This retains some variability, but also is smooth to understand the general trend.

Looking at Injured vs. Non-Injured Closer:

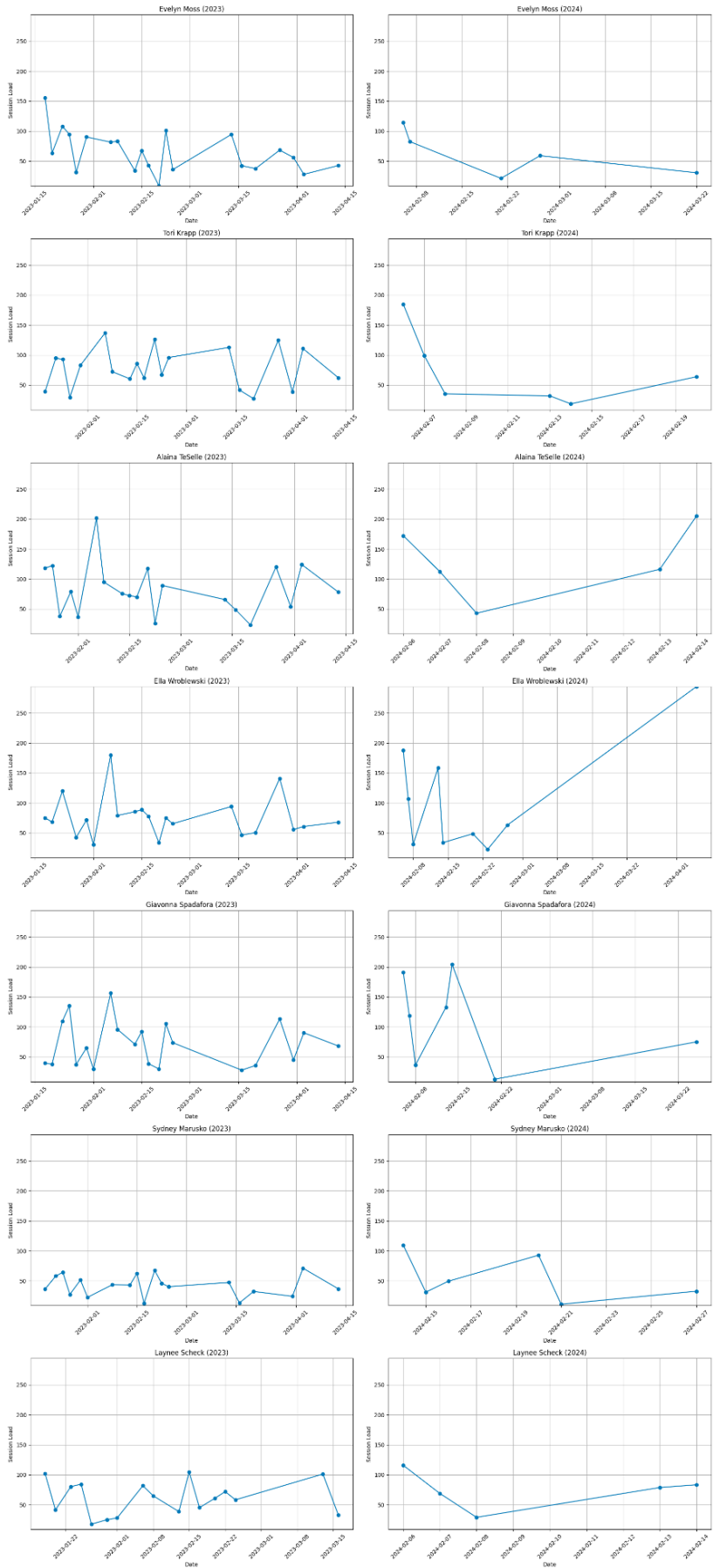




- Now looking at the differences between the injured and non-injured individuals, it appears that there is nothing that showcases why they may have had any lower extremity injuries.
- This is the initial visualization and will require more testing, but it doesn't look favorable for the outcomes to be statistically significant.

Training Load:

Training Load for Each Player Over Time (2023 vs 2024)



ACWR:

ACWR for Each Player Over Time (2023 vs 2024)



Looking for Statistical Significance

- Using the methods of ANOVA, we hope to find whether there is a difference between the injured vs. non injured group in the session load and ACWR of the averages across the periods of 2023 and 2024.
- Then, seeing the values of ACWR for these two groups, we can determine whether or not there is really a relationship between high ACWR and injuries. Unfortunately, most of the data doesn't go above 1.5 for ACWR anyways. Therefore, it may be hard to find conclusive results related to the high injury risk.
- Here are some of the following graphs to look at that we assessed to understand the relationship of these differences both as a whole between injured and non-injured and through pairwise differences.

	Average ACWR (2023)	Average ACWR (2024)
name		
Alaina TeSelle	0.936731	1.151107
Ella Wroblewski	0.982374	1.086442
Evelyn Moss	0.876851	0.867174
Giavonna Spadafora	0.988252	1.267695
Laynee Scheck	0.990923	1.106300
Sydney Marusko	0.973796	1.143767
Tori Krapp	1.019235	1.031326

- - This showcases the Average ACWR for each individual both in 2023 and 2024.

	Average Session Load (2023)	Average Session Load (2024)
name		
Alaina TeSelle	82.780000	129.720000
Ella Wroblewski	76.600000	105.177778
Evelyn Moss	65.085714	61.520000
Giavonna Spadafora	71.242857	110.142857
Laynee Scheck	61.064706	75.120000
Sydney Marusko	42.000000	54.333333
Tori Krapp	78.215000	72.300000

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- This showcases the average session load for each individual in 2023 and 2024.

Year	F-statistic	p-value
2023	3.869605	0.051189
2024	0.017060	0.896720

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- There appears to be a significant difference with a p-value below 0.05 in the 2023 group. That is interesting since I didn't expect to see a difference between the two groups. However, the 2024 group went as expected for the results. Look at the values for the Session Load averages to showcase how much of a difference is there between the injured vs. non-injured.

Year	Player Group	Session Load
2023	Injured	75.191803
2023	Non-Injured	63.343590
2024	Injured	86.875000
2024	Non-Injured	89.600000

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- There was slightly an increase in the session load for 2023 injured athletes. This is interesting to take into consideration. Perform a post-hoc Tukey HSD test now to see the pairwise differences.

Tukey HSD Test Results for 2023:
Multiple Comparison of Means - Tukey HSD, FWER=0.05

group1	group2	meandiff	p-adj	lower	upper	reject
Alaina TeSelle	Ella Wroblewski	-6.18	0.9973	-38.0209	25.6609	False
Alaina TeSelle	Evelyn Moss	-17.6943	0.6411	-49.5352	14.1466	False
Alaina TeSelle	Giavonna Spadafora	-11.5371	0.9315	-43.3781	20.3038	False
Alaina TeSelle	Laynee Scheck	-21.7153	0.4617	-55.3339	11.9033	False
Alaina TeSelle	Sydney Marusko	-40.78	0.005	-73.4282	-8.1318	True
Alaina TeSelle	Tori Krapp	-4.565	0.9995	-36.7919	27.6619	False
Ella Wroblewski	Evelyn Moss	-11.5143	0.9282	-42.9645	19.9359	False
Ella Wroblewski	Giavonna Spadafora	-5.3571	0.9987	-36.8074	26.0931	False
Ella Wroblewski	Laynee Scheck	-15.5353	0.8015	-48.7841	17.7135	False
Ella Wroblewski	Sydney Marusko	-34.6	0.027	-66.8672	-2.3328	True
Ella Wroblewski	Tori Krapp	1.615	1.0	-30.2259	33.4559	False
Evelyn Moss	Giavonna Spadafora	6.1571	0.9971	-25.2931	37.6074	False
Evelyn Moss	Laynee Scheck	-4.021	0.9998	-37.2698	29.2278	False
Evelyn Moss	Sydney Marusko	-23.0857	0.3344	-55.353	9.1815	False
Evelyn Moss	Tori Krapp	13.1293	0.8793	-18.7116	44.9702	False
Giavonna Spadafora	Laynee Scheck	-10.1782	0.9693	-43.427	23.0707	False
Giavonna Spadafora	Sydney Marusko	-29.2429	0.1029	-61.5101	3.0244	False
Giavonna Spadafora	Tori Krapp	6.9721	0.9947	-24.8688	38.8131	False
Laynee Scheck	Sydney Marusko	-19.0647	0.6319	-53.0874	14.958	False
Laynee Scheck	Tori Krapp	17.1503	0.7278	-16.4683	50.7689	False
Sydney Marusko	Tori Krapp	36.215	0.0194	3.5668	68.8632	True

- - There were only some pairwise differences that were significant enough.
- - These were Alaina TeSelle, Sydney Marsuko; Ella Wroblewski, Sydney Marusko; Sydney Marusko, Tori Krapp.
 - - Alaina was injured and Sydney wasn't. That showcases one that was clearly different and an injured result happened. The mean difference is

negative indicating Sydney must have had lower training load contributing to the result since Alaina was injured.

- - Ella and Sydney, however, weren't injured and theirs were significantly different. This isn't helpful for what we are looking for. Showcasing that potentially one of these individuals could be an outlier messing with the results. this might be Sydney since it is significantly lower again.
- - Finally, Tori and Sydney were significantly different and Sydney once again was lower. This could contribute that since Tori was injured, we can understand the higher session loads to potentially increase injury risk.

Tukey HSD Test Results for 2024:						
Multiple Comparison of Means - Tukey HSD, FWER=0.05						
group1	group2	meandiff	p-adj	lower	upper	reject
Alaina TeSelle	Ella Wroblewski	-24.5422	0.9931	-137.6432	88.5587	False
Alaina TeSelle	Evelyn Moss	-68.2	0.6459	-196.4444	60.0444	False
Alaina TeSelle	Giavonna Spadafora	-19.5771	0.9985	-138.3084	99.1541	False
Alaina TeSelle	Laynee Scheck	-54.6	0.834	-182.8444	73.6444	False
Alaina TeSelle	Sydney Marusko	-75.3867	0.4833	-198.1713	47.398	False
Alaina TeSelle	Tori Krapp	-57.42	0.766	-180.2047	65.3647	False
Ella Wroblewski	Evelyn Moss	-43.6578	0.8878	-156.7587	69.4432	False
Ella Wroblewski	Giavonna Spadafora	4.9651	1.0	-97.2225	107.1527	False
Ella Wroblewski	Laynee Scheck	-30.0578	0.9802	-143.1587	83.0432	False
Ella Wroblewski	Sydney Marusko	-50.8444	0.7517	-157.7148	56.0259	False
Ella Wroblewski	Tori Krapp	-32.8778	0.9593	-139.7481	73.9926	False
Evelyn Moss	Giavonna Spadafora	48.6229	0.8573	-70.1084	167.3541	False
Evelyn Moss	Laynee Scheck	13.6	0.9999	-114.6444	141.8444	False
Evelyn Moss	Sydney Marusko	-7.1867	1.0	-129.9713	115.598	False
Evelyn Moss	Tori Krapp	10.78	1.0	-112.0047	133.5647	False
Giavonna Spadafora	Laynee Scheck	-35.0229	0.9668	-153.7541	83.7084	False
Giavonna Spadafora	Sydney Marusko	-55.8095	0.7171	-168.6216	57.0025	False
Giavonna Spadafora	Tori Krapp	-37.8429	0.9391	-150.6549	74.9692	False
Laynee Scheck	Sydney Marusko	-20.7867	0.9982	-143.5713	101.998	False
Laynee Scheck	Tori Krapp	-2.82	1.0	-125.6047	119.9647	False
Sydney Marusko	Tori Krapp	17.9667	0.999	-99.1039	135.0373	False

- 2024 even showcased that there were no significant pairwise differences for any of the athletes. This showcases that everyone had a similar session load most of the time.
- Now look at the ACWR differences in ANOVA.

Year	F-statistic	p-value
2023	8.174637	0.004913
2024	11.151891	0.001796

- Interestingly, there is a significant differences in the ACWR averages from the injured vs. non-injured group. Let's look at the averages in relation to one another through a dataframe.

Year	Injured Players	Non-Injured Players
2023	0.943167	0.98373
2024	1.017460	1.14985

- This does showcase that there is a significant difference, but not in the way that we would have hoped. Interestingly, the players with injuries had smaller ACWRs than the players without injuries. Therefore, we are beginning to see that the ACWR value wasn't very helpful for this study. However, there were very small sample sizes in the data collected and the players with injuries. So, that could contribute some bias to the study.

Tukey HSD Test Results for 2023:							
Multiple Comparison of Means - Tukey HSD, FWER=0.05							
group1	group2	meandiff	p-adj	lower	upper	reject	
Alaina TeSelle	Ella Wroblewski	0.0456	0.4437	-0.024	0.1153	False	
Alaina TeSelle	Evelyn Moss	-0.0599	0.1425	-0.1295	0.0098	False	
Alaina TeSelle	Giavonna Spadafora	0.0515	0.2948	-0.0181	0.1212	False	
Alaina TeSelle	Laynee Scheck	0.0542	0.2992	-0.0194	0.1277	False	
Alaina TeSelle	Sydney Marusko	0.0371	0.7116	-0.0344	0.1085	False	
Alaina TeSelle	Tori Krapp	0.0825	0.0109	0.012	0.153	True	
Ella Wroblewski	Evelyn Moss	-0.1055	0.0002	-0.1743	-0.0367	True	
Ella Wroblewski	Giavonna Spadafora	0.0059	1.0	-0.0629	0.0747	False	
Ella Wroblewski	Laynee Scheck	0.0085	0.9998	-0.0642	0.0813	False	
Ella Wroblewski	Sydney Marusko	-0.0086	0.9998	-0.0792	0.062	False	
Ella Wroblewski	Tori Krapp	0.0369	0.6924	-0.0328	0.1065	False	
Evelyn Moss	Giavonna Spadafora	0.1114	0.0001	0.0426	0.1802	True	
Evelyn Moss	Laynee Scheck	0.1141	0.0001	0.0413	0.1868	True	
Evelyn Moss	Sydney Marusko	0.0969	0.0013	0.0264	0.1675	True	
Evelyn Moss	Tori Krapp	0.1424	0.0	0.0727	0.212	True	
Giavonna Spadafora	Laynee Scheck	0.0027	1.0	-0.0701	0.0754	False	
Giavonna Spadafora	Sydney Marusko	-0.0145	0.9963	-0.085	0.0561	False	
Giavonna Spadafora	Tori Krapp	0.031	0.8358	-0.0387	0.1006	False	
Laynee Scheck	Sydney Marusko	-0.0171	0.993	-0.0916	0.0573	False	
Laynee Scheck	Tori Krapp	0.0283	0.9102	-0.0452	0.1019	False	
Sydney Marusko	Tori Krapp	0.0454	0.4807	-0.026	0.1169	False	

- Initially, we saw that there were significant differences in the values of the ACWR between the injured vs. noninjured in their averages. However, there is some possibility that is related to the overall averages, so it helps to once again look at the Tukey HSD to see the pairwise differences that are evident to really understand if there is a relationship between the ACWR predicting injured athletes.
 - The pairwise differences that were significant here were Alaina TeSelle, Tori Krapp; Ella Wroblewski, Evelyn Moss; Evelyn Moss, Giavonna Spadafora;

Evelyn Moss, Laynee Scheck; Evelyn Moss, Sydney Marusko; Evelyn Moss, Tori Krapp

- - Alaina and Tori were both injured so that is disappointing that they have significantly different ACWR indicating that one or both may be outliers. Alaina appeared to be much lower than Tori.
- - Ella wasn't injured and Evelyn was. The mean difference showcases that Evelyn had lower ACWR which doesn't contribute to the goal of the predictability of ACWR and injuries.
- - Evelyn was injured and Giavonna wasn't. Once again Evelyn had lower ACWR.
- - Evelyn was injured and Laynee wasn't. Once again Evelyn had lower ACWR.
- - Evelyn was injured and Sydney wasn't. Once again Evelyn had lower ACWR.
- - Evelyn was injured and Tori was as well. Evelyn had a lower ACWR, which doesn't help us then for the differences.
- - We might consider Evelyn's value to be an outlier. However, the small sample sizes don't help with the data.

Tukey HSD Test Results for 2024:

Multiple Comparison of Means - Tukey HSD, FWER=0.05

group1	group2	meandiff	p-adj	lower	upper	reject
Alaina TeSelle	Ella Wroblewski	-0.0647	0.8617	-0.2238	0.0945	False
Alaina TeSelle	Evelyn Moss	-0.2839	0.0004	-0.4644	-0.1035	True
Alaina TeSelle	Giavonna Spadafora	0.1166	0.3321	-0.0505	0.2836	False
Alaina TeSelle	Laynee Scheck	-0.0448	0.986	-0.2253	0.1356	False
Alaina TeSelle	Sydney Marusko	-0.0073	1.0	-0.1801	0.1654	False
Alaina TeSelle	Tori Krapp	-0.1198	0.3396	-0.2925	0.053	False
Ella Wroblewski	Evelyn Moss	-0.2193	0.0022	-0.3784	-0.0601	True
Ella Wroblewski	Giavonna Spadafora	0.1813	0.0061	0.0375	0.325	True
Ella Wroblewski	Laynee Scheck	0.0199	0.9997	-0.1393	0.179	False
Ella Wroblewski	Sydney Marusko	0.0573	0.8935	-0.093	0.2077	False
Ella Wroblewski	Tori Krapp	-0.0551	0.9099	-0.2055	0.0953	False
Evelyn Moss	Giavonna Spadafora	0.4005	0.0	0.2335	0.5676	True
Evelyn Moss	Laynee Scheck	0.2391	0.0035	0.0587	0.4196	True
Evelyn Moss	Sydney Marusko	0.2766	0.0003	0.1038	0.4494	True
Evelyn Moss	Tori Krapp	0.1642	0.0717	-0.0086	0.3369	False
Giavonna Spadafora	Laynee Scheck	-0.1614	0.064	-0.3285	0.0057	False
Giavonna Spadafora	Sydney Marusko	-0.1239	0.2134	-0.2827	0.0348	False
Giavonna Spadafora	Tori Krapp	-0.2364	0.0008	-0.3951	-0.0776	True
Laynee Scheck	Sydney Marusko	0.0375	0.9931	-0.1353	0.2102	False
Laynee Scheck	Tori Krapp	-0.075	0.8215	-0.2477	0.0978	False
Sydney Marusko	Tori Krapp	-0.1124	0.3576	-0.2772	0.0523	False

- Looking again at the Tukey HSD for the pairwise differences in the ACWR averages for 2024 found some interesting significance as well.

- There were significant differences between Alaina TeSelle, Evelyn Moss; Ella Wroblewski, Evelyn Moss; Ella Wroblewski, Giavonna Spadafora; Evelyn Moss, Giavonna Spadafora; Evelyn Moss, Laynee Scheck; Evelyn Moss, Sydney Marusko; Giavonna Spadafora, Tori Krapp.

- - Alaina and Evelyn were both apart of the injured group unfortunately.

It appears that Evelyn had a much lower ACWR value.

- - Ella was non-injured and Evelyn was injured. Therefore, there was a significant difference with Evelyn having a lower ACWR.
- - Ella was non-injured and so was Giavonna. Ella had the lower ACWR.
- - Evelyn was injured and Giavonna wasn't. Evelyn's ACWR was much lower than Giavonna's.
- - Evelyn was injured and Laynee wasn't. Evelyn's ACWR was lower than Laynee's.
- - Evelyn was injured and Sydney wasn't. Evelyn's ACWR was lower than Sydney's.
- - Giavonna wasn't injured but Tori was. Also, Tori had a higher ACWR than Giavonna.
- - From the players above for both 2023 and 2024 values, we found that generally the ACWR of the injured was significantly lower than the ACWR of the non-injured in the pairwise differences. However, the major differences were only showcased in one individual. That individual might be an outlier with lower ACWR based on the timing of the training stimulus that was given to them. With more data samples, we would be able to understand the predictability more clearly.

Conclusion

- Looking at the relationship between session load and how it computes the ACWR helped to understand some metrics on how hard a training session would be.

- However, there were many more variables at play that caused injuries, and because of our small sample size, there was no way to understand if there were statistically significant differences in the ACWR of the injured vs. non-injured individuals that would indicate ACWR being helpful in understanding injury risk.
- But, the players that were injured had relatively lower ACWR typically on average. That could play a factor in the misleading statistics.
- Therefore, it is important to understand without samples of more individuals in the injured and non-injured groups, it will be hard to directly understand the relationship.
- Overall, we can conclude that there might still be a relationship but it hasn't been found yet, and we would need more samples to indicate that as an outcome. Currently, it appears that there are a lot of other factors at play that would affect a person's injury risk. ACWR may be something that can be included in that prediction, but it doesn't appear to be the largest indicator or only indicator for that matter.

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