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OVERTRAINING SYNDROME: CAUSES, CONSEQUENCES, AND METHODS FOR PREVENTION

Carter, JG[1], Potter, AW[2], and Brooks, KA[3]

[1]*Texas A&M University College Station, TX 77843*

[2]*New England Baptist Hospital, Boston, MA 02120*

[3]*Texas A&M University Corpus Christi, TX 78412*

ABSTRACT

Exercise has the potential to improve the fitness level of an individual if he or she is able to optimally recover from the training stress. If unable to recover fully, the individual runs the risk of developing overtraining syndrome (OTS). Overtraining syndrome is a complex occurrence in the body, which can result from several training and non-training factors. Fortunately, there are several ways to avoid the development and detrimental effects of OTS. This article will discuss the causes, consequences, and methods for prevention for OTS.

Keywords: OTS; training; fatigue; muscle weakness; physical activity

INTRODUCTION

According to the specific adaptations to imposed demands (SAID) principle, the body specifically adapts to the imposed demands placed upon its systems (1). Therefore, in order to elicit the greatest adaptations from a training program, a strength coach needs to prescribe a systematic, progressive, and specific training regimen for their athlete(s). The concepts and philosophies of modern day periodization allow strength coaches to prescribe systematic, progressive, and specific training programs by manipulating exercise programming variables (i.e. intensity, volume, frequency, mode, consistency, variation, etc.) in a scientific and evidence based format allowing the athletes to obtain the desired training outcomes. Although the SAID Principle is an agreed upon standard in the strength and conditioning community, strength coaches often focus primarily on the training aspect of the principle, and emphasize to a lesser extent the recovery portion of the SAID Principle. The recovery aspect of training is often overlooked (2), and according to the SAID Principle, if the recovery portion of training is neglected the body will be maladaptive in responding to the stress placed upon it. If the individual is

unable to recover for a continued duration, he or she increases their chance for developing overtraining syndrome (OTS). Fortunately, there are several ways to avoid the development and detrimental effects of OTS. This article will discuss the causes, the consequences, and the methods for preventing OTS.

OVERTRAINING SYNDROME

Positive adaptations from exercise occur only when the anabolic response is greater than the catabolic dosage. According to the Overload Principle, in order to elicit continued adaptations from training, the body needs to be overloaded to stimulate adaptive and anabolic processes in the body in order to reach new levels of fitness (3). While overloading the body through training, the body may reach a state of overreaching (OR) and/or overtraining. Overreaching has been defined as, "an accumulation of training and nontraining stress resulting in a short-term decrement in performance capacity with or without related physiological and psychological signs and symptoms of overtraining in which restoration of performance capacity may take from several days to several weeks" (4). Whereas, overtraining has been defined as, "an accumulation of training or nontraining stress resulting in long-term decrement in performance capacity with or without related physiological and psychological signs and symptoms of overtraining in which restoration of performance capacity may take several weeks or months" (4). For trained athletes, it may be necessary and beneficial to induce a state of OR in order to bring about greater performance (5).

There are two types of OR, functional OR (FOR) and nonfunctional OR (NFOR). Functional OR is when, through the process of supercompensation, the body has positive improvements in fitness because recovery has occurred. Nonfunctional OR is when recovery does not occur, and therefore, detriments in performance and fitness begin to surface. If the body is not allowed to recover after having reached NFOR, the individual can develop OTS. Currently, there is no clear distinction or assessment for determining if an individual has reached a state of NFOR and/ or OTS. The difference between FOR, NFOR, and OTS are dependent upon the time necessary for the body to recover (6-8). Functional OR may take between days to weeks to recover, NFOR between weeks to months, and OTS between months to years to fully recover (6, 9).

An athlete in preparation is always along a training continuum where at one end is acute fatigue from an exercise session and on the opposite end is OTS (6). Despite the amount of research on OTS, there is currently no agreed upon theory on its development. Although there have been several theories on what causes OTS such as glycogen depletion (10, 11), central fatigue (12), tissue trauma/ increased cytokine levels (13, 14), and glutamine depletion (15), none of these proposed OTS mechanisms fully explain the development of OTS. However, the common theme for the development of OTS is the improper ratio of recovery to stress.

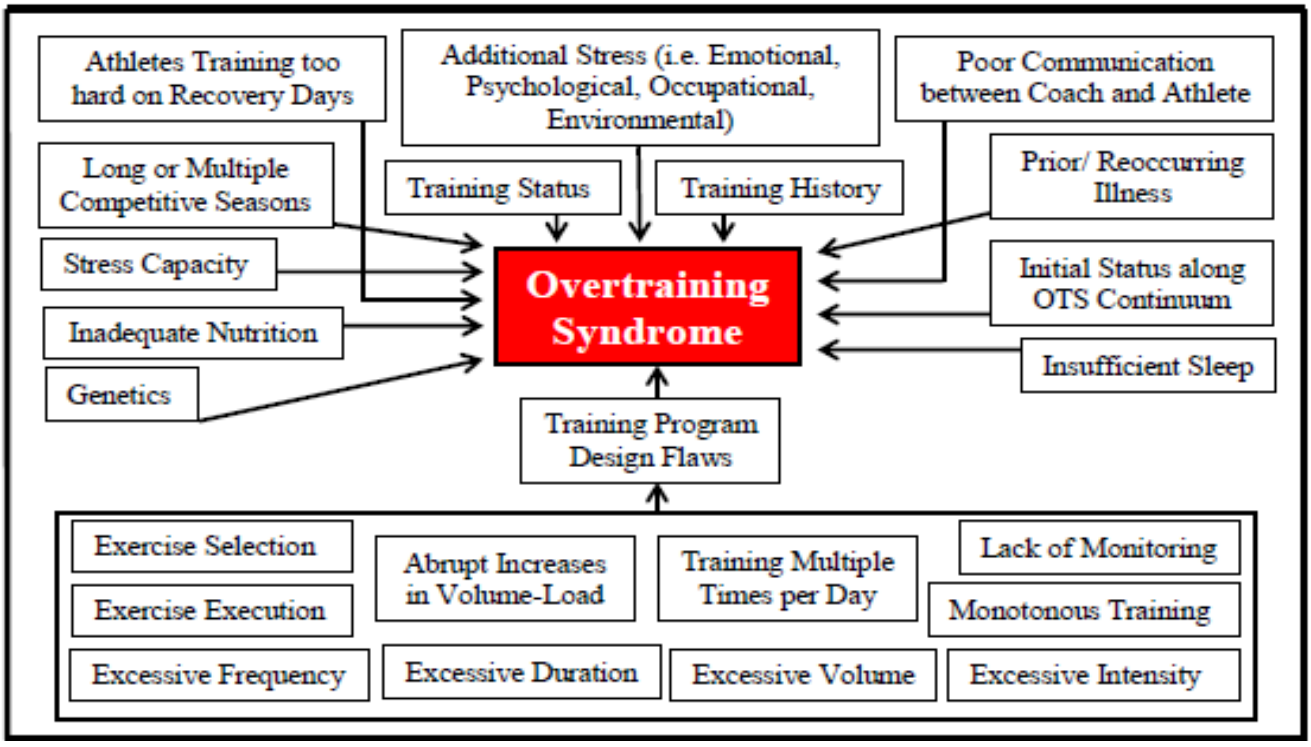
Overtraining syndrome is a complicated issue to study because 1) its effects are highly individualistic, 2) people have different stress capacities, and 3) you cannot truly determine if an individual has developed OTS or NFOR until after the conclusion of the study or episode (4, 6). Currently, there are no biomarkers to determine if an individual is in a stage of FOR, NFOR, or OTS (6, 9). For example, a high level of creatine kinase (a marker of muscle damage) has been seen in both overtrained and non-overtrained individuals. However, creatine kinase appears to be more

prevalent in contact sports over nonimpact sports, and is more indicative of muscle damage and not OTS (16, 17). The ratio of testosterone and cortisol, although indicative of the anabolic to catabolic environment of the body, is not a reliable tool for diagnosing OTS since it reflects the physiological strain of an athlete (18). Furthermore, certain populations when overtrained may exhibit sympathetic responses (i.e. elevated resting heart rate), whereas others may develop parasympathetic responses (i.e. decreased resting heart rate) (19). Parasympathetic overtraining has been shown more likely to occur for endurance athletes, whereas sympathetic overtraining is more likely to occur in anaerobic athletes and/ or a result of nontraining stress (20, 21). However, resting heart rate has also been seen to go unaltered in some individuals who develop overtraining syndrome (22, 23).

It is beyond the scope of this article to discuss the research on overtraining fully, but the reader should note that there are review articles (6, 13, 24-26), book chapters (21), and books (4) also dedicated to the topic. The amount of theories on OTS (10-15) illustrates the complexity of OTS and furthermore, this demonstrates that the development of OTS is multifaceted. Overtraining simply occurs from the body being unable to recover, which can be caused from several factors. For example, OTS can occur due to excessive exercise volume, frequency, and duration (19, 27-29). It has also been shown as a product of high intensity exercise (19), inadequate and poor nutrition (6, 21, 24), monotonous training (30), abrupt increases in training volume-load (31), or training multiple times per day (31). Overtraining has also been found to occur in response to insufficient quantity/ quality of sleep (27, 32), and/or uncontrolled or excessive emotional, environmental, occupational, and psychological stress (4, 9, 24, 33), and is related to the individual's stress capacity (34). Furthermore, OTS can occur from a lack of communication between the athlete and coach on the training load's perceived exertion (19), athletes training too hard on recovery sessions (25), prior or reoccurring illnesses (6), or long/ multiple consecutive competitive seasons (35). It should be noted that monotonous training is not just mode specific (i.e. long distance running), but also effort specific. For example, monotonous training could involve continuous training at the same level of intensity/ effort by not including light, moderate, and hard days/ weeks in the training program (19). If the body is unable to recover for a prolonged period of time, a person is at risk of becoming overtrained, which ultimately decreases an individual's performance.

A distinction should be made between burnout and OTS. An athlete who experiences burnout will lose motivation, whereas an athlete suffering from OTS could still possess high levels of motivation (36). Therefore, highly motivated athletes are at risk of becoming overtrained because they might neglect the recovery portion of their training by opting to increase their training volume, frequency, or intensity in order to achieve greater results, especially when they notice a decrease in performance (19, 25, 37). Endurance athletes are particularly prone to developing OTS (4, 31). Research (6, 38-41) has suggested that the incidence of OTS may vary from 7 to 64%, and an individual is prone to relapse once he or she has developed OTS (6). However, it has been suggested that the incidence of developing OTS is over reported and more than likely the athlete has reached a state of NFOR compared to OTS (9).

Figure 1: Causes of Overtraining Syndrome



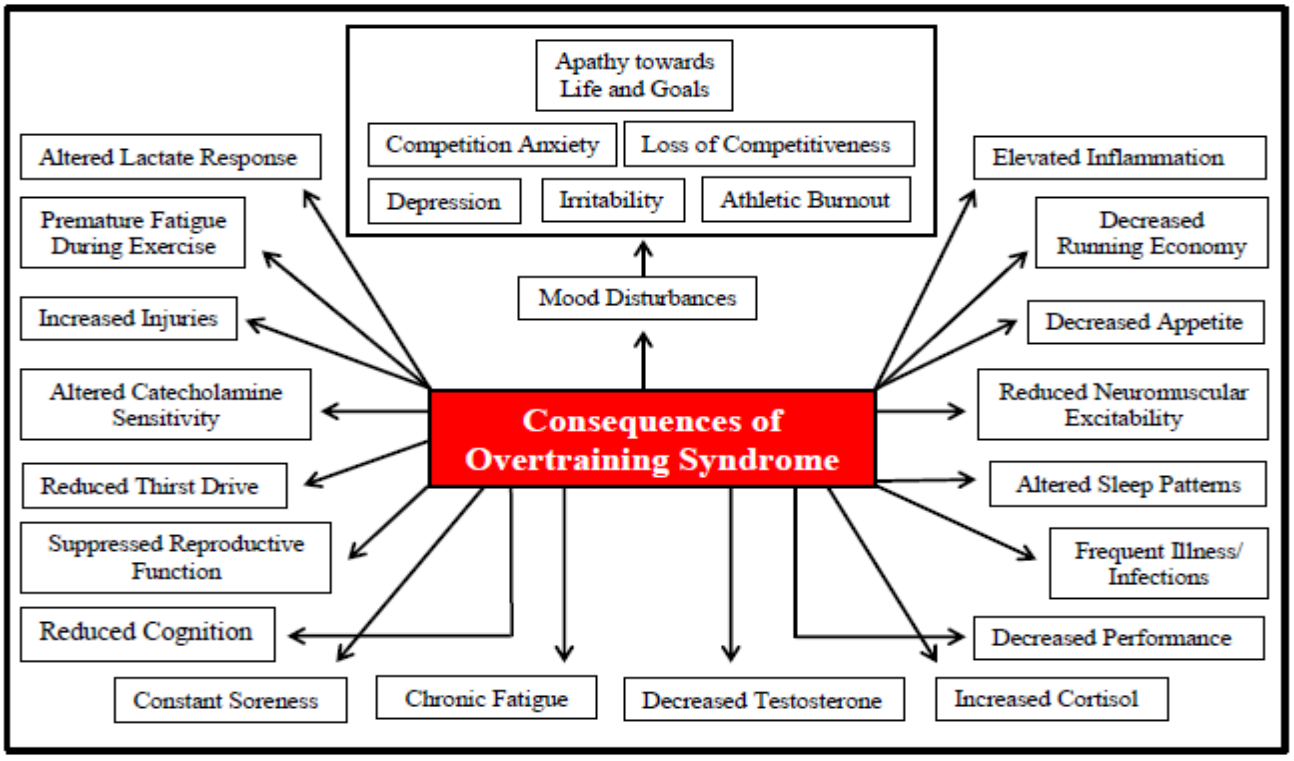
Overtraining has been associated with disturbances in physiological performance, psychological/ information processing, biochemical markers, and immunological function (6, 13, 19, 33, 42, 43). This can lead to such things as depression, irritability, chronic fatigue, decreased performance, loss of competitive desire, frequent illnesses/ infections, altered sleep patterns, changed responses to catecholamine sensitivity, suppressed reproductive function, decreased testosterone, elevated cortisol, loss of appetite, reduced thirst, premature fatigue during exercise, reduced neuromuscular excitability, decreased running economy, altered lactate response, competition anxiety, reduced cognition/ ability to process large amounts of information, constant soreness, and increased injuries (6, 13, 19-21, 31-33, 35, 41-45). Depending on the severity of overtraining, the symptoms and decrease in performance could last from several months to years (6, 9, 26, 46, 47). Since OTS has symptoms such as apathy, chronic fatigue, decreased performance, and frequent illnesses, strength coaches and health professional should ensure that their athletes do not have an illness or disorder such as anemia or an infection (6).

Moderate intensity exercise has been shown to improve immunity, whereas high intensity exercise can impair an individual's ability to fight off infection even without the development of OTS (31, 48). Cortisol, a catabolic and proteolitic hormone released in times of stress, has been linked to the suppression of the immune system following intense exercise (43). Impaired immunity has been linked to the environment, stress, injuries, and nutrition (49), and exercise can impair immunity for several hours following the exercise bout (31). Overtraining syndrome and intense exercise have been associated with an impaired immune system, increased

infection rates, and a high incidence rate of upper respiratory tract infections, especially for endurance athletes (6, 31).

Since OTS is the result of the inability to recover from the cumulative stresses placed upon the body, frequent illnesses further impair the body's ability to recover. It should be mentioned that individuals will handle training loads and additional stresses differently due to genetics, training history, initial status on the OTS continuum entering the training program (50), and their stress capacity (34). That is to say, some individuals can tolerate more stress than others due to a higher stress capacity (34), and their disposition on the situation affects their reaction to the training load and outside stress (9). Furthermore, exercise selection and execution plays a role in OTS. For example, training with free weights taxes the body more than training with weight machines (51), and training to failure repeatedly throughout the micro, meso, and macrocycle can lead to OTS (52).

Figure 2: Consequences of Overtraining Syndrome



METHODS TO REDUCE OTS

Hoffman and Meir (37) state that, "overtraining may be the culmination of repeated warnings that went unacknowledged or unnoticed by the athlete or coach." Lehmann et al (20), state that, "the risk of overtraining is increased by 1) one-sided, monotonous training without altering hard and easy training days, 2) a lack of one complete rest day per week, 3) a high total and increasing training load combined with additional significant nontraining stress, and 4) too many competitions." As mentioned, there is no agreed upon marker for determining the onset of OTS, and an athlete could be moving along the continuum

towards OTS until there is a noticeable detriment in performance, which is too late. Therefore, it is agreed upon that the best method to manage the effects of OTS is to prevent it from occurring, especially considering athletes who develop OTS are more likely to experience a repeated episode in the future compared to individuals who do not develop OTS (6). Furthermore, an athlete who develops OTS has the potential to harm their health (9). Therefore, the authors will briefly discuss several methods to reduce OTS in order for the reader to gain the best outcomes for their training population.

Periodization: Periodization is a concept that involves "preplanned, systematic variations in training specificity, intensity, and volume organized in periods or cycles with an overall program (53)" in efforts to elicit optimal training adaptations. It is beyond the scope of this article to discuss periodization fully, but the reader should note that there are several appropriate articles (54-56), book chapters (53, 57), and books (58, 59) dedicated solely to the topic of periodization. Periodization has been shown to be the superior training philosophy in the strength and conditioning realm (60). Periodization and its concepts have shown that providing athletes with recovery days within a microcycle (30, 54), a full recovery microcycle (19, 54), and/ or a period of tapering (54, 55, 61, 62) allows the body to recover. Through the process of supercompensation, the body returns to baseline or preferably to a new higher level of fitness, which has the potential to reduce OTS, overuse syndrome, physical/ mental exhaustion, and injuries (63).

Research has shown that abrupt increases in volume-load (31), as well as training for three weeks or more without a restoration microcycle, can potentially lead to OTS (27, 41). Therefore, it is often prescribed to arrange mesocycles into a 3:1 loading paradigm where the athlete gradually increases their volume-load over three weeks followed by a fourth week of recovery (54). If the goal is to achieve a state of FOR, the coach might prescribe a loading paradigm of 4:2 to facilitate supercompensation by overloading the athlete for four weeks then providing a two week tapered training period (54). The appropriate ratio of training to rest is needed to avoid a state of NFOR or OTS, as this will likely impact the macrocycle or interfere with competitions. If the athlete reaches NFOR or OTS, the recovery period should be prolonged to ensure restoration. An increase in the duration of restoration could lead to deconditioning. Therefore, to avoid both deconditioning and OTS, appropriate periodized training programs will be systematic and progressive in nature, will not have drastic increases in volume or intensity, avoid several consecutive high volume-load microcycles (i.e. >3-4 weeks), and incorporate adequate recovery periods.

Monitoring Training and Recovery: Avoidance of OTS should be of significant concern for both the coach and the athlete throughout the training and competitive seasons. Therefore, it is important to monitor for OTS by administering tests and monitoring elements of their training (i.e. resting heart rate, profile of mood states (POMS), rate of perceived exertion (RPE) scales, body mass, sprints, 1RM tests, muscle soreness, and sleep patterns). Furthermore, it is beneficial to have the athlete keep a training journal to assess their response to the training dosage routinely throughout the macrocycle (6, 13, 19, 21, 25, 31, 37, 63-65).

Often times, the first noticeable change for an athlete who has developed OTS is a reduction in performance (6, 37). Performance detriments can be in the form altered lactate threshold, power, strength, endurance, RPE, coordination, and overall

fatigue. Performance assessments should be included regularly in training programs to ensure the athlete is responding positively. However, as mentioned, OTS is multifaceted and often times can be developing under the surface without noticeable performance detriments (50). Fry et al (51) suggest not relying solely on specific strength measurements (i.e. 1RM) since OTS can be developing and impairing other performance variables without affecting an individual's maximal strength (i.e. 1RM). It appears that maximal strength is not as sensitive to the detrimental effects of OTS as early as power or speed (6), which is why Hoff and Meir suggest using sprints to monitor the training response and onset of OTS (37).

A unique way of monitoring the training load is by using the session-rating RPE scale, which monitors the internal training load of the exercise session (19, 25) The internal training load is subjectively based on the athlete's perception of the difficulty of the exercise session, whereas the external training load is more objectively based (i.e. how much distance is covered, how many sets are performed, the elevation in the athlete's heart rate, the amount of weights lifted, etc.). Compared to monitoring the external training load, monitoring the internal training load takes into account that each athlete will perceive the training load differently based upon their fitness level, status along the OTS continuum, nutrition, amount of sleep, and nontraining stress. The session-rating RPE method measures the RPE of the exercise session using a 10 point Borg scale taken 30 minutes after the exercise multiplied by the duration of the exercise session. For example, an athlete who exercised for 45 minutes at an overall RPE level of 8 would receive a value of 360 in arbitrary units. By using the session-rating RPE scale, the coach can determine how the athlete responded to the training session, and this method can be used throughout the training program to ensure that the athlete is not having consecutive hard training days. In their research, Wallace et al (19) showed that the way coaches and athletes perceive the difficulty level of training sessions are not always consistent. For example, Wallace et al (19) demonstrated that the coach perceived lighter designed training sessions as being easier than the way the athlete perceived them, and the coach perceived the harder designed training sessions as being harder than the way the athletes perceived them. Therefore, the session-rating RPE scale can be a valuable assessment tool for the coach and the athlete throughout the entire macrocycle.

Nederhof et al (9) suggest that when using markers to determine OTS that it should fulfill six criteria: 1) objectivity, 2) not easily manipulated, 3) applicable during training, 4) not demanding upon the athlete, 5) affordable to the majority of the athletic population, and 6) selection of the assessment be based off a sound theoretical framework. A potentially effective way of monitoring exercise performance, recovery, and OTS is through psychomotor tests such as reaction time (6, 9). Individuals who develop OTS have also been shown to be prone to depression and be chronically fatigued. Furthermore, individuals who suffer from chronic fatigue syndrome (66, 67), depression (68), and OTS (6, 69) have reported cognitive decline, and this cognitive decline affects reaction time and decision making (9, 69). Therefore, employing psychomotor assessments such as reaction time/ choice tests in a training program may be able to detect the development of OTS earlier in the continuum.

The ability to predict OTS early on from using reaction time tests is potentially valuable since it is non-invasive, quick, objective, not taxing to the athlete, affordable, and can be easily administered using

specialized software. It appears that the reaction time test needs to be complex in nature, since simple reaction tests do not appear to be sensitive to OTS (9). However, further research is needed in this area to determine its sensitivity and effectiveness for determining OTS (6, 9).

Sleep: One way to reduce the potential of developing OTS, is to obtain adequate quality and quantity of sleep (27, 70). While sleeping, the body can devote its functions to rebuilding the body. Furthermore, growth hormone, which has anabolic properties, is secreted via the pituitary gland during sleep. Sleep becomes more important during intense training periods (27, 71, 72), and inadequate sleep is a major contributor to perceived fatigue in elite and competitive athletes (24, 28, 29). Besides impairing recovery, inadequate sleep can affect mood, reaction times, arousal, attention, neuroendocrine function, cardiovascular performance, and cognition (27, 30). Anxiety can impair sleep quality (46), and improving sleep habits in collegiate basketball players not only improved their level of fatigue, but improved performance (sprinting and shot accuracy) and mental wellness (61) A person's sleep debt can accumulate over a period of time and can greatly affect the individual in every aspect of life. Three suggestions for improving one's sleep include: 1) identifying the amount of sleep needed per individual, 2) keeping a regular sleep schedule, and 3) creating an optimal sleeping environment (30).

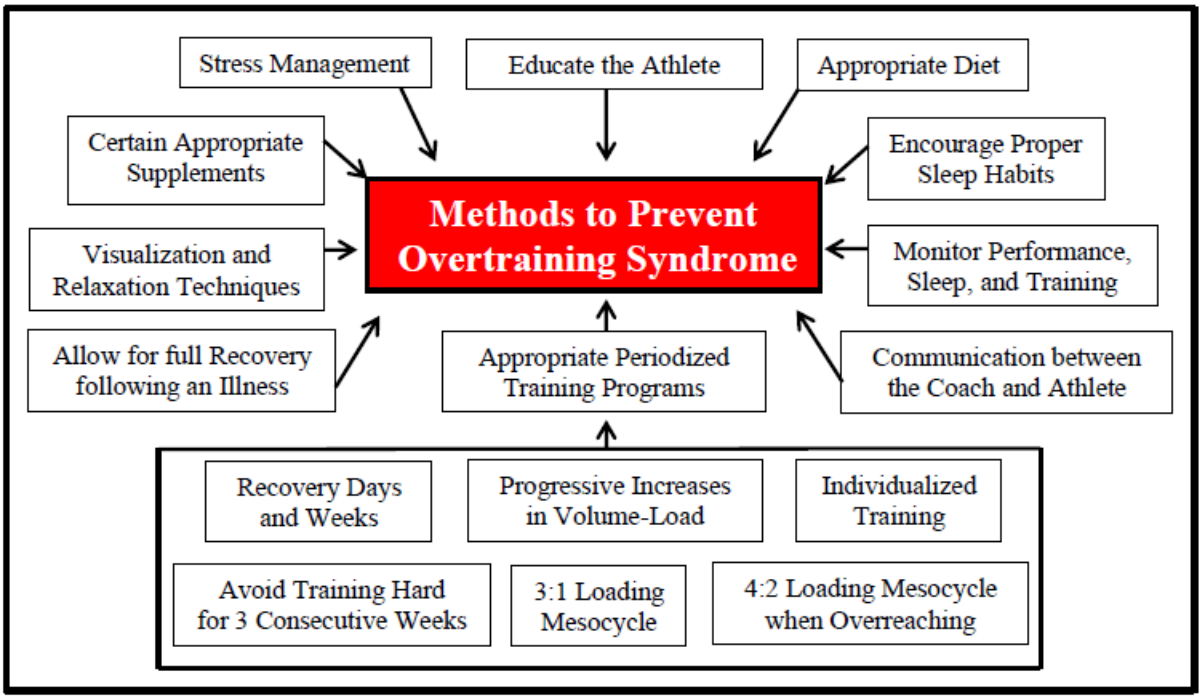
Nutrition: Nutrition is intuitively important because without the correct amount and proportions of macro and micronutrients, the athlete will not have the building materials or energy necessary for recovery. Deficiencies in either the macro or micronutrients can impair the immune system, hinder recovery, and impair performance, thus moving the athlete along the OTS continuum (73). Overtraining syndrome has been shown to decrease an individual's appetite, which is counterproductive since continuous caloric deficits while training elevate both the stress hormone and cytokine response to exercise. This further moves the athlete along the OTS continuum (6). It has been proposed that cytokines could be a major contributor to the development of OTS (13, 14). To ensure adequate nutrition for their athlete, the health professional should seek guidance from a sports nutritionist or registered dietician, as well as be up to date on the latest research on sports nutrition.

Communication between the Coach and Athlete: Communication between the coach and athlete is critical. It has been observed that often times mood states will change prior to a drop in performance (13, 23, 45, 74). Furthermore, an increase in nontraining stress can lead to the development of OTS several weeks later (75). Therefore, a strong relationship between the coach and athlete can potentially reduce OTS, which promotes both health and performance for the athlete. Communication between the athlete and coach allows for education on OTS, as well as education on the methods to reduce OTS and enhance performance.

Education on OTS: The strength coach needs to educate their athletes on proper methods to enhance recovery, the warning signs and consequences of OTS, and how "less is sometimes more" in regards to training volume and intensity. As mentioned, research (6, 38-40) has suggested that the incidence of OTS may vary from 7 to 64%, and an individual is prone to relapse once he or she has developed OTS (6). Therefore, educating

the athlete on proper training philosophies can make a significant difference on potentially reducing OTS, improving performance, and maintaining health. This can include education on proper dietary practices, sleep habits, training principles, and possibly the addition of certain safe and effective supplements to the athlete's diet. A previous article (2) on educating athletes about OTS suggests educating athletes on three elements of the training program: 1) training load, 2) recovery ability, and 3) summative stresses.

Figure 3: Methods to Prevent Overtraining Syndrome



SUMMARY

Overtraining syndrome results from the inability to recover optimally. The development of OTS is multifaceted (Figure 1), and there are several negative consequences of OTS (Figure 2). The authors have presented several methods to help the strength coach and athlete mitigate the risk for developing OTS (Figure 3). To enhance recovery and promote positive adaptations from training, the athlete should be educated on the symptoms and consequences of OTS. Education should encompass and promote proper nutrition, the safety/ effectiveness of certain supplements, training philosophies, and the necessity of adequate sleep. The coach/ health professional can help reduce OTS by being educated and current with the latest research and methodologies to enhance recovery. The field of strength and conditioning is always progressing, and tactics such as cold water immersion (76) and reaction time tests (6, 9) appear to be promising in recovery and monitoring exercise, respectively.

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