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Fatigue and underperformance in athletes: the overtraining syndrome

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Introduction

When athletes fail to recover from training they become progressively fatigued and suffer from prolonged underperformance. They may also suffer from frequent minor infections (particularly respiratory infections). In the absence of any other medical cause, this is often called the overtraining syndrome, burnout, staleness, or chronic fatigue in athletes.[1–3] The condition is secondary to the stress of training but the exact cause and pathophysiology is not known. Many factors may lead to failure to recover from training or competition.

Definition

"The overtraining syndrome is a condition of fatigue and underperformance, often associated with frequent infections and depression which occurs following hard training and competition. The symptoms do not resolve despite two weeks of adequate rest, and there is no other identifiable medical cause."

This contrasts with the definition of chronic fatigue syndrome, for which symptoms must last at least six months.[1]

Normal response to training

All athletes, in any sport, must train hard in order to improve. Initial hard training causes underperformance but if recovery is allowed, there is supercompensation and improvement in performance.[4] Training is designed in a cyclical way (periodisation) allowing time for recovery with progressive overload. During the hard training/overload period, transient symptoms and signs and changes in diagnostic tests may occur; this is called overreaching.[5]

There are changes in the profile of mood state (POMS) questionnaire which show reduced vigour and increased tension, depression, anger, fatigue, and confusion.[6] Muscle glycogen stores are depleted and resting heart rate rises. The testosterone:cortisol ratio is reduced as the result of lower testosterone and higher cortisol levels. Microscopic damage to muscle also leads to raised creatine kinase levels if there is eccentric exercise.[7]

All these changes are physiological and normal if recovery occurs within two weeks. Overreaching is a vital part of training for improved performance.[5]

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Abnormal response to training

In some athletes there is underrecovery as the result of excessively prolonged and/or intense exercise, stressful competition, or other stresses. This leads to progressive fatigue and underperformance. The reaction to this underperformance is often an increase in training rather than rest.[8]

Intensive interval training, in which one to six minutes of hard exercise is repeated several times with a short rest, is most likely to precipitate the overtraining syndrome. There may also be a history of a sudden increase in training, prolonged heavy monotonous training, and very commonly some other physical or psychological stress. Nevertheless, however hard the training, most athletes will recover fully after two weeks of adequate rest. The cyclical nature of most training programmes (periodisation) allows this recovery and full benefit from hard exercise.[9] Figure 1 summarises the responses to training.

Eventually fatigue becomes so severe that recovery does not occur despite two weeks of relative rest. At this stage a diagnosis of the overtraining syndrome can be made.

SYMPTOMS

The main complaint is of underperformance. Athletes will often ignore fatigue, heavy muscles, and depression until performance is chronically affected.[10] Sleep disturbance occurs in over 90% of cases with difficulty in getting to sleep, nightmares, waking in the night, and waking unrefreshed.[11] There may also be loss of appetite, weight loss, loss of competitive drive and libido, and increased emotional ability, anxiety, and irritability. The athlete may report a raised resting pulse rate and excessive sweating. Upper respiratory tract infections or other minor infections frequently recur every time an athlete tries to return to training when they have not fully recovered. This gives an apparent cycle of recurrent infection every few weeks (fig 2).[1]

SIGNS

Reported signs are often caused by associated illness and are inconsistent and generally unhelpful in making the diagnosis. Cervical lymphadenopathy is very common. There may be an increased postural fall in blood pressure and postural rise in heart rate, probably related to the underlying pathophysiology.[12] Physiological testing may show a reduced maximum oxygen consumption and maximum power output and an increased submaximum oxygen consumption and pulse rate, with a slow return of the pulse rate to normal after exercise.[11]

PREVENTION AND EARLY DETECTION

Overtraining for one athlete may be insufficient training for another. Athletes tolerate different levels of training, competition, and stress at different times, depending on their level of health and fitness through the season. The training load must therefore be individualised and reduced or increased, depending on the

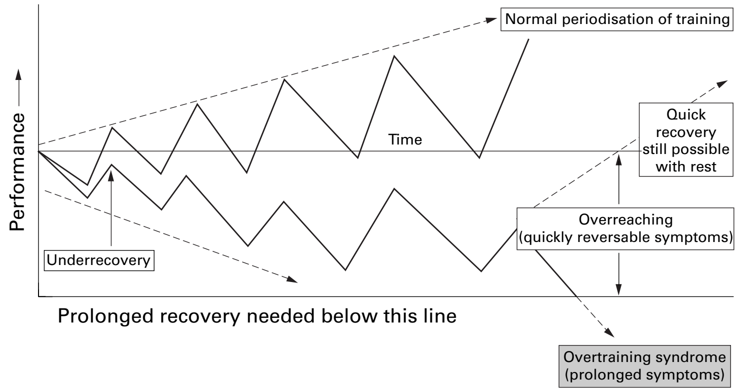

Figure 1 Overtraining or underrecovery, leading to the overtraining syndrome.

athlete's response. Other stresses such as exams need to be taken into account.[13]

In practice it is very difficult to distinguish between overreaching and the overtraining syndrome. Researchers have attempted to follow blood parameters such as haemoglobin, packed cell volume, and creatine kinase but these do not help. Mood state profiling on a regular basis can give useful guidance.[14]

Many athletes monitor their heart rate. This is non-specific but can provide objective evidence that something is wrong.[15] Other prevention strategies are a good diet, full hydration, and rest between training sessions. It is more difficult for athletes who have a full time job and other commitments to recover quickly after training.

Because it is very difficult to predict which athletes will slip into an overtrained state during a period of prolonged overreaching, it is prudent to allow full recovery at least every two weeks. Many sports scientists and coaches are advising alternate-day hard and light training within the normal cyclical programme.[9]

Training intensity and spacing of the training are the most important factors in optimising performance and minimising the risk of overtraining. Morton[16] used a complex mathematical model to optimise periodisation of athletic training. In this he suggested intensive training on alternate days over a 150 day season, with a build up over the first half tapering off over the second half. This was more effective than moderate training throughout the whole year.

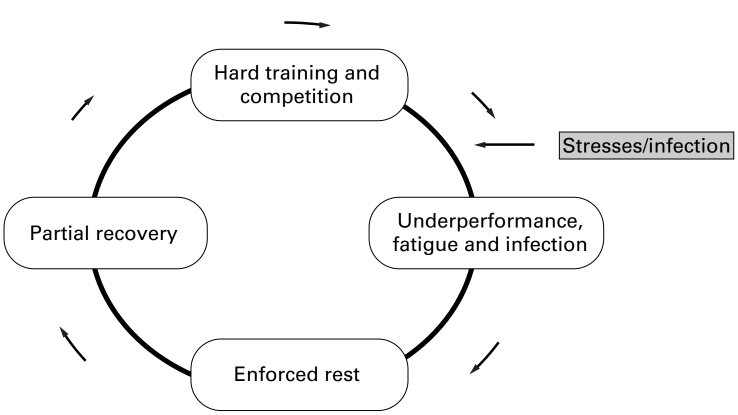

Figure 2 Cycle of recurrent minor infections.

CLINICAL INVESTIGATIONS

Athletes presenting with chronic fatigue and underperformance are often looking for a specific diagnosis and expect investigations. There is no diagnostic test available, so the aim of clinical investigations must be to exclude other causes of chronic fatigue and reassure the athlete that there is no serious pathology. The range of any test depends on a sensible approach to clinical possibilities, guided by the history and examination. A routine haematological screen may be all that is necessary, but occasionally more extensive investigations are justified to exclude serious disease such as viral myocarditis and arrhythmia.

A history of recurrent upper respiratory tract infections may represent allergic rhinitis or exercise induced asthma, in which case lung function tests are needed.[8] Creatine kinase levels are often very high in athletes, and the rise is proportional to the intensity, volume, and type of exercise (particularly eccentric work).[12] Unfortunately, creatine kinase cannot be used to indicate who will fail to recover from hard training. Many athletes also have a low packed cell volume and relatively low haemoglobin. This athletic anaemia is physiological; it is due to haemodilution and does not affect performance.

The history may suggest a post-viral illness. To make a firm diagnosis, viral titres must be shown to rise. There may also be reactive lymphocytes, and a positive Paul-Bunnell test is highly suggestive of Epstein-Barr viral infection.

Many athletes use supplements, but these do not seem to offer any protection from chronic fatigue. Trace elements and minerals such as magnesium have been investigated, but there is no proven link to the overtraining syndrome.[5]

Pathophysiology

TRAINING AND PSYCHOLOGY

Fry *et al*[17] tried to induce overtraining by short near maximum high intensity exercise but failed, suggesting that this is a safe regimen. This may be because of the frequent long periods of rest between efforts. This supports our own observations that sprinters and power athletes do not suffer from the overtraining syndrome.

Other researchers have shown a fall in the "lactate:rating of perceived exertion" ratio with heavy training.[18] Thus, for a set lactate level, the perceived exertion is higher, but this may represent glycogen depletion causing lower lactate levels rather than the overtraining syndrome.

The POMS questionnaire was used on a group of collegiate swimmers in the United States by Morgan *et al.*[14] Training was increased whenever the mood state improved and reduced whenever it deteriorated. The incidence of burnout, which was previously around 10% per year, was reduced to zero.

The mood state is most significant if it does not improve during tapering in the lead up to a competition, but unfortunately it may then be too late to prevent underperformance. The advice is therefore to taper and recover regularly throughout the season to enable regular monitoring of recovery.

At the British Olympic Medical Centre we have shown that both performance and mood state improve with five weeks of physical rest. Low level exercise has also been shown to speed recovery from chronic fatigue syndrome.[11]

HORMONAL CHANGES

The role of hormones in the overtraining syndrome is still not fully understood. Stress hormones, such as adrenaline and cortisol, have been shown to be increased in overtrained athletes compared with controls. Salivary cortisol levels (reflecting free cortisol levels) in a group of swimmers were significantly higher in stale underperforming athletes, and this correlated with the depressed mood state.[19]

A low testosterone:cortisol ratio has been suggested as a marker of the overtraining syndrome, reflecting a change in the balance of anabolism to catabolism. This ratio also falls in response to overreaching, so only a very low ratio is useful. In some athletes there is no significant change, despite all the symptoms of the overtraining syndrome.[19] There is one report of the (prohibited) use of anabolic steroids to treat the overtraining syndrome.[20]

A reduced response to insulin induced hypoglycaemia was shown by Baron and Noakes and colleagues[21] suggesting hypothalamic dysfunction.

Noradrenaline levels have been shown to be higher in overtrained swimmers than in controls, particularly during tapering, but levels were generally proportional to the training stress. There was no change in cortisol levels.[22] Plasma catecholamine levels and stress ratings (assessed by questionnaire) were a useful predictor of staleness, and a well being rating questionnaire during tapering predicted performance.[23]

The rise in noradrenaline levels and fall in basal nocturnal plasma dopamine, noradrenaline, and adrenaline levels have been proposed as a method of monitoring overtraining. These levels correlate with symptoms.[24]

CENTRAL FATIGUE

The British Olympic Medical Centre has shown that overtrained athletes produce a lower peak power in 20 second Wingate sprint tests and weaker isometric and concentric quadriceps contractions than do controls. Superimposed tetanic stimulation produced a rise in isometric power. This suggests that there is central fatigue with a failure to activate fast twitch muscle fibres fully and is consistent with the history of an inability to lift the pace at the end of a race and to sprint for the line.[25]

AMINO ACIDS AND CENTRAL FATIGUE

The neurotransmitter 5-hydroxytryptamine (5HT, serotonin) may be important in tiredness and sleep. The amino acid tryptophan is converted in the brain into 5HT and competes with the branched chain amino acids for entry into the brain on the same amino acid carrier. Thus a decrease in levels of branched chain amino acids in the blood as the result of an increased rate of utilisation by muscle will increase the ratio of tryptophan to branched chain amino acids in the bloodstream and favour the entry of tryptophan into the brain. This may result in fatigue originating in the brain. Free tryptophan is further increased by a rise in plasma fatty acid levels. In endurance activity, non-esterified fatty acids increase and branched chain amino acids decrease. In rats it has been shown that this increases the concentration of 5HT in the hypothalamus and brainstem.[26]

5HT-containing cells are widespread in the central nervous system, and changes in 5HT levels could account for many of the symptoms of overtraining affecting sleep, causing central fatigue and loss of appetite, and inhibiting the release of factors from the hypothalamus that control pituitary hormones.[27,28]

IMMUNOSUPPRESSION AND GLUTAMINE

There is evidence that moderate regular exercise helps to reduce the level of infection in normal individuals. However, intense heavy exercise increases the incidence of infection.[29] Upper respiratory tract infections have been shown to be more likely with higher training mileage[30] and after a marathon.[31] A number of factors probably contribute to this apparent immunosuppression, such as raised cortisol levels, reduced salivary immunoglobulin levels, and low glutamine levels. Glutamine is an essential amino acid for rapidly dividing cells such as lymphocytes. Low levels of glutamine have been found in overtrained athletes compared with controls, and levels are known to be lower after hard training.[32]

Glutamine intervention studies have been carried out and there is some evidence that the incidence of infection after prolonged exercise in endurance athletes taking glutamine is reduced compared with those taking placebo.[33]

Management

Athletes suffering from chronic fatigue and underperformance are different from sedentary individuals because they present earlier, they tend to recover more quickly, and there is an opportunity to alter the major stress in their lives (training and competition). Nevertheless, management is similar to that for any individual with chronic fatigue and requires a holistic approach. Rest and regeneration strategies are central to recovery.[1]

If told to rest, athletes will not comply. So they should be given positive advice and told to exercise aerobically at a pulse rate of 120–140 beats per minute for five to ten minutes each day, ideally in divided sessions, and slowly build this up over 6–12 weeks. The exercise programme has to be individually designed and depends on the clinical picture and rate of improvement. The cycle of partial recovery followed by hard training and recurrent breakdown needs to be stopped. It is often necessary for athletes to avoid their own sports, and cross training should be used because of the tendency otherwise to increase exercise intensity too quickly. A positive approach is essential, with an emphasis on slowly building up volume rather than intensity to about one hour per day. Once this volume is tolerated, then more intense work can be incorporated above the onset of blood lactate accumulation.[18]

Very short (less than 10 seconds) sprints/power sessions with at least three to five minutes of rest are safe and allow some hard training to be carried out.

There have been no trials of the regeneration strategies widely used in the old Eastern Block countries.[25] These include rest, relaxation, counselling, and psychotherapy. Massage and hydrotherapy are used and nutrition is looked at carefully. Large quantities of vitamins and supplements are given, but there is no evidence that they are effective. Stresses outside sport are reduced as much as possible. Occasionally, depression may need to be treated with antidepressants but normally drugs are of no value, although any concurrent illness must be treated.

Athletes who have been underperforming for many months are often surprised at the good performance they can produce after 12 weeks of extremely light exercise. At this point, care must be taken not to increase the intensity of training too fast and to allow full recovery after hard parts of the training cycle. We recommend that athletes recover completely at least once a week.

Summary

The overtraining syndrome affects mainly endurance athletes. It is a condition of chronic fatigue, underperformance, and an increased vulnerability to infection leading to recurrent infections. It is not yet known exactly how the stress of hard training and competition leads to the observed spectrum of symptoms. Psychological, endocrinogical, physiological, and immunological factors all play a role in the failure to recover from exercise.

Careful monitoring of athletes and their response to training may help to prevent the overtraining syndrome. With a very careful exercise regimen and regeneration strategies, symptoms normally resolve in 6–12 weeks but may continue much longer or recur if athletes return to hard training too soon.

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