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Case Study

Insight into the Heart Rate Variability of a Recovering Female High Jump Athlete

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Abstract
Background: High jump is a sport that requires a superior level of musculoskeletal and biomechanical function. Athletes perform a countermovement jump during the take-off phase whereby utilizing muscle spindle activation. This autonomic response has been examined for its interplay with the cardiac autonomic nervous system. Cardiac autonomic modulation, as derived using heart rate variability (HRV) remains a useful index for practitioners examining the dose-response to exercise. **Purpose**: This case-study examined the daily cardiac autonomic response of a university female high jump athlete who completed a novel exercise program in the effort to regain her health and performance. **Methods**: This study involved 115 consecutive days of data collection from the month of December to April. A resistance training and cardiorespiratory exercise program was provided to the participant that involved a significant reduction in training volume and exercise intensity. **Results**: Reductions in resistance training volume and cardiorespiratory exercise intensity over 80 consecutive days elicited improved cardiac autonomic function. When resorting back to a traditional track and field exercise regime during days 80-115, cardiac vagal activity significantly decreased. **Conclusion:** HRV can support track and field athletes as well as coaches through identifying alterations in cardiac autonomic function and its interplay with health and performance.
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Introduction

High jump is a sport that requires a superior level of musculoskeletal and biomechanical function (Isolehto et al., 2007; Philpott et al., 2021). For this reason, high jump athletes regularly perform resistance training to enhance both muscular strength and neuro-muscular power. These attributes play a pivotal role towards supporting the take-off component of a jump. Both muscle strength and power can be achieved through an increase in hypertrophy or neuromuscular function (Deschenes & Kraemer, 2002). In addition to performing resistance training, high jump athletes regularly perform speed training, like that of track athletes. This style of training is directed towards enhancing the approach component prior to take-off. Together, resistance training and speed work place a significant stress on both the musculoskeletal and nervous systems (Ross et al., 2001). Thus, prescribing adequate recovery between sessions is essential for maximizing the dose-response to exercise to facilitate positive physiological and anatomical adaptations over time (Banister et al., 1992).

High jump athletes utilize a countermovement jump during the take-off to propel themselves in a horizontal and vertical direction. Muscle spindle activation has shown to be an important mechanism in a countermovement jump (Van Hooren & Zolotarjova, 2017). This component is often trained through using plyometric exercises (de Villarreal et al., 2009). The autonomic function of a muscle spindles discharge in response to lengthening, and its resulting contribution to enhancing a voluntary muscular contraction has been well examined in humans (Burke et al., 1978). Cardiac autonomic activity, a proxy of the autonomic nervous system (Variability, 1996) has been examined for its utility to represent peripheral autonomic function (Barker et al., 2022; Perrotta et al., 2024). These inquiries have failed to observe a significant association between peripheral and cardiac autonomic function. Nevertheless, cardiac autonomic modulation, as derived using heart rate variability (HRV) remains a useful index for practitioners examining the dose-response to exercise. Significant inverse associations have been observed between HRV and both resistance training volume (Marasingha-Arachchige et al., 2022) and high-intensity cardiorespiratory exercise (Stanley et al., 2013). The interplay between HRV and exercise stress allows practitioners to monitor an athlete's response throughout a microcycle to curtail the development of non-functional overreaching or over-training syndrome (Armstrong et al., 2022).

This case study examined a university female high jump athlete over a three-month period. The participant was suffering from soft tissue injuries in the anterior aspect of the hip due to overuse as diagnosed by an athletic therapist. As a result, they were not performing nor training within a varsity program. A clinical diagnosis of over-training syndrome from a medical doctor was not established at the start of the study. This case study examined the daily cardiac autonomic response of a university female high jump athlete who completed a novel exercise program in the effort to regain her health and performance.

Methods

Participants

This case study examined one female Canadian University high jump athlete. The participant provided written informed consent for their data to be analyzed, and ethical approval was obtained from the University Research Ethics board. The study adhered to the guidelines established by the Declaration of Helsinki and its later amendments.

Experimental Design

This case study involved 115 consecutive days of data collection from the month of December to April. All data was retrospectively analyzed.

At the commencement of this study, the objective of the participant was to return to their varsity program and begin competing injury-free within a 12-month period. A resistance training and cardiorespiratory exercise program was provided to the participant by a clinical exercise physiologist and a certified strength and conditioning coach. She was advised by both practitioners the novel exercise program provided involved a significant reduction in the weekly cardiorespiratory and resistance training volume. Comparisons between the participant's old and novel exercise programs are displayed in Table 1.

Table 1: Weekly Exercise Program of the Participant.

Day	Pre-Study Exercise Prescription	Novel Exercise Prescription
Monday	**Tempo Running Training** • Warm Up • Tempo Training • Abdominal Circuit • Hurdle Mobility • 20-minute cardiorespiratory exercise	**High Jump Training** • Warm up • High Jump Training • Cool-Down
Tuesday	**Speed Workout & Resistance Training** • Warm Up • Speed Exercises • Resistance Training (5 exercises | 3 sets/exercise | 6-10 repetitions) • 20-minute cardiorespiratory exercise	**Cardiorespiratory Training** • 1 hour Cycle Ergometer (75% HR max)
Wednesday	**High Jump & Cardiorespiratory Training** • Warm Up • High Jump Training • 1hr High Intensity Cardiorespiratory Training • Cool-Down	**High Jump Training** • Warm up • High Jump Training • Cool-Down
Thursday	**Speed Training** • Warm Up • Resistance Training • 20-minute cardiorespiratory exercise	**Cardiorespiratory Training** • 1 hour Cycle Ergometer (75% HR max)
Friday	**High Jump & Tempo Running Training** • Warm Up • High Jump Training • Tempo Running Training • 20-minute cardiorespiratory exercise	**Resistance Training** • Warm up • Whole Body Resistance Training program (3 Upper & 3 Lower body exercises | 3 accessory exercises | 3 sets/exercise | 6 repetitions) • Cool-Down
Saturday	**Resistance Training** • Warm up • Resistance Training (5 exercises | 3 sets/exercise | 6-10 repetitions) • 20-minute cardiorespiratory exercise	**Cardiorespiratory Training** • 1 hour Cycle Ergometer (75% HR max)
Sunday	**Cardiorespiratory Training** • Warm up • Mobility Exercises • Abdominal Circuit • 1hr High Intensity Cardiorespiratory Training • Static Stretching	**Cardiorespiratory Training** • 1 hour Cycle Ergometer (75% HR max)

The novel exercise program provided a resistance training program to increase her strength before transitioning to power development. All cardiorespiratory exercise within the novel exercise program was prescribed to be performed at a light exercise intensity that equalled aerobic threshold (ventilatory threshold-

1) as determined by a graded exercise test. Each cardiorespiratory session was performed using a heart rate monitor to ensure the appropriate exercise intensity was achieved. On day 80, the participant began increasing her resistance training volume in addition to starting a new track and field exercise program.

Methodologies Employed

The participant was allocated a POLAR H10 heart rate monitor and chest strap (Polar, Electro, Oy, Kempele, Finland) equipped to sample at 1000 Hz for the duration of the study. An ultra-short recording period (60-sec) of R-R intervals (ms) under spontaneous breathing (Esco & Flatt, 2014) was recorded immediately upon awakening each morning in the supine position. Beat-to-beat intervals were transferred via Bluetooth® technology to a smartphone application, Elite HRV (Elite HRV Inc., Asheville, NC, USA) for HRV analysis (Perrotta et al., 2017). Data filtering was automatically performed using a proprietary algorithm provided within the smartphone application. The square root of the mean squared differences of successive R–R intervals (rMSSD), was selected for examining parasympathetic activity based on its validity to represent resting cardiac vagal modulation (Variability, 1996), its resilience against respiratory sinus arrhythmia during spontaneous breathing (Penttilä et al., 2001), and when not accounting for menstrual cycle phase (Pestana et al., 2018) or oral contraceptive usage. Beat-to-beat intervals were analyzed and reported as R-R intervals (ms) as well as resting heart rate (bpm). All data collection procedures were standardized throughout the 115 day period to enhance intra-rater and inter-rater reliability when analyzing HRV (Perrotta & Gnatiuk, 2023).

Statistical Analysis

All data sets were analyzed for normality using a Shapiro-Wilk test prior to analysis ($p > 0.05$). Data was analyzed using Microsoft Excel®. Regression analysis was used to examine the association between training days and each cardiac index. Both linear and polynomial (2^{cd} degree) regression analyses were performed to assess the relationship between variables. The square root of the coefficient of determination (R^2) was calculated to derive a correlation coefficient (r) for interpreting the strength of association. The following principles were applied for identifying the strength of correlation; 0.10–0.29 small, 0.30–0.49 moderate, >0.50 large (Cohen, 1988). The typical error of each cardiac index was calculated using the first 10 days of the study period and is expressed as the coefficient of variation (CV %).

Results

115 consecutive data points were collected from December to April. The mean (± SD) for each cardiac index over the 155-day period were as follows: rMSSD = 74.4 ± 19.2 ms, R-R = 1131.9 ± 94.4 ms, and RHR = 53.3 ± 4.7 bpm. The range for each index was as follows: rMSSD = 32.0 – 124.0 ms, R-R = 878.7 – 1315.3 ms, and RHR = 46.0 – 68.0 bpm. The CV for each index was: rMMSD = 21.7%, R-R = 6.9% and RHR = 6.7%. Daily fluctuations in each cardiac index are provided in Figure 1 (a-c). Both R-R interval length and rMSSD values displayed a positive trend over the initial 80-day period, with a greater amount of values residing above the typical error compared to values residing below the

typical. However, between days 80-120, vagal activity displayed a negative trend resulting in most R-R intervals and rMSSD values residing below the typical error.

Both R-R and rMSSD values demonstrated a quadratic association over days 1-80. This relationship became linear from days 80-120 (see Figure 2).

Figure 1: Regression analysis examining the following associations: a) resting heart rate (RHR) and day number, b) root mean square of successive differences between consecutive cardiac cycles (rMSSD) and day number, and c) mean time period between successive cardiac cycles (R-R) and day number. Grey dotted lines represent the coefficient of variation for each index. Trend lines are provided using a 2cd degree polynomial. The black line represents an increase in training load.

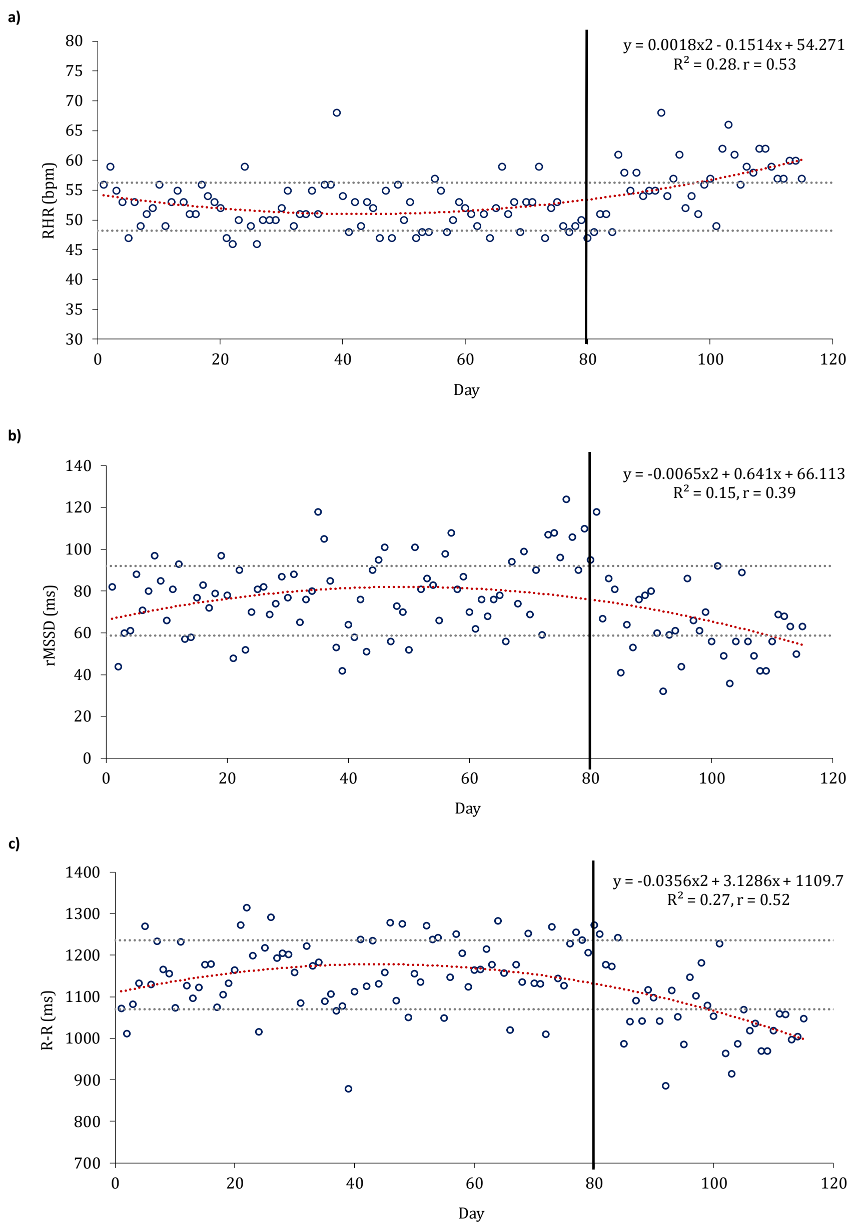
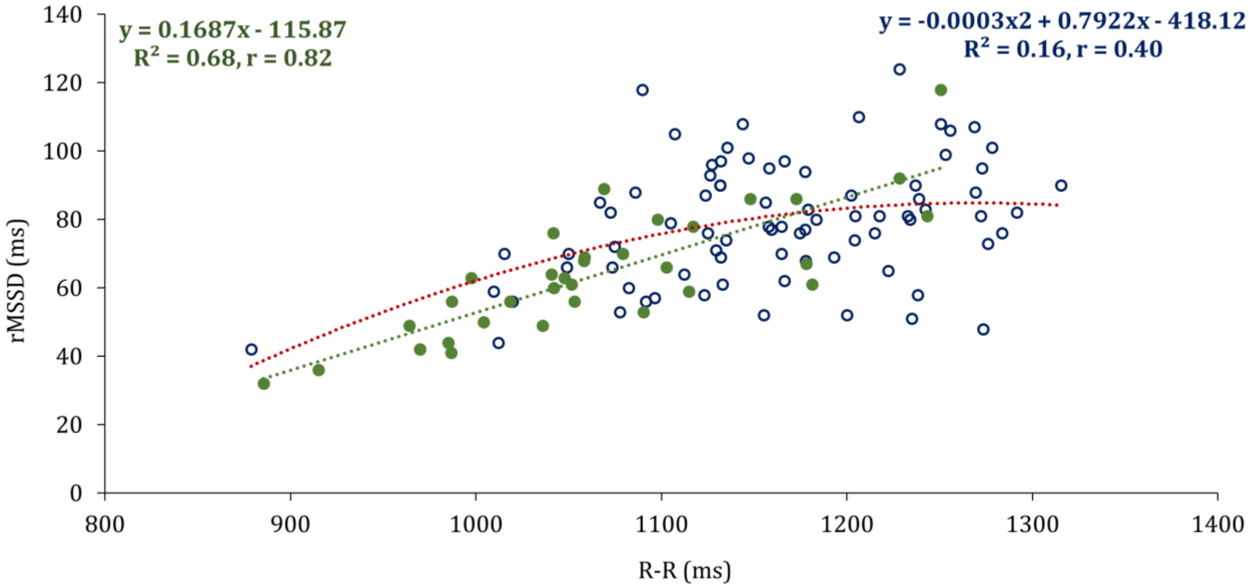


Figure 2: Regression analysis examining the association between the mean time of successive cardiac cycles (R-R) and the root mean square of successive differences between consecutive cardiac cycles (rMSSD). Green data points and trend line represent days 80 to 115 where training load was increased. Blue open data points and red trend line represent days 1 to 79 where training load was reduced.



Discussion

The purpose of this study was to analyze the daily cardiac autonomic activity in a recovering university female high jump athlete who participated in a novel exercise program. Data was retrospectively analyzed using 115 consecutive days from December to April. Our observations showed an improvement in both cardiac autonomic tone (R-R) and cardiac autonomic modulation (rMSSD) over the first 80 days (Figure 1a-c). This was in response to following a significant reduction in resistance training load and when performing only low-intensity cardiorespiratory exercise.

As displayed in Figure 1 (a-c), most data points for each cardiac index resided within the typical error. Moreover, there was a greater percentage of data points above the typical error than below it. Daily fluctuation in HRV is expected in response to varying exercise intensities as well as environmental factors. The large day-to-day variation in parasympathetic activity over days 1-80, is suggestive of a positive physiological response, whereby demonstrating a propensity to regain cardiovascular stability in a quick time frame (Plews et al., 2012). This hypothesis is further supported when observing the vagal tone to vagal modulation ratio (Figure 2). During days 1-80, similar R-R values displayed a high variability for a given rMSSD value. This association was best presented using polynomial regression. On day 80, the participant began increasing her resistance training volume in addition to starting a new track and field exercise program. This change elicited a significant reduction in each cardiac index. Between days 80-115, most data points resided below the typical error. Furthermore, we observed less variation in rMSSD for a given R-R interval, with this association being best expressed using linear regression. This evidence suggests she was unable to cope with the increase in exercise intensity, training frequency, and overall volume with the return to a typical track and field exercise program.

The participant was receiving rehabilitative care prior to and during the study period. However, within the first 80 days, she reported an improvement in symptoms from previous soft tissue injuries. This outcome may have been due to the combination of a reduction in high-intensity exercise and resistance training volume, enabling tissue recovery. Furthermore, this outcome may have consequently improved HRV due to enhanced physiological functioning as well as improved mental wellbeing (Aubert et al., 2003).

An athlete's psychological capacity to embrace new exercise regimes must be considered before implementing new strategies. This study examined a female university high jump athlete who was willing to perform a novel exercise program in the effort to regain excellence within her sport, as well as to improve her physiological well-being. The decision to implement previous training regimes at day 80 after seeing physiological and performance improvements may have been premature as evidenced by the decline in cardiac autonomic activity. This case study demonstrated HRV to be a sensitive proxy to the underlying physiological functioning of a female university high jump athlete. HRV may be a valuable index for practitioners when examining the dose-response to exercise regimes in university high jump athletes.

The ambition of this case study was to provide evidence of how the cardiac autonomic nervous system responds when altering traditional high jump exercise programs. HRV can support track and field athletes as well as coaches through identifying alterations in cardiac autonomic function and its interplay with health and performance. The utility of monitoring daily HRV in relation to daily exercise provides an evidence-based approach to designing exercise programs and monitoring the daily health of a high jump athlete.

Conclusions

Reductions in resistance training volume and cardiorespiratory exercise intensity over 80 consecutive days elicited improved cardiac autonomic function in a female university high jump athlete. However, when resorting back to a traditional track and field exercise regime during days 80-115, cardiac vagal activity significantly decreased.

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Authors' Qualifications

The authors' qualifications are as follows: Andrew S. Perrotta, B.A.Sc (hon), M.Kin, Ph.D., CEP, CSCS, USSF-C; Madelyn MF Eybergen, BSc (hons) candidate.

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