Markers of Excessive Exercise

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Abstract/Résumé

Overtraining is of serious concern to long-distance runners and will affect 65% of them at some time in their competitive career. The clinical presentation is nonspecific but the classical symptoms include fatigue, mood disturbances, frequent upper respiratory infections and injury, and a decrease in performance. Dysfunction of the hypothalamic pituitary axis from repeated stress, of a physical or nonphysical nature, represents the most likely pathogenesis of this condition. There is no single biological marker that is diagnostic of an overtrained state; however, several parameters deserve further study. The time to voluntary fatigue on a cycle ergometer at an intensity of 110% of the individual anaerobic threshold represents a possible laboratory test. Salivary IgA holds promise as a useful immunological marker of the overtrained state and further research is needed to determine the validity of plasma glutamine as a blood marker. The most promising tool at present is a measure of the athlete's mood state, and several psychological tools can be used for this purpose.

Le suretraînement inquiète énormément les coureurs de fond et d'ailleurs, 65% des coureurs en sont affectés à un moment ou un autre de leur carrière. Le portrait clinique n'est pas net mais les symptômes classiques sont la fatigue, les variations d'humeur, de fréquentes infections des voies respiratoires supérieures, des blessures et une baisse de performance. Une dysfonction de l'axe hypothalamo-hypophysaire due au stress répété, qu'il soit de nature physique ou non, est la pathogenèse la plus vraisemblable du suretraînement. Il n'y a pas de marqueur biologique spécial qui puisse servir au diagnostic de suretraînement; il y a cependant d'autres variables méritant une attention. Le temps de performance sur ergocycle à 110% de l'intensité de travail au seuil anaérobie constitue une épreuve potentielle en laboratoire. Un marqueur immunologique, l'IgA salivaire, s'avère prometteur pour déceler un état de suretraînement. La validité de la glutamine plasmatique en tant que marqueur

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66
sangvin n’est pas encore établie. La variable la plus prometteuse en ce moment est l’humeur de l’athlète et des tests psychométriques sont disponibles.

Introduction

In order to optimize athletic performance, athletes must optimize training. Whereas the goal of training is to prepare athletes for competition, when the training program exceeds the ability to adapt, and this maladaptation continues for an unspecified time, overtraining may occur. The clinical symptoms of this disorder are varied, nonspecific, and legion, and the recognition of overtraining has become an area of concern for high performance athletes, coaches, and sport scientists. The importance of monitoring these athletes to avoid this phenomenon has also attracted considerable attention in the literature. With reference to the endurance athlete, performance is dependent upon positive physiological adaptations gained through strenuous physical training, without induction of maladaptation or injury to any system. This is often a fine line and it is not surprising that 65% of all endurance athletes have reported symptoms of overtraining at some time in their competitive career (Morgan et al., 1987).

Overtraining

Many terms have been used in the literature on overtraining: overreaching, staleness, overwork, overtraining, overstress, and burnout. This leads to confusion in describing the condition. It is possible that these terms merely describe one phenomenon at different points along a time scale from fatigue to the classical clinical presentation of the overtrained athlete. There are no clear criteria as to the diagnosis of overtraining, nor are there any specific guidelines on the treatment and prevention of this disorder. This paper will review the presentation of the athlete who is overtrained, along with the suggested pathogenesis. It will also emphasize the markers that have been used to identify and follow athletes to prevent this syndrome.

CLINICAL PRESENTATION

Multiple signs and symptoms have been associated with overtraining, and Fry et al. (1991) have published a comprehensive list of the major symptoms reported in the literature. This list is so complete that it merely serves to emphasize the nonspecific, diverse nature of this disorder. The classical symptoms are as follows:

- Decreased performance;
- Fatigue;
- Mood disturbances—irritability, anger, depression, apathy, poor attitude toward training, mental exhaustion;
- Frequent upper respiratory tract infections;
- Injury;
- Muscle soreness and diffuse joint pain.

A decrease in performance is universally accepted as the hallmark of overtraining, yet many studies that have attempted to induce overtraining have failed to achieve this goal and merely overworked the participants instead. This has led to erroneous conclusions about overtraining.
A careful review of the training diary offers valuable clues to overtraining. A failure of adaptation is either a consequence of too much training or too little recovery. Fatigue is a common complaint of high performance athletes, and there are valid medical reasons for this condition. Clinically, it has been suggested that prolonged training produces an autonomic imbalance; this has led to the description of two types of overtraining. Fatigue and apathy predominate in the parasympathetic type of overtraining, which is reported to be typical for endurance sports (Lehmann et al., 1998), whereas restlessness and hyperexcitability predominate in the sympathetic type of overtraining, which is seen more in the explosive sports. It is possible that the overtraining response follows a progression from a predominance of sympathetic stimulation to parasympathetic symptoms. There is little empirical evidence to support the classification of the overtraining syndrome into two types (Hooper and Mackinnon, 1995).

PATHOGENESIS

Although the precise mechanism of overtraining has not been established, several studies support the hypothesis of a central neuroendocrine role in the development of this condition. A study by Barron et al. (1985) was the first to show a blunted response of the stressor hormones GH, ACTH, and cortisol to insulin-induced hypoglycemia in athletes who were suffering from the overtraining syndrome. Several investigators have reported a decrease in the ratio of free testosterone (T) to cortisol (C) in athletes who have symptoms of overtraining (Adlercreutz et al., 1986; Roberts et al., 1993). Other researchers have not been able to confirm this relationship (Lehmann et al., 1992; Urhausen et al., 1987; Wittert et al., 1996). More recent work by Urhausen et al. (1995) indicates that the changes in T and C, and the decrease in the T/C ratio, likely reflect the physiological response to the previous training bout rather than the overtraining syndrome.

The effects of heavy physical exercise and training on the neuroendocrine system and the relationship to overtraining is far from unanimous, but Keizer (1998) suggests that changes in mood state, recovery rate, the reproductive state, as well as sleep disturbances and the prolonged symptoms of fatigue, are all consistent with a maladaptation in certain parts of the brain with consequent changes in hypothalamic effector output. These changes are caused by exercise-induced changes in neurotransmitter metabolism.

PHYSIOLOGICAL TOOLS

There have been many attempts to find a simple measurement that might identify the athlete who is approaching the overtrained state, for example:

- Time to volitional fatigue on a cycle ergometer at 110% IAT (individual anaerobic threshold);
- Salivary immunoglobulin A;
- Plasma glutamine;
- Psychological assessment tool.

As it is unethical to induce overtraining in a high performance athlete, detailed studies of the overtraining syndrome in humans have been difficult to achieve, and there is not a good animal model that can be used to research this disorder.
There does not appear to be a strong role for laboratory testing of physiological parameters in identifying athletes who are developing the overtraining syndrome. Investigators have been unable to confirm physiological markers of overtraining (Fry et al., 1991; Kuipers and Keizer, 1988; Lehmann et al., 1993). Heart rate, because of its ease of measurement, has been tried extensively as a marker for maladaptation to physical stress. Increases in resting heart rate, increases in heart rate at a standardized workload, increases during recovery from exercise, and lowered maximal heart rate have all been used in an attempt to identify the overtrained state. These changes have been attributed to exhaustion of the neuroendocrine system or a decrease in catecholamine sensitivity (Lehmann et al., 1993; Noakes, 1987; Stone et al., 1991).

Blood pressure has also been investigated as a marker for overtraining. Increases in both systolic and diastolic pressure have been reported in a group of athletes who had the symptoms of overtraining (Stone et al., 1991). Postural hypotension has also been reported to be more noticeable in this population (Ryan et al., 1983). Regrettably, there is not a consensus on the usefulness of these measurements in monitoring the training of endurance athletes. Studies have investigated resting and maximal oxygen uptake and anaerobic capacity, and no significant changes have been demonstrated relative to overtraining.

Very recently, Urhausen and colleagues (1998) have reported that an exercise stress test, performed on a cycle ergometer at an intensity of 110% of the individual’s anaerobic threshold, resulted in a significant (27%) decrease in time to exhaustion when the athletes were in an overtrained state. Blood concentrations of ACTH and GH were also significantly reduced following the stress test. Other biological markers and laboratory variables could not discriminate between well-trained and overtrained athletes. These data support the hypothesis of hypothalamic-pituitary dysfunction in overtraining and provide a laboratory test that may prove useful in identifying this condition. More work is required to validate this observation.

**BIOLOGICAL MARKERS**

A complete range of hematological (Dressendorfer et al., 1981), biochemical (Fry et al., 1993; Rowbottom et al., 1995, 1996, 1997), hormonal (Barron et al., 1985; Urhausen et al., 1995), and immune system markers (Hooper et al., 1993; Mackinnon and Hooper, 1994) have been studied by scientists and clinicians in an attempt to identify the overtrained athlete. It is clear that many of these variables change with both acute and chronic exercise. However, it is equally clear that the relationship to the overtrained state is spurious.

Our own experience verifies this observation. In 1988 we followed the Canadian National Rowing team for 20 weeks from the preseason period to the end of the competitive cycle. Every week, resting blood samples were taken after a 24-hr recovery period and analyzed for hemoglobin, hematocrit, white blood cell count and differential, serum ferritin, erythrocyte sedimentation rate, creatine kinase, cortisol, and free testosterone. Although a decrease in the free testosterone/cortisol ratio appeared to be associated with the clinical presentation of overtraining in several athletes, this was not unanimous. Other variables demonstrated changes with time but were not useful for predicting which athletes were in danger of becoming overtrained. All of these studies, taken together, confirm that no single biological parameter has been identified as a reliable marker of overtraining.
IMMUNE FUNCTION

Since one of the most common symptoms of overtraining is an increased susceptibility to infection, it is not surprising that the effects of prolonged endurance training on the immune system have been the subject of numerous scientific reports (Mackinnon and Hooper, 1994; Shephard and Shek, 1998). There is compelling evidence that endurance trained athletes are more prone to upper respiratory tract infections (URTI), and that the risk of these infections increases with intense training and competition (Mackinnon, 1998). Surprisingly, the relationship between the incidence of URTI and overtraining in athletes has received little attention. In a study by Mackinnon and Hooper (1996) in which 24 swimmers were followed throughout a period of intense training, 33% of the swimmers developed overreaching and 42% exhibited URTI. Interestingly, the incidence of URTI was much greater in the well-trained swimmers (56%) than in those who exhibited the symptoms of overtraining (12.5%). This suggests that the symptoms of URTI are related more to intense training than to overtraining.

Although the resting white blood cell (WBC) count is increased following intense exercise, there have been reports of lowered WBC counts with prolonged exercise (Lehmann et al., 1992). The values tend to remain within the normal clinical range; Tvede et al. (1991) found no difference in resting WBC counts of elite cyclists following low and high intensity training. Neutrophil counts are not affected by intense training, although neutrophil function is adversely affected. However, there was no clear link between changes in neutrophil oxidative activity and the incidence of URTI in a group of elite swimmers who were trained intensely for 12 weeks (Pyne et al., 1995). NK cell numbers are reduced significantly with prolonged physical training and they continue to decrease into a recovery period (Fry et al., 1994).

Perhaps the most promising immune system indicator of overtraining is secretory IgA, which is responsible for the humoral immune response of the mucosal surface. The levels of secretory IgA are highly correlated with resistance to certain viruses responsible for URTI. IgA can easily be measured from a saliva sample and is used as a marker of mucosal immune status (Mackinnon, 1998). Intensive exercise has been associated with a decrease in secretory IgA and this seems to be related to increased training intensity (Tharp and Barnes, 1990). Mackinnon and Hooper (1994) have reported a significantly lower concentration of salivary IgA in a group of elite swimmers who were clinically diagnosed as suffering from overtraining, compared to their teammates who were considered well-trained. These observations deserve further study.

A decrease in plasma glutamine concentration has been demonstrated in a group of athletes showing symptoms of overtraining, in comparison to well-trained athletes (Parry-Billings et al., 1992). Since lymphocytes rely on glutamine as a source of energy, it has been suggested that the low plasma glutamine levels associated with intense training and overtraining may compromise lymphocyte function and that this may be related to an increased incidence of infectious disease in this population (Mackinnon, 1998).
PSYCHOLOGICAL TOOLS

There is a general consensus that, at present, the most promising tool for monitoring the high performance athlete is a measure of mood state. Sport psychologists have argued that overtraining is a complex interaction of stress and coping that involves physical training variables; biological response systems; individual cognitive, behavioural, and emotional characteristics and skills of the athlete; and a rich variety of environmental stresses and supports (Meyers and Whelan, 1998). Morgan et al. (1988) were the first to use the Profile of Mood States (POMS) with athletes, and this psychological tool has been useful in following athletes throughout a training program.

Other tools have been used to quantify all the stressors that influence the elite athlete. We have had success using a 10-item questionnaire that highlights the different stressors and creates a stressor index for medical, psychological, training, and miscellaneous conditions (McKenzie, 1995). This monitoring device can be computerized and the results expressed graphically. Like other psychological tools, this questionnaire is useful for following individual athletes.

Athletes who become overtrained tend to show a pattern to the change in their stressor indices. The first noticeable change is in the psychological markers. Next come symptoms of an upper respiratory tract infection, muscle or joint pain, generalized fatigue, or sleep disturbances (the medical index). Performance can still be maintained, but it will be affected within a day or two if there is no intervention. The pattern of decrement seems to be, in order—psychological status, medical condition, performance. The perception of training does not appear to play a major role in the development of this condition. This monitoring tool has been used effectively to follow athletes and it allows intervention in order to prevent full-blown overtraining.

Summary

Overtraining is of serious concern to long-distance runners and affects 65% of them at some time or other. Dysfunction of the hypothalamic pituitary axis from repeated stress, of a physical or nonphysical nature, represents the most likely pathogenesis. Currently there is no single biological marker that is diagnostic of an overtrained state. However, several parameters deserve further study. Time to volitional fatigue on a cycle ergometer at an intensity of 110% of the individual’s anaerobic threshold represents a possible laboratory-based test. Salivary IgA holds promise as a useful immunological marker of the overtrained state. Further research could help determine the validity of plasma glutamine as a blood marker. The most promising tool at present is a measure of mood state, and there are several psychological tools that can be used for this purpose.

References


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