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Graduate Studies

HORMONAL AND PERFORMANCE RESPONSES TO A PEAK-TAPER CYCLE IN  
COLLEGIATE THROWERS

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the  
Degree of Master of Science

Alexandra Kern

College of Science and Health  
Clinical Exercise Physiology

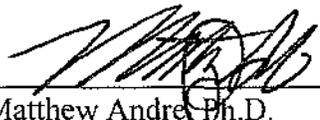
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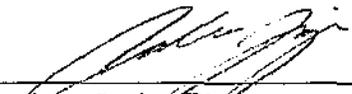
By Alexandra J. Kern

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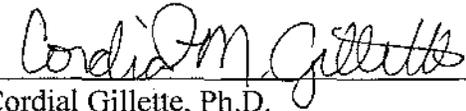
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Matthew Andre, Ph.D.  
Thesis Committee Chairperson

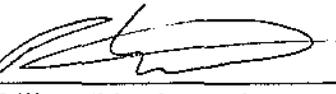
05/12/2016  
Date

  
\_\_\_\_\_  
Andrew Jagun, Ph.D.  
Thesis Committee Member

5/12/16  
Date

  
\_\_\_\_\_  
Cordia Gillette, Ph.D.  
Thesis Committee Member

5/12/2016  
Date

  
\_\_\_\_\_  
Philip Whitesitt, M.S.  
Thesis Committee Member

5/11/16  
Date

Thesis accepted

  
\_\_\_\_\_  
Steven Simpson, Ph.D.  
Graduate Studies Director

4/1/16  
Date

## ABSTRACT

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The purpose of this study was to monitor changes in performance and physiological markers in collegiate throwers across a training cycle. Four NCAA Division III male throwers reported once weekly for 8 consecutive weeks and were assessed for testosterone, cortisol, testosterone/cortisol ratio, training load, shot-put stand-throw, vertical jump height, estimated vertical jump peak power, broad jump distance, perceived recovery, and perceived lifestyle stress. Weekly sport-training volume and weekly resistance-training volume were recorded so that changes in these variables could be compared to changes in the other variables. Additionally, athletes were pre-post tested for body-composition. The main findings of this study demonstrated a trend for the athletes to respond directly to changes in training volume, so that increases in training volume led to decreases in recovery, and vice-versa, thus suggesting that recovery can be manipulated in collegiate throwers simply by altering total training volume so that throws, conditioning, and resistance-training all increase or decrease together. Since there was an improvement in competition performance from last season to this season in the returning athletes, and each athlete improved from the beginning of the season to the end without incidence of injury, it can be assumed that this was an effective training program.

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## INTRODUCTION

Testosterone (T) and cortisol (C) are steroid hormones that are produced in the body. Both together and separately, changes in these hormones have been measured in competitive athletes as potential symptoms of overreaching and/or overtraining (Fry & Hoffman, 2008; Goodman, 2009). The testosterone/cortisol ratio (T/C) is the amount of free (i.e. unbound) testosterone found in the blood or saliva sample divided by the amount of cortisol found in the same blood or saliva sample. The majority of the literature suggests a positive correlation between T/C ratio and an athlete's strength, power, and recovery status (Fry & Hoffman, 2008). Additionally, the T/C ratio has been used as an indicator of training stress in both acute and chronic exercise and training. Typically, as the training stress increases, T will increase or decrease slightly, while C will increase significantly. This typically leads to a decrease in T/C ratio. When a decrease in training load occurs, the T/C ratio typically increases and/or returns to baseline (Fry & Hoffman, 2008).

Researchers have attempted to evaluate the relationship between changes in T/C and changes in performance in anaerobic strength-power athletes, such as elite weightlifters. Haff et al. (2008) tested T, C, and T/C ratio in female elite weightlifters during an eleven-week training cycle. The results demonstrated that, when an elite weightlifter's volume-load increased, it resulted in a decrease in T/C ratio, which appeared to result in a decrease in force-production capabilities (Haff et al., 2008). In a study done by Wu, Hung, Wang, and Chang (2008), T and C serum samples from an elite

male weightlifter were evaluated across a 21-week preparation period leading into a major international competition. They (Wu, Hung, Wang, and Chang, 2008) found that testosterone generally increased throughout the cycle, but that a significant decrease in testosterone occurred when training volume increased. Cortisol increased significantly during high-volume training and continued to stay elevated for several weeks. These findings suggested that both testosterone and cortisol have chronic changes which indicate higher levels of stress during high-volume training, and it may take several weeks of reduced volume to correct this balance. Therefore, Wu et al. (2008) suggested that a greater decrease in training volume and longer taper may be needed for these particular athletes, and that T/C is a useful indicator for determining an individual's physiological recovery abilities.

Another study (Obmiński & Wiśniewska, 2008) observing male Olympic weightlifters looked at T, C, and T/C ratio and weightlifting performance. Throughout the study, all athletes exhibited a higher mean level of cortisol and lower mean level of testosterone. Contradictory to Wu et al. (2008) and Haff et al. (2008), Obmiński and Wiśniewska (2008) concluded that, despite negative changes in hormone concentrations, improvement in performance can still occur. As the literature appears to focus on elite weightlifters and recreationally-trained subjects, there are gaps which should be addressed with other populations. For example, research evaluating changes in T/C and performance in collegiate throwers is scant. One published abstract (Nelson et al., 2008) found significant correlations between changes in T, C, and T/C, changes in volume-load, and changes in physical performance in NCAA Division I male throwers. However, the performance measures were broad jump and isometric force production, which may be

related to throwing performance, but still do not indicate whether or not the athletes could throw farther. Additionally, testing was only done 3 times as opposed to weekly. To solve this discrepancy, further research is needed to address the relationship between changes in training load, hormone concentrations, and performance measures while also examining the influence of other contributing aspects of stress, including practice volume, resistance-training volume, and lifestyle stress across an entire training cycle in collegiate throwers. Therefore, the purpose of this study is to monitor changes in performance and physiological markers in collegiate throwers across a training cycle.

## **METHODS**

### **Experimental Approach to the Problem**

This observational study followed a repeated measures design and monitored collegiate throwers across an 8-week indoor season. The measured variables included training load, vertical jump height (VJ), estimated vertical jump peak power (VJPP), broad jump distance (BJ), shot-put stand-throw (throw), T, C, T/C, perceived recovery status (PRS), and perceived lifestyle stress. It was hypothesized that weekly changes in the measured variables would reflect the weekly changes in training load.

### **Subjects**

Four NCAA Division III male throwers (mean  $\pm$  SD; 106.2  $\pm$  12.4 kg, 1.88  $\pm$  .06 m, 19.5  $\pm$  1.0 yr; best shot-put: 13.99  $\pm$  1.33 m; best weight-throw: 15.95  $\pm$  2.03 m), participated in the study. Athletes signed informed-consent forms (previously approved by the University Institutional Review Board) to take part in this study. All athletes were members of the same team and followed the same training program with the same coach. The coach designed and implemented all throwing, resistance training, and conditioning workouts, with specific attention given to manipulation of volume (repetitions).

### **Protocol**

Athletes reported to Thursday practice as usual for 8 consecutive weeks and were instructed not to brush their teeth, eat, or drink anything other than water, for one hour prior to practice. At rest, subjects were given an oral swab (Salimetrics Oral Swab, Salimetrics, PA, USA) and asked to place it in their mouth for 2 minutes before releasing

the swab into a centrifuge tube (Swab Storage Tube, Salimetrics, PA, USA). Samples were stored at -80° C for later analysis. Saliva has been demonstrated to be a safe, non-invasive, valid, and reliable method for measuring T and C in athletes, and is very strongly correlated with serum concentrations (Papacosta & Nassis, 2011).

After each saliva collection, subjects were asked to complete one questionnaire, the Perceived Stress Scale (PSS), which attempts to quantify general life stress (Cohen, Kamarck, & Mermelstein, 1983). After saliva collection and completion of PSS, each subject performed their usual dynamic warm-up followed by three vertical jumps on a contact mat (Just Jump, Probotics, USA) with 1-minute rest periods between attempts. In an attempt to minimize technique requirements, each subject was asked to place their hands on their hips when performing the vertical jump. The best jump was used for analysis. Following vertical jump, each subject performed three broad jump trials. Broad jump was measured using an ordinary tape measure. Subjects were asked to start with their toes behind zero. Arm swings were allowed but no preparatory step could be used. Upon sticking the landing, distance was measured to the athlete's closest heel. Subjects were given one minute between jumps for recovery with the best broad jump used for analysis. Then, each subject performed a stand-throw test (throw) using a 7.26 kg shot. This test was used as a sport-specific test for the shot-put event that would involve throwing while minimizing the skill component of the event. Subjects were given three warm-up throws that were not recorded. Then, the PRS questionnaire was given to determine an individual's subjective recovery status (Laurent et al., 2011). Finally, the athletes performed three maximal-effort throws. The furthest of those three throws was used for analysis.

Weekly sport-training volume (number of throws, jumps, and sprints) and weekly resistance-training volume (repetitions) were recorded so that changes in these variables could be compared to changes in the other variables. Additionally, athletes were pre-post tested for body-composition, including the following variables: body-mass (BM), fat-mass (FM), fat-free mass (FFM), and percent body-fat (%BF). Body-composition testing was performed using air displacement plethysmography (BOD POD Gold Standard Body Composition Tracking System, COSMED, USA), which has been deemed a highly reliable and valid method for determining body composition in adult humans (McCrory et al, 1995).

For the salivary analysis, assay plates with samples, standards, and controls all added in duplicate, were read in a plate reader (Epoch, Biotek Instruments, USA). The minimal concentration that can be distinguished from zero with these assays (Salimetrics, PA, USA) is less than 0.03 nmol/L and 0.20 nmol/L for T and C, respectively. Correlations with serum T and C for these specific assays are very strong ( $r = .96$ ,  $p < .001$ ;  $r = .91$ ,  $p < .0001$ ; for T and C, respectively).

## STATSITICAL ANALYSIS

One-way (time) RM ANOVA (with partial eta squared ( $\eta_P^2$ ) effect sizes) were used to determine which weekly values differed from the previous week. Paired-samples *t*-tests (with Cohen's *d* effect sizes) were used to determine changes in body composition and other variables from preseason to the conference meet. Pearson correlations were used to determine the magnitude of relationships (*r*) between changes in weekly group averages for performance, training, and hormonal data. While *P*-values were calculated and reported to allow the reader to interpret the probability of a type-I error, we have chosen to focus on effect sizes (ES) and 90% CI, a solution which is gaining momentum in sport-science studies with necessarily small sample sizes and for research in general (Cohen, 1994; Drinkwater, 2008; Lehmann, 1993; Tomczak & Tomczak, 2014), with the goal of avoiding a type-II error. Based on currently accepted practices (Bakeman, 2005; Maher, Markey, & Ebert- May, 2013), we have chosen to evaluate ES in the following ways: when  $\eta_P^2$  is greater than .02, .13, .26, and .39, the relationship is described as small, medium, large, and very-large, respectively; when *d* is greater than .20, .50, .80, and 1.30, the relationship is described as small, medium, large, and very-large, respectively; when *r* is greater than .10, .30, .50, and .70, the relationship is described as small, medium, large, and very-large, respectively.

## RESULTS

Listed in order of effect size from greatest to least, there were very-large effects for group changes over time in VJPP ( $F(7) = 9.806, P < .001, \eta_p^2 = .766$ ), VJ ( $F(7) = 7.605, P < .001, \eta_p^2 = .717$ ), throw ( $F(7) = 6.065, P = .001, \eta_p^2 = .669$ ), BW ( $F(7) = 5.836, P = .001, \eta_p^2 = .660$ ), BJ ( $F(7) = 5.757, P = .001, \eta_p^2 = .657$ ), C ( $F(7) = 4.741, P = .003, \eta_p^2 = .612$ ), PRS ( $F(7) = 3.977, P = .006, \eta_p^2 = .570$ ), T ( $F(7) = 3.739, P = .009, \eta_p^2 = .555$ ), and T/C ( $F(7) = 2.875, P = .029, \eta_p^2 = .489$ ). There was a non-meaningful small effect for PSS ( $F(7) = .514, P = .814, \eta_p^2 = .146$ ), likely due to very high individual variability. Refer to Table 1 for weekly data, including weekly changes in total volume for the training program. Originally, repetitions for resistance-training, throws, plyometrics, and sprints were all measured and compared separately. However, the total of all of these repetitions were very-strongly correlated to each individual component ( $r = .98-1$ ), as each variable followed the same pattern for changes in volume. Therefore, only the total number of repetitions across training exercises was used for the sake of reducing redundant data.

For pre-post changes in body-composition, paired *t*-tests revealed very large effects for changes in FFM ( $t = -5.691, P = .011, d = 2.85, 90\% \text{ CI} = -2.51-(-1.04)$ ), %BF ( $t = 4.076, P = .027, d = 2.04, 90\% \text{ CI} = .25-.95$ ), and mass ( $t = -3.281, P = .046, d = 1.64, 90\% \text{ CI} = -2.36-(-.39)$ ), with a large effect for changes in FM with a relatively-high probability of a type-I error ( $t = 1.578, P = .213, d = .79, 90\% \text{ CI} = -.17-.87$ ). Refer to Table 2 for all body-composition data. There were very-large effects (listed in order of

largest effect size) for an increase in BJ ( $t = -10.598$ ,  $P = .002$ ,  $d = 5.30$ , 90% CI =  $-.14$ - $(-.09)$ ), an increase in BW ( $t = -9.574$ ,  $P = .002$ ,  $d = 4.79$ , 90% CI =  $-1.71$ - $(-1.04)$ ), an increase in VJPP ( $t = -6.246$ ,  $P = .008$ ,  $d = 3.12$ , 90% CI =  $-610.36$ - $(-276.30)$ ), an increase in VJ ( $t = -5.170$ ,  $P = .014$ ,  $d = 2.59$ , 90% CI =  $-6.69$ - $(-2.51)$ ), a decrease in C ( $t = 5.145$ ,  $P = .014$ ,  $d = 2.57$ , 90% CI =  $1.99$ - $5.35$ ), an increase in throw ( $t = -4.013$ ,  $P = .028$ ,  $d = 2.01$ , 90% CI =  $-.68$ - $(-.18)$ ), an increase in PRS ( $t = -2.480$ ,  $P = .089$ ,  $d = 1.24$ , 90% CI =  $-5.36$ - $(-.14)$ ), an increase in T/C ( $t = -2.194$ ,  $P = .116$ ,  $d = 1.10$ , 90% CI =  $-.372$ - $.013$ ), and an increase in T ( $t = -1.514$ ,  $P = .227$ ,  $d = .76$ , 90% CI =  $-.238$ - $.052$ ) from the start of pre-season to the conference meet. There was a non-meaningful small effect for group changes in PSS ( $t = -.195$ ,  $P = .858$ ,  $d = .10$ , 90% CI =  $-9.78$ - $8.28$ ), likely due to very high individual variability.

Pearson correlation coefficients revealed very large relationships between C and BJ ( $r = -.80$ ,  $P = .018$ ), T/C and PRS ( $r = .78$ ,  $P = .023$ ), VJ and volume ( $r = -.71$ ,  $P = .047$ ), VJPP and BJ ( $r = .70$ ,  $P = .054$ ), VJPP and volume ( $r = -.70$ ,  $P = .051$ ), BJ and throw ( $r = .72$ ,  $P = .044$ ), and BJ and BW ( $r = .94$ ,  $P = < .001$ ). Remaining correlation coefficients can be found in Table 3. Scores for PSS were removed from the weekly-average correlation analysis because the individual members were changing independently from each other and from the training program, as demonstrated in the RMANOVA data, which created nonsense relationships.

Table 1. Weekly Changes in Performance and Stress Variables (X±SD)

	<u>T1</u>	<u>T2</u>	<u>T3</u>	<u>T4</u>	<u>T5</u>	<u>T6</u>	<u>T7</u>	<u>T8</u>
T (nmol/L)	.462±.14	.624±.14*	.614±.18	.717±.18*	.800±.25	.640±.22*	.555±.07	.535±.10
C (nmol/L)	6.74±3.0	4.30±2.1*	4.21±1.9	3.37±0.9	4.80±1.7*	2.86±1.2*	3.07±1.9	3.51±1.5
T/C Ratio	.074±.02	.189±.13*	.172±.08	.219±.06*	.173±.03*	.239±.07*	.253±.18	.168±.06*
PRS	5.8±1.3	8.3±.5*	7.5±1.3	7.3±.5	8.3±.5*	7.8±.5	8.5±1.3	7.3±.5*
PSS	9.0±2.4	8.0±2.4	9.8±4.8	12.5±3.1	9.3±5.6	10.3±4.2	9.8±6.9	10.3±5.4
VJ (cm)	57.4±3.1	56.5±3.0	56.9±2.1	56.8±2.6	58.2±2.0*	58.7±1.5	62.0±2.6*	60.2±2.8*
VJPP (W)	6647±594	6579±659	6692±686*	6668±591	6802±644*	6837±698	7090±699*	6969±621
BJ (m)	2.53±.15	2.58±.09	2.63±.08*	2.63±.09	2.65±.15	2.67±.12	2.65±.23	2.70±.10
Throw (m)	11.49±.49	11.60±.45	11.44±.66	11.95±.51*	11.93±.79	12.19±.56*	11.92±.38*	11.93±.38
BW (kg)	104.5±13.1	104.6±13.1	106.0±13.1*	105.6±12.4	106.0±12.6*	106.0±12.7	106.0±12.9	106.2±12.4
Volume	656	524	600	668	642	432	434	362

\*Very-large effect for change from previous week

Table 2. Correlation Coefficients for Average Weekly Changes

	<u>C</u>	<u>T/C</u>	<u>PRS</u>	<u>VJ</u>	<u>VJPP</u>	<u>BJ</u>	<u>Throw</u>	<u>BW</u>	<u>Volume</u>
T	.29	.41	.55 <sup>†</sup>	-.29	-.16	.32	.39	.36	.36
C		-.93*	-.65 <sup>†</sup>	-.43	-.53 <sup>†</sup>	-.80*	-.69 <sup>†</sup>	-.68 <sup>†</sup>	.61 <sup>†</sup>
T/C			.78*	.41	.47	.63 <sup>†</sup>	.67 <sup>†</sup>	.55 <sup>†</sup>	-.45
PRS				.32	.37	.51 <sup>†</sup>	.40	.42	-.36
VJ					.98*	.56 <sup>†</sup>	.49	.53 <sup>†</sup>	-.71*
VJPP						.70*	.57 <sup>†</sup>	.69 <sup>†</sup>	-.70*
BJ							.72*	.94*	-.63 <sup>†</sup>
ST								.62 <sup>†</sup>	-.46
BW									-.43

\*Very-large relationship; <sup>†</sup>Large relationship

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Table 3. Pre-post changes in body-composition, performance variables, and salivary hormones

	Pre	Post	Change	<i>d, P [90% CI]</i>
Mass (kg)	104.5±13.1	105.9±12.9	1.4±.3	4.79, .002 [1.04-1.71]
Fat-free mass (kg)	82.4±4.7	84.2±5.0	1.8±.3	2.85, .011 [-2.51-(-1.04)]
Fat mass (kg)	21.2±7.9	20.9±7.6	0.3±.3	.79, .213 [-.17-.87]
Percent body-fat (%)	20.0±5.1	19.4±4.8	0.6±.3	2.04, .027 [.25-.95]
Standing throw (m)	11.49±.49	11.92±.38	0.43±.21	2.01, .028 [.18-.68]
Vertical jump (cm)	57.4±3.1	62.0±2.6	4.6±1.8	2.59, .014 [2.51-6.69]
Jump power (W)	6647±593	7090±699	443±142	3.12, .008 [276-610]
Broad jump (m)	2.53±.15	2.65±.13	0.12±.02	5.30, .002 [.09-.14]
Testosterone (nmol/L)	.462±.135	.555±.073	0.093±.123	.76, .227 [-.052-.238]
Cortisol (nmol/L)	6.74±3.02	3.08±1.93	-3.67±1.43	2.57, .014 [-5.34-(-1.99)]
T/C Ratio	.074±.017	.253±.175	0.180±.164	1.10, .116 [.013-.372]

## DISCUSSION

The main findings of this study demonstrated a trend for the athletes to respond directly to changes in training volume, so that increases in training volume led to decreases in recovery, and vice-versa, thus suggesting that recovery can be manipulated in collegiate throwers simply by altering total training volume so that throws, conditioning, and resistance-training all increase or decrease together. Since there was an improvement in competition performance from last season to this season in the returning athletes, and each athlete improved from the beginning of the season to the end without incidence of injury, it can be assumed that this was an effective training program.

The program started with relatively-high training volume, which was reflected in a negative hormonal profile, decrease in performance measures, and a decrease in PRS. When volume was reduced by 20% in the following week, there were large improvements in the hormonal profile and PRS, but none of the performance measures. This suggests that power performance requires more time to recover than the hormonal profile (i.e. improvements in the hormonal profile following a reduction in training volume may lead to delayed improvements in performance). The intentional taper, featuring reduced training volume, at the second half of the indoor season led to further improvements in the hormonal profile and performance measures.

Overall findings in this study were similar with the findings of Wu et al. (2008), Haff et al. (2008), and Nelson et al. (2008). Wu et al. (2008) and Haff et al. (2008) saw hormonal changes that responded to training volume in elite weightlifters (Huff et al.,

2008). Nelson et al. (2008) found strong correlations between salivary hormones and several physical performance variables, which appeared to be responding to changes in training volume, in collegiate throwers. In the current study, when volume increased, there was a decrease in jump performance and power and an increase in C, thus indicating that volume was a significant stressor in these athletes, and that volume manipulations could be used to manipulate performance and endocrine variables. Similar results were seen in Nelson et al. (2008) when throwers had an increase in training volume followed by a taper, leading to a hormonal and performance profile that reflected the programming decisions.

When comparing pre-post data, athletes showed an increase in mass and FFM with a decrease in %BF from preseason to the conference meet at the end of the indoor season. These results suggest that an increase in FFM is achievable across an indoor season, and could contribute to improved performance potential. In contrast, Kyriazis, Terizis, Karampatsos, Kavouras, and Georgiadis (2010) found that, across a season, FFM was unaltered in national-level shot-putters. However, those athletes were older ( $25.4 \pm 1$  yr) and more experienced than the athletes in the current study, so it is possible that increases in FFM are more common in developing collegiate throwers as opposed to older, more experienced throwers.

There were positive correlations between changes in BW and VJ, VJPP, and T/C ratio, with an inverse correlation between changes in BW and C, suggesting that collegiate throwers may be more recovered when they are heavier. It is unclear as to whether or not this was due to a reduction in training volume, an increase in dietary intake, or other factors. Similar results were found in shot put athletes that performed countermovement jump (CMJ) pre-season and after a 12-week training period (Kyriazis,

Terzis, Boudolos, & Georgiadis, 2009). These results lead to the belief that lower extremity muscular power is a good predictor of rotational shot put performance during competition season (Kyriazis et al., 2009).

Previous research (Uppal & Ray, 1978) shows a significant relationship between shot-put performance and broad jump. Similarly, there was a very-large relationship between changes in BJ and changes in stand-throw in the current study. Based off of these findings, changes in BJ could be used as a predictor of changes in throwing potential in collegiate throwers. Similar to Nelson et al. (2008), there was a very-strong inverse relationship between BJ and C, suggesting that changes in BJ could reflect changes in the hormonal profile in collegiate throwers.

Finally, there was a very-strong relationship between PRS and the hormonal profile, suggesting that the athletes' subjective perceptions of recovery matched their physiological recovery. Therefore, PRS could be a simple, inexpensive way to help monitor recovery in collegiate throwers. While PSS did not change as a group, there were large individual fluctuations. Therefore, when an athlete is not responding to a training program in the same manner as the rest of the team, it is possible that perceived stress is an independent variable that is affecting their recovery.

In conclusion, collegiate throws coaches should consider monitoring weekly jump power and performance, BJ, PRS, and PSS across a season to help monitor recovery. If a program has been designed to manipulate total training volume to alter recovery so that athletes are tired when they should be and fresh when they should be, then these monitoring variables can be used to assess if athletes are responding to the program as desired.

## REFERENCES

- Bakeman, R. (2005). Recommended effect size statistics for repeated measures designs. *Behavior Research Methods*, 37(3), 379-384.
- Cohen, J. (1994). The earth is round ( $p < .05$ ): Rejoinder. *American Psychologist*, 50(12), 997-1103.
- Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, 24, 385-396.
- Drinkwater, E. (2008). Applications of confidence limits and effect sizes in sport research. *The Open Sports Sciences Journal*, 1, 3-4.
- Goodman, H. M. (2009). *Basic Medical Endocrinology: 4th Edition*. Academic Press: Burlington, MA.
- Haff, G. G., Jackson, J. R., Kawamori, N., Carlock, J. M., Hartman, M. J., Kilgore, J. L., Morris, R. T., Ramsey, M. W., Sands, W. A., & Stone, M. H. (2008). Force-time curve characteristics and hormonal alterations during an eleven-week training period in elite women weightlifters. *The Journal of Strength & Conditioning Research*, 22(2), 433-446.
- Kuzmits, F. E., & Adams, A. J. (2008). The NFL combine: does it predict performance in the National Football League?. *The Journal of Strength & Conditioning Research*, 22(6), 1721-1727.
- Kyriazis, T. A., Terzis, G., Boudolos, K., & Georgiadis, G. (2009). Muscular power, neuromuscular activation, and performance in shot put athletes at preseason and at competition period. *The Journal of Strength & Conditioning Research*, 23(6), 1773-1779.
- Kyriazis, T., Terzis, G., Karampatsos, G., Kavouras, S., & Georgiadis, G. (2010). Body composition and performance in shot put athletes at preseason and at competition. *International Journal Sports Physiology Perform*, 5(3), 417-421.
- Laurent, C. M., Green, J. M., Bishop, P. A., Sjökvist, J., Schumacker, R. E., Richardson, M. T., & Curtner-Smith, M. (2011). A practical approach to monitoring recovery: Development of a perceived recovery status scale. *The Journal of Strength & Conditioning Research*, 25(3), 620-628.

- Lehmann, E. L. (1993). The Fisher, Neyman-Pearson theories of testing hypotheses: One theory or two? *Journal of the American Statistical Association*, 88(424), 1242-1249.
- Maher, J. M., Markey, J. C., & Ebert-May, D. (2013). The other half of the story: Effect size analysis in quantitative research. *CBE-Life Sciences Education*, 12(3), 345-351.
- Nelson et al. (2008). Hormonal markers and physical performance during a peak-taper cycle in elite track and field athletes. *Medicine and Science in Sports and Exercise*, 41(5), 336 (published abstract).
- Obmiński, Z., & Wiśniewska, K. (2008). Fluctuations of resting blood hormones levels and athletic performance in Olympic male weightlifters over a training period. *Research Yearbook*, 14(2), 99-102.
- Papacosta, E, and Nassis, GP. (2011). Saliva as a tool for monitoring steroid, peptide and immune markers in sport and exercise science. *Journal of Science and Medicine in Sport*, 14(5), 424–434.
- Uppal, AK and Ray, P. Relationship of selected strength and body composition variables to performance in shot put and javelin throw. *Snipes Journal*, 9: 34-38, 19.
- Wu, C. L., Hung, W., Wang, S. Y., & Chang, C. K. (2008). Hormonal responses in heavy training and recovery periods in an elite male weightlifter. *Journal of Sports Science & Medicine*, 7(4), 560.

APPENDIX A  
INFORMED CONSENT

# Informed Consent

**Project Title:** Monitoring Collegiate Throwers across a Season

**Principal Investigator:** Alexandra Kern  
509 N 12 St. Apt. 9  
La Crosse, WI 54601  
(608) 843-7942

**Emergency Contact:** Matthew J. Andre, PhD  
138 Mitchell Hall, UW-L 1725 State St.  
La Crosse, WI 54601  
(608) 386-5206

- ***Purpose & Procedure***
  - The purpose of this study is to monitor salivary testosterone, cortisol, and jump/throw performance in collegiate throwers.
  - My participation will involve arriving for regularly-scheduled practice and giving a saliva sample and a jump performance. Each collection should take 2 minutes.
- ***Potential Risks***
  - Saliva collection is non-invasive and the data will be kept locked and secured. Therefore, any risk should be minimal. This project is intended to “monitor” my training; therefore, no changes will be made to my training other than adding a jump to my warm-up, and no direct impact on my immediate performance should be expected.
- ***Rights & Confidentiality***
  - My participation is voluntary. I can withdraw or refuse to give a saliva sample or jump performance at any time.
  - I can withdraw from the study at any time for any reason without penalty.
  - The results of this study may be published in scientific literature or presented at professional meetings using grouped data only (no individual data will be revealed whatsoever).
  - All information will be kept confidential through the use of number codes. My data will not be linked with personally identifiable information.
- ***Possible Benefits***
  - I and other athletes may benefit by understanding how training impacts our hormonal status and physiological recovery. This information could possibly be used to adjust next year’s training to lead to improved future performance.

Questions regarding study procedures may be directed to Matt Andre, Department of Exercise and Sport Science, UW-L (608-386-5206), the principal investigator. Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects (608-785-8124 or [irb@uwlax.edu](mailto:irb@uwlax.edu)).

Participant \_\_\_\_\_ Date \_\_\_\_\_

Researcher \_\_\_\_\_ Date \_\_\_\_\_

APPENDIX B  
PERCEIVED STRESS SCALE

Name \_\_\_\_\_ Date \_\_\_\_\_

The questions in this scale ask you about your feelings and thoughts **during the last week**. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.

**0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often**

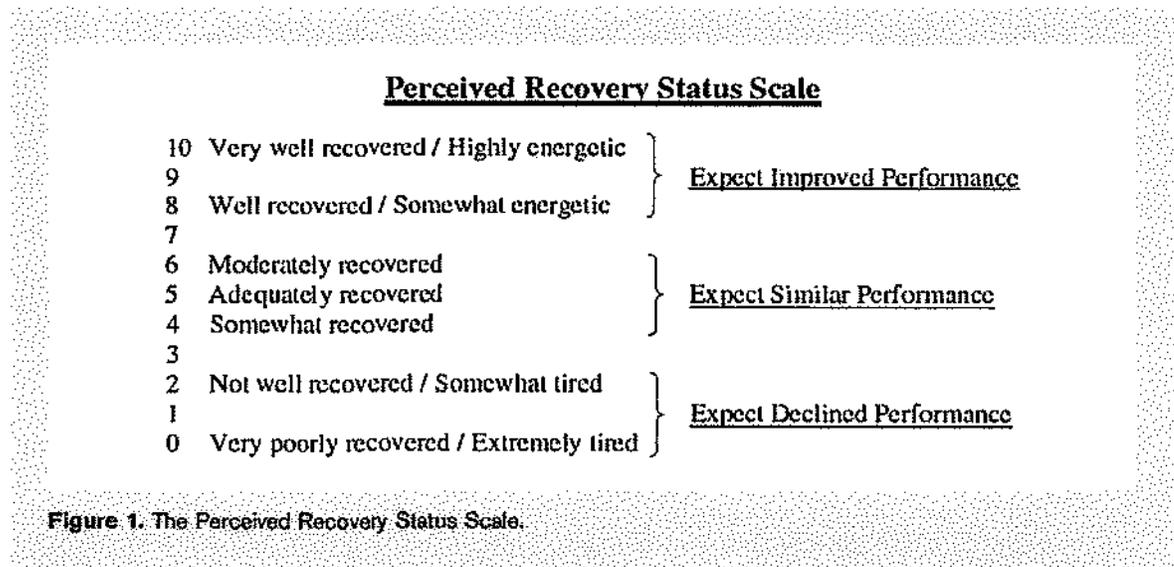
1. In the last week, how often have you been upset because of something that happened unexpectedly?..... **0 1 2 3 4**
2. In the last week, how often have you felt that you were unable to control the important things in your life? ..... **0 1 2 3 4**
3. In the last week, how often have you felt nervous and “stressed”? ..... **0 1 2 3 4**
4. In the last week, how often have you felt confident about your ability to handle your personal problems? ..... **0 1 2 3 4**
5. In the last week, how often have you felt that things were going your way?..... **0 1 2 3 4**
6. In the last week, how often have you found that you could not cope with all the things that you had to do? ..... **0 1 2 3 4**
7. In the last week, how often have you been able to control irritations in your life?..... **0 1 2 3 4**
8. In the last week, how often have you felt that you were on top of things?.. **0 1 2 3 4**
9. In the last week, how often have you been angered because of things that were outside of your control?..... **0 1 2 3 4**
10. In the last week, how often have you felt difficulties were piling up so high that you could not overcome them? ..... **0 1 2 3 4**

APPENDIX C

PERCEIVED RECOVERY STATUS SCALE

Name \_\_\_\_\_ Date \_\_\_\_\_

Please estimate your perceived level of recovery for today by circling one number on this chart:



**Figure 1.** The Perceived Recovery Status Scale.

APPENDIX D  
REVIEW OF LITERATURE

## **REVIEW OF LITERATURE**

This current review of literature covers testosterone, cortisol, the ratio of testosterone to cortisol, how these hormones are related to athletes, their relationship to collegiate throwers, and the measures of subjective stress and recovery related to these hormones. The review starts with a general introduction of testosterone and cortisol. The next section is on the testosterone to cortisol ratio and how these hormones are related to different athletes and performance. Last, there is a review of the research done on collegiate throwers and how subjective stress can affect athlete performance and hormonal markers, as well as suggestions for future research.

### **Testosterone**

Testosterone (T) is a steroid hormone, meaning it is synthesized from cholesterol. About 2% is considered free T; the remainder is bound to sex hormone-binding globulin (SHBG) or albumin (Fry & Hoffman, 2008; Goodman, 2009). Testosterone is the primary androgen in males, which stimulates and controls the development and maintenance of male characteristics. Primarily formed in the testis in males, to a lesser extent, T is also produced in the adrenal glands (Goodman, 2009). Women, on average, have been noted to produce about 10% of T compared to men, most of which is formed in the ovaries (Fry & Hoffman, 2008).

The testosterone response to endurance exercise is dependent on intensity and duration. During lower intensity exercises, there is little to no change in testosterone concentration. As intensity reaches maximum, there is a significant increase in

testosterone in the blood (Fry & Hoffman, 2008). As endurance exercise increases in duration, testosterone starts showing a biphasic response (Fry & Hoffman, 2008). Overall, testosterone has an inverse relationship with training stress; when training stress increases, testosterone concentration in the blood decreases (Fry & Hoffman, 2008).

Testosterone has been shown to increase during acute resistance training session. The most noticeable change can be seen when the weight-training session has at least a moderate training volume (Fry & Hoffman, 2008). A greater response is seen in testosterone levels when an individual utilizes large muscle-group, multi-joint, and high power exercises, for example, Olympic weightlifting movements (Fry & Hoffman, 2008). Time during acute resistance training sessions can also affect testosterone levels. Testosterone levels will often increase when there is a decrease in recovery period (Fry & Hoffman, 2008).

### **Cortisol**

Cortisol (C) is a steroid hormone that is secreted by the adrenal cortex. During times of physical and psychological stress, C is released to ensure there is enough glucose in the blood (Fry & Hoffman, 2008; Goodman, 2009). Cortisol plays an important role in maintaining carbohydrate availability through the process of gluconeogenesis. Cortisol is considered a catabolic hormone because it helps in the process of breaking down proteins to amino acids when the body needs energy (Fry & Hoffman, 2008; Goodman, 2009).

Cortisol is considered an intensity-dependent hormone. As endurance exercise load increases during acute or chronic bouts, cortisol levels increase dramatically (Fry & Hoffman, 2008). During low intensity exercise, cortisol might have little or no response but when exercise intensity is above 50% of an individual's maximal oxygen

consumption ( $VO_2$ ), cortisol increases due to the energy required to perform (Fry & Hoffman, 2008).

Cortisol has a similar response during acute resistance training. There is a greater response seen in cortisol during large, multi-joint, and high-power exercise (Fry & Hoffman, 2008). Cortisol concentrations increase when intensity and volume are increased. It is also typical to observe an increase in C when rest periods are shortened (Fry & Hoffman, 2008).

### **Testosterone/Cortisol Ratio**

The testosterone/cortisol (T/C) ratio is the amount of free or unbound testosterone found in the blood or saliva sample divided by the amount of cortisol found in the blood or saliva sample. Several studies suggest a positive correlation between T/C ratio and athlete's strength, power and recovery (Balsalobre-Fernández, Tejero-González, & del Campo-Vecino, 2014; Fry & Hoffman, 2008; Moore & Fry 2007). The T/C ratio is used as an indicator of training stress in both acute and chronic exercise and training. Typically, as the training stress increases, T will increase or decrease slightly, while C will increase significantly. This typically leads to a decrease in T/C ratio. When a decrease in exercise training load or tapering period begins, the T/C ratio increases and/or returns to original levels (Fry & Hoffman, 2008). Moore and Fry (2007) state the T/C ratio is a measure of total anabolic/catabolic activity taking place in the body.

When overtraining occurs, symptoms could remain persistent and prevent an athlete from competing for several months (Moore & Fry, 2007). There are two types of overreaching: functional and non-functional. Functional overreaching occurs when training stress is increased resulting in super-compensation. With proper recovery, an

athlete is able to recover with greater performance capability (Moore & Fry, 2007). Non-functional overreaching occurs when athletes still have trouble returning to baseline after reduced training load (Moore & Fry, 2007).

### **Testosterone/Cortisol Ratio: Monitoring in Athletes**

Several studies have observed changes in T/C ratio and its relationship to training stress and recovery; however there are many conflicting conclusions. Several studies involving long distance runners have found similar results. Hejazi and Hosseini (2012) studied thirteen endurance elite male runners for 14 weeks, with 12 training sessions per week. Blood samples were collected for levels of testosterone and cortisol during three phases: prior to the study, at the end of training (preparation) phase and before competition. Results found that the T/C ratio increased during the preparation and competition phase (taper). Cortisol levels decreased significantly during the preparation and competition phase, while testosterone levels increased during both the preparation and competition phase (Hejazi & Hosseini, 2012). Another study done by Houmard et al. (1990) observed elite, male long distance runners during training and reduced training phase. Blood samples were collected for analysis of testosterone and cortisol weekly. Results found that testosterone, cortisol, and T/C ratio did not change during reduced training.

Flynn et al. (1994) studied training stress during the competitive season in cross country runners and swimmers. Cross country runners had blood samples collected for hormonal analysis during increased training, prior to competition (pre-taper) and post competition (post-taper). Swimmers had blood samples collected for hormonal analysis during two training sessions, normal training and hard training, along with samples taken

before competition (pre-taper) and following competition (post-taper). Testosterone, cortisol and T/C ratio had no significant changes during training sessions in both swimming and cross-country subjects. Because there were no significant changes, Flynn et al. states this could be due to a training volume that was not large enough.

In a study done on rugby league players, biochemical, muscular strength, power and endurance measures were completed during an overtraining and taper cycle. Seven semi-professional rugby league players completed 6 weeks of progressive overload training with limited time to recover. Once the 6 weeks of overload were completed, a 7-day taper cycle followed. Several performance measures, along with blood samples, were taken prior to the overload period, immediately post-training, and after the 7-day taper. Results showed a significant decrease in T/C ratio during the progressive overtraining cycle but no T/C ratio changes were observed during the 7-day taper (Coutts, Reaburn, Piva & Murphy, 2007). Previous research supports a significant decrease in the T/C ratio during increased training stress and the ability to create a diagnosis of overtraining, however, testosterone and cortisol levels did not return to baseline following the taper cycle. Coutts, Reaburn, Piva and Murphy (2007) expressed the idea that the subjects potentially had an inadequate recovery and therefore T/C ratios remained unchanged. Therefore, more research may need to address the need for longer or more significant tapers.

Moore and Fry (2007) studied collegiate American football player's testosterone and cortisol levels during a 15-week off-season training program. Results found no significant changes in the T/C ratio during the overtraining and taper phases. Moore and Fry (2007) came to the conclusion that the training stress placed on the subjects did not

lead to overtraining and that the subjects recovered adequately. Although some of this research suggests that the T/C ratio is not affected by a taper, several studies do support the concept of monitoring competitive athletes during a taper. O'Connor, Morgan, Raglin, Barksdale and Kalin (1989) measured mood and salivary cortisol in female swimmers during an increase in volume training followed by training taper. The results found mood correlated with cortisol levels and training stress. As the athletes increased in training volume, cortisol levels increased significantly. Similar research was done with triathletes and monitoring T, C and T/C ratio during an intensified training cycle and taper. The triathletes T/C ratio increase dramatically during the two-week taper cycle (Coutts, Ballace, & Slattery, 2007). With non-functional overreaching, performance and hormonal markers return to baseline after taper without an improvement, leading Moore and Fry (2007) to suggest that T/C ratio may help determine the effectiveness of a peak-taper cycle.

Research has been done with anaerobic athletes as well, specifically elite weightlifters. Haff et al. (2008) specifically looked at female elite weightlifters and tested hormonal concentrations in addition to isometric and dynamic mid-thigh pull force-time characteristics during an eleven-week training cycle. The training consisted of core exercises that included, clean, clean and jerk and snatch, along with supplement exercises that included clean pull, snatch pull, squat, and front squat. Over the eleven-week study, significant differences were found in the T/C ratio depending on the weekly changes in volume-load (Haff et al., 2008). Haff et al. (2008) postulated that 67% of the athletes experienced suppressed preparedness due to a 30% or more decrease in their T/C ratio compared to baseline measurements. There was little change in T/C ratio when a

decrease in volume-load occurred, but the main findings suggest that, when an elite weightlifter's volume-load increases, it results in a decrease in T/C ratio, which appears to result in a decrease in force-production capabilities. This could be considered a marker for decreased readiness in female weightlifters (Haff et al., 2008).

Similarly, serum samples from an elite male weightlifter were analyzed for testosterone and cortisol over 21 weeks in a study done by Wu, Hung, Wang and Chang (2008). The study included the preparation, taper, and recovery period leading up to and following the World Championships. Results found that testosterone generally increased throughout the cycle, but a significant decrease in testosterone occurred when training volume increased. Cortisol increased significantly during high-volume training and continued to stay elevated for several weeks. These findings suggested that both testosterone and cortisol increase during high-volume training and cortisol can remain elevated for several weeks. Therefore, Wu et al. (2008) suggested that a greater decrease in training volume and longer taper may be needed for these particular athletes, and that T/C is a useful indicator for determining individuals' recovery. Last, a study done on male Olympic weightlifters looked at blood testosterone, cortisol, T/C ratio and weightlifting performance (Obmiński & Wiśniewska, 2008). Throughout the study, all athletes exhibited a higher mean level of cortisol and lower mean level of testosterone. Contradictory to Wu et al., (2008) and Haff et al. (2008), Obmiński and Wiśniewska believe despite hormonal levels, improvement in performance can take place and does not necessarily impair performance.

### **Testosterone, Cortisol, T/C: Relationships with Collegiate Throwers**

Although minimal research is done on collegiate throwers relative to measuring hormonal levels correlating with performance, Winchester (2009) collected saliva samples in five, male NCAA Division I throwers as part of a published dissertation. Salivary samples were collected following a two-week elevation in training volume and intensity along with salivary samples taken following a reduction in training volume and intensity of one week. Subjects were also tested for physical performance. This was measured using the broad jump and mid-thigh pull. Results found a significant correlation between testosterone and physical performance measures. There was a significantly negative correlation between cortisol and physical performance measures. Therefore, Winchester's (2009) study found that hormonal markers in testosterone, cortisol, and T/C ratio had a positive relationship with physical performance. However, they were unable to address competition performance or performance in training exercises that are directly-related to competition performance, such as the "stand-throw" for a shot-putter.

### **Measure of Subjective Stress and Recovery**

The perceived recovery status scale (PRS) was developed to monitor recovery and overtraining in athletes without using invasive or laborious techniques, such as lactate threshold and maximal oxygen consumption (Laurent et al., 2011). This numeric scale was based on the Rating of Perceived Exertion (RPE), with a rating from 0-10 that represents various levels of recovery an individual perceives (Laurent et al., 2011). Researchers took sixteen volunteers and had them perform four, separate bouts of high-intensity intermittent sprint exercises. Subjects were given the PRS scale after 24, 48,

and 72 hours of recovery after each high-intensity sprinting exercise. Results from the PRS scale were matched with performance to determine individual's recovery. The results did not have a great level of significance, but subjects were able to identify whether the training session would be improved or declined using the PRS scale with accuracy (Laurent et al., 2011).

The Perceived Stress Scale (PSS) was designed to measure the degree of stress in one's life, both at the global and event-specific level (Cohen, Kamarck & Mermelstein, 1983). The PSS is a questionnaire involving 14 items, where individuals should respond relatively fast and treat each question separately. Cohen et al. (1983) used the PSS scale in three different populations: two different college student groups and one group of participants in a community smoking-cessation program. Results found that the PSS was a better predictor than were life-event scores. The PSS is a practical way to measure an individual's appraised stress in life (Cohen et al., 1983).

Additionally, a study done by O'Connor, Morgan, Raglin, Barksdale, and Kalin (1989) found that mood could alter an athlete's physical training. O'Connor et al. (1989) took female college swimmers and studied salivary cortisol levels and mood state during a progressively increasing and decreasing training season. Mood was measured with the Profile of Mood States (POMS) questionnaire. The POMS assessed tension, depression, anger, vigor, fatigue, and confusion. Results for the study found a strong correlation between salivary cortisol and depressed mood during the overtraining phase. Separately, mood state in tension, depression, anger, vigor and fatigue increased during the overtraining and returned to baseline levels following the taper. Salivary cortisol

increased during the overtraining phase and returned to baseline, post taper (O'Connor et al., 1989).

### **Conclusion**

Previous research has looked at several different types of competitive athletes and how changes in training load and performance relate to changes in T/C, but little (if any) data is currently available measuring this relationship in NCAA DIII throwers. While it is plausible that NCAA DIII throwers will display a similar relationship as other types of athletes previously have, it is important to test this notion. By measuring hormonal concentrations in a non-invasive manner and doing sport-specific testing that is not additional beyond their normal training load, researchers can determine if any of these markers indicate whether or not throwers are recovering well. A clear relationship between training load, T/C, and a simple performance marker will help coaches monitor recovery in their athletes. Then, coaches can adjust training if it appears that some athletes need more or less training stress, which could potentially lead to greater performance and reduced injury and illness.

## REFERENCES

- Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, 24, 385-396.
- Coutts, A., Reaburn, P., Piva, T. J., & Murphy, A. (2007). Changes in selected biochemical, muscular strength, power, and endurance measures during deliberate overreaching and tapering in rugby league players. *International Journal of Sports Medicine*, 28(2), 116-124.
- Coutts, A. J., Wallace, L. K., & Slattery, K. M. (2007). Monitoring changes in performance, physiology, biochemistry, and psychology during overreaching and recovery in triathletes. *International Journal of Sports Medicine*, 28(2), 125-134.
- Flynn, M. G., Pizza, F. X., Boone Jr, J. B., Andres, F. F., Michaud, T. A., & Rodriguez-Zayas, J. R. (1994). Indices of training stress during competitive running and swimming seasons. *International Journal of Sports Medicine*, 15(1), 21-26.
- Fry, A. C., & Hoffman, J. R. (2008). Training responses and adaptations of endocrine system. *Conditioning for Strength and Human Performance*, eds. Chandler, T. J. & Brown, L. E.
- Goodman, H. M. (2009). *Basic Medical Endocrinology: 4th Edition*. Academic Press: Burlington, MA.
- Haff, G. G., Jackson, J. R., Kawamori, N., Carlock, J. M., Hartman, M. J., Kilgore, J. L., Morris, R. T., Ramsey, M. W., Sands, W. A., & Stone, M. H. (2008). Force-time curve characteristics and hormonal alterations during an eleven-week training period in elite women weightlifters. *The Journal of Strength & Conditioning Research*, 22(2), 433-446.
- Hejazi, K., & Hosseini, S. R. A. (2012). Influence of selected exercise on serum immunoglobulin, testosterone and cortisol in semi-endurance elite runners. *Asian Journal of Sports Medicine*, 3(3), 185.
- Houmard, J. A., Costill, D. L., Mitchell, J. B., Park, S. H., Fink, W. J., & Burns, J. M. (1990). Testosterone, cortisol, and creatine kinase levels in male distance runners during reduced training. *International Journal of Sports Medicine*, 11(1), 41-45.

- Laurent, C. M., Green, J. M., Bishop, P. A., Sjökvist, J., Schumacker, R. E., Richardson, M. T., & Curtner-Smith, M. (2011). A practical approach to monitoring recovery: Development of a perceived recovery status scale. *The Journal of Strength & Conditioning Research, 25*(3), 620-628.
- Moore, C. A., & Fry, A. C. (2007). Nonfunctional overreaching during off-season training for skill position players in collegiate American football. *The Journal of Strength & Conditioning Research, 21*(3), 793-800.
- Obmiński, Z., & Wiśniewska, K. (2008). Fluctuations of resting blood hormones levels and athletic performance in olympic male weightlifters over a training period. *Research Yearbook, 14*(2), 99-102.
- O'Connor, P. J., Morgan, W. P., Raglin, J. S., Barksdale, C. M., & Kalin, N. H. (1989). Mood state and salivary cortisol levels following overtraining in female swimmers. *Psychoneuroendocrinology, 14*(4), 303-310.
- Winchester, J. B. (2008). *The use of endocrine markers to predict and monitor performance in strength and power activities*. (Doctoral dissertation, University of Wisconsin–La Crosse).
- Wu, C. L., Hung, W., Wang, S. Y., & Chang, C. K. (2008). Hormonal responses in heavy training and recovery periods in an elite male weightlifter. *Journal of Sports Science & Medicine, 7*(4), 560.