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Relationship of the SRSS Questionnaire with Physiological and Performance Measures

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Relationship of the SRSS Questionnaire with Physiological and Performance Measures

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of the requirements of the degree
Master of Science in Sport Science and Coaching Education
Concentration in Applied Sport Science

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by
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ABSTRACT

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The overall purpose of this thesis was to validate the SRSS questionnaire. This was accomplished by conducting a single investigation using eleven well-trained weightlifters with at least one year of competition experience. These weightlifters completed five testing sessions over the course of five microcycles leading up to a competition. Every testing session took place on Monday morning prior to regular training and included: hydration testing, SRSS questionnaire, blood draws followed by a standardized warm-up protocol and squat jumps with 0kg and 20kg. While the majority of SRSS recovery and stress items did not change with changes in volume-load or volume-load-displacement, emotional balance and lack of activation did correlate with changes in volume-load-displacement. Additionally, decreases in SRSS recovery items physical performance capability and emotional balance coincide with decreases in squat jump height and increases in cortisol following the first taper microcycle. The findings of this investigation partly support the SRSS as a monitoring tool for weightlifters.

DEDICATION

The author’s thesis is dedicated to anyone, past, present and future, who has started and complete a master’s thesis. As any of them will tell you, this is an exhaustive process. However, after everything the author has been put though to complete this thesis, he can only describe the entire process as, “Fun.”

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CHAPTER 1

INTRODUCTION

The goal of developing an annual training plan and subsequent program design is to enhance an athlete's performance beyond current levels. Planning involves progressive overload which is a process of gradually applying a greater stimulus to an athlete to attain a desired level of physical, physiological, psychological, and performance adaptations (Cunanan et al., 2018; DeWeese, Hornsby, M. Stone & M. H. Stone, 2015a, M. H. Stone, M. Stone & Sands, 2007). The overload stimulus, disturbs homeostasis and results in acute fatigue. Once fatigue subsides during recovery, the athlete will be able to express accrued adaptations from training (Meeusen et al., 2012). The extent of adaptation can be positively or negatively affected by more than just the training stress; non-training stressors such as work, school, social life and sleep can also affect an athlete's adaptation to training (Stone et al., 2007). The accumulation of these stressors can lead to maladaptation, such as non-functional overreaching, causing a temporary plateau in performance, or overtraining, which manifest as a decline in performance (Stone et al., 1991). Developing an annual training plan, using the principles of periodization, is the first step in preventing maladaptation's to training. However, because there are numerous outside stressors, advanced planning alone cannot fully prevent maladaptations. Only through continuous athlete monitoring of stress affecting the athlete's present state, as well as recovery from that stress, can a sport scientist or sport coach detect the early signs of non-functional overreaching and overtraining (Stone et al., 2007). With this early warning, coaches can adjust an athlete's training load and to try to prevent a performance plateau or decline.

Investigations have examined different indicators of maladaptation in an attempt to identify early warning signs. Prior studies have shown that vertical jumps can be used to monitor general athlete performance (Hornsby et al., 2017; Ostojić, 2009) as well as weightlifting performance (Häkkinen, Komi & Kauhanen, 1986; Hornsby et al., 2017; Carlock et al., 2004). Häkkinen et al. (1987), found that serum testosterone, testosterone/cortisol ratio and testosterone/Sex hormone binding globulin ratio would decrease during stressful training and a later study by Haff et al. (2008), found that the testosterone, testosterone/cortisol ratio was inversely related to weightlifting training volume. Investigators using mood state questionnaires and found that changes in perceived recovery and stress states correspond with changes in training load (González-Boto, Salguero, Tuero, González-Gallego, & Márquez, 2008; Kellmann, & G*ü*nther, 2000; Kellmann, Altenburg, Lormes, & Steinacker, 2001) and decreases in sport related athletic performance (Coutts, & Reaburn, 2008). A study by Morgan, Brown, Raglin, O'connor, & Ellickson, (1987) collected ten years of data with male and female swimmers and found that mood disturbances increased with training stress; however, as training was reduced, mood disturbances fell back to baseline. Coutts, Wallace, & Slattery, (2007) examined at performance, physiological, biochemical and psychological indicators and found that performance testing and mood state questionnaires were the most reliable indicators for athlete monitoring.

A 2012 survey conducted by Taylor, Chapman, Cronin, Newton, & Gill, found that 84% of professional and non-professional/elite programs, across a wide variety of sports, use self-reported questionnaires of regular monitoring. Follow-up questions in the study suggest questionnaires are often chosen because of their economical and practical means for monitoring. Early questionnaires used for athlete monitoring, such as the profile of mood states (POMS) (McNair, Lorr & Droppleman, 1992), daily analysis of life demands (DALDA) (Rushall, 1990) and the recovery-stress questionnaire for athletes (REST-Q) (Kellmann and Kallus, 2001;

Kellmann and Kallus, 2016), were too long to be repeated often enough for effective monitoring and do not reflect the athlete’s current recovery-stress state (Nicolas, Vacher, Martinent & Mourot, 2016). In response to these limitations both the acute recovery and stress scale (ARSS) and the short recovery and stress scale (SRSS) were conceived to provide a more streamlined measurement tool of the athlete’s recovery-stress state. While both the recovery and stress scales for the ARSS and the SRSS were correlated with REST-Q’s scales, the SRSS is the shortest and therefore most suited for continuous athlete monitoring (Nässi, Ferrauti, Meyer, Pfeiffer & Kellmann, 2017).

Although several experimental studies have shown the SRSS to be responsive to training load, convergent validity in an actual athletic setting has not been established between physiological and performance measures and the SRSS recovery and stress scales. The purpose of this study is to 1) determine the time course of changes in biochemical markers, jumping performance, and SRSS responses following an overreach microcycle and tapering period in a subset of weightlifters preparing for a competition, and 2) determine whether changes in training load correlate to changes in the SRSS questionnaire. To ensure pronounced variation in training load, measurements were performed during the planned overreach and subsequent taper prior to a competition. We hypothesized that 1) blood markers of training stress and SRSS stress scores would increase following the planned overreach and decrease following the taper, whereas jumping performance and SRSS recovery scores would exhibit the opposite pattern, and that 2) changes in training load would be positively related to changes in SRSS stress scores and inversely related to changes in SRSS recovery scores.

CHAPTER 2

REVIEW OF THE LITERATURE

The purpose of this review is to provide the reader a broad outline of training and monitoring practices used for strength and power sports with an emphasis on weightlifting. This review will include: basic concepts and training principles used when designing a periodized annual training plan, a review on periodization, the fitness phase and program design for resistance training and common indicators of maladaptation used in monitoring general strength and power athletes and including weightlifters.

Training Process

General Adaptation Syndrome

Around 1928, Hans Selye began to develop the theory of general adaptation syndrome (GAS), which describes the ability of an organism to adapt to stress throughout its lifetime (Cunanan et al., 2018; Selye, 1936; Stone et al., 2007). The GAS provides sport scientists and coaches a theoretical framework for the training process. General adaptation syndrome consists of three phases: alarm, resistance and exhaustion. The alarm phase represents an athlete's initial response to training stress, during which performance is negatively affected (Turner, 2011). The alarm phase sets in motion adaptive mechanisms, bringing about the resistance phase where the athlete either recovers to baseline or adapts to a higher state. This adaptation above baseline has been referred to as supercompensation. If the accumulation of stress is too excessive, the athlete enters the exhaustion phase. The exhaustion phase represents a state of non-functional overreaching or even overtraining. General adaptation syndrome can be applied to a single bout of exercise or to continuous training over a period of weeks or months (Cunanan et al., 2018; Stone et al., 2007).

Stimulus-Fatigue-Recovery-Adaptation

The stimulus-fatigue-recovery-adaptation (SFRA) model suggests that fatigue accumulates in proportion to the strength and duration of a training stimulus. Once the training stimulus is removed or reduced, the recovery process begins, enabling fatigue to dissipate and adaptations to occur (Stone et al., 2007; Turner, 2011). If a new training stimulus is not applied with sufficient frequency, detraining will occur and adaptations gained will be lost (Turner, 2011). It should also be understood that this concept is not limited to describing a single training response, but can also be applied to longer periods of time to produce long-term training adaptations. This long-term training adaptation can be observed when using concentrated loading of strength or strength endurance at the start of a mesocycle or peaking block. Once the athlete begins a low volume, high intensity training phase, performance can increase above initial values (Stone et al., 2007).

Fitness-Fatigue Paradigm

The fitness-fatigue model was proposed by bannister in 1982 (Bannister, 1991). Unlike the cause and effect relationship of GAS and SFRA, the fitness-fatigue model states that an athlete's preparedness is determined by the summation of positive (fitness) and negative (fatigue) responses to training stimulus (Stone et al., 2007). In general, the negative responses to training are large in magnitude and last for a relatively short period of time during recovery phases. This results in the initial decrease in preparedness during intense training. The positive responses to training stimulus are smaller in magnitude and last for a longer period of time. This manifests as a long-term improvement in athlete performance (Chiu & Barnes, 2003). Therefore, preparedness can be enhanced through strategies that maximize fitness and minimize fatigue during training such as a taper (Turner, 2011) or unload microcycle.

Periodization

Periodization is defined as, "the logical integration and sequencing of training factors into mutually dependent periods of time designed to optimize specific physiological and performance outcomes at predetermined time points' (Haff, 2016)." In the simplest terms, periodization is a way to organize training into specific timelines and fitness phases. The goals of periodization are to: elevate an athlete's performance at predetermined points of time, maximize specific physiological and performance adaptations, reduce the overtraining potential, and provide for long-term athletic development (Bompa and Haff, 2009).

Periodization Hierarchy

There are several interconnected levels that create an overall hierarchy of training, which must be considered when first constructing a periodized training plan (Haff, 2016). Each of these levels are established based upon the competition calendar and both long-term and short-term performance goals established by an individual athlete or team (Haff, 2016). In the end, periodization is simply a means to organizing a long-term training intervention but dividing and subdivided the program multiple times, into specific periods of time (Table 1) (Haff, 2015). The periodized training program can be subdivided into seven levels including: (1) multi-year plan, (2) annual training plan, (3) macrocycle, (4) mesocycle, (5) summated microcycle, (6) microcycle, and (7) training day.

Multi-year Plan

The upper most level of the periodization hierarchy is the multi-year plan. The multi-year plan is the least detailed training cycle within periodization (Haff, 2015). A multi-year plan is composed of 2 to 4 interconnected annual training plans. The central concept to a multi-year plan is to sequence an athletes training goals in a way to allow for long-term development at predetermined time points. This means, each annual training plan serves as a foundation for the subsequent annual training plan (Haff, 2016).

Annual Training Plan

The annual training plan encompasses a one-year outline of planned training and performance goals. Typically, an annual training plan will contain at least one macrocycle; however, there could be several macrocycles depending on the number of competition seasons there are within one year (Haff, 2015).

Macrocycle

A macrocycle is a large duration training cycle, that's duration is based a sport's competition calendar (Viru, 1986). Typically, a macrocycle should begin a few weeks following the last primary competition (World championship, National championship, etc.) and conclude a few weeks following the next primary competition. This means a macrocycle could last anywhere from approximately one year to half a year or even less (DeWeese et al., 2015a; Issurin, 2010; Viru, 1986). The construction of a macrocycle should follow a long-term training plan and goals designed, either for an individual athlete or team. If there is a conflict between the long-term training plan and the competition calendar, the first must be prioritized (Viru, 1986). The macrocycle is sub-divided into smaller training cycles known as a mesocycle (citations).

Mesocycle

A mesocycle, sometimes referred to as a stage (Issurin, 2008, 2010) or main adaptation cycle (Verkhoshansky, 1998a, 1998b), is a medium duration training cycle that can last several months (Haff, 2004a; Stone et al, 2007; Verkhoshasky & Siff, 2009) and consists of multiple blocks of summated microcycles (Stone et al., 2007). Mesocycles are typically divided into four different periods or fitness phases: general preparation, specific preparation (first transition), competition and Transition (second transition) (O’Bryant, 1982 DeWeese et al., 2015a, Stone, O'Bryant & Garhammer, 1981; Stone, O’Bryant, Garhammer, McMillan & Rozenek, 1982). However, in some instances, a mesocycle can focus on a single fitness phases (Stone et al., 2007). The number of mesocycles that occur in one year depend on the number of individual competitions (weightlifting, swimming, etc.) or number of competition seasons throughout the year (Verkhoshansky, 1998b). There could be as few as two mesocycles (Stone, 2016; Stone et al., 2007) or as many as seven (Issurin, 2008, 2010). With multiple mesocycles, the general preparation period will be the longest during the first mesocycle and should gradually decrease in length with each successive mesocycle that year. Simultaneously, with each successive mesocycle, the duration of the specific preparation and competitions periods should increase in duration (Verkhoshansky, 1998b; Issurin, 2010).

Preparatory Period

The preparatory period is the initial period when constructing a periodized training plan (Charniga et al., 1986a; Charniga et al., 1986b) and occurs when there are no competitions, focusing instead on accumulating a base level of conditioning to increase the athlete’s ability to tolerate more intense training in later phases (Haff, 2015). In classical periodization, the preparation period can be further subdivided into general preparation and specific preparation periods (Matveyev, 1981).

General Preparatory Period

The general preparatory period, sometimes referred to as an accumulation phase (Cunanan et al., 2018; Issurin, 2008, 2010), occurs during the initial portion of the preparatory period and focuses on the development of general physical base (Bompa & Haff, 2009). While this period is termed “general”, this period is not necessary general (i.e. exercise specificity) but less specific (Haff, 2004a). During the general preparatory period, volume is at its highest and intensity is kept low (Charniga et al., 1986a; Haff, 2004a). The volume of general preparatory exercises during this period is high, while the volumes of specific preparatory and competition exercises are low (Matveyev, 1981).

The primary goal of this period is to increase short-term endurance to will improve the athlete's physiological and psychological capacity to tolerate the demands of both higher intensity of training and competition (Charniga et al., 1986a; Haff, 2004a; Haff, 2004b; Bompa & Haff, 2009). Due to the fatiguing nature of high volume work compared to low volume work, emphasis on technique is kept low during this period of training (Charniga et al., 1986b). Competitions are also not advisable during this period of training (Bompa & Haff, 2009).

Specific Preparatory Period

The specific preparatory period, sometimes referred to as the first transition period (Stone et al., 1982) or transmutation phase (Cunanan et al., 2018; Issurin, 2008, 2010), occurs towards the end of the preparatory period and represents a transition from emphasizing physical development to emphasizing competition preparedness (Bompa & Haff, 2009). The volume of general preparatory exercises are reduced, while the volume of specific preparatory and competition exercises are increased (Matveyev, 1981). During the specific preparation period, the total volume of work is high; however, as this period of training progress, volume is progressively reduced while intensity is progressively increased (Charniga et al., 1986a; Haff, 2004a; Bompa & Haff, 2009). There is also a strong upward trend in technique during this phase; therefore, more emphasis is placed on specificity of movement to complement the biomechanical patterns of the athlete’s sport (Charniga et al., 1986a).

Competition Period

The competition period, occasionally referred to as the realization phase (Cunanan et al., 2018; Issurin, 2008, 2010), should stabilize an athlete's performance and bring performance to a peak through further decreases in volume and increases in intensity (Charniga et al., 1986a). Maintaining competitive preparedness during the competition period is a balancing act, as proper volume and intensity are needed to optimize performance. If training volume is reduced to much fatigue will dissipate, however, overall fitness will decrease to, leading to a decrease in overall competitive preparedness (Haff, 2015). During this period, time spent performing physical conditioning is decreased, while time spent practicing sport specific skills, tactics and techniques are dramatically increased (Charniga et al., 1986a). Like the preparatory period, the competition period can be divided into two subcategories: a peaking or maintenance phase. For sports where competition periods last anywhere from one day to two weeks, a peaking phase is utilized (Haff, 2015). A true peak, at most, can be maintained for three weeks (Charniga et al., 1986b). Attempting to prolong this type of training beyond a peak will lead to reduced fitness and could lead to overtraining (Bompa and Haff, 2009; Charniga et al., 1986b). A maintenance phase is typically required for team sports, were the competition period can last for many months (Haff, 2015).

Transition Period

The transition period, also known as second transition period or active rest (Stone et al., 1982), follows the competitive period and precedes the next preparatory period of a new mesocycle or macrocycle. During this period athletes enter the active rest phase sometimes referred to as the active recovery or restoration period (Charniga et al., 1986a; Haff, 2015). This period of training can last between one and four weeks (Bompa & Haff, 2009). If the active rest phase is prolonged beyond four weeks, the athlete will require a longer preparatory period to accumulate the needed base level of conditioning (Haff & Burgess, 2012). Because of this, Haff (2015) recommends no more than four weeks of active rest unless additional time is required for an athlete to recover from injuries.

Summated Microcycle

A summated microcycle, sometimes referred to as a block (Issurin 2008, 2010), is a group of microcycles that uses specific loading paradigms to achieve or maintain a specific adaptation (DeWeese et al., 2015a, Haff, 2004a). Summated microcycles can contain two to six microcycles but generally contain four microcycles (DeWeese et al., 2015; Haff, 2004a; Issurin, 2008; 2010; Stone and Plisk, 2003; Stone et al., 2007), which allows for the desired adaptations without accumulating excessive fatigue (Issurin, 2010). Several summated microcycles, who's primary focus is on different training characteristics, can be linked together to bring about a main adaptation prior to the a competition or competition season (Stone et al., 2007). Summated microcycles can also be repeated multiple times too continuously reintroduce a particular training characteristic throughout a mesocycle (Stone et al., 2007; Stone & Plisk, 2003). The use of summated microcycles create situations which allow for greater variation to be introduced within a mesocycle (Haff, 2016; Stone and Plisk, 2003).

Microcycle

A microcycle is a short duration training cycle that can last three to 14 days (McHugh & Tetro, 2003), but typically lasts one week (Bompa & Haff, 2009; Tuner, 2011). The microcycle consists of several training sessions which together form a repeatable training cycle (DeWeese et al., 2015a; Verkhoshansky, & Siff, 2009). The structure and type of a microcycle is dependent upon the focus of the larger training cycles and competition calendar (Matveyev, 1981). There are several different types of microcycles that can be organized into a summated microcycle (Table 2) (Bompa & Haff, 2009; Matveyev, 1981; Haff, 2016). The summation of several different types of training microcycles in table 2, can allows for additional variation within a summated microcycle.

Table 2.1: *Types of Training Microcycles*

Microcycle	Description
Ordinary	Microcycles that contain lower total volume preformed with sub-maximal training intensities. When several ordinary microcycles are summated together, they gradually and uniformly increase in total volume. This is seen when using step loading.
Shock	Microcycles that contain a sudden increase in total volume either by increasing repetition volume or training intensity. The number of training sessions can also be increased during a shock microcycle. These microcycles are sometimes referred to as concentrated loading or planned overreaching.
Introductory	Microcycles that can be used to establish or re-establish a fitness characteristic or skill. These microcycles elevate performance capacity.
Competitive	Microcycles that contain primary competitions set the official rules of the sport. This microcycle is focused on optimal performance as well as recovery from and preparation for future competitions. Training session within the microcycle are positioned depending on the number and placement of the competitions.
Rehabilitating	Microcycles that contain an overall reduction in total volume to induce recovery and reduce accumulated fatigue. These microcycles typically follow tough competitions or at the conclusion of a series of training microcycles.

Programming

While periodization forms the underlying strategies of an annual training plan, it is programming that lays out the fine details used in training athletes.

Summated Microcycle Model

O'Bryant (1982), published a hypothetical model of strength training, which included broad recommendations for training, based on the phase of training an athlete is preforming (Table 1). The set recommendations in Table 1, do not include warm-up sets. Later observations by Stone et al. (1982), narrowed the focus of O'Bryant and colleagues' original recommendations as it pertained to sets and repetitions. This included using 3-5 sets of 10 repetitions during hypertrophy, 3 sets of 5 repetitions during basic strength and 3-5 sets of 2-3 repetitions during strength-power phase. These paradigms, and the order they were placed, where the beginning of the concept of phase potentiation or the summated microcycle model.

The summated microcycle model uses both vertical integration and horizontal sequencing to organized training (Haff, 2016). Vertical integration is a concept by which multiple training factors are organized into a hierarchy where, primary emphasis is placed on a single training factor and secondary emphasis is placed on additional complementary training factors (Haff, 2016). Horizontal sequencing, also referred to as phase potentiation, is a way to logically organized primary training factors in such a way that physiological adaptations developed in one summated microcycle, potentiates further adaptations in subsequent summated microcycles (Haff, 2016; Stone et al., 1981; O'Bryant, 1982, Stone et al., 1982).

Table 2.2**:** *A Hypothetical Model of Strength Training*

	Preparatory Period		1st Transitional Period	Competition Period
Phase	Hypertrophy	Basic Strength	Strength and Power	Peaking or Maintenance
Sets	3-5	3-5	3-5	1-3
Reps	8-20	2-6	2-3	1-3
Day/Week	3-4	3-5	4-6	1-5
Times/Day	1-3	1-3	1-2	1
Intensity Cycle (weeks)	2-3/1	2-4/1	2-3/1	---
Intensity	Low	High	High	Very High to low
Volume	High	Moderate to High	Low	Very low

Table 2.2: Adapted from O’Bryant et al., 1982.

Exercise Selection

The types of exercise selected when designing a training program is equally as important as the information in Table 1. Both multiple- and single-joint exercises have been shown to be effective at increasing muscular strength in targeted muscle groups. Single-joint exercises are typically used to target specific muscle groups, are considered to pose less risk of injury due to reduced level of skill and technique required (Kreamer & Ratamass, 2004) and are consider less important to improving sport performance (Shepard & Triplett, 2016). Multiple-joint exercises are generally regarded as the most effective exercises for increasing muscular strength and power due to large muscle mass involvement, complex neural activation and coordination (Fleck & Kreamer, 1997; Stone, Plisk & Collins, 2002). Multiple-joint exercises also receive priority due to their direct application to sport (Shepard & Triplett, 2016). Multiple-joint exercises have also been shown to be affective at improving general athleticism. Strong correlations have been found between the back squat and both sprint times (Wisløff, Castagna, Helgerud, Jones & Hoff, 2004; Chelly, Fathloun, Cherif, Amar, Tabka, & Van Praagh, 2009; McBride, Blow, Kirby, Haines, Dayne & Triplett, 2009; Comfort, Bullock, & Pearson, 2012) and jumps height (Chelly et al., 2009; Hartman, Clark, Bemben, Kilgore & Bemben, 2012; Seitz, Reyes, Tran, de Villarreal & Haff, 2014; Wisløff et al., 2004). The high force, high velocity exercises preformed in weightlifting training programs have also been shown to improve sprint times (Hoffman, Cooper, Wendell & Kang, 2004; Tricoli, Lamas, Carnevale & Ugrinowitsch, 2005) and vertical jumps performance (Hoffman et al., 2004; Tricoli et al., 2005; Channell & Barfield (2008); Arabatzi, Kellis & De Villarreal, 2010).

Exercise Order

Exercise order is another important aspect of programming a training program. Kraemer & Ratamess (2004) recommend performing large muscle group exercises before small muscle group exercises, multiple-joint exercises before single-joint exercises (Stone and Wilson, 1985; Sforzo and Touey, 1996; Spreuwenberg, Kraemer, Spiering, & Volek, 2006) and power exercises, such as the snatch or clean, before basic exercises (Fleck & Kraemer, 2014; Spreuwenberg et al., 2006), such as the back squat or bench press. Power exercises require the highest level of skill and concentration of all the exercises and are most affected by fatigue (Fleck & Kraemer, 2014). Fatigued athletes, are prone to using poor technique and consequently are at higher risk of injury. The speed of movement and extensive muscular involvement of power exercises results in significant energy expenditure (Stone, 1986). This is another reason for athletes to perform power exercises first, while they are still metabolically fresh. However, exercise order does not always follow these recommendations. A review of the literature concluded that regardless acute or chronic responses, coaches should prioritize exercises based on the individual needs and training objectives of the athlete (Simao, De Salles, Figueiredo, Dias, & Willardson, 2012). Weightlifting coaches often place a high priority on increasing an athlete's maximal strength; therefore, back squats are sometimes performed at the start of training sessions. In support of this, when other exercises were performed at the start of a training session prior to back squats, the number of repetitions completed during a back squat declined significantly (Sforzo & Touey, 1996; Spreuwenberg et al., 2006).

Training Day

The number of sessions programmed in a single day can be pivotal to an athletes training. Häkkinen, Pakarinen & Kallinen (1992) and Häkkinen & Kallinen (1994) investigated the possible advantages of performing either one or two training sessions per day with equated volume. Significant increases were found in cross-sectional area (CSA) and in maximal voluntary strength when preforming two training sessions and no significant increases when preforming a single training session in the same period. While not statistical significantly, a similar study using national level weightlifter by Hartman, Clark, Bemben, Kilgore & Bemben (2007), found greater increases in muscle strength and resting testosterone during two per day session as compared to one session per day. These studies demonstration the need to use multiple training session in a day whenever possible.

Training Load

During the course of the training process, training load is intentionally manipulated to facilitate adaptations that enhance athletic performance. Training load is the combination of training intensity, repetition volume and frequency. External training load is used to describe the work the athlete performs, while internal training load is used to describe relative physiological and psychological response to the work they perform (Halson, 2014).

Estimating Volume in Resistance Training

Stone et al. (1999) describes volume as the amount of work performed per exercise. Work is defined as the product of force and displacement (W = F x d). Because work is proportional to energy used during resistance exercises, measuring work is useful in estimating energy consumption and training stress. Due to the nature of working with large groups of athletes at a time, reasonable estimates are needed. There are different methods of estimating total external training load in weightlifting.

The most basic method of calculating volume in resistance training is by calculating the total number of repetitions (Haff, 2010). However, the total repetition method (TR) assumes that 3 sets of 10 repetitions and 10 sets of 3 repetitions equal the same amount of work and training stress. McCaulley et al., (2009) equated work done with resistance exercises to investigate acute hormone and neuromuscular responses to hypertrophy, strength and power training sessions. By doing this, 4 sets of 10 repetitions at 75% of 1 repetition maximum (1-RM) and 11 sets of 3 repetitions preformed the same amount of work. Using TR would assume that these two set and repetition schemes do not equal the same amount of work.

Volume-load (VL) has been suggested as a better estimation of work performed with resistance exercise than the repetition method. Stone et al. (1999) calculates VL by multiplying the total number of repetitions by the mass lifted (VL = mass x sets x repetitions). The disadvantage of VL is that it assumes the distance a mass is moved is unchanged among different exercises.

Haff (2010) has suggested including barbell displacement when calculating VL to increase the accuracy of estimating work performed by an athlete. This concept of using displacement when estimating work was utilized by Stone et al. (1987), during an investigation using back squats An investigation using volume-load-displacement (VLd) was conducted by Hornsby (2013) and found that while the addition of displacement was not significantly different from VL, VLd did detect more modest alterations in training volume, especially when using large displacement exercises, such as the snatch or clean and jerk. Hornsby (2013) determined that in a non-laboratory settings (training hall, etc.) the benefit of including barbell displacement to VL calculations would have to be weighed against its disadvantage (measuring displacement for each athlete) by the strength and conditioning coaches monitoring their training sessions.

Normal Training

Normal training relies on using the overload principle. Overload is accomplished by providing the appropriate training stimulus to attain a desired level of physical, physiological, psychological and performance adaptations (Stone et al., 2007). If overload is not included in a training program, an athlete’s ability to make improvements is severally limited (Shepard & Triplett, 2016). The application of this principle in the design of resistance training programs involves increasing the total volume assigned during training. The intent is to apply a training session or program of greater intensity than the athlete is accustomed (Shepard & Triplett, 2016). Periodized, resistance exercise training programs typically use variations in either volume and/or intensity to elicit the desired performance adaptations (Stone et al., 1982). Other changes can include: increasing the number of sessions per week, adding exercises, and emphasizing complex over simple exercises, decreasing the length of the rest periods between sets and exercises, or changing the displacement of the exercise (Shepard & Triplett, 2016). When the overload principle is correctly applied to a training program, the desired adaptation can occur.

A microcycle is the shortest repeatable cycle in training and can repeated several times and grouped together to form a summated microcycle also referred to as a block (DeWeese, Hornsby & Stone, 2015b). Summated microcycles manipulate repetition volume and training intensity in such a way, leading toward achieving a specific goal (DeWeese et al., 2015a). Resistance training blocks, used to enhance strength, are typically arranged in a 3:1 loading paradigm. For the initial three microcycles, the volume is gradually increased until the fourth microcycle (Turner, 2011). This consistent increase in volume provides a training stimulus to an athlete, beyond the normal levels of their physical performance (DeWeese et al., 2015b). However, as volume is increased across these three microcycles, accumulated fatigue also increases, which can result in a performance decrease (Haff, 2004a).

Unloaded microcycles occur at the end of a resistance training block, where volume has consistently been increased to provide an overload stimulus. Significantly decreasing the volume during the final microcycle of a block permits fatigue to dissipate and promote the recovery-adaptations process (Haff, 2004a, Haff, 2004b, Stone and Plisk, 2003). This was observed in a study by Häkkinen, Kallinen, Komi, & Kauhanen (1991), which followed two microcycles of normal training with a third unloaded microcycle. This third microcycle was 33% less training volume than the preceding microcycle and allowed for a statistically significant increase in isometric force. Once the unloaded microcycle has been completed, the preceding training stimulus can be re-introduced to the athlete at progressively higher workloads (Haff, 2004a).

Intensified Training

Intensified training (INT) are periods of time were training volume has been increased above the standard overload typically used during normal training. The European College of Sport Science and the American College of Sports Medicine have categorized responses to training along a continuum depending on the balance between stress and recovery (Meeusen et al., 2013). If the training is intensified for several days or weeks, an athlete can reach a state of overreaching (Stone et al., 1991). In a joint statement by the American College of Sport Medicine and European College of Sport Science, overreaching was defined as: “an accumulation of training and/or non-training stress results in short-term decrement in performance capacity with or without related physiological and psychological signs and symptoms of maladaptation’s in which restoration of performance capacity may take from several days to weeks (Meeusen et al., 2013).

Overreaching is often used by coaches during a training program to enhance an athlete’s performance prior to an important competition (Meeusen et al., 2013; DeWeese et al., 2015b) These “planned” overreaching periods typically last for one microcycle and can be either referred to as a functional overreaching or as a non-functional overreaching based on the athletes performance outcome (Meeusen et al., 2013). During a planned overreach, INT results in a performance decline; however, when adequate recovery has been provided to an athlete, a supercompensation effect occurs, increasing an athlete’s performance above baseline levels (Meeusen et al., DeWeese et al., 2015). This delayed increase in performance indicates the overreach was a functional overreach. If an athlete’s performance remains depressed or only returns to baseline following recovery, the overreach was a non-functional overreach (Meeusen et al., 2013). For resistance training, planned overreaching involves a large increase in volume-load (VL). Planned overreaching has been studied, using experienced weightlifters and can range from 11% (Häkkinen, Pakarinen, Alen, Kauhanen & Komi, 1987) to 94% (Pistilli, Kaminsky, Totten & Miller, 2004) or even as high as 200% above normal training VL (Warren et al., 1992; Fry et al., 1993; Stone & Fry, 1998).

Reduced Training

Reduced training (RED) has been defined as a "non-progressive standardized reduction in the quantity of training (Mujika, 1998), which may maintain or even improve many of the positive physiological and performance adaptations gained with training (Neufer, Costill, Fielding, Flynn & Kirwan, 1987; Graves et al., 1988; Martin, Scifres, Zimmerman & Wilkinson, 1994; Mujika, 1998)." Reductions in training load can transpire over the course of several microcycles forming a taper. With resistance training, this reduction could be from: training intensity, training volume and frequency of training.

A taper is the final step of an athlete's training program and the success of that training program hinges on the tapers implementation and execution (Pritchard, Keogh, Barnes & McGuigan, 2015). A taper is defined as a progressive reduction in training load during a variable period of time before a major competition (Mujika & Padilla, 2003). Mujika, Busso, Lacoste, Barale, Geyssant & Chatard (1996) found that all physiological adaptations from the training stimulus are achieved before the start of a taper, producing improved performance levels as soon as accumulated fatigue dissipates and performance enhancing adaptations become apparent. The fitness-fatigue paradigm is often used to explain the mechanisms of how a taper improves an athlete's performance. The aim of a taper is to reduce the negative physiological and psychological impact of daily training rather than achieve further improvements in the positive consequences of training (Mujika & Padilla, 2003).

Periodization literature for strength training has recommended that during the peaking phase, that training intensity remain high while repetition volume be decreased (Stone et al., 1981; O'Bryant, 1982; Stone et al., 1982). Several tapering studies have shown increases in maximal strength are maintained or improved when intensities are kept high (Häkkinen et al., 1991; Zaras et al., 2014). Both Pritchards et al. (2015) and Mujika and Padilla (2003) recommend that training intensity be maintained to avoid detraining, provided that other training variables, such as training volume and/or frequency, be reduced. Mujika and Padilla (2003) concluded that moderately trained athletes can maintain training adaptations with low training frequencies of about 30-50% of pre-taper values. However, well- trained athletes should maintain training frequency, of above 80% of pre-taper values, while executing a taper. The need to maintain a normal frequency of training seems to be needed to avoid detraining and/or a "loss of feel" (Mujika, Goya, Ruiz, Grijalba, Santisteban & Padilla, 2002). In 2015 Pritchards and colleagues published taper recommendations specific for strength performance. Like Mujika et al., (2002), Pritchards and colleagues recommended maintaining training frequency unless necessary to attain the desired volume reductions. Additional recommendations included a reduction in training volume of 30-70% during the taper and a taper lasting at least one week and no more than four weeks using a step taper or a progressive taper.

Weightlifting Monitoring Indicators

Performance Measures

A 2012 survey of professional and non-professional/elite sports programs reported that 61% of respondents use some form of performance test as a part of regular monitoring (Taylor et al., 2012). Several methods have been proposed an ideal means to monitor weightlifting performance. The isometric mid-thigh pull has been used by many, to monitor weightlifting performance and is used to evaluate several variables such as isometric peak force and isometric rate of force development. Isometric mid-thigh pull variables have been strongly correlated to dynamic movements such as the 1-Repetition Maximum back squat, snatch and clean (Beckham et al., 2013; Stone et al., 2005). Vertical jump tests were identified as the most commonly used performance measure (Taylor et al., 2012) and have been used to evaluate general athletic ability (Ostojić et al., 2009) such as muscle power (Hartman et al., 2007; Chelly et al., 2009) and strength (Stone et al., 1979; Stone et al., 2003; Nuzzo et al., 2008; Chelly et al., 2009). Vertical jumps have been observed to have mechanical similarities to weightlifting movements (Canavan, Garrett & Armstrong, 1996; Garhammer, 1981) and has been proposed as a method of evaluating weightlifting performance (Carlock et al., 2004). A recent study by Travis, Goodin, Beckham, & Bazyler (2018), reported moderate to strong correlations between squat jump height and Sinclair total in male (r = 0.686) and female weightlifters (r = 0.487) in female weightlifters. Squat Jumps are consistently started at the same knee angle each time (Hornsby et al., 2017). This consistent knee angle removes the major contributions of the series elastic elements in the hip, knees and ankles, preventing changes in jump depth from changing jump height. Static jumps appear to be more sensitive to fatigue than countermovement jumps (Sams, 2014).

The force platform is known as the ‘gold standard’ for testing vertical jumps (Cronin, Hing, & Mcnair, 2004; Giroux, Rabita, Chollet & Guilhem, 2015; Linthorne, 2001). Several studies involved in measuring jump height have used a combination of the film analysis method and the flight time method (Kibele, 1998; Luhtanen & Komi, 1978; Bobbert, Mackay, Schinkelshoek, Huijing & van Ingen Schenau, 1986; Komi & Bosco, 1978). The film analysis method in these studies used data from Dempster’s center of gravity model (Dempster, 1955) to calculate center of gravity displacements for test subjects. When performing vertical jumps on a force platform, jump height can be estimated using the flight time method. This method assumes that an athletes center of mass at the instant of takeoff and landing is at the same height (Linthorne, 2001). This assumption causes the true jump height to be overestimated. Komi and Bosco (1978) found that the displacement data gave an error of ± 2.0 percent for the computation from the platform when compared to film analysis method and Kibele (1998) found that flight time method overestimated jump height by 0.5 to 2 cm. If the test subject employs arm swing during a vertical jump, the difference between center of mass at takeoff and landing will be even more pronounced (Linthorne, 2001).

Prior studies have shown that vertical jumps can be used to monitor weightlifting performance as they are strongly correlated (Hakkinen et al. 1986; Carlock et al. 2004). Many studies have investigated the change in jump height during periods of INT and RED. Warren et al. (1992) examined jump performance, using elite junior weightlifters, during seven days of INT. Vertical jumps height decreased significantly from pre to post INT. Fry et al. (1993) and Stone et al. (1998) found similar decreases in vertical jump height, among elite junior weightlifters, following 7 days of INT. After two weeks of INT, Storey, Birch, Fan, & Smith (2016), reported a 7% decrease in vertical jump height then, after one week of RED, vertical jump height recovered to baseline measurements.

Psychological Measures

In 2012, Taylor et al. conducted a survey of high level professional and non-professional/elite programs and found across a wide variety of sports, 84% use self-reported questionnaires. Follow-up questions in the study suggest questionnaires are often chosen because of their economical and practical means for monitoring. Researchers have examined mood state questionnaires and found that “negative” responses correspond with increases in TL (González-Boto et al., 2008; Kellmann, & Günther, 2000; Kellmann et al., 2001) and decreases in performance (Coutts & Reaburn, 2008). Morgan et al., (1987) collected ten years of data and found that mood disturbances increased with training stress; however, as training was reduced, mood disturbances fell back to baseline. Several reliable and valid instruments can be applied among athlete populations. The profile of mood states (POMS) (McNair et al., 1992), Daily Analysis of Life Demands (DALDA) (Rushall, 1990) and the Recovery-stress questionnaire for athletes (RESTQ-Sport) (Kellmann and Kallus, 2001; Kellmann and Kallus, 2016) are commonly reported. However, 80% of those surveyed by Taylor et al. (2012), reported using custom made self-report questionnaires, with POMS, REST-Q and DALDA being used 13%, 2% and 2%, respectively. Additional questions revealed that self-report questionnaires commonly studied in scientific literature were not concise and targeted enough to fit the monitoring situation (Taylor et al., 2012). Custom made questionnaires used by respondents tend to consist of 5-12 items using a 1-5 or 1-10 Likert scale or were modified from existing questionnaires, placing greater emphasis on muscle soreness, physical fatigue and general wellbeing (Taylor et al., 2012).

Early questionnaires used for athlete monitoring were too long to be repeated often enough for effective monitoring and did not necessarily reflect the athlete’s current recovery-stress state (Taylor et al., 2012; Nicolas et al., 2016). In response to these limitations both the Acute Recovery and Stress Scale (ARSS) and its abridged version, the Short Recovery and Stress Scale (SRSS) were conceived to provide a more streamlined measurement tool that estimates the current recovery-stress state of the athlete. While both the recovery and stress scales for the ARSS and the SRSS were correlated with the REST-Q recovery-stress scales, the SRSS is the shortest and therefore most suited for continuous athlete monitoring (Nässi et al., 2017). Though correlations between the SRSS and the REST-Q are encouraging, convergent validity needs to be established between physiological, performance measures and the SRSS in weightlifters.

Several recent studies have been published that used the SRSS for its psychological measurement. A 2016 study by Reader et al., investigated the effectiveness of neuromuscular, physiological and perceptual markers to represent changes in fatigue and recovery after a 6-day intensified strength training microcycle. Two selected perceptual markers were the physical performance capacity (PPC) and muscular strain (MS) scales of the SRSS. Both markers were sensitive to changes in training induced fatigue, showing a decrease in PPC and an increase in MS after the INT training period. After a 3-day of RED, both markers returned to baseline levels. Wiewelhove et al. (2016) used the SRSS while investigating the effect of repeated use of active recovery during a 4-day shock microcycle. During the four days of INT, the SRSS recovery scales were statistically significantly decreased while stress scales were statistically significantly increased. In addition, changes in recovery scales were large to very large whereas changes in stress scales were small to moderate. The authors conclude that the INT training induced physical rather than mental fatigue. Pelka et al. (2017) used the SRSS to examine how soccer matches affect self-report measures of physical, mental and emotional states. They found that athletes accumulating more than 60 minutes of play time were less recovered and more stressed than athletes that played less than 60 minutes. However, athletes that played less than 60 minutes were more affected on an emotional level, experiencing higher emotional stress and were less emotionally balanced (Pelka et al., 2017). Hitzschke et al. (2017) examined the inter-individual change and performance criterion sensitivity of the ARSS and the SRSS, and their response to a 6-day microcycle of INT. They found that both the ARSS and SRSS reflect the fatigue and recovery phases in a very change sensitive and practical way; however, the questionnaires could not exactly discriminate athletes in fatigued or recovery states in relation to performance measures. While these studies show good results for the SRSS, no study has yet to use the questionnaire in actual athletic setting.

Biochemical Markers

Several different biochemical markers and their effects on weightlifting performance have been studied over the last few decades. The most examined hormone, testosterone (T), is an anabolic hormone secreted in the testes. Testosterone is the primary androgen hormone that interacts with skeletal muscle tissue, promoting amino acid incorporation into proteins and preventing protein breakdown (Kraemer, Vingren, & Spriering, 2015) Testosterone is considered a major promoter of muscular hypertrophy, strength and power (Cardinale and Stone, 2006; Vingren et al., 2010). Luteinizing hormone (LH) and follicle-stimulating hormone (FSH) are produced in the anterior pituitary gland. When secreted, LH promotes secretion of estradiol (Stone et al., 2007) and stimulates Leydig cells in the testes to produce T (Kraemer et al., 2015). While FSH does not stimulate the production of sex hormones (Kraemer et al., 2015), FSH works synergistically with LH (Stone et al., 2007). Glucocorticoids are released from the adrenal cortex in response to exercise; cortisol (C) accounts for 95% of all glucocorticoid activity (Guyon, 1991). Cortisol is a catabolic hormone that promotes the breakdown of protein and inhibits the incorporation of amino acids into protein (Kraemer et al., 2015). Sex hormone binding globulin (SHBG) is a hormone-binding protein that tightly binds to T in circulation (Hooper et al., 2017). Changes in serum SHBG concentrations may influence the magnitude of T availability (Kraemer & Ratamess, 2003). Creatine Kinase (CK) is an enzyme that catalyzes the reaction in which creatine phosphate donates its phosphate group to adenosine diphosphate, reforming adenosine triphosphate (Stone et al., 2007). Typically, the damage to muscle tissue is accompanied by a release of CK (Koch, Pereira & Machado, 2014).

Prior acute studies have established concurrent validity between biochemical markers and resistance exercise. Acute exercise-induced increases in serum T has been reported in males performing resistance training (Weiss, Cureton & Thompson, 1983; Chandler, Byrne, Patterson & Ivy, 1994; Hakkinen & Pakarinen 1995; Kraemer, W. J., Volek, Bush, Putukian & Sebastianelli, 1998; Kraemer et al., 1999) and elite weightlifters in response to moderate to high training intensity and volume (Häkkinen, Pakarinen, Alen, Kauhanen & Komi, 1988; Kraemer et al., 1992; Marsit et al., 1998). Studies have shown during acute bouts of resistance training, cortisol levels significant increase (Kraemer, Noble, Clark & Culver, 1987; Kraemer et al., 1992; Kraemer et al., 1993; Hakkinen et al., 1988; McCaulley et al., 2009). Hakkinen et al. (1988), found no change in SHBG after a morning training session with elite wieghtlifters; however, increases were reported following afternoon training sessions. McCaulley et al., (2009) investigated acute changes in commonly examined hormones, following resistance exercise sessions for hypertrophy, strength and power. Only following the hypertrophy training session was a significant increase in SHBG noted. In several acute studies (Machado et al., 2011; Machado, Willardson, Silva, Frigulha, Koch & Souza, 2012) positive relationships have been seen between VL and serum CK.

Previous chronic studies have investigated the concentrations of biochemical markers for both trained individuals and athletes during both INT and RED periods. During a two microcycle period of training Häkkinen et al. (1987) detected significant decreases in serum T among eleven elite male weightlifters. Similar decreases in serum T during INT were observed in other studies using high level weightlifters (Häkkinen et al., 1988; Busso et al., 1992) and strength trained males (Raastad, Glomsheller, Bjøro & Hallén, 2001). In both Häkkinen et al., (1988) and Raastad et al. (2001), serum T levels returned to baseline after eight days of normal training and four days of no training, respectfully. Increases in C levels have been observed during periods of INT (Häkkinen et al., 1987; Fry et al., 1993; Fry et al., 2000; Haff et al., 2008). Once athletes entered into a RED period C levels returned to baseline (Häkkinen et al., 1987; Haff et al., 2008). Häkkinen et al. (1987) observed decreases in the Testosterone/Cortisol Ratio (T/C) ratio following two weeks of INT. This decrease was due more to a decline in serum T then an increase in serum C levels. However, following a period of RED, the T/C ratio recovered almost to baseline measures, due to a significant drop in C levels (Häkkinen et al., 1987). Haff et al. (2008) similarly found that the T/C ratio decreased with INT and increases following RED training. Short term chronic studies that used both INT and RED found no changes in SHBG (Häkkinen et al., 1987; Häkkinen et al., 1990; Häkkinen et al., 1992). Long term chronic studies (Häkkinen et al 1985; Häkkinen et al 1988; McCall, Byrnes, Fleck, Dickinson & Kraemer, 1999) also found no significant changes in SHBG concentrations. Studies investigating CK chronic response to exercise have found that serum CK levels increase significantly after the initial bout of INT (Newham, Jones & Clarkson, 1987; Evangelista, Pereira, Hackney & Machado, 2011; Machado et al., 2011; Machado et al., 2012). However, after each additional bout of training the CK response was attenuated indicating a repeated bout of effect (Newham et al., 1987).

Conclusions

The purpose of this review is to provide the reader a broad outline of training and monitoring practices used for strength and power sports with an emphasis on weightlifting. The main findings of this literature review include: 1) the possibility of VLd being a superior estimate of training volume or work completed by an athlete during resistance training 2) overreaching as a common method of increasing an athlete’s performance before a competition 3) the use of vertical jump performance for monitoring an athlete’s training. 4) the extensive use of biochemical markers and their relationship to weightlifting performance 5) Self-report questionnaires being the most common form of athlete monitoring across a wide variety of sports. However, coaches tend to create their own questionnaires as these coaches feel that questionnaires developed by sport scientist are too long and do not reflect the athlete’s current recovery-stress state. To fill this gap in the literature a shorter coach and athlete friendly questionnaire needs to be validated.

CHAPTER 3

VALIDATION OF THE SRSS QUESTIONAIRE WITH PHYSIOLOGICAL AND PERFORMNACE MEASURES

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Abstract

Purpose: The purpose of this study is to determine whether changes in volume-load (VL) and volume-load-displacement (VLd), biochemical markers and squat jump performance correlate to changes in the newly created Short Recovery and Stress Scale questionnaire (SRSS). To ensure pronounced variation in VL and VLd, measurements were taken during the over-reach and subsequent taper prior to a competition. Subjects: Eleven well-trained weightlifters with at least one year of competition experience agreed to participate in the study. Methods: Weightlifters completed five testing sessions (T_1, T_2, T_3, T_4, and T_5) over the course of five microcycles (unload, overreach, and 3-week taper) leading up to a competition. Every testing session took place on Monday morning prior to regular training and included: hydration testing, SRSS questionnaire, blood draws followed by a standardized warm-up protocol and squat jumps (SJ) with 0kg and 20kg. Results: There was a likely, moderate decrease in physical performance capability from B to T_4 (probability = 86.2%, negative mean change ± 90% CI = -0.67 ± 0.81%) and B to T_5 (probability = 91.4%, mean change ± 90% CI = -0.67 ± 0.59%). There was a likely, small decrease in mental performance capability from B to T_3 (probability = 89.4%, negative mean change ± 90% CI = -0.42 ± 0.31%) and a likely, moderate decrease from B to T_5 (probability = 82.9%, negative mean change ± 90% CI = -0.75 ± 1.06%). There was a likely, small decrease in emotional balance from B to T_3 (probability = 75.5%, negative mean change ± 90% CI = -0.42 ± 0.48%) and a likely, moderate decrease in emotional balance from B to T_4 (probability = 93.3%, negative mean change ± 90% CI = -1.08 ± 0.95%). There was a near perfect negative correlation between the change in VLd from B to T_3 and the emotional balance scale (r value = -0.909, p value = 0.01). Also, there was a strong positive correlation between the decrease of in VLd form B to T_5 and lack of activation scale (r value = 0.616, p value = 0.043). Conclusions: While the majority of SRSS recovery and stress items did not change with alterations in VL or VLd, emotional balance and lack of activation did correlate with changes in VLd. Decreases in SRSS recovery items physical performance capability and emotional balance coincide with decreases in SJ height and increases in cortisol following the first taper microcycle. The findings of this investigation partly support the SRSS as a monitoring tool for weightlifters.

Keywords: Weightlifting, Recovery, Stress, Jump Performance, Training Monitoring, Overreaching, Tapering

1. Introduction

The goal of developing an annual training plan and subsequent programming is to enhance an athlete’s performance. Exercise sessions disturb homeostasis and result in acute fatigue. Continual training can result in accumulated fatigue (Meeusen et al. 2012; M. H. Stone, M. Stone & Sands, 2007). Evidence indicates that most adaptation occurs during recovery/rest periods post training session and that the final physiological/performance adaptation represent a “summary” of the stimulus-fatigue-recovery process (Stone et al. 2007). However, fatigue can mask the ability of an athlete to realize or express these adaptations (Plisk & Stone, 2003). Thus, as fatigue subsides during recovery the athlete will be able to express accrued adaptations (Meeusen et al., 2012). Furthermore, the extent of adaptation can be positively or negatively affected by more than just the training stress; non-training stressors such as work, school, social life, sleep, etc. (Stone et al., 2007). The accumulation of these stressors can lead to maladaptation (overtraining), cause a plateau and/or a decline in performance (Stone et al., 1991). Continuous monitoring of stressors affecting an athlete’s present state, as well as recovery from stress, can be used by coaches to detect early signs of overtraining and non-functional overreaching (Stone et al., 2007).

Investigations have examined different indicators of maladaptation in an attempt to identify the indicators that most consistently reflect degrees of adaptation or maladaptation. Prior studies have shown that squat jumps (SJ) can be used to monitor weightlifting performance as these variables are strongly correlated (Häkkinen, Komi & Kauhanen, 1986; Carlock et al. 2004). Häkkinen, Pakarinen, Alen, Kauhanen & Komi (1987), found that serum testosterone (T), testosterone/cortisol (T:C) ratio and testosterone/Sex hormone binding globulin (T:SHBG) ratio would decrease during stressful training (i.e. overreaching) and a later study by Haff et al.

(2008), found that the T:C ratio was inversely related to training volume. Other researchers have examined mood state questionnaires and found the "negative" response to correspond with increases in training load (González-Boto, Salguero, Tuero, González-Gallego & Márquez, 2008; Kellmann, & Günther, 2000; Kellmann, Altenburg, Lormes & Steinacker, 2001) and decreases in sport related athletic performance (Coutts, & Reaburn, 2008). Morgan et al., (1987) collected ten years of data and found that mood disturbances increased with training stress; however, as training load was reduced, mood disturbances decreased back to baseline. Coutts, Wallace & Slattery (2007), examined at performance, physiological, biochemical and psychological indicators and found that performance testing and mood state questionnaires were the most reliable indicators for athlete monitoring.

In 2012, Taylor et al. conducted a survey of high level professional and non-professional/elite programs and found across a wide variety of sports, 84% use self-reported questionnaires. Follow-up questions in the study suggest questionnaires are often chosen because of their economical and practical means for monitoring. Early questionnaires used for athlete monitoring were too long to be repeated often enough for effective monitoring and did not reflect the athlete's current recovery-stress state (Nicolas, Vacher, Martinent & Mourot, 2016). In response to these limitations both the Acute Recovery and Stress Scale (ARSS) and the Short Recovery and Stress Scale (SRSS) were conceived to provide a more streamlined measurement tool that measured the current recovery-stress state of the athlete. While the scales for both the ARSS and the SRSS were correlated with the Recovery-Stress Questionnaire's (REST-Q) scales, the SRSS is the shortest and therefore best suited for continuous monitoring of athlete performance (Nässi, Ferrauti, Meyer, Pfeiffer & Kellmann, 2017). While correlations between the SRSS and the REST-Q are encouraging, convergent validity needs to be established between physiological and performance measures and the SRSS.

The purpose of this study were to 1) determine the time course of changes in biochemical markers, jumping performance, and SRSS responses following an overreach and taper period in a subset of weightlifters preparing for a competition, and 2) determine whether changes in training load correlate to changes in the SRSS questionnaire. To ensure pronounced variation in training load, measurements were taken during the planned overreach and subsequent taper prior to a competition. We hypothesized that 1) blood markers of training stress and SRSS stress scores would increase following the planned overreach and decrease following the taper, whereas jumping performance and SRSS recovery scores would exhibit the opposite pattern, and that 2) changes in training load would be positively related to changes in SRSS stress scores and inversely related to changes in SRSS recovery scores.

2. Materials and Methods

2.1 Athletes

A group of well-trained weightlifters (n = 11) with at least one year of competition experience agreed to participate in the study (Table 1). Athletes participated in an ongoing athlete-monitoring program, and were familiar with all tests performed. The study examined athlete responses to a training program designed by the coaching staff to preserve ecological validity. A subset (n = 6) completed a unload week, followed by a 1-week overreach and 2-week taper in preparation for a competition, whereas the other athletes (n = 5) completed a 4-week basic strength training phase (Table 2). As a result, the first analysis examined the time course of changes in variables following an overreach and taper (n = 6), and the second analysis examined the relationship between changes in weightlifter’s volume-load and other variables throughout the 4-week training program (n = 11). Before data collection began, the athletes received detailed information about the purpose of the study. All participants signed an informed consent document and completed a health history questionnaire before participating in the study. The study was approved by the East Tennessee State University Institutional Review Board.

Table 3.1: *Descriptive Characteristics.*

Characteristics	Total Weightlifters (n = 11)	Subset Weightlifters (n = 6)
Age (years)	24.11 ± 4.58	22.85 ± 3.23
Height (cm)	170.36 ± 7.42	167.17 ± 7.90
Body Mass (kg)	81.78 ± 18.36	73.22 ± 15.97

All values are expressed as mean ± standard deviation.

2.2 Training

Weightlifters trained according to predetermined training programs written by their sport coaches (Table 2). All weightlifters kept training journals as a part of regular monitoring. The study was carried out over a period of five consecutive microcycles prior to an important competition. During this period the training was divided into push, pull and sport specific days (Table 3). Monday and Thursday were push days. Thursday was generally lighter than the preceding Monday. Push days began with the back squat for the morning session. Additional Squatting, jerks and other pressing exercises were performed during the afternoon session. Wednesday was a pull day that was also broken up into a morning and afternoon session as well. Pull days consisted of shoulder shrugs as well as snatch and clean pull variations. Saturday was a sport specific day, similar in design to Wednesday’s pull day with competition lifts in place of pull variations. Each athlete’s training program was supervised by trained National level, United States Weightlifting Coaches.

Table 3.2: *Example Training Program.*

Phase	Microcycle	Sets x Reps	Relative Intensity			
			Day 1	Day 2	Day 3	Day 4
Strength-Endurance	1	3 x 10	ML (75-80%)	ML (75-80%)	L (70-75%)	VL (65-70%)
	2	3 x 10	M (80-85%)	M (80-85%)	L (70-75%)	VL (65-70%)
	3	3 x 10	MH (85-90%)	MH (85-90%)	L (70-75%)	VL (65-70%)
	4	3 x 10	ML (75-80%)	L (70-75%)	VL (65-70%)	VL (65-70%)
Basic Strength	5	3 x 5 (1 x 5)	M (80-85%)	M (80-85%)	L (70-75%)	VL (65-70%)
	6	3 x 5 (1 x 5)	MH (85-90%)	MH (85-90%)	L (70-75%)	VL (65-70%)
	7	3 x 3 (1 x 5)	MH (85-90%)	MH (85-90%)	L (70-75%)	VL (65-70%)
	8	3 x 3 (1 x 5)	ML (75-80%)	L (70-75%)	VL (65-70%)	VL (65-70%)
Strength-Power	9	3 x 3 (1 x 5)	MH (85-90%)	M (80-85%)	L (70-75%)	VL (65-70%)
	10	3 x 3 (1 x 5)	H (90-95%)	MH (85-90%)	L (70-75%)	VL (65-70%)
	11	3 x 3 (1 x 5)	VH (95-100%)	H (90-95%)	VL (65-70%)	VL (65-70%)
	12	3 x 3 (1 x 5)	ML (75-80%)	L (70-75%)	VL (65-70%)	VL (65-70%)
Overreach	13	5 x 5	MH (85-90%)	M (80-85%)	L (70-75%)	VL (65-70%)
Taper	14	3 x 3 (1 x 5)	M (80-85%)	MH (85-90%)	L (70-75%)	VL (65-70%)
	15	3 x 3 (1 x 5)	MH (85-90%)	M (80-85%)	L (70-75%)	VL (65-70%)
	16	3 x 2 (1 x 5)	ML (75-80%)	L (70-75%)	VL (65-70%)	Competition

Note: Parenthesis are down sets at 60% of target weight; box indicates microcycles examined during this investigation; VH – very heavy, H – heavy, MH – moderately heavy, M – moderate, ML – moderately light, L – light, VL – very light

Table 3.3: *Example Exercise Selection.*

Phase	Monday and Thursday	Wednesday	Saturday
Strength-Endurance Phase	A.M.	A.M.	A.M.
	Back Squat	CG SS, CG Pull (knee)	SG SS, Snatch, Clean and Jerk, SG SLDL, SG Bent-Row
	P.M.	P.M.	
	Push Press, Lockout, DB Press	CG SS, MTP, CG SLDL, CG Bent-Row	
Strength Phase	A.M.	A.M.	A.M.
	Back Squat	CG SS, CG Pull (knee)	SG SS, Snatch, Clean and Jerk, SG SLDL, SG Bent-Row
	P.M.	P.M.	
	Push Press, FN Press, DB Press	CG SS, MTP, CG SLDL, CG Bent-Row	
Strength-Power Phase	A.M.	A.M.	A.M.
	Back Squat	CG SS, CG Pull	SG SS, Snatch, Clean and Jerk, SG SLDL, SG Bent-Row
	P.M.	P.M.	
	Split Jerk, JKR, DB Press	CG SS, MTP, CG SLDL, CG Bent-Row	
Overreach	A.M.	A.M.	A.M.
	Back Squat	CG SS, CG Pull	SG SS, Snatch, Clean and Jerk, SG SLDL, SG Bent-Row
	P.M.	P.M.	
	DSPBS, Split Jerk, BN Press, DB Press	CG SS, MTP, CG SLDL, CG Bent-Row	
Taper	A.M.	A.M.	A.M.
	Back Squat	CG SS, CG Pull	SG SS, Snatch, Clean and Jerk, SG SLDL, SG Bent-Row
	P.M.	P.M.	
	Split Jerk, BN Press, DB Press	CG SS, MTP, CG SLDL, CG Bent-Row	

Note: BN – Behind Neck, CG – Clean Grip, FN – Front Neck, DSPBS – Dead Stop Parallel Back Squat, JKR – Jerk Recovery, MTP – Mid-thigh Pull, SG – Snatch Grip, SLDL – Stiff-legged Deadlift, SS – Shoulder Shrugs

2.3 Estimating Training Volume

External training load for each training session was estimated using VL (weight x sets x reps) and VLd (weight x sets x reps x barbell displacement) (Haff, 2010). Displacement of each exercise was measured using potentiometers and a custom lab view program for analysis. All warm-up sets, target sets and down sets were used to calculate VL and VLd.

2.4 Testing Procedures

Athletes completed five testing sessions (T_1, T_2, T_3, T_4, T_5) (Figure 1). Testing sessions T_1 and T_2 were averaged together to act as a baseline (B). Every testing session was performed on a Monday, before the athletes began their scheduled sport training and included: hydration testing, SRSS questionnaire, blood draws followed by a standardized warm-up protocol and squat jumps (SJ) with 0kg and 20kg. All participating athletes were currently involved with an on-going monitoring program. Before each morning training session, weightlifters reported their body weight, heart rate, blood pressure and current injuries. At the end of each summated microcycle hydration and isometric mid-thigh pull testing was performed; counter-movement and SJ were added to testing at the conclusion of a training program.

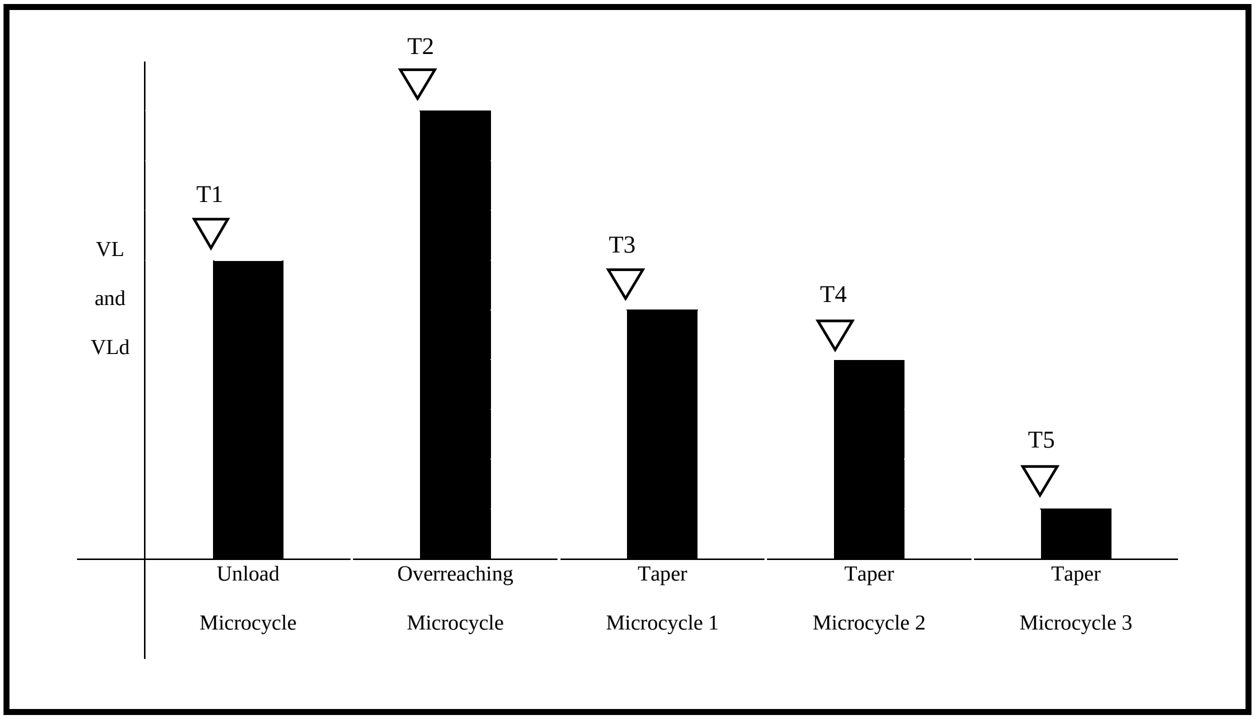

Figure 3.1: *Testing sessions and Example VLd*

2.4.1 Hydration

The hydration status of all athletes was estimated by using a handheld refractometer that calculates urine specific gravity (USG) on a scale ranging from 1.000 to 1.060 (Atago 4410 PAL-10S, Tokyo, Japan). If the refractometer indicated USG<1.020, the athlete passed and would continue with the testing procedure. If the refractometer indicated USG≥1.020, the athlete failed the test and was instructed to begin drinking water. After twenty minutes, the athlete was retested. Hydration testing continued until the athlete showed a satisfactory USG indicating proper hydration in progress.

2.4.2 Perceived Recovery and Stress

The rating of perceived recovery and stress was determined at the start of each testing session using SRSS. The SRSS consists of eight items that measure the physical, mental, emotional and overall aspect of both recovery and stress. The items include: physical performance capability (PPC), mental performance capability (MPC), emotional balance (EB), overall recovery (OR), muscular stress (MS), lack of activation (LA), negative emotional state (NES), and overall stress (OS). Each item is supported by a list of adjectives. The athletes were instructed to read the question and list of adjectives, then rate on a scale of 0 (does not apply at all) to 6 (fully applies) how much this apples to themselves. Numbers “1” to “5” on this scale were undefined and were used to better define the degrees of perceived recovery and stress between the two endpoints of the scale.

2.4.3 Biochemical Makers

Blood collections occurred after an overnight fast before the training session and 46-48 hours after the previous training session (between 6:15 and 7:00 am). Blood was collected from an antecubital vein and placed into a serum clot tube. Blood was allowed to clot for 20 minutes then placed in a centrifuged at 3400 rpm for 15 minutes; this occurred at room temperature. Serum was then aliquoted into smaller storage tubes and stored in a -80°C freezer. Blood markers that were analyzed include: testosterone (T), cortisol (C), testosterone:cortisol (T:C) ratio, sex hormone binding globulin (SHBG), and Creatine Kinase (CK). These markers was measured in duplicate using an IMMULITE 2000 automated immunoassay analyzer and Beckman Coulter AU 480 chemistry analyzer.

2.4.4 Squat Jumps Performance

Squat jumps were performed on dual uniaxial force plates with a sampling frequency of 1000 Hz (Rice Lake Weighing Systems, Rice Lake, WI); the plates were embedded, side by side, into an 8’ x 8’ plywood platform. An athlete began by stepping on the force plates and placing a PVC pipe across their shoulders to prevent arm swing. The athlete was then instructed to perform a squat to a knee angle of 90° (measured using a handheld goniometer) and maintain this static position until the force-time trace was stable (Cavagna et al., 1965). Once the force-time trace was stable, the test administrator shouted “3,2,1...jump!” and the athlete performed a maximal effort SJ. The athlete will perform additional SJ until two trails have been recorded with a difference of < 2 centimeters. All jump trials will be recorded and analyzed using a custom program (Lab View 2010, National Instruments Co., Austin, TX).

2.5 Statistical Analysis

Data were analyzed using a magnitude-based inference approach as previously recommended for sport science research (Hopkins et al., 2009). The probabilities that the true difference in a measurement relative to baseline were positive, trival, or negative are expressed as percentages derived using a published online spreadsheet (Hopkins, 2007). Qualitative terms corresponding to the probabilities were classified as almost certainly not (< 1%), very unlikely (< 5%), unlikely (< 25%), possible (25% - 75%), likely possible (> 75%), very likely (> 95%), and almost certain (> 99%). The magnitude of within-athlete changes between baseline and subsequent testing sessions were interpreted using 0.3, 0.9, 1.6, 2.5, and 4.0 of the within-athlete variation (CV from T_1 - T_2) as thresholds for small (i.e. smallest worthwhile change, SWC), moderate, large, very large, and extremely large, respectively (Hopkins et al., 2009). Relationships between changes in SRSS data and other measurements were evaluated using Pearson correlations with 90% CIs. Magnitudes for correlation coefficients were based on the following scale: trivial, ≤ 0.10; small, 0.10 – 0.29; moderate, 0.30 – 0.49; large, 0.50 – 0.69; very large, 0.70 – 0.89; and nearly perfect, ≥ 0.90 (Hopkins et al., 2009). Analyses were performed using SPSS software version 23 (IBM Co., New York, NY, USA), and Microsoft Excel 2013 version 15 (Microsoft Corporation, Redmond, WA, USA).

3. Results

3.1 Short Recovery and Stress Scale

There was a likely, moderate decrease in physical performance capability from B to T_4 (probability = 86.2%, negative mean change ± 90% CI = -0.67 ± 0.81%) and B to T_5 (probability = 91.4%, mean change ± 90% CI = -0.67 ± 0.59%). There was a likely, small decrease in mental performance capability from B to T_3 (probability = 89.4%, negative mean change ± 90% CI = -0.42 ± 0.31%) and a likely, moderate decrease from B to T_5 (probability = 82.9%, negative mean change ± 90% CI = -0.75 ± 1.06%). There was a likely, small decrease in emotional balance from B to T_3 (probability = 75.5%, negative mean change ± 90% CI = -0.42 ± 0.48%) and a likely, moderate decrease in emotional balance from B to T_4 (probability = 93.3%, negative mean change ± 90% CI = -1.08 ± 0.95%). No statistically significant changes were found in any other recovery or stress scales.

3.2 Correlation Results

There was a near perfect negative correlation between the increase of VLd from B to T_3 and the emotional balance scale (r value = -0.909, p value = 0.01). Also, there was a strong positive correlation between the decrease of in VLd form B to T_5 and lack of activation scale (r value = 0.616, p value = 0.043). No other statistically significant correlations were found.

3.3 Biochemical Analysis

There was a likely, small increase in serum cortisol levels from B to T_4 (probability = 77.5%, positive percent change ± 90% CI = 17.16 ± 28.05%). There was a likely, extremely large increase in creatine kinase levels from B to T_3 (probability = 81.2%, positive percent change ± 90% CI = 257.14 ± 536.26%). No meaningful changes were found in any other biochemical markers.

3.4 Squat Jump Performance

There was a likely, moderate decrease in unloaded squat jump height from B to T_4 (probability = 85.6%, negative percent change ± 90% CI = -3.67 ± 4.2%). No meaningful changes were found in any other squat jump variables at either condition.

3.5 Volume Load and Volume Load Displacement

Both VL and VLd increased statistically significant from B to T_3, 49% (figure 2) and 30% (figure 2), respectfully. Only VLd approached a statistically significant decrease from B to T_5 (see figure 3). No meaningful changes were found in any other repeated measure of VL or VLd.

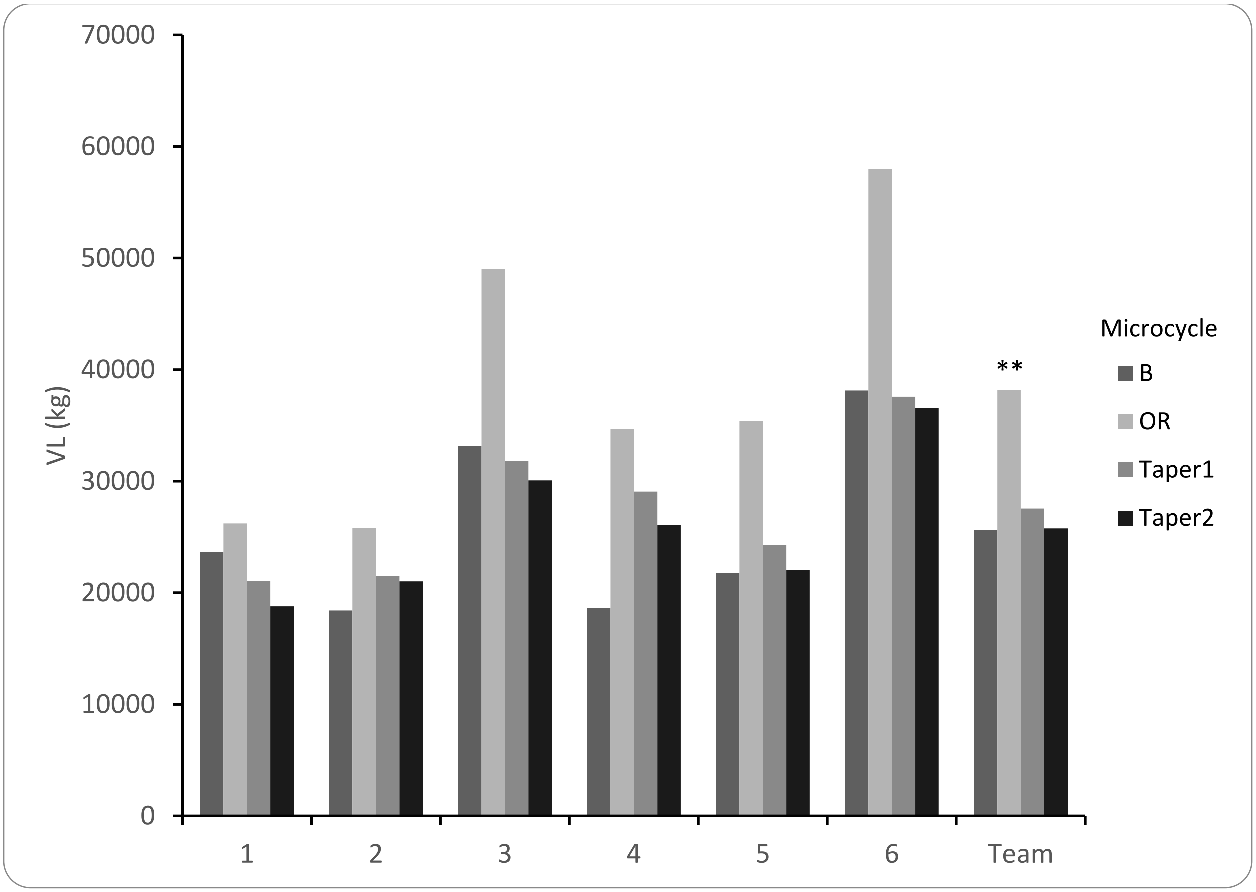

Figure 3.2: *Mean VL estimates for all 6 athletes and team average*

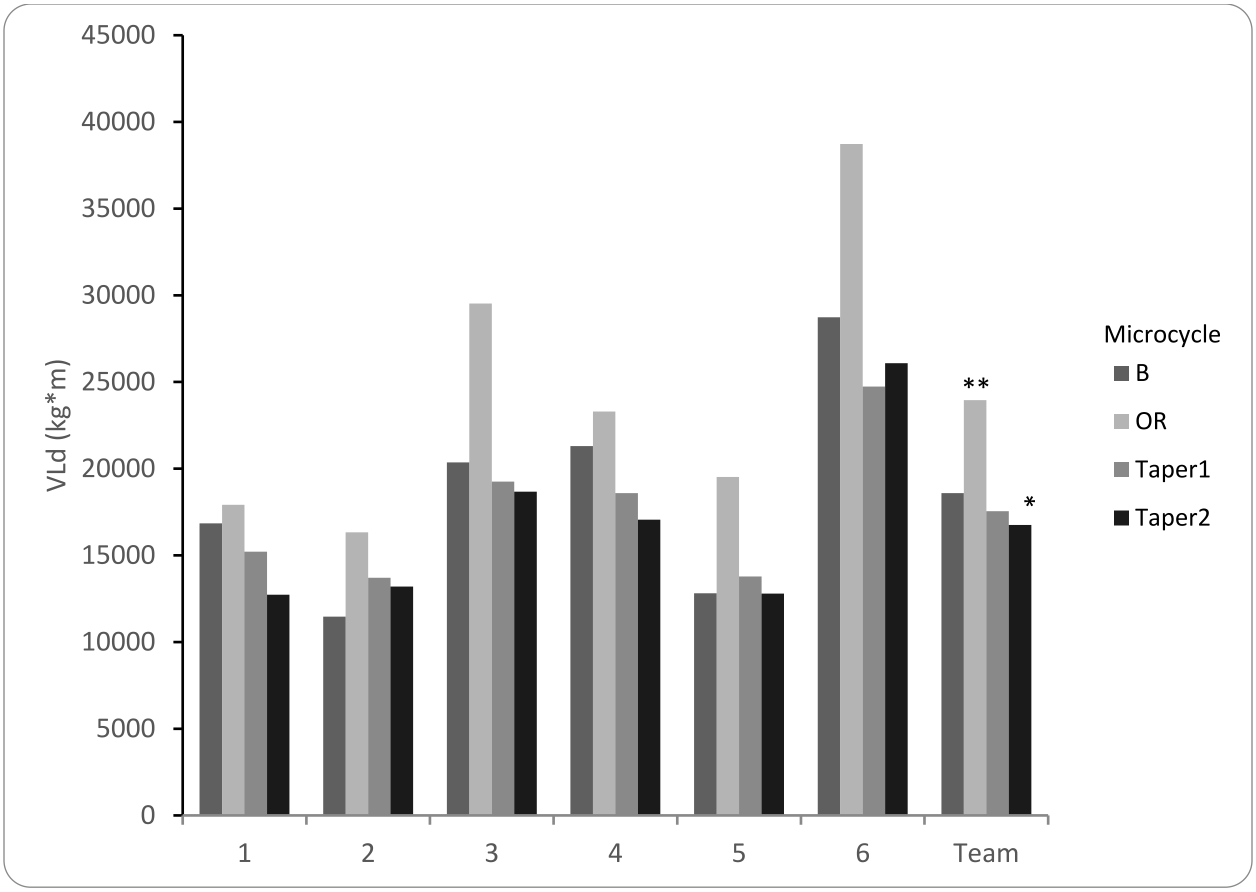

Figure 3.3: *Mean VLd estimates for all 6 athletes and team average*

Table 3.4: *Jumping Performance and Biochemical Markers Results*

	Mean ± SD					Percent Change ± 90% CI		
	B	T3	T4	T5	SWC (%)	B v T3	B v T4	B v T5
Jumping Performance								
SJH 0kg (cm)	33.47 ± 9.60	32.44 ± 8.12	32.10 ± 8.75*	33.76 ± 8.58	±1.19	-2.16 ± 4.68	-3.67 ± 4.2	1.79 ± 13.08
PPa 0kg (W/kg0.67)	234.09 ± 57.23	230.65 ± 52.52	231.38 ± 55.19	237.17 ± 56.29	±0.81	-1.08 ± 2.39	-1.01 ± 2.41	1.51 ± 3.29
SJH 20kg (cm)	24.97 ± 7.77	24.89 ± 7.40	24.93 ± 7.51	25.36 ± 8.03	±1.19	0.49 ± 11.28	0.41 ± 11.66	1.74 ± 4.41
PPa 20kg (W/kg0.67)	230.72 ± 53.59	232.21 ± 56.85	230.52 ± 56.29	231.77 ± 56.60	±0.79	0.45 ± 2.07	-0.23 ± 9.68	0.36 ± 2.96
Biochemical Markers								
Total Testosterone (ng/dL)	201.4 ± 198.01	233.80 ± 237.65	202.20 ± 193.96	217.00 ± 227.30	±8.39	8.91 ± 13.01	1.87 ± 75.32	4.41 ± 10.49
Cortisol (ng/dL)	17.67 ± 5.02	19.28 ± 5.42	19.88 ± 4.45*	18.02 ± 2.97	±6.16	10.95 ± 21.46	17.16 ± 28.05	5.83 ± 42.25
T:C Ratio (A.U.)	13.28 ± 13.81	14.31 ± 14.97	10.56 ± 10.12	13.04 ± 13.55	±15.91	-0.45 ± 0.50	-10.25 ± 14.06	-1.08 ± 6.65
Creatine Kinase (U/L)	178.70 ± 165.60	519.80 ± 745.35*	196.20 ± 156.32	190.20 ± 140.79	±7.34	257.14 ± 536.26	24.78 ± 157.08	33.18 ± 379.82

B – Baseline, T3 – Testing Session 3, T4 – Testing Session 4, T5 Testing Session 5, SWC – Smallest Worthwhile Change, SJH – Squat Jump height, PPa – Peak power allometrically scaled, T:C – Testosterone: cortisol

*likely different from B (precision>75% positive)

Table 3.5: *SRSS Results*

	Mean + SD					Percent Change + 90% CI		
	B	T3	T4	T5	SWC (%)	B v T3	B v T4	B v T5
SRSS								
PPC	4.33 ± 1.08	4.17 ± 1.47	3.67 ± 1.86*	3.67 ± 0.82*	±0.18	-0.17 ± 0.56	-0.67 ± 0.81	-0.67 ± 0.62
MPC	3.92 ± 1.24	3.50 ± 1.52*	4.17 ± 1.17	3.17 ± 0.41*	±0.20	-0.42 ± 0.31	0.25 ± 1.00	-0.75 ± 1.06
EB	4.58 ± 0.86	4.17 ± 1.17*	3.50 ± 1.52*	4.00 ± 1.26	±0.24	-0.42 ± 0.48	-1.08 ± 0.95	-0.58 ± 1.15
OR	3.92 ± 1.16	3.50 ± 1.52	4.17 ± 1.47	3.67 ± 0.52	±0.17	-0.42 ± 1.02	0.25 ±1.06	-0.25 ± 1.24
MS	2.33 ± 0.82	1.83 ± 1.17	1.67 ± 1.37	1.83 ± 0.41	±0.43	-0.50 ± 1.25	-0.67 ± 0.77	-0.50 ± 0.78
LA	2.75 ± 1.25	3.17 ± 1.47	2.83 ± 2.14	2.50 ± 1.05	±0.39	0.42 ± 0.99	0.08 ± 1.69	-0.25 ± 0.62
NES	1.50 ± 1.41	2.00 ± 1.79	2.17 ± 1.72	2.00 ± 1.26	±0.32	0.50 ± 1.65	0.67 ± 1.15	0.50 ± 0.97
OS	2.17 ± 0.82	2.33 ± 0.82	2.50 ± 1.05	2.67 ± 1.75	±0.33	0.17 ± 0.77	0.33 ± 0.96	0.50 ± 1.65

B – Baseline, T3 – Testing Session 3, T4 – Testing Session 4, T5 Testing Session 5, SWC – Smallest Worthwhile Change, PPC - physical performance capability, MPC - mental performance capability, EB - emotional balance, OR - overall recovery, MS - muscular stress, LA - lack of action, NES - negative emotional state, OS - overall stress

*Likely Different from B ($p < 0.05$)

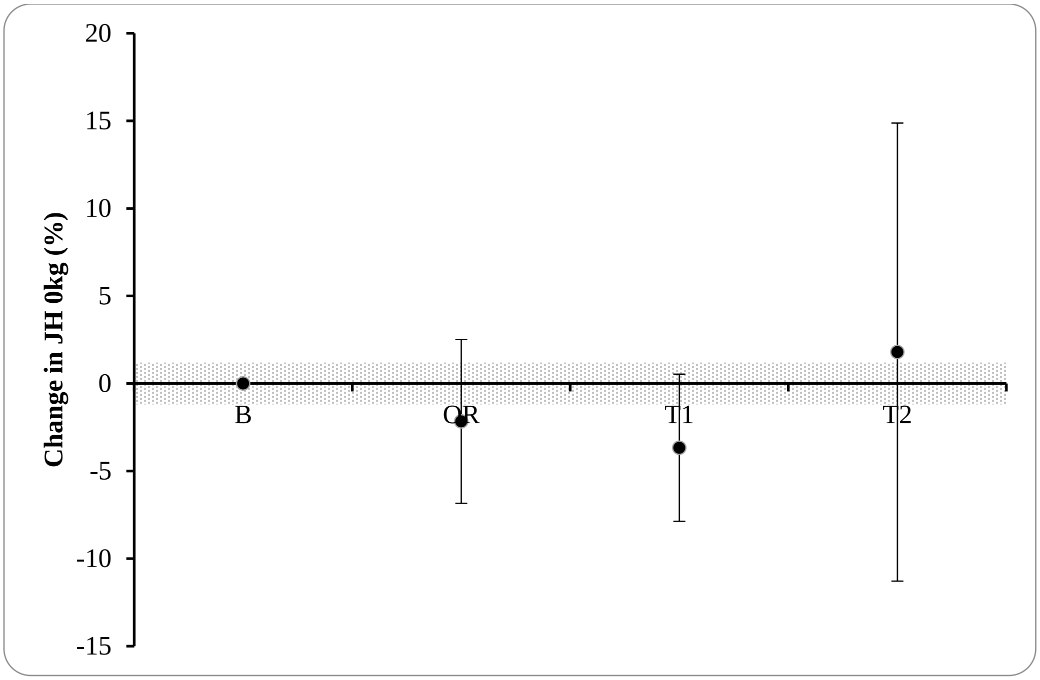

Figure 3.4: *Squat Jump Height at 0kg*

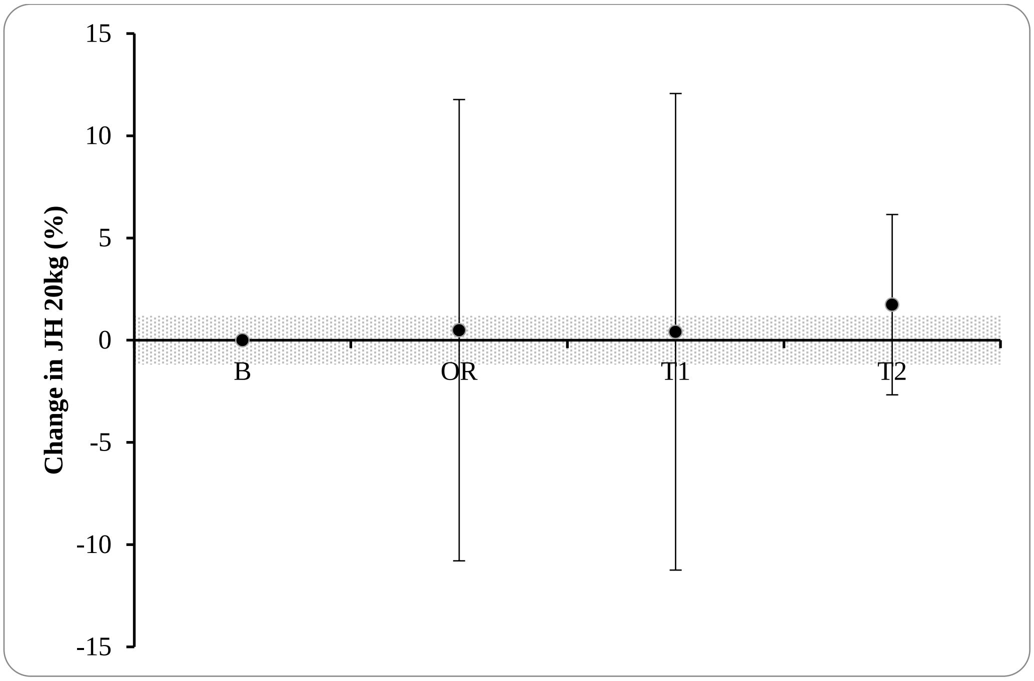

Figure 3.5: *Squat Jump Height at 20kg*

4. Discussion

The purpose of this study was to 1) determine the time course of changes in biochemical markers, jumping performance, and SRSS responses following an overreach and taper period in a subset of weightlifters preparing for a competition, and 2). Determine whether changes in training load, biochemical markers and SJ performance correlate to changes in the SRSS questionnaire. The primary result of this investigation, found changes in SRSS recovery and stress scale variables that coincide with fluctuations in both estimates of training volume as well as other variables.

The SRSS is a recently developed questionnaire used to an athlete's perceived recovery and stress levels. In this study, the recovery scales: physical performance capability, mental performance capability and emotional balance were affect by changes in VL and VLd. The only stress scale affected was lack of activation. Physical performance capability was mostly unaffected following the overreach microcycle during this study. However, following the taper, results for T_4 and T_5 showed physical performance capability experienced a likely, moderate decrease compared to B. These results oppose the current literature that show an inverse relationship between physical performance capability and VL. In a study by Reader et al., (2016), physical performance capability is significantly depressed following 6 days of intensified resistance training. After 3 days of reduced training, physical performance capacity returned to baseline measures. Following the increased VL and VLd during the overreach microcycle, mental performance capability exhibited a likely decrease. This decrease after one microcycle of intensified training is in agreement results with Reader et al. (2016) and Hitzschke et al. (2017) who found decreases in this recovery marker following intensified training. Since VL and VLd decreased following the taper, it was unexpected to find mental performance capability significantly decrease again after the second taper microcycle. Similarly to mental performance capability, emotional balance likely decreased after the overreach microcycle. This is in agreement with the literature (Reader et al., 2016; Hitzschke et al., 2017). However emotional balance was further reduced after the first taper microcycle. This contradicts the current findings of other studies. A near perfect inverse relationship was found between emotional balance and increases in VL and VLd. This is consistent with other studies that found emotional balance decreased following a short period of intensified training (Wiewelhove et al., 2016; Hitzschke et al., 2017). Decreases in the lack of activation item were correlated with decreases as VLd. This direct relationship was consistent with studies by Wiewelhove et al. (2016) and Hitzschke et al. (2017) who found significant increases in lack of activation following a short period of high-intensity and interval training and intensified resistance training. Changes in lack of activation was the only meaningful change found among the stress scale questions during the course of this observation.

Several different biochemical markers and their effects on weightlifting performance have been studied over the last few decades. Biochemical markers used in this study included: T, C, T:C, SHBG and CK. Only C and CK exhibited a meaningful change over the course of this investigation. Even though, mean C levels were elevated during T_3, following the overreach microcycle, it was not until T_4 that changes in mean C levels increased enough to exhibit a meaningful change. The increase in C during T_4 coincided with likely, moderate decreases in both physical performance capability and emotional balance (Table 6). These findings are inconsistent with the literature as C is typically significantly elevated following a large increase in VL (Häkkinen et al., 1987; Fry et al., 1993; Fry et al., 2000; Haff et al., 2008) and decrease during reduced training (Häkkinen et al., 1987; Haff et al., 2008). The cause of these delayed effects are not currently understood. There is some speculation that the inconsistencies in VL during the overreach microcycle in this study and what has been reported in previous studies may be a factor.

Typically, the damage to muscle tissue is accompanied by a release of CK (Koch, Pereira & Machado, 2014). This relationship has made increases in CK levels a commonly accepted marker of muscle damage. Our results show an extremely large increase in mean CK concentration from B to T_3 which is consistent with previous studies on intensified training (Newham, Jones & Clarkson, 1987; Evangelista, Pereira, Hackney & Machado, 2011; Machado et al., 2011; Machado et al., 2012). While most of the athletes realized an increase in CK levels, one athlete in particular experienced a 1,235% increase in CK following the overreach microcycle. The increases in CK corresponded with likely, small decreases in mental performance capabilities and emotional balance (Table 6).

Vertical jumps are a commonly used performance measure to evaluate general athletic ability (Taylor et al., 2012, Ostojić et al., 2009) such as muscle power (Hartman, Clark, Bemben, Kilgore & Bemben, 2007; Chelly et al., 2009) and strength (Stone, Johnson & Carter, 1979; Stone et al., 2003; Nuzzo, McBride, Cormie & McCaulley, 2008; Chelly et al., 2009). A recent study by Travis, Goodin, Beckham & Bazyler (2018), reported moderate to strong correlations between countermovement jumps, squat jumps and Sinclair total. The strongest correlations were between SJH at ($r = 0.686$) in male weightlifters and ($r = 0.487$) in female weightlifters. In the current study, unloaded SJH exhibited meaningful changes following the training program, whereas loaded SJH did not. This conflicts with results from Hornsby et al. (2017), who found 20kg to be more sensitive to fatigue that 0kg SJ. Unloaded SJH was possibly decreased during T_3 following the overreach microcycle, but the change was not statistically significant. There was a likely moderate decrease in SJH during T_4. This is an unusual result, as it was expected that SJH would have decreased the most following the increase in total training volume during the overreach microcycle. However, the decrease in SJH during T_4 corresponds with likely decreases found in the SRSS's physical performance capability and emotional balance recovery scales as well as a likely increase in C (Table 6). It's possible that training volume during the first microcycle of the taper was too high contributing to a further decrease in unloaded SJH.

During this investigation, both VL and VLd were used to estimate total training volume or work completed by the athletes (Stone et al., 1999). Both estimates of training volume displayed statistically significant increases from B to the overreach microcycle. However, only VLd approached a statistical decrease from B to second taper microcycle. This provides evidence that VLd can detect more modest fluctuations in training volume than VL. When comparing B (normal training) to the overreach microcycle, mean VL increased by 49%. Previous studies examining overreach microcycles, have reported a large ranger of percentage increases in VL from an 11% (Häkkinen et al., 1987) to 94% (Pistilli, Kaminsky, Totten & Miller, 2004) or even as high as 200% above normal training VL (Warren et al., 1992; Fry et al., 1993; Stone and Fry, 1998). While Häkkinen et al. (1987) reported the lowest recorded increase in VL, it should be noted that the overreach observed during that study lasted for two microcycles. All other studies referenced here examined overreaching periods lasting only one microcycle. Additionally, when displacement included in the calculation, the percent increase from B to the overreach microcycle, is reduced to only a 30% increase above normal training (figure 3). When compared to previous investigations, the relatively lower VL during the overreach microcycle may have contributed to the lack of meaningful changes in variables recorded during T_3. It should also be noted that during the microcycles observed, the coaches did not regulate the number of sets, repetitions per set or load used during exercise warm-ups for any of their athletes. Coaches only chose the loads used for predetermined target and down sets (Table 2). This could have contributed to the unusual distribution of volume observed in this study (Figure 2 and 3).

Table 3.6: *Summary of Variable Results*

Summary

Dependent Variables	OR	T1	T2
C	↑ S	↑* S	–
CK	↑* EL	–	–
SJH	↓ S	↓* M	–
PPC	–	↓* M	↓* M
MPC	↓* S	–	↓* M
EB	↓* S	↓* M	–

C - Cortisol, CK - Creatine Kinase, SJH - Squat Jump Height, PPC - Physical Performance Capability, MPC - Mental Performance Capability, EB - Emotional Balance, S - Small, M - Moderate, EL - Extremely Large

*75% likely

The current study was an observational study; accordingly the study staff could not control or manipulate any variables of the course of the five microcycles. During the observation period, VL during the overreaching microcycle was considerably lower than what has been reported in the literature (Häkkinen et al., 1987; Warren et al., 1992; Fry et al., 1993; Stone et al. 1998; Pistilli et al., 2004). Another limitation in this study was the small sample size (n = 6) for the longitudinal analysis. While there was a larger total number of athletes (n = 11) used to examined the relationship between changes in weightlifter's VLd and SRSS items throughout the 5 microcycles of training, VLd may not have fluctuated enough to detect further significant correlations.

5. Conclusion

The aim of this study was to determine whether changes in VL and VLd, biochemical markers and squat jump performance correlate to changes in the newly created SRSS questionnaire. While the majority of SRSS recovery and stress items did not change with alterations in VL or VLd, EB and LA did correlate with changes in VLd. Decreases in SRSS recovery items physical performance capability and emotional balance coincide with decreases in SHJ and increases in C following the first taper microcycle. Evidence was presented in this study showing that in the future, sport coaches may want to regulate the warm-up sets used by their athletes to better control the total volume accumulated in each microcycle. Further, the findings of this investigation partly support the SRSS as a monitoring tool for weightlifters.

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CHAPTER 4

SUMMARY AND FUTURE INVESTIGATIONS

The purpose of this study was 1) determine the time course of changes in biochemical markers, jumping performance, and SRSS responses following an overreach microcycle and tapering period in a subset of weightlifters preparing for a competition, and 2) determine whether changes in training load correlate to changes in the SRSS questionnaire. To ensure pronounced variation in VL and VLd, measurements will be taken during the over-reach and subsequent taper prior to a competition. The primary results of this investigation include: (1) evidence that VLd can detect more subtle undulations in training volume over VL, (2) changes in SRSS recovery and stress scale variables that coincide with fluctuations in both estimates of training volume as well as other variables and (3) a pronounced increase in creatine kinase following an overreach microcycle. We hypothesized that 1) blood markers of training stress and SRSS stress scores would increase following the planned overreach and decrease following the taper, whereas jumping performance and SRSS recovery scores would exhibit the opposite pattern, and that 2) changes in training load would be positively related to changes in SRSS stress scores and inversely related to changes in SRSS recovery scores. Our hypothesis was only partly supported by the findings of this investigation.

The current study used the SRSS in an observational study design that lasted for five microcycles of typical training used by weightlifters in preparation for a competition. This differs from previous investigations that used the SRSS in an experimental study designs (Hitzschke et al., 2017; Reader et al., 2016; Wiewelhove et al., 2016), focusing on a single microcycle of intensified training aimed at producing signs of overreaching. This difference in study design most likely led to differences in study results. In the present study, only the SRSS recovery items, mental performance capability and emotional balance, showed significant negative changes when VL and VLd was intensified during the overreach microcycle. This is a smaller effect when compared to Hitzschke et al. (2017) who found after one microcycle of intensified resistance training all recovery items significantly decreased while all stress items were significantly increased. This inconsistency between this study and Hitzschke et al. (2017) may have been caused by the current studies VL during the overreach microcycle being too low when compared to normal training. In the four days following the intensified microcycle training was ceased to allow for recovery (Hitzschke et al., 2017). This halt in training allowed for all recovery and stress items to return to baseline by the end of the four day period. In this study, athletes began a three microcycle taper after the overreach microcycle. Following the first taper microcycle, recovery items, physical performance capability exhibited a meaningful negative change along with emotional balance's continued negative change. This did coincide with a statistically significant increase in serum cortisol levels and decrease in jump height performance. This was unexpected since the VL and VLd had been reduced. At the end of the second taper microcycle, physical performance capability was still significantly decreased along with mental performance capability again. Emotional balance at this point was recovered enough to know longer be significantly decreased. No testing was done before the competition to determine if the recovery scales continued to remain decrease or if they recovered.

While the current study did not find meaningful changes in all recovery and stress items, the SRSS was still shown to be sensitive the recovery stress state of the athletes and coincide with changes in other measures used for athlete monitoring such as biochemical markers and jumping performance. Athletic programs, such as small colleges and high schools, which lack the resources to conduct athlete monitoring with communing used physiological and performance markers can use the SRSS to track the recovery and stress of their athletes. The information collected from the SRSS can be used to adjust the teams or individual athletes training program. An example of this can be seen in this study. The overreach did not produce the expected performance decrease in physiological or psychological results. This information can then be used, by the coaches, to increase the training volume of the team and/or an individual weightlifter's overreach microcycle during the next peaking phase before a competition.

While this study did much to show the usefulness and practicality of the SRSS for athlete monitoring, more is needs to be done in future research. Additional studies concentrating on the SRSS questionnaire should be conducted. Currently, papers by Hitzschke et al. (2017), Reader et al. (2016) and Wiewelhove et al. (2016) have used the SRSS as a psychological marker of perceived the recovery and stress state. However, the papers by Reader et al. (2016) and Wiewelhove et al. (2016) were primarily focused on the physiological and performance makers used in their studies, minimizing the involvement of the SRSS. Besides the current study, Hitzschke et al. (2017) is the only other paper to the author's knowledge, where the primary focus is on the SRSS and its sensitivity to changes in training load. Studies similar in design to the current investigation should observe the SRSS's responsiveness to the gradually increased intensity of a summated microcycles of normal training, during both a basic strength block and a hypertrophy/strength endurance block. As a final point, studies using the SRSS should be conducted on other athletes that use other forms of conditioning (sprinting, jumping and/or throwing) as a part of their sports training, in addition to regular resistance training.

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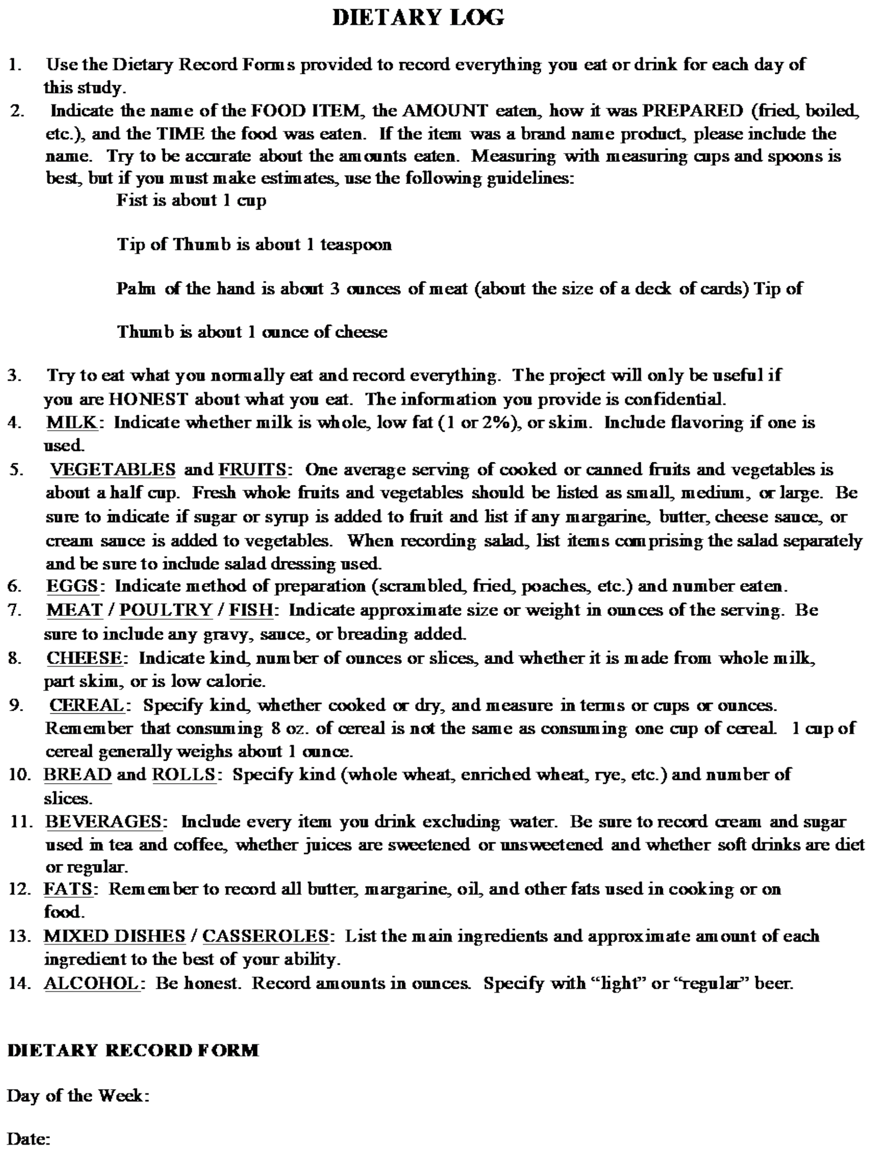
APPENDICES

Appendix A: Dietary Food Log



DIETARY LOG

1. Use the Dietary Record Forms provided to record everything you eat or drink for each day of this study.
2. Indicate the name of the FOOD ITEM, the AMOUNT eaten, how it was PREPARED (fried, boiled, etc.), and the TIME the food was eaten. If the item was a brand name product, please include the name. Try to be accurate about the amounts eaten. Measuring with measuring cups and spoons is best, but if you must make estimates, use the following guidelines:

   Fist is about 1 cup

   Tip of Thumb is about 1 teaspoon

   Palm of the hand is about 3 ounces of meat (about the size of a deck of cards) Tip of

   Thumb is about 1 ounce of cheese

3. Try to eat what you normally eat and record everything. The project will only be useful if you are HONEST about what you eat. The information you provide is confidential.
4. MILK: Indicate whether milk is whole, low fat (1 or 2%), or skim. Include flavoring if one is used.
5. VEGETABLES and FRUITS: One average serving of cooked or canned fruits and vegetables is about a half cup. Fresh whole fruits and vegetables should be listed as small, medium, or large. Be sure to indicate if sugar or syrup is added to fruit and list if any margarine, butter, cheese sauce, or cream sauce is added to vegetables. When recording salad, list items comprising the salad separately and be sure to include salad dressing used.
6. EGGS: Indicate method of preparation (scrambled, fried, poaches, etc.) and number eaten.
7. MEAT / POULTRY / FISH: Indicate approximate size or weight in ounces of the serving. Be sure to include any gravy, sauce, or breading added.
8. CHEESE: Indicate kind, number of ounces or slices, and whether it is made from whole milk, part skim, or is low calorie.
9. CEREAL: Specify kind, whether cooked or dry, and measure in terms or cups or ounces. Remember that consuming 8 oz. of cereal is not the same as consuming one cup of cereal. 1 cup of cereal generally weighs about 1 ounce.
10. BREAD and ROLLS: Specify kind (whole wheat, enriched wheat, rye, etc.) and number of slices.
11. BEVERAGES: Include every item you drink excluding water. Be sure to record cream and sugar used in tea and coffee, whether juices are sweetened or unsweetened and whether soft drinks are diet or regular.
12. FATS: Remember to record all butter, margarine, oil, and other fats used in cooking or on food.
13. MIXED DISHES / CASSEROLES: List the main ingredients and approximate amount of each ingredient to the best of your ability.
14. ALCOHOL: Be honest. Record amounts in ounces. Specify with "light" or "regular" beer.

DIETARY RECORD FORM

Day of the Week:

Date:

FOOD ITEM	AMOUNT	TIME

Express approximate measures in cups (C), tablespoons (T), teaspoons (t), grams (g), ounces (oz.), pieces, etc.

APPENDIX E: Sample of Short Recovery Stress Scale

Short Recovery Scale

Below you find a list of expressions that describe different aspects of your current state of recovery. Rate how you feel **right now** in relation to your best ever recovery state.

Physical Performance Capability

e.g.
strong,
physically capable,
energetic,
full of power

does not apply at all	○	○	○	○	○	○	○	fully applies
	0	1	2	3	4	5	6	

Mental Performance Capability

e.g.
attentive,
receptive,
concentrated,
mentally alert

does not apply at all	○	○	○	○	○	○	○	fully applies
	0	1	2	3	4	5	6	

Emotional Balance

e.g.
satisfied,
balanced,
in a good mood,
having everything under control
stable,
pleased

does not apply at all	○	○	○	○	○	○	○	fully applies
	0	1	2	3	4	5	6	

Overall Recovery

e.g.
recovered,
rested,
muscle relaxation,
physically relaxed

does not apply at all	○	○	○	○	○	○	○	fully applies
	0	1	2	3	4	5	6	

Short Stress Scale

Below you find a list of expressions that describe different aspects of your current state of stress. Rate how you feel **right now** in relation to your highest ever stress state.

Muscular Stress

e.g.
muscle exhaustion,
muscle fatigue,
muscle soreness,
muscle stiffness

does not apply at all	○	○	○	○	○	○	○	fully applies
	0	1	2	3	4	5	6	

Lack of Activation

e.g.
unmotivated,
sluggish,
unenthusiastic,
lacking energy

does not apply at all	○	○	○	○	○	○	○	fully applies
	0	1	2	3	4	5	6	

Negative Emotional State

e.g.
feeling down,
stressed,
annoyed,
short-tempered

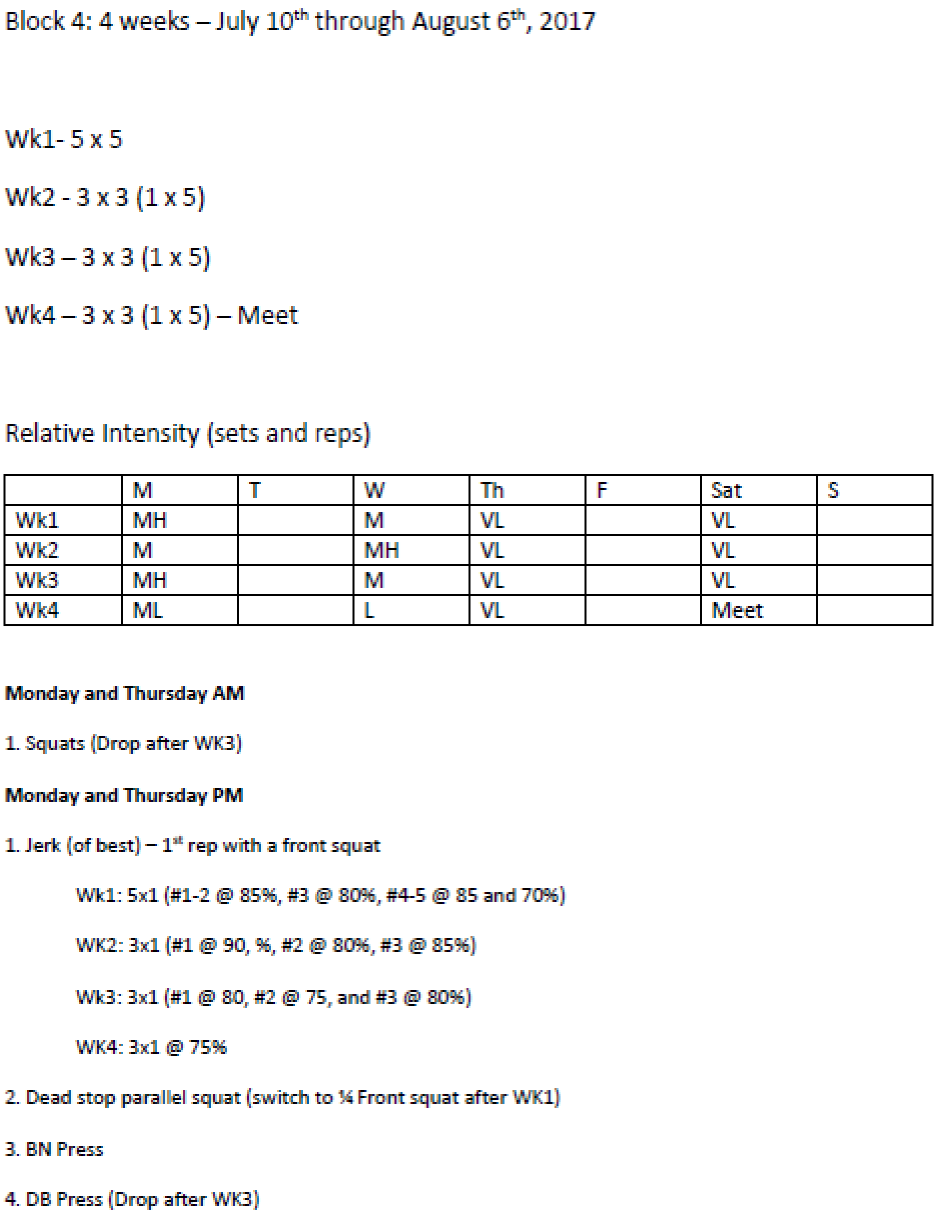
does not apply at all	○	○	○	○	○	○	○	fully applies
	0	1	2	3	4	5	6	

Overall Stress

e.g.
tired,
worn-out,
overloaded,
physically exhausted

does not apply at all	○	○	○	○	○	○	○	fully applies
	0	1	2	3	4	5	6	

APPENDIX F: Sample of Training Program



Block 4: 4 weeks – July 10th through August 6th, 2017

Wk1- 5 x 5

Wk2 - 3 x 3 (1 x 5)

Wk3 – 3 x 3 (1 x 5)

Wk4 – 3 x 3 (1 x 5) – Meet

Relative Intensity (sets and reps)

	M	T	W	Th	F	Sat	S
Wk1	MH		M	VL		VL	
Wk2	M		MH	VL		VL	
Wk3	MH		M	VL		VL	
Wk4	ML		L	VL		Meet	

Monday and Thursday AM

1. Squats (Drop after WK3)

Monday and Thursday PM

1. Jerk (of best) – 1st rep with a front squat

    Wk1: 5x1 (#1-2 @ 85%, #3 @ 80%, #4-5 @ 85 and 70%)

    WK2: 3x1 (#1 @ 90, %, #2 @ 80%, #3 @ 85%)

    Wk3: 3x1 (#1 @ 80, #2 @ 75, and #3 @ 80%)

    WK4: 3x1 @ 75%

2. Dead stop parallel squat (switch to ¼ Front squat after WK1)

3. BN Press

4. DB Press (Drop after WK3)

Wednesday AM

0. Snatch warm-up/tech 3x5

1. CGSS

2. CG pull from power position

Wednesday PM

0. Snatch warm-up/tech 3x5

1. SGSS

2. SG pull from floor

3. CG SLDL

4. DB row (Drop after WK 3)

Saturday

1. SGSS

2. Snatch

   - WK1: 5x1 (#1 @ 85, #2 @ 75, #3 @ 80, #4-5 @ 65 and 60%)
   - WK2: 3x1 (#1 @ 90, #2 @ 70, and 60%)
   - WK3: 3x1 (#1 @ opener, #2 @ 65 and #3 @ 60%)
   - WK4: Meet

3. C & J

   - WK1: 5x1 (#1 @ 85%, #2 @ 80, #3-5 @ 60, 55, and 50%)
   - WK2: 3x1 (#1 @ opener, #2 @ 70, #3 @ 60%)
   - WK3: 3x1 (#1 @ 85, #2 @ 75, #3 @ 60%)
   - WK4: Meet

3. SG SLDL

4. DB row (Drop after WK3)

VITA

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