Interpreting Heart Rate Variability Trends in National Collegiate Athletic Association Division II Intercollegiate Football Athletes

Justin Pioske, MSIS, CSCS; Kristi Fox, PhD, CSCS; Paul McCawley, MSE, CSCS; Michael Mutehart, PhD; Chad Maas, PhD

Department of Health, Human Performance, and Sport, Wayne State College

Introduction

Intercollegiate (American) football athletes are exposed to numerous of sport- and non-sport- related stressors throughout the sport season, which, when not addressed, can negatively impact athletic performance and lead to nonfunctional overreaching (NFOR). Coaches overseeing these athletes can use heart rate variability (HRV), a non-invasive and easily accessible stress marker, to monitor and adjust each athlete's training to mitigate fatigue and avoid NFOR. This monitoring system may assist coaches in optimizing athlete performance throughout the season. The purpose of this study was to identify HRV trends in intercollegiate football players across the sport season, including pre-season camp.

Methods

Eight (four linemen and four non-linemen) NCAA DII football athletes completed this study. Resting heart rate (RHR), natural logarithm root mean square of successive differences (lnRMSSD), lnRMSSD covariance (lnRMSSDcv), vertical jump (VJ), and psychometric scores were obtained Monday-Thursday with a minimum of three recordings being averaged to represent a weekly value. Each HRV assessment (Polar H10 chest strap, EliteHRV app) were obtained between 6:30 am and 9:30 am before resistance training sessions and under fasted conditions. Recordings consisted of a 1-minute stabilization period followed by a 1-minute recording period. Measurements were taken at baseline, each week of pre-season camp, bi-weekly through the competitive season, and post-season. Maximal oxygen uptake (VO_{2max}) was assessed via McArdle Step Test at baseline, after pre-season camp, at mid-competitive season, and post-season. One-way repeated measures ANOVA and Pearson correlation (r) were used to identify statistical differences ($p<0.05$) and relationships between variables at baseline, pre-season, mid-season, and post-season.

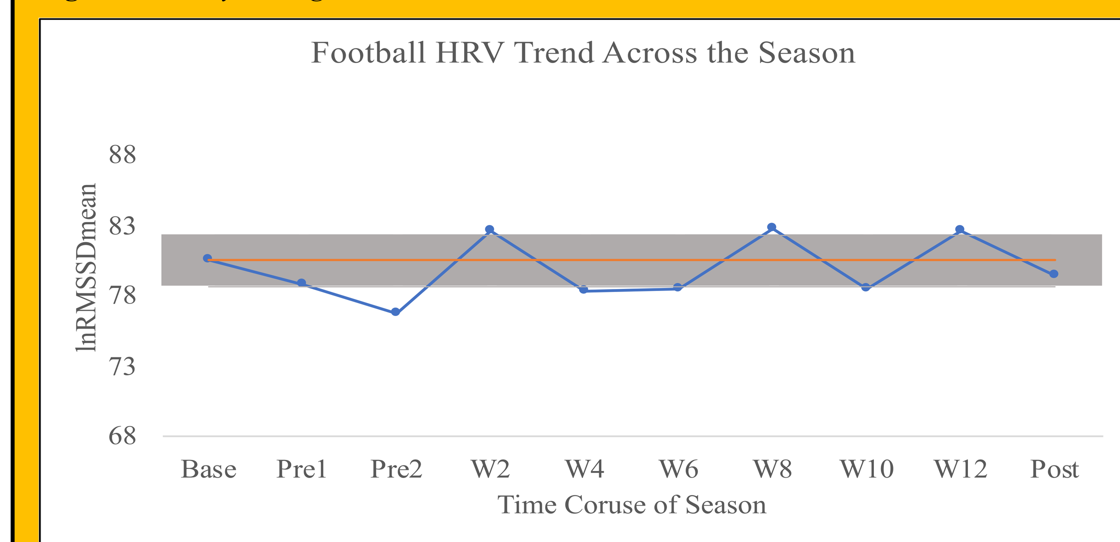
Table 1. *Competitive Season Game and Data Recording Schedule*

Week	Game	Home/ Away	Start Time	Estimated Travel Time	Win/Lose	HRV Recorded	VO_{2max} Recorded
Baseline	-	-	-	-	-	Y	Y
Pre1	-	-	-	-	-	Y	N
Pre2	-	-	-	-	-	Y	Y
1	-	-	-	-	-	N	N
2	1	H	6:00 p.m.	0	W	Y	N
3	2	A	6:00 p.m.	4 hours	L	N	N
4	3	H	6:00 p.m.	0	W	Y	N
5	4	A	6:00 p.m.	7.75 hours	W	N	N
6	5	A	1:00 p.m.	9 hours	W	Y	N
7	6	H	1:00 p.m.	0	W	N	N
8	7	H	12:00 p.m.	0	L	Y	Y
9	8	A	6:00 p.m.	4.75 hours	L	N	N
10	9	H	12:00 p.m.	0	W	Y	N
11	10	A	1:00 p.m.	2 hours	W	N	N
12	11	A	12:00 p.m.	5.5 hours	W	Y	N
Post	-	-	-	-	-	Y	Y

Note. Abbreviation Key: Home (H), Away (A), Win (W), Lose (L), Yes (Y), No (N).

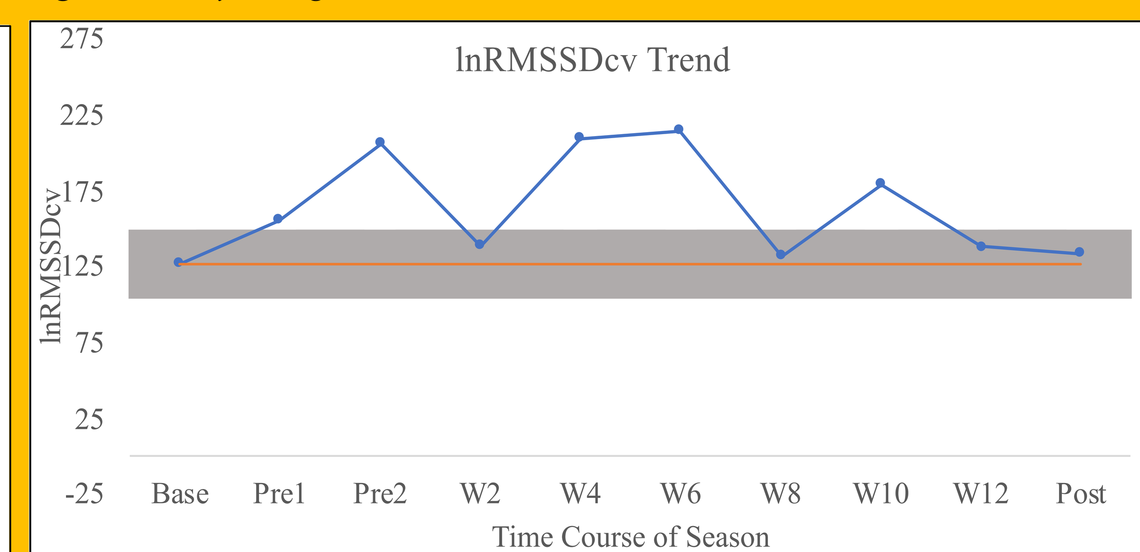
On weeks following long (> 4 hours) road games, rolling week lnRMSSDmean **declined** and lnRMSSDcv **increased** outside the SWC indicating increased **physiological stress and fatigue** resulting in the **decline** in the athlete's fitness capabilities.

Figure 1. *Weekly Average lnRMMSD Across the Season*



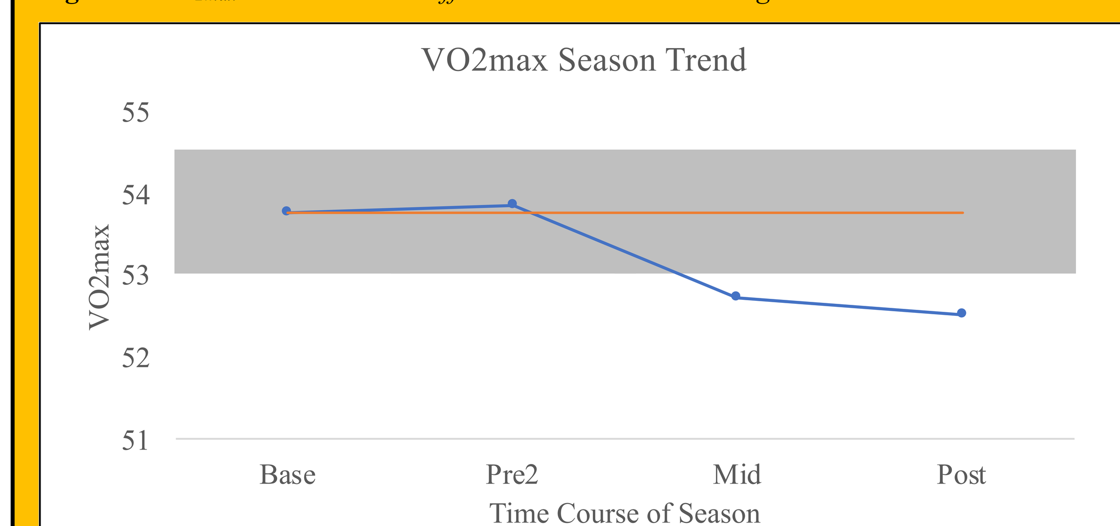
Note. The red line represents baseline value. The shaded region represents the smallest worthwhile change (±1.83676). lnRMSSDmean was multiplied by 20 to fit a 100-point scale.

Figure 2. *Weekly Average lnRMSSDcv Measures Across the Season*



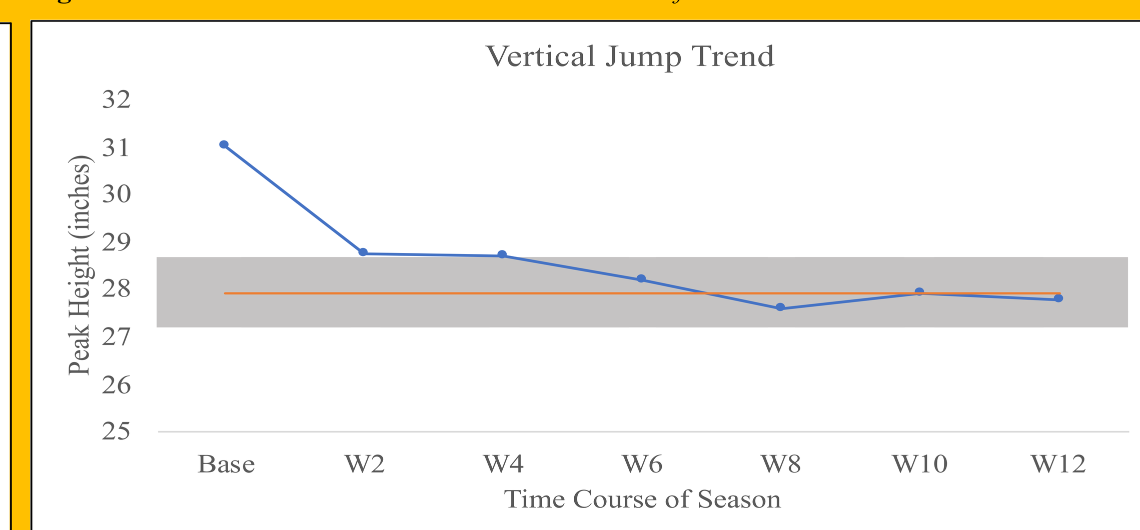
Note. The red line represents baseline value. The shaded region represents the smallest worthwhile change (±22.4042). lnRMSSDcv was multiplied by 20 to fit a 100-point scale.

Figure 3. *VO_{2max} Trend at Four Different Time Periods During the Football Season.*



Note. The red line represents baseline value. The shaded region represents the smallest worthwhile change (0.75659) from the baseline value.

Figure 4. *External Load Measurement to Monitor Performance Readiness.*



Note. The red line represents 90% of the personal best jump. The shaded region represents the smallest worthwhile change (0.742007412) from 90% of their best jump.

Practical Application

The addition of HRV assessment to a coach's current athlete monitoring system offers greater sensitivity in reading an athlete's fatigue status than other athlete monitoring methods to inform coaches on training decisions to accelerate recovery and avoid overtraining. Interpreting HRV trends may aid coaches in objectively planning weekly training loads following travel and/or adjusting travel itineraries to minimize performance decrements imposed by the accumulation of unmanaged stress. Sport performance coaches should aim for changes within the SWC of mean HRV values to manage sport- and non-sport-related stressors. Coaches should consider utilizing the covariance of HRV measures for greater sensitivity in detecting sympathetic stress response from sport- and non-sport-related stressors during the competitive season.

Training Recommendations

When HRV is suppressed for three consecutive days, one or more of the following training options may be considered:

- Short (≤ 30min), low intensity activity.
- A day of passive rest with no scheduled training.
- Cold-water immersion or other recovery modalities.
- Reducing planned training loads.
- Light or limited contact practice.

Results

The repeated measures ANOVA revealed no statistical significance ($p>0.05$) for lnRMSSDmean, lnRMSSDcv, RHRmean, soreness, feeling, vertical jump, and VO_{2max}. The repeated ANOVA did identify statistical significance for sleep time and sleep quality, however, post hoc Bonferroni identified no statistical significance ($p>0.05$) for any specific time point. lnRMSSD had a strong to very strong positive relationship with VO_{2max} ($r=1$, $p<0.001$), while VJ had a weak to very weak relationship with lnRMSSD ($r=0.05$-0.271, $p=0.556$-0.907) throughout the season. The relationship between HRV measures and psychometric scores throughout the season were unclear due to its inconsistency.

Table 2. *Baseline Correlations with HRV Measures*

	lnRMSSDmean	lnRMSSDcv	RHRmean
VO_{2max}	1	-0.809	-0.644
Vertical Jump	0.05	0.33	0.061
Soreness	-0.558	0.52	0.424
Feeling	-0.499	0.42	0.214
Sleep Time	0.359	-0.466	-0.306
Sleep Quality	-0.260	0.092	0.228

Table 3. *Pre-Season Correlations with HRV Measures*

	lnRMSSDmean	lnRMSSDcv	RHRmean
VO_{2max}	1	-0.319	-0.602
Soreness	-0.523	0.376	0.323
Feeling	0.843	0.132	-0.339
Sleep Time	0.106	-0.784	-0.352
Sleep Quality	0.386	0.589	0.309

Table 4. *Mid-Season Correlations with HRV Measures*

	lnRMSSDmean	lnRMSSDcv	RHRmean
VO_{2max}	1	0.36	-0.517
Vertical Jump	0.17	0.063	0.145
Soreness	-0.517	0.28	1
Feeling	-0.079	0.294	0.011
Sleep Time	-0.055	-0.172	0.465
Sleep Quality	-0.232	0.252	0.087

Table 5. *Post-Season Correlations with HRV Measures*

	lnRMSSDmean	lnRMSSDcv	RHRmean
VO_{2max}	1	-0.275	-0.606
Vertical Jump	0.271	-0.196	-0.554
Soreness	0.336	0.266	0.242
Feeling	0.562	0.266	0.068
Sleep Time	0.342	0.056	-0.390
Sleep Quality	0.561	0.429	0.125

Note. Thresholds used to quantify strength of relationship are coded on a color gradient, where the lightest shade of blue represents a very weak relationship (<0.2) and the darkest shade of blue represents a very strong relationship, (<0.8). Shades between the two extremes represent the following relationship strength; 0.2-0.4, weak; 0.4-0.6, moderate; 0.6-0.8, strong.

Conclusion

Increased fatigue was identified in the week following each long (>4 hours) road game. lnRMSSDcv showed greater sensitivity to game travel compared to lnRMSSD. The accumulation of fatigue identified by HRV measures aligned with the gradual decline in VO_{2max} across the season. HRV appeared to be a better indicator of fatigue than peak VJ height and the single-item psychometric questionnaire protocols that were previously used.

References

Borresen, J., & Lambert, M. I. (2008). Autonomic control of heart rate during and after exercise: measurements and implications for monitoring training status. *Sports Medicine*, *38*, 633-646.

Buchheit, M. (2014). Monitoring training status with HR measures: do all roads lead to Rome?. *Frontiers in Physiology*, *5*, 73.

Flatt, A. A., Allen, J., Bragg, A., Keith, C., Earley, R., & Esco, M. R. (2020a). Heart rate variability in college football players throughout preseason camp in the heat. *International Journal of Sports Medicine*, *41*(09), 589-595.

Flatt, A. A., Esco, M. R., Allen, J. R., Robinson, J. B., Bragg, A., Keith, C. M., Fedewa, M. V., & Earley, R. L. (2020b). Cardiac-autonomic responses to in-season training among division-1 college football players. *The Journal of Strength & Conditioning Research*, *34*(6), 1649-1656.

Flatt, A. A., Allen, J. R., Keith, C. M., Martinez, M. W., & Esco, M. R. (2021). Season-long heart-rate variability tracking reveals autonomic imbalance in American college football players. *International Journal of Sports Physiology and Performance*, *16*(12), 1834-1843.

Flatt, A. A., & Howells, D. (2022). Effects of long-haul travel and the Olympic games on heart-rate variability in rugby sevens medalists. *International Journal of Sports Physiology and Performance*, *17*(6), 951-960.

Iizuka, T., Kon, M., Maegawa, T., Yuda, J., Aoyanagi, T., Takahashi, H., Atomi, T., Shimizu, M., & Atomi, Y. (2020a). Comparison of morning heart rate variability at the beginning and end of a competition season in elite speed skaters. *Sports*, *8*(12), 164.

Lehmann, M., Foster, C., Dickhuth, H. H., & Gastmann, U. (1998). Autonomic imbalance hypothesis and overtraining syndrome. *Medicine and Science in Sports and Exercise*, *30*(7), 1140-1145.

Naranjo, J., De la Cruz, B., Sarabia, E., De Hoyo, M., & Domínguez-Cobo, S. (2015). Heart rate variability: a follow-up in elite soccer players throughout the season. *International Journal of Sports Medicine*, *94*(11), 881-886.

Plews, D. J., Laursen, P. B., Kilding, A. E., & Buchheit, M. (2013a). Evaluating training adaptation with heart-rate measures: a methodological comparison. *International Journal of Sports Physiology and Performance*, *8*(6), 688-691.

Plews, D. J., Laursen, P. B., Le Meur, Y., Hausswirth, C., Kilding, A. E., & Buchheit, M. (2014b). Monitoring training with heart-rate variability: How much compliance is needed for valid assessment?. *International Journal of Sports Physiology and Performance*, *9*(5), 783-790.

Stanley, J., Peake, J. M., & Buchheit, M. (2013). Cardiac parasympathetic reactivation following exercise: implications for training prescription. *Sports Medicine*, *43*, 1259-1277.