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A CASE STUDY: EXAMINING STRENGTH AND PHYSIOLOGICAL VARIABLE CHANGES OVER ECP

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ABSTRACT

Objective: To document change in performance and hormone levels over the course of a one year training cycle in a professional CrossFit® athlete. The current study is the first to document changes resulting from a one-year training cycle in an extreme conditioning program. **Design:** Case control study. **Setting:** Data were collected following three periodized mesocycles across a one-year macrocycle in a clinical lab setting. **Participant:** A 28-year old male professional CrossFit® athlete. **Interventions:** Three distinct extreme conditioning mesocycles including preparation, first transition, and competition. **Main Outcome Measures:** Percent change in performance (i.e., aerobic capacity, hand grip strength, body composition, vertical jump and 1-RM deadlift, back squat, shoulder press, snatch, clean and jerk) and blood hormone levels (i.e., cortisol, insulin, testosterone, and human growth hormone) across training cycles. The relationship between motor fitness and blood hormone levels across the training year. **Results:** Performance variables increased between 1 to 20% during preparation, remained stable during maintenance, and actually decreased slightly during the competition cycle. Insulin and testosterone decreased during preparation with increases in cortisol, testosterone, and human growth hormone demonstrated during the competition cycle. Insulin and testosterone were strongly related to muscular strength and aerobic capacity, respectively across the macrocycle. **Conclusions:** Muscular strength and power increases across the macrocycle were consistent with periodized resistance training programs for elite athletes although there were fitness declines across the competition microcycle.

Keywords: Extreme Conditioning Programs; High Intensity Interval Training; Periodization; Training Cycles; CrossFit®

INTRODUCTION

High-intensity training (HIT) is a general term used to describe vigorous exercise programming (1). A variety of training programs fall under the HIT umbrella, with each consisting of a different training stimulus and/or goal. High-Intensity Interval Training (HIIT) is a program option that alternates vigorous aerobic training (i.e., 80-95% maximum heart rate) with active rest (i.e., 40-50% of maximum heart rate). The HIIT work:rest ratios are typically 1:1 and exercise/training stages can last 15 seconds to several minutes (2,3). This type of training program has been associated with important health and performance benefits, including improved aerobic fitness, insulin sensitivity, blood vessel health, and motivation (3,4). HIIT has also been shown to induce physiological adaptations that are consistent with long-duration endurance training despite the low total exercise volume (5,6,7,8).

Alternatives to aerobic-based HIT programs are referred to by a number of names, including body weight HIIT, resistance HIIT, or extreme conditioning programs (ECPs). For the purposes of clarity, we will use the term ECP for the remainder of the article. ECPs utilize resistance modes of exercise to target muscular, rather than primarily aerobic, fitness goals (4). Similar to HIIT, ECPs have the potential to deliver important training benefits such as improved cardiovascular health, metabolic function, and insulin sensitivity (9,1). Additionally, these programs have been shown to improve aerobic capacity and body composition among subjects of both sexes and varied fitness levels (10,11,12). A variety of commercial (e.g, CrossFit®, P90X) and non-commercial (e.g., plyometrics, boot camps) options fit this training description. However, compared with the volume of research conducted on strength and endurance training on sedentary and moderately trained individuals, little research has been conducted on elite athletes with regards HIT (13).

CrossFit® as an Extreme Conditioning Program (ECP)

CrossFit® is an example of an ECP that has gained in popularity over the past decade. This ECP has gained global attention for its type of successive high intensity exercises that target muscular strength and endurance improvement (14). CrossFit® training incorporates functional movements that individuals typically use in daily life and aims to improve the safety and efficiency of these movements. For example, squatting exercises are included in exercise programming because they are instrumental to sitting and standing, deadlifting exercises are included because the actions mimic picking items up; shoulder pressing movements are included because they are instrumental to putting objects above the head. Unlike most periodized resistance training programs, CrossFit® aims to prepare individuals for unknown and unknowable events, which is why its daily programming is non-linear (or, stated different, why the exercises and intensities are constantly varied; 15). This training impetus probably explains why this ECP has been incorporated by military and police programs (14). CrossFit® also aims to improve ten specific physical skills, namely cardiorespiratory endurance, stamina, strength, flexibility, power, speed, coordination, agility, balance, and accuracy (16).

As stated previously, limited empirical evidence exists on the effectiveness of ECPs for elite athletes, including CrossFit®. Therefore, it is no surprise that the Consortium for Health and Military Performance and the American College of Sports Medicine have called for empirical investigations of CrossFit® and other ECPs (1). Specifically, the consensus paper on this topic stated that research priorities involving ECPs should include the assessment of “the efficacy and magnitudes of increase (or decrease) in key performance metrics (e.g., functional strength, power and endurance, agility, mobility).” Therefore, the purpose of this study was to examine the changes in fitness across a training year in an elite (professional) ECP athlete.

Changes in Performance

“The science of training elite athletes is progressing rapidly, as insights into the physiological adaptations resulting from varying program configurations become available. Resistance training impacts several body systems, including muscular, endocrine, skeletal, metabolic, immune, neural, and respiratory. An understanding and appreciation of basic scientific principles related to resistance training is necessary in order to optimize training responses" (17). Considering limited evidence exists on the outcomes of ECPs in elite athletes, the researchers sought to examine performance changes across a competitive training year in an elite (professional) CrossFit® athlete. Additionally, since hormonal changes are associated to performance improvements in traditional resistance training, we assessed resting cortisol, insulin, testosterone, and human growth hormone at baseline and the end of each training cycle to determine if the endocrine adaptation response during ECPs was consistent to traditional resistance programming. To our knowledge, there have not been any published articles that have examined the changes in performance (i.e., motor fitness) or resting hormone variables across a periodized macrocycle of an elite CrossFit® athlete. Thus, the purpose of the current case study was to: 1) document changes in performance variables over the course of a one-year training cycle in a professional ECP athlete, and 2) examine how these changes related to hormonal changes across the same year.

MATERIALS AND METHODS

Participant

The athlete was a 28-year-old male who had just completed his fifth competition at the CrossFit Games. He placed second in his first CrossFit Games in 2010 and won the next four CrossFit Games of 2011, 2012, 2013, and 2014. Before CrossFit®, his athletic background was high school baseball for four years and high school football for one year. At the start of the study, the athlete was 69 inches tall and weighed 197 pounds at the beginning of testing. Institutional Review Board (IRB) and subject's consent were obtained prior to data collection.

Timeline

The subject was tested quarterly for a total of four times throughout the year of training (September 2014 through September 2015). Testing began one month following the athlete competing in the CrossFit Games for the fourth year in a row. The subject underwent a thorough blood analysis performed the morning of each testing day before the other tests. The subject fasted overnight before each blood draw testing date.

The tests for each testing day began at 9:00 a.m. The subject was tested for height, weight, grip strength, body composition, vertical jump, and $VO_{2\ Max}$. After a period of rest, 1-RM was assessed for the shoulder press, back squat, and deadlift exercises. Four days later, the subject was administered 1-RM assessments of the snatch and clean & jerk for the final test of each testing period.

Instruments & Administration Procedures

Demographics. The subject was weighed on an electronically calibrated scale to the nearest 0.01 kilogram. Height was measured by the Seca® 213 portable stadiometer to the nearest 0.1 centimeter with the subject standing flat footed while shoeless. Body Mass Index (BMI) was calculated by dividing body mass in kilograms by height in meters squared.

Body Composition. Percentage of body fat was determined using the hydrostatic weighing device. Prior to use, the water was heated to the designated temperature of 33 °C. The subject entered the water wearing only tight fitting compression shorts. Weight was measured underwater for a total of three trials.

Aerobic Capacity. The subject performed a $VO_{2\ Max}$ at the end of the morning data collection period. The Maskud and Coutts (1971) protocol (18) was used for each of the $VO_{2\ Max}$ tests. The subject went through a five minute warm up at 3.5 mph (5.633 kph) at 0% grade. The subject began the test at the five-minute mark. The speed was raised to 7.0 mph (11.265 kph) and the grade was raised 2.5% every two minutes. Heart rate was recorded each minute along with respiratory exchange ratio (RER). Rate of Perceived Exertion (RPE) was assessed every two minutes. A TrueOne® Metabolic Measurement System was used to assess VO_{2Max}

Muscular Strength. The subject dynamically warmed up for each lift. The deadlift, back squat, and shoulder press were all assessed through standard 1-RM assessment procedures within a one-hour period. Grip strength was tested with the Lafayette® hand-grip dynamometer test (HDT). Three trials were performed on the dominant hand and non-dominant hand, alternating hands each trial. The subject would first stand with the dynamometer to his side then bend his arm at 90-degrees and squeeze the dynamometer as hard as he could. The highest of the three trials was recorded as the grip strength.

Muscular Power. The snatch and clean & jerk were tested on a separate day from muscular strength testing but in the same week. Standard 1-RM protocols were used to assess both snatch and clean & jerk. Vertical jump (VJ) was assessed using a Vertec®. The subject performed a dynamic warm up to prepare for the VJ. The subject jumped from a standing position and reached to the highest marker on the Vertec®. The subject's vertical was measured to the nearest 0.25 in. (0.635 cm). The highest of three trials was recorded as the VJ.

Procedures

The athlete had a comprehensive blood analysis completed after each testing. Every workout the athlete completed following the first testing date was recorded for the entire training year. Being a case study, this design may help determine if it is possible for an elite athlete to improve over these various exercise variables while utilizing a periodized ECP training method.

Analysis

Percent change was used to analyze the improvement or decline on each performance and hormone variable across each training cycle and from baseline to the conclusion of the competition mesocycle. Correlation coefficients were used to examine the pattern between blood chemistry markers (i.e., cortisol, testosterone, insulin, and human growth hormone) and each performance variable across the training year.

RESULTS

Preparation Cycle

Scores improved on all performance variables with the exception of body composition (See Table 1 Below).

Table 1. Change in Performance Variables.

Variable	*Baseline*	*Preparation*	*First Transition*	*Competition*
Body Fatness (%)	4.13	8.33	4.13	4.13
$VO_{2\ Max}$ ($ml*kg^{-1}*min^{-1}$)	63	73.9	66.9	60.2
Muscular Strength				
Deadlift (kg)	243.7	258.5	258.5	251.7
Back Squat (kg)	199.6	215.5	215.5	215.5
Shoulder Press (kg)	86.2	95.3	95.3	93.0
Dominant Hand Grip (kg)	50	52	53	53
Non-Dominant Hand Grip (kg)	50	58	58	56
Muscular Power				
Vertical Jump (in)	31.5	32	33	34.5
Snatch (kg)	127.0	129.3	129.3	129.3
Clean & Jerk (kg)	154.2	156.5	165.6	165.6

Table 2. Percent Change (%) in Performance Variables.

Motor Fitness Variable	*Preparation*	*Maintenance*	*First Transition*	*Baseline to Competition*
Body Fatness	102	-50	0	0
$VO_{2\ Max}$	17	-9	-10	-4
Muscular Strength				
Deadlift	7	0	-3	4
Back Squat	8	0	0	8
Shoulder Press	11	0	-2	8
Dominant Hand Grip	4	2	0	6
Non-Dominant Hand Grip	16	0	-3	12
Muscular Power				
Vertical Jump	2	3	5	10
Snatch	2	0	0	2
Clean & Jerk	1	6	0	7

Gains ranged from 1% (clean & jerk) to 17% ($VO_{2\ Max}$; See Table 2 above). Strength increased 5-10% across test items with power exercises demonstrating a smaller response. Resting cortisol and HGH increased over the cycle whereas insulin and testosterone both decreased (See Tables 3-4 below). Total volume during this training period was 18.3 $hours*wk^{-1}$.

Table 3. Change in Blood Chemistry Values

Variable	*Baseline*	*Preparation*	*First*	*Competition*
Cortisol (ug/DL)	20	21	19	21
Insulin (uU/ml)	5.5	4.0	2.5	*
Testosterone (mg/dL)	544	467	484	597
Human Growth Hormone	.10	.23	.10	.21

*There was a reading error for the insulin measure on the final assessment.

Table 4. Percent Change in Blood Chemistry Values

Variable	*Preparation*	*Maintenance*	*First Transition*	*Baseline to Competition*
Cortisol (ug/DL)	5	-10	11	5
Insulin (uU/ml)	-27	-38	*	*
Testosterone (mg/dL)	-14	4	23	10
Human Growth Hormone	130	-57	110	110

*A laboratory reading error prevented an insulin score at the conclusion of competition mesocycle.

First Transition

Performance measures remained stable during this mesocycle with the exception of a decline in body fatness and $VO_{2\ Max}$. Training volume was increased during this mesocycle to 20.3 hours*wk^{-1}. There was a small improvement demonstrated on power measures (See Tables 1-2 above). Decreases in blood hormone values were present with the exception of an increase in testosterone.

Competition Cycle

The final mesocycle resulted in small decreases in performance scores. These decreases were larger than expected, possibly due to the extended tapering period required for the Open completion. Total training time consisted of 20.2 hours*wk^{-1}. Aerobic capacity continued to decline as well as muscular strength. Unlike the maintenance cycle, resting blood hormone levels increased.

Insulin was most related to strength and power scores across the macrocycle. Correlation coefficients exceeded -.85, indicating that insulin levels decreased as performance score increased. Testosterone was strongly related to both body fatness and aerobic capacity ($r \geq -.63$). Cortisol changes across the year were not related to motor fitness changes but resting human growth hormone levels were moderately-related to most variables.

DISCUSSION

The purpose of this study was to document change in strength and physiological variables over the course of a one-year training cycle in a professional ECP athlete. Three major findings are worth noting. One, muscular strength and power increases across the macrocycle were consistent with periodized resistance training programs for elite athletes. The current case demonstrated 5-10% increases in muscular strength, an outcome consistent with the 6-11% increases in upper- and lower-body strength scores across two-years of periodized training in professional rugby union players (19). Greater gains have been noted over two years of periodized training in professional volleyball players; however, the training age and baseline performance was significantly less than the current participant (20). Two, aerobic capacity increases were consistent with HIIT improvements despite use of varied anaerobic training modes rather than strictly running (2,3). Three, strength and aerobic capacity declined during the competition mesocycle, possibly reflecting the need to support ECPs with complimentary training options or enhanced recovery modalities (e.g., massages, foam rolling). Overall, ECPs may be an effective training program for elite athletes.

Preparation Cycle

The improvement in strength (5-10%) was consistent with elite athletes in a traditional periodized resistance training program (21,22). It is difficult for experienced athletes to increase muscular fitness because longitudinal training has brought an athlete closer to his/her genetic ceiling (23). Findings from the current study reflect the ability of ECPs to provide a meaningful training load and stimulus despite the reduced rest periods and non-linear design. It is important to note, however, that this mesocycle lasted approximately 18 weeks so caution is warranted when comparing to most preparatory cycles.

Distinct from traditional resistance training programs, however, was the 17% increase in aerobic capacity. For comparison purposes, competitive runners (initial $VO_{2\ Max}$ = 69.8 ml*kg^{-1}*min^{-1}) demonstrated a 6% increase in aerobic capacity following a one-year periodized training program (24). HIT programs, especially HIIT options, are recognized for their ability to improve aerobic capacity in addition to muscular fitness variables (2, 3). It has been shown that HIIT training does not necessarily need to be sport-specific (25). These authors documented a 10% increase in aerobic capacity across a training mesocycle that replaced cycle training volume with a shorter HIIT running mode. The large increase within a four-month mesocycle was unexpected considering the baseline score ($VO_{2\ Max}$ = 63 ml*kg^{-1}*min^{-1}) and reflects the high aerobic demand of ECPs. Even among elite athletes, it seems clear that ECPs can result in improved aerobic capacity during a preparatory training cycle. Finally, the increases in cortisol and human growth hormone with corresponding decreases in insulin and testosterone reflect the typical response to increased volume in a traditional resistance training program.

First Transition Cycle

Consistent with traditional aerobic and anaerobic programs, performance variables changed very little during the transition phase. This mesocycle lasted approximately 8 weeks and was associated with a decrease in body fatness which resulted from a one pound change in overall body weight. The subject's already extremely low body fat percentage can be altered by a minor change in body weight. This mesocycle also had typical responses of hormone levels to reduced training volume (See Table 3 above). However, aerobic capacity decreased, likely indicating that high volume of ECP training is necessary to maintain this performance variable. Based on the decline, complimentary aerobic training or enhanced recovery techniques may be necessary to maintain gains when the ECP volume is reduced to prevent overuse. It is important to note that CrossFit® competition requires athletes to qualify for the Open competition approximately 5 months before the competition. Therefore, the current athlete chose to maximize performance variables before the first qualification tryouts (February) and maintain adaptations through the end of the qualification period (transition mesocycle). Regardless, the sharp decline in aerobic capacity was both unexpected and possibly detrimental to performance.

Competition Cycle

The current competition mesocycle lasted approximately 22 weeks (from beginning of the Open competition to the CrossFit Games). Individual competitions typically have a tapering period of 7-14 days and result in significant improvements in both muscular strength (1-10%) and muscular power (5-25%; 26). However, in the current study, muscular power remained the same (with the exception of the vertical jump) and muscular strength decreased slightly (2-3%). These changes are consistent to the 2-3%

strength and power decreases demonstrated across a 13-week competition cycle among elite rugby union players (27). Current findings are also consistent with no change in power (as measured by vertical jump) across a competitive soccer season (28) and a 5% decrease in power demonstrated during a 7-week competition cycle using traditional resistance training among female volleyball players (29). Aerobic capacity decline during an extended competition mesocycle is also typical among competitive endurance athletes but the amount of decrease (10%) exceeded those for competitive endurance athletes (24). This difference; however, is not necessarily unexpected since the adaptation goal for the current participant was anaerobic rather than aerobic. Lastly, changes in hormone levels reflected the increased physical and mental stress of competition (See Tables 3-4 above). The study by Argus, Gill, Keogh, Hopkins, and Beaven, (27), reported greater increases in testosterone (54%) and cortisol (97%) following a competitive rugby union season with the multi-competition format likely explaining the greater change compared to the current single-competition participant.

ECP Macrocycle

Despite the decreases in strength and aerobic performance during the competition phase, performance over the training year increased for all performance variables with the exception of body fatness and aerobic capacity. Specific to body fatness, the current athlete had an extremely low level at baseline, making change in this variable unlikely. Specific to aerobic fitness, the athlete improved during the preparation phase but then returned to baseline by the conclusion of the macrocycle. Aerobic capacity decreases in competitive runners over time rather than increases. This decrease is accompanied by improved running economy and lactate threshold (30). Applied to the current findings, as technique and movement efficiency increase, a decrease in aerobic capacity for ECPs may not be necessarily problematic for an individual with a high baseline value. However, the inability of the athlete to maintain his improvement from the preparation cycle may reflect a need to complement ECP training with outcome-specific training (e.g., aerobic capacity). ECP athletes are encouraged to consider the ramifications of performance decreases over an extended competition cycle or to include restorative microcycles to help prevent large decreases.

Study Limitations

There are some limitations worth noting. One, competition mesocycle scores were collected one-week after the Open competition. Therefore, reported performance variables are likely lower than pre-competition values. The athlete, understandably, did not want to complete testing the week prior to competition. However, current competition mesocycle scores must be projected with caution as they are likely lower than peak ability during performance. Two, a lab reading score error resulted in no insulin score for the competition mesocycle. It is unclear how a fourth insulin measure would affect the correlation between this hormone and performance variables across the entire macrocycle. Regardless, resting level changes for cortisol, human growth hormone, and testosterone were consistent with changes demonstrated during periodized resistance training. Prior to the third data collection date, the athlete had completed an extremely rigorous workout which resulted in soreness significantly affecting the third $VO_{2\,Max}$. Also the last data collection day was affected by lack of motivation from the athlete as he had just completed the CrossFit Games two weeks previous to testing.

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CONCLUSIONS

Findings from the current case study reflect motor fitness improvements over the course of a non-linear extreme conditioning program macrocycle. Changes in motor fitness variables were consistent with adaptations documented for traditional aerobic and resistance training programs. However, the decline in aerobic capacity warrants training considerations when ECP volume is decreased.

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REFERENCES

1. Bergeron N, Nindl B, Deuster P, Baumgartner N, Kane S, Kraemer W, Sexauer L, Thompson W, O'Connor F. CHAMP/ACSM executive summary: High-intensity training workshop. Med Sci Sports Exerc. 2011.
2. American College of Sports Medicine. ACSM Information on high intensity interval training. [Internet].
3. Roy B. High-intensity interval training: Efficient, effective, and a fun way to exercise. ACSMs Health Fit J. 2013;17(3):3.
4. Kilpatrick M, Jung M, Little J. High-intensity interval training: A review of physiological and psychological responses. ACSMs Health Fit J. 2014;18(5).
5. Babraj J, Vollaard N, Keast C, Guppy F, Cottrell G, Timmons J. Extremely short duration high intensity interval training substantially improves insulin action in young healthy males. BMC Endocr Disord. 2009;9(3):1-8.
6. Gibala MJ, Little JP, MacDonald MJ, Hawley JA. Physiological adaptations to low-volume, high-intensity interval training in health and disease. J Physiol. 2012;590:1077-1084.
7. Gibala MJ, McGee SL. Metabolic adaptations to short-term high-intensity interval training: A little pain for a lot of gain? Med Sci Sports Exerc. 2008;36(2):58-63.
8. Little JP, Safdar A, Wilkin GP, Tarnopolsky MA, Gibala MJ. A practical model of low-volume high-intensity interval training induces mitochondrial biogenesis in human skeletal muscle: Potential mechanisms. J Appl Physiol. 2010;588(6):1011-1022.
9. American College of Sports Medicine. ACSM information on extreme conditioning programs. [Internet].
10. Smith MM, Sommer AJ, Starkoff BE, Devor ST. Crossfit-based high-intensity power training improves maximal aerobic fitness and body composition. J Strength Cond Res. 2013;27(11):3159-3172.
11. Tremblay A, Simoneau JA, Bouchard C. Impact of exercise intensity on body fatness and skeletal muscle metabolism. Metabolism. 1994;43(7):814-818.
12. Trilk JL, Singhal A, Bigelman KA, Cureton KJ. Effect of sprint interval training on circulatory function during exercise in sedentary, overweight/obese women. Eur J Appl Physiol. 2011;111(8):1591-1597.
13. Driller M, Fell J, Gregory J, Shing C, Williams A. The effects of high-intensity interval training in well trained rowers. Int J Sports Physiol Perform. 2009;4:110-121.

14. Weisenthnal BM, Beck CA, Maloney MD, DeHaven KE, Giordano BD. Injury rate and patterns among CrossFit athletes. Orthop J Sports Med. 2014;2(4).
15. Glassman G. The crossfit level 1 training guide. The CrossFit Journal. 2010:1-125.
16. Glassman G. What is fitness? The CrossFit Journal. 2002:1-11.
17. Kraemer WJ, Duncan ND, Volek JS. Resistance training and elite athletes: Adaptations and program considerations. J Orthop Sports Phys Ther. 1998;28(2):110.
18. Maskud MG, Coutts KD. Comparison of a continuous and discontinuous graded treadmill test for maximal oxygen uptake. Med Sci Sports. 1971;3(2):63-65.
19. Appleby B, Newton RU, Cormie P. Changes in strength over a two year period in professional union rugby players. J Strength Cond Res. 2012:26(9):2538-2546.
20. Sheppard JM, Nolan E, Newton RU. Changes in strength and power qualities over two years in volleyball players transitioning from junior to senior national team. J Strength Cond Res. 2012;26(1):152-157.
21. Baker DG, Newton RU. Adaptations in upper-body maximal strength and power output resulting from long-term resistance training in experienced strength-power athletes. J Strength Cond Res. 2006;20(3):541-546.
22. Davis WJ, Wood DT, Andrews RG, Elkind LM, David WB. Concurrent training enhances athletes' strength, muscle endurance, and other measures. J Strength Cond Res. 2008;22(5):1487-1502.
23. Fleck, S, Kraemer, W. Designing Resistance Training Programs. 4th ed. Human Kinetics; 2014.
24. Galbraith A, Hopker J, Cardinale M, Cunniffe B, Passfield L. A 1-year study of endurance runners: Training, Laboratory tests, and Field tests. Int J Sports Physiol Perform. 2014;9:1019-1025.
25. Støren Ø, Bratland-Sanda S, Haave M, Helgerud J. Improved VO2 max and time trial performance with more high aerobic intensity interval training and reduced training volume: A case study on an elite national cyclist. J Strength Cond Res. 2012;26(10):2705–271.
26. Bompa, T, Haff, G. Periodization Theory and Methodology of Training. Fifth ed. Human Kintetics Champaign, IL: Kendall/Hunt Publishing Company; 2009.
27. Argus C, Gill N, Keogh J, Hopkins W, Beaven C. Changes in strength, power, and steroid hormones during a professional rugby union competition. J Strength Cond Res. 2009;23(5):1583-1592.
28. Jajtner AR, Hoffman JR, Scanlon TC, Wells AJ, Townsend JR, Beyer KS, Mangine GT, McCormack WP, Bohner JD, Fragala MS, Stout JR. Performance and muscle architecture comparisons between starters and nonstarters in national collegiate athletic association division I women's soccer. J Strength Cond Res. 2013;27(9):2355-2365.
29. Newton RU, Rogers RA, Volek JS, Häkkinen K, Kraemer WJ. Four weeks of optimal load ballistic resistance training at the end of season attenuates declining jump performance of women volleyball players. J Strength Cond Res. 2006;20(4):955-961.
30. Jones. A. A five year physiological case study of an olympic runner. Br J Sports Med. 1998;32.