Overtraining Syndrome in the Athlete: Current Clinical Practice

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Abstract

Competitive athletes are pushed routinely to the limits of their physical abilities. When tempered with periods of rest and recovery, a highly demanding training schedule can have tremendous benefits. However when an athlete is pushed too far, overtraining syndrome (OTS) can develop and result in career-ending damage. Overreaching and overtraining are part of the same spectrum that can lead to OTS. The pressure to perform placed on elite athletes is a real danger. Athletes and coaches understand the importance of rest days, but the insidious onset of OTS slowly saps the efficacy of recovery times so the athlete is no longer able to reach previously attainable goals. Identifying markers that correlate with overreaching and overtraining can arrest progression of a potentially negative cycle. We will examine the current literature and discuss possible screening tests and red flags that will assist in preventing OTS from occurring.

Introduction

Competitive athletes are pushed routinely to the limits of their physical abilities. When tempered with periods of rest and recovery, a highly demanding training schedule can have tremendous benefits. However, when an athlete is pushed too far, overtraining syndrome (OTS) can develop and result in career-ending damage. Overreaching and overtraining are part of the same spectrum that can lead to OTS. The intense pressure to perform placed on elite athletes makes a very real danger, the screening for which must be incorporated into any aggressive workout schedule. Many athletes and coaches understand the importance of rest days, but the insidious onset of OTS slowly saps the efficacy of recovery times so the athlete is no longer able to reach previously attainable goals. Identifying markers that correlate with overreaching and overtraining can arrest progression of a potentially negative cycle. This article will examine the current literature and discuss possible screening tests and red flags that will assist in preventing OTS from occurring.

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Epidemiology

Described as early as 1923, OTS has long been an enigmatic ailment. Studies are limited and conflicting in estimates of incidence and prevalence, indicating that somewhere between 5% and 64% of elite athletes experience OTS at least once (1,5,11,13). This wide range can be attributed to small sample sizes, differing diagnostic criteria, and varied definitions for what truly qualifies as OTS. One study shows that lifetime prevalence is higher among male athletes, while another found that females are more likely to be affected (7,9). However it is accepted that endurance athletes in sports like cycling, running, rowing, and swimming, where the body is under tremendous stress for long periods, are at greatest risk. In addition, the risk of OTS is positively correlated with skill level as well as prior incidence of OTS.

The epidemiology of OTS is complicated by the fact that one clear definition is lacking. Many researchers include overreaching, which is subdivided into functional (FO) and nonfunctional (NFO), as a precursor to OTS. Overreaching data are often quantified with OTS data, thus skewing the prevalence rightward.

FO is simply an acute period where training load or intensity is significantly increased (11). As its name implies, FO can be a highly beneficial part of a training regimen as planned overreaching can yield positive physiological adaptations and performance improvements. Full restoration of performance or improvement will typically occur within 3 to 14 days.

NFO is similar to OTS in that it lies on the same spectrum and is differentiated only by the time to recovery. NFO typically is caused by a brief period of training overload followed by inadequate recovery, usually occurring over days to weeks. If rest intervals are not incorporated in the workout regimen, this overreaching can progress to OTS (Fig. 1). The distinction between NFO and OTS is not determined by the severity of the symptoms but by the

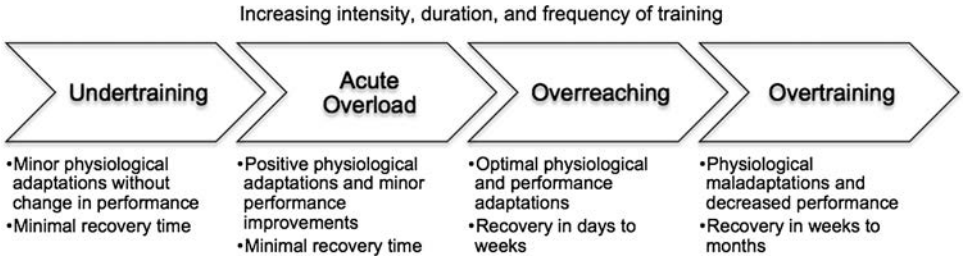

Figure 1

duration of time needed for recovery, which currently is identified more easily after complete rest (1,7,9).

OTS will be defined as an accumulation of stress, due to training and additional life stressors, that results in long-term performance decrement that may or may not be accompanied by psychological and physiological signs and symptoms (1,2,7). This definition is quite ambiguous, which is one reason diagnosis of OTS is so difficult. Previous studies disagree on specific signs and symptoms that can make a definitive diagnosis of OTS, other than general performance decline and retrospective evaluation of rest time needed for recovery, which can take several weeks to months. It may help to think of OTS by some of its synonyms to picture what an athlete experiencing OTS looks like: burnout, staleness, underrecovery, chronic fatigue, and unexplained underperformance syndrome (UUS).

Underperformance syndrome is used more frequently by European physicians and researchers and may be a more apt phrase for describing this syndrome. Coaches and trainers may be more accepting of this term and thus more likely to screen for the syndrome since the implication that they have pushed their athletes too far by "overtraining" is removed from the name (8). This subtle, yet important, distinction is relevant since the catalyst for the onset of OTS is often a stressor found outside the training world like social, scholastic, relational, or financial difficulties (2). However the major cause is the accumulation of stress primarily through intense training and inadequate recovery periods with nonathletic stressors functioning as the tipping point.

Pathophysiology

Numerous hypotheses have been suggested to explain the pathophysiology of OTS. Any successful explanation must account for the complexity and variance of the symptoms. The cytokine, hypothalamic, glycogen, and branched-chain amino acid (BCAA) hypotheses are the most strongly supported, although none are definitive.

Cytokine Hypothesis

Joint movement and muscle contraction can cause tissue microtrauma in sports with highly repetitive movements (9,17). This trauma stimulates an acute local inflammatory response and cytokine recruitment (Fig. 2). Prolonged activation of muscles and joints without adequate rest can shift local acute inflammation to chronic inflammation, thus stimulating an amplified inflammatory response with correlated pathology (9,17). The most important cytokines implicated in OTS are IL-1β, IL-6, and TNF-α (9,17). These three cytokines and their effects explain most of

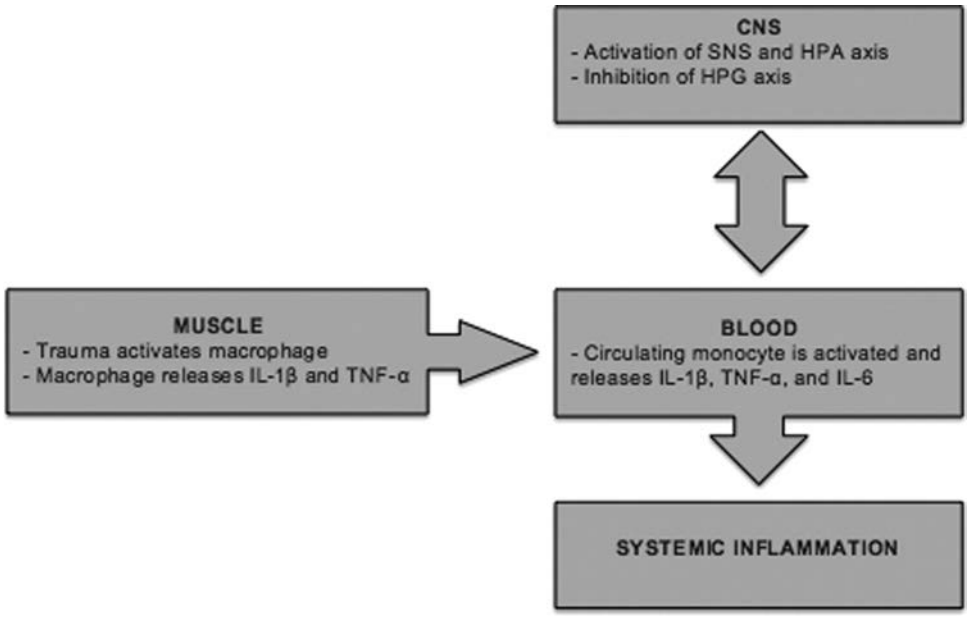

Figure 2

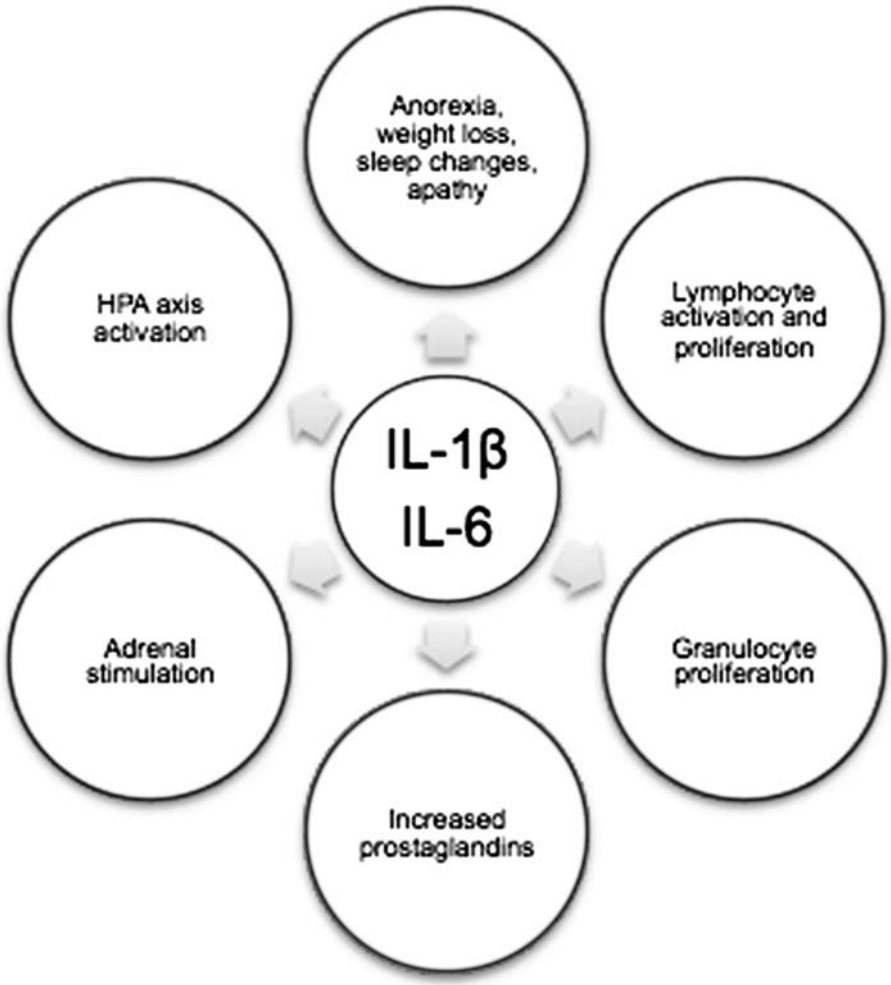

Figure 3

the symptoms and account for a number of early hypotheses being abandoned for a more inclusive explanation.

For example, cytokines that act in the hypothalamus can decrease hunger, which results in decreased glycogen stores (9,17). This line of thinking has superseded the glycogen hypothesis, which accounted for some of the symptoms present in OTS, but failed to determine a cause for low glycogen levels. In addition to appetite suppression, TNF-α and IL-1β also can account for sleep disturbances and depression due to their activity in the brain. Some research has shown elevated cytokine levels in depressed patients, while others have induced depression after cytokine administration.

Similarly studies have linked decreased GLUT-4 transporters with down-regulation of protein synthesis by TNF-α. The decreased transporter numbers are unable to overcome the glycogen usage deficit in stressed muscles and likely account for muscle fatigue and the sensation of heavy legs while training (9,17).

There is preliminary evidence to show that this increase in cytokines can be measured through the resulting increase in lymphocytes, specifically, TH2 lymphocytes. Certainly, the lymphocyte profile is dependent on the inducing cytokines, which can vary greatly. However several studies have shown increased TH2-favoring cytokines after intense exercise, while TH1-favoring cytokines remain undetectable (18).

The cytokine hypothesis is the most inclusive explanation for OTS (Fig. 3). It explains "why" OTS occurs by presenting a primary cause with effects all over the body that correlate with the symptoms of overtrained athletes (9,17). Despite this hypothesis fitting nicely as the etiology of OTS, some limitations still remain. There is very little evidence showing elevated cytokines in overtrained athletes. The few studies that have explored the relationship of cytokines and overtraining were only short term and limited to participants who were extremely fit at baseline. Therefore conclusions made from these studies may not be applied to the general population, nor may it hold up as a true explanation for OTS due to lack of follow through. More thorough research is required before definitive suppositions can be made about this complex syndrome.

Hypothalamic Hypothesis

Another mechanism that may potentially cause OTS is dysregulation of the hypothalamus and its axes. Specifically the hypothalamic-pituitary-adrenal (HPA) and hypothalamic-pituitary-gonadal axes would account for many of the symptoms seen in overtrained athletes (7,9,17).

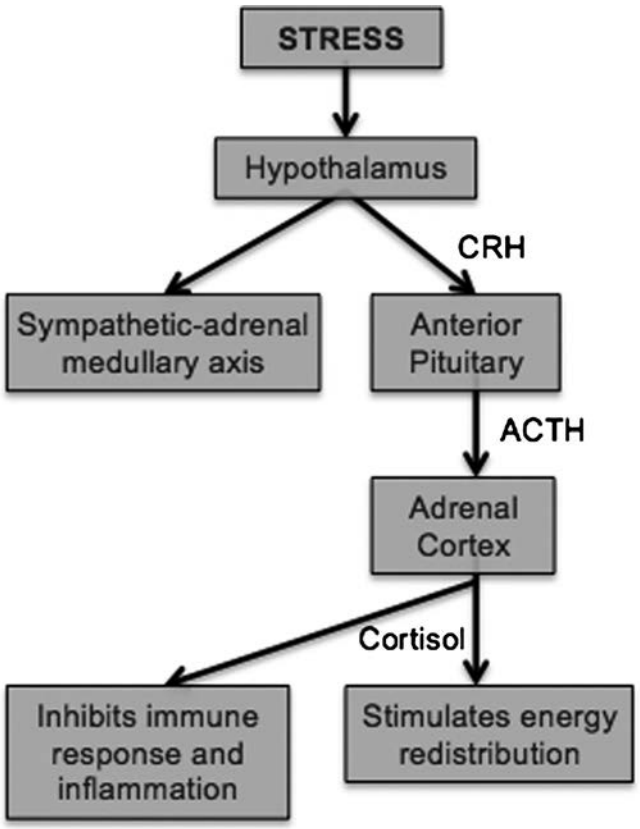

Figure 4: The two hormonal axes used in response to stressors are the sympathetic-adrenal medulla and HPA. CRH, corticotrophin-releasing hormone; ACTH, adrenocorticotropic hormone.

These athletes can have drastic changes primarily in cortisol, adrenocorticotropic hormone (ACTH), testosterone, and subsequently estrogen, which could explain the increased susceptibility to upper respiratory tract infection (URTI) and decreased inflammation, as well as early increases in pre- and postexercise catecholamine levels (Fig. 4) (1,11).

Unfortunately studies that quantify these hormone levels in athletes have varied widely; some showing increases and others decreases. Much of this can be attributed to variability of testing practices, exercise capacity of the individual being tested, and other hormone levels. Specifically resting cortisol, testosterone levels, and the testosterone/cortisol ratio have not been supported by research due to contradictory results (7,9), although the real weakness in this theory, as well as most others, is that it cannot account for all of the symptoms.

Low serum cortisol indicates adrenal depletion and can be present with elevated or decreased ACTH levels, depending on which aspects of the HPA are affected. The symptoms of cortisol depletion are consistent with many of the parasympathetic manifestations described in Table 1 (4). Indeed, low cortisol is implicated in the broad family of fatigue disorders, in which OTS can be included. Researchers have described an Addison type of OTS where adrenal glands are functioning minimally, and these result in performance decrement (4). The hypothesis is that prolonged training causes autonomic imbalance and reduced responsiveness to ACTH. This ACTH insensitivity is compensated by increased ACTH release from the pituitary.

This compensation can mask developing symptoms of overreaching until the physiological stress of training surpasses the individual's ability to cope. Eventually, as the adrenals are continually overworked, the increased ACTH levels will cease to compensate and the athlete will begin showing signs reminiscent of Addison disease: fatigue, weight loss, lack of ambition, etc. (4).

An argument could be made that an Addison type dysfunction of the HPA could cause OTS. Conversely prolonged and untreated OTS may actually result in complete adrenal insufficiency due to overuse (4). Severely overtrained athletes can develop Addison disease after adrenal depletion and loss of responsiveness to hypothalamic/pituitary hormones (4).

Glycogen Hypothesis

Low muscle glycogen can have a negative effect on training and performance by not providing enough energy for the high workload. Because of this, some researchers have proposed that decreased glycogen can cause OTS. Decreased glycogen causes increased oxidation and decreased levels of BCAA, which are involved in central neurotransmitter synthesis and thereby fatigue development (9,13).

This seems plausible; however studies have shown that athletes who consume inadequate carbohydrates may fatigue more quickly, but do not meet the requirements to diagnose OTS (9,13). In addition, athletes who maintain normal glycogen levels through increased carbohydrate consumption during heavy training may still develop OTS (9). While certainly related to fatigue development in athletes, the link of glycogen to OTS is weak and unsupported by the literature.

Table.

Parasympathetic Alterations	Sympathetic Alterations	Other
Fatigue	Insomnia	Anorexia
Depression	Irritability	Weight loss
Bradycardia	Tachycardia	Lack of concentration
Loss of motivation	Agitation	Heavy, stiff muscles
	Hypertension	Anxiety
	Restlessness	Awakening unrefreshed

Some physiologists have proposed that chronically elevated levels of catecholamines may stimulate a reduced rate of glycogen synthesis after intense exercise, although there is no research to validate this (1).

BCAA Hypothesis

Tryptophan, the serotonin (5-HT) precursor, competes with BCAA for the same carrier in the blood-brain barrier. This hypothesis proposes that decreased BCAA levels ultimately allow more tryptophan into the brain, which drastically elevates central 5-HT concentration. This requires the amount of 5-HT to rise so high as to induce a state of fatigue in the individual as well as other OTS symptoms like mood and sleep disturbances (1,5,9).

Exercise decreases BCAA due to oxidation, which would then facilitate increased tryptophan entry into the brain. Anecdotally athletes have reported feeling more energized and clear minded when supplementing BCAA during training. Conversely giving serotonin reuptake inhibitors has caused increased fatigue and decreased overall performance (5,9).

However some research has shown that athletes with OTS may actually have increased 5-HT receptor sensitivity as opposed to higher 5-HT concentration. Well-trained athletes are less sensitive to 5-HT, but OTS athletes may have lost that adaptation (9). The main problems with this hypothesis are 1) distinguishing the effects of central 5-HT from peripheral 5-HT is difficult and 2) mood and fatigue are subjective variables that are problematic to quantify as well as plagued by confounding factors (5,9). In addition, it fails to account for the increased incidence of URTI in OTS athletes. Therefore the 5-HT hypothesis has limited applications when discussing OTS.

Diagnosis

Diagnosis of OTS is made really by excluding all other etiological possibilities. When an athlete presents with fatigue, mood changes, and decreased performance accompanied by more frequent injuries and increased achiness, the differential should include, but is not limited to, major depression or other psychological disorder, drug abuse, anemia, mononucleosis, hypothyroidism, diabetes, adrenal disease, eating disorder, and hepatitis (2,13). The clinical and endocrinological manifestations of OTS can mimic man other diseases, as listed above, which makes diagnosis exceedingly difficult. The first step should always include ruling out systemic infections like mononucleosis and caloric imbalance, which can be done quickly and is relatively inexpensive. Following that, organic diseases can be eliminated through blood panels and drug challenges (13).

By obtaining a thorough history, a clinical diagnosis of OTS can be determined by showing 1) decreased performance despite adequate rest, 2) mood changes, and 3) lack of other causes of underperformance (9). However if a patient presents with decreased performance but has not attempted more than 2 to 3 wk of rest, a diagnosis of OTS should not be made, although it could be considered NFO and treated with adequate rest (9). If the patient fails to recover after appropriate rest of at least 2 wk, OTS can be diagnosed empirically.

When considering OTS in a patient, it is important to couple the previously discussed tests with identifying events surrounding the initiation of performance decline. The emotional and psychosocial factors related to school, work, sexual partners, or even the pressure of training can catalyze the onset of symptoms and must be thoroughly explored.

Unfortunately there is no reliable way to quantify how much stress is too much or where the threshold lies in regard to crossing into OTS from FO/NFO (13). Even when the patient and the physician are able to identify the causative psychological event(s), the physical triggers described in the above hypotheses may be transient and difficult to recognize or absent at the time of presentation (13). In addition, because there are multiple factors involved with the development of OTS, some researchers have declared it more appropriate to rename it UUS, as described previously.

The lack of definitive diagnostic markers for OTS is evident in the inconsistent findings seen in recent research in the field. The ideal biological marker should be easy to measure, minimally invasive, and affordable (13). It also should not interfere with the training process. In reality, there are no currently available or suggested markers that satisfy these criteria (13). There are a few, like creatinine kinase (CK), heart rate variability (HRV), and blood lactate, that show some promise as part of a group of tests to identify OTS at an early stage.

Many biochemical and hormonal changes are present in OTS individuals and may be useful eventually in diagnosis once the specific relationships are extrapolated. Blood lactate has been posited as a useful marker due to its inverse relationship to glycogen levels in muscle and liver (13,19). Easily obtained from an earlobe blood sample, blood lactate levels can be affected by the training status of the athlete. Numerous metabolic variables also affect blood lactate, so it is not effective in identifying OTS on its own. One consistent finding shows that strength and endurance athletes with OTS have diminished maximal lactate concentration while submaximal concentrations are within normal limits (13,19). While useful in identifying OTS, this parameter is not sensitive enough to rule out NFO (9).

In addition, circulating levels of CK increase with eccentric and unaccustomed exercise and last for days to weeks. CK levels coupled with urea levels measured at rest should be accurate representations of muscular and/or metabolic strain, but they are ineffective at recognizing overreaching or OTS (13,19). A recent study showed no statistical difference in CK changes between normal and overreached athletes (10). This research also indicated that circulating catecholamine levels did not change in any discernable pattern among test subjects, nor was cognitive function affected.

HRV is the phrase that describes the change in the interval between consecutive heartbeats. It is representative of cardiac autonomic balance, with an increase in variability relating to increased parasympathetic tone. OTS individuals tend to have lower maximal heart rates (HR_{max}) with increased variation when compared with healthy subjects (7,10,13). Monitoring athletes' HR before and during training sessions and comparing them with baseline values for each individual can be another tool to help distinguish OTS from some other cause of underperformance. Unfortunately studies have shown significant inconsistencies in HR_{max} reliability for predicting OTS. One reason for this is that there is no standardization of methods to log and calculate

the data. In addition, most of the studies involving HRV in this population induced OTS through drastically increasing training protocols over a short period. This could inaccurately reflect autonomic cardiac adaptations that may ordinarily take some time to equalize. HR abnormalities may be attributed also to adrenergic receptor changes, decreased responsiveness to catecholamines, reduced sympathetic activity, or reduced cardiac power output, any of which could stem from numerous initial causes unrelated to OTS (13).

Part of the clinical diagnosis of OTS includes mood changes. The Profile of Mood States questionnaire (POMS) is the most widely used tool to gauge variations in mood among athletes. It is a 65-item form that measures total mood disturbances and 6 mood states (tension, depression, anger, vigor, fatigue, and confusion) (8). The POMS questionnaire is a useful tool to assess the early indicators of overtraining, but it is unable to include information about the causes.

As a result, the Recovery-Stress Questionnaire for Athletes (RESTQ-Sport) was developed to pinpoint mood disturbances related to or affecting training. It is a 77-point form that explores general stress, emotional stress, social stress, conflicts/pressure, fatigue, lack of energy, and physical complaints in addition to recovery scales and sport-specific stress scales (8,13). Using these parameters, the RESTQ-Sport is effective in identifying individuals at risk for OTS, although alone it cannot provide the final diagnosis that someone is already overtrained.

Despite the inconsistencies among study results, the two most important factors in identifying OTS at an early stage are monitoring HR and blood lactate. These two parameters alone are able to classify 89.5% of athletes who may be entering OTS (10). Although blood lactate will normally decrease as an adaptation to improved physical fitness, a 2001 study examined this rightward shift. Research showed that it is possible to correct for the potentially confounding low blood lactate caused by regular training by expressing the value as a percentage of peak blood lactate (3). This adjusts for any rightward shift and shows that blood lactate is a useful biochemical marker for identifying OTS. By utilizing HR and blood lactate along with the POMS or RESTQ-Sport, the clinician or trainer can recognize OTS and intervene to prevent progression of the disorder and potential lifelong complications.

Treatment/Prevention

Because the manifestation of OTS can vary greatly in individuals, treatment must be appropriate for the specific cluster of symptoms in each person. There is no panacea for this complicated diagnosis, and each athlete needs a custom management plan to successfully recover. Consistently the major element of all treatment plans is relative or absolute rest, depending on the severity of the symptoms (2). Relative rest may be indicated as high-performing athletes could experience from increased stress by mandated complete inactivity (9). Mild cases may recover after only a few weeks of rest or decreased training load. More severe cases of OTS require longer intervals of rest and may not ever resolve.

Regular recording of HR, blood lactate, and mood changes are the most effective tools for recognizing when an athlete is moving beyond overreaching and into OTS. HR is easy to monitor and is likely already incorporated in the individual's training program. Mood questionnaires can be effective when used on a monthly basis to gauge how an athlete is coping with training/competition as well as psychosocial elements. Similarly many people have success with using training logs to track fluctuations in performance and recovery that may not be obvious across many weeks or months. Blood lactate levels can be assessed during periods of maximal exertions once per quarter or only after performance begins to diminish since it is the most invasive test.

A recent hypothesis argues that SSRIs and SNRIs may be effective in diminishing many of the symptoms of OTS as well as reducing recovery time. This usage is not FDA approved and is therefore strictly off label. Caution must be used with antidepressants in athletes as they can affect thermoregulation and predispose the individual to overheating (2,9). If the patient is experiencing sleep disturbances, trazodone or amitriptyline also may be incorporated to the plan (9).

There is also new research showing that a high carbohydrate diet can help prevent development of OTS and speed its recovery. This study used 9.4 g $CHO \cdot kg^{-1}$ bodyweight in an oral solution to be consumed before and after exercise. The results are promising, although the *n*-value was small (56) and the rest of the subjects' diets were uncontrolled. Theoretically maintaining positive energy balance through CHO supplementation will help replenish glycogen and thereby keep catecholamine, cortisol, and glucagon levels in check (13). Of course, a balanced diet complete with carbohydrates, protein, and fluids in amounts sufficient to meet the demands of intense training is very important. Supplementing amino acids has not been shown to reduce symptoms of OTS, however (13).

Conclusion

Although OTS is manifested by varying symptoms, researchers are starting to understand this complex disease more fully. Individuals are being identified earlier, which yields better outcomes and faster recovery. The most challenging factor in recognizing OTS is that it usually develops insidiously over months. Future research needs to look at OTS individuals on a more long-term basis, instead of the few weeks before and after overtraining was induced. This will allow for a more accurate definition of what OTS is and what causes it.

Search Methods

We searched the following databases for articles published between January 1, 2000, and July 10, 2013, related to overtraining in fatigued athletes: PubMed, Google Scholar, Elsevier, and Cochrane. Additional resources were identified using bibliographies of related studies.

The authors declare no conflicts of interest and do not have any financial disclosures.

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