Bengt Kayser[1], Gérald Gremion[2]

[1] Faculté de médecine, Université de Genève, 1211 Genève 4, Suisse
[2] Hôpital Orthopédique de la Suisse romande, av. Pierre-Decker, 1005 Lausanne, Suisse

Chronic fatigue and loss of performance in endurance athletes: overtraining

Summary

Overtraining, a decrease in performance despite training that does not disappear after 2 weeks of relative rest, accompanied by symptoms like fatigue, anorexia, and muscle and joint pain, mood changes and feeling burnt out or stale is a frequent syndrome in endurance athletes. It is generally the result of excessive activity from training and competition in combination with insufficient rest. It can be exacerbated and/or triggered by other stresses. Excluding other illnesses its diagnosis is made on history and serial exercise test data, no simple discriminative laboratory tests exist yet. Treatment is rest and gradual reintroduction of training. Prevention is possible and can be done by carefully monitoring subjective exertion from training and general mood combined with simple exercise test results. Its aetiology is not well known. The cytokine model of excessive stress leading to a generalized inflammatory state may explain the overtraining syndrome and represents an interesting avenue of further research to improve the diagnosis and management of this frequent and debilitating health problem in athletes.

Résumé

Le surentraînement est une perte de la performance malgré un entraînement intensif et qui ne disparaît pas avec deux semaines de repos relatif. Il est accompagné de symptômes comme la fatigue, l'anorexie, des douleurs dans les muscles et les tendons, changements d'humeur et sentiments de surcharge et est un syndrome fréquent chez l'athlète d'endurance. C'est généralement le résultat d'une activité physique excessive (entraînement et compétition) avec une récupération insuffisante et peut être aggravé et/ou déclenché par d'autres stress. Son diagnostic se base sur l'histoire et les résultats de tests d'effort sériels, aucun test de laboratoire discriminatif simple n'existe encore. Le traitement est le repos et une réintroduction progressive de l'entraînement. La prévention est possible en surveillant attentivement la sensation subjective de l'effort à l'entraînement et de l'humeur général, combinés avec les résultats de test d'effort simples. Son étiologie n'est pas connue. L'hypothèse des cytokines liées à un stress excessif menant à un état inflammatoire généralisé pourrait expliquer ce syndrome du surentraînement et représente une avenue intéressante de recherche pour améliorer le diagnostic et la gestion de ce problème de santé fréquent et débilitant chez les athlètes.

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Endurance training: a delicate balance between too much and too little

The purpose of this article is to give a short overview of what is known today about the aetiology, prevention and treatment of the so-called overtraining syndrome: a decrease in performance in spite of intensive training that does not go away with 2 weeks of relative rest. This article is not a complete review, but instead gives a concise and applied general overview illustrated with two practical case samples. For brevity mostly review articles are cited where the reader is referred to for further in-depth background information.

Humans are built for physical exercise. Several millions of years of selective pressure of a hunter-gatherer lifestyle have yielded an organism that is well equipped for endurance type activity. An adequate balance between rest and activity is needed for the organism to remain healthy. A modern societies' sedentary lifestyle is not good for one's health, but life on the other extreme of the spectrum of physical activity may also lead to health problems. Elite endurance athletes operate «on the edge» of what the organism can adapt to. There are physical limits to the strain imposed by endurance exercise on the organism and to the average daily maximum energy flux through the organism that can be maintained. This not only applies to the duration of extreme endurance events, but also to the intensity, frequency and duration of training sessions in preparation for such events.

Performance in endurance events is function of prior training in preparation for such events. A combination of talent, determined in large part by a person's genetic make-up, and a well designed training regime make a good endurance performer. Training aims at maintaining a base level of performance as well as achieving an improved performance in preparation of peak performance events like competitions. The principle of training is to burden the organism in such a way that it adapts, during a resting period, to the increase in load that was imposed, by increasing its capacity to cope with future loads [1].

Every athlete must train hard to improve performance. Training can be described in terms of frequency, duration and intensity. Hard training initially causes under-performance, but after appropriate recovery, there is an increase in performance often called «super-compensation». Athletes, trainers and coaches have empirically found that proper training is designed in a cyclical way (periodization) allowing time for recovery from overload. Well dosed overload leads to a temporary decrease in performance and fatigue. Periods of reduced training intensity and rest then allow the organism to repair and develop capacity beyond that available prior to the intensive training session, so that one obtains what is sought, an increase in performance resulting from proper training. During especially hard training/overload periods, transient symptoms and signs and changes in diagnostic tests may occur; this is called overreaching, which may be viewed as the last station before the advent of overtraining. The problem is that in order to perform at the top of their potential, athletes have to push close to the limit beyond which increases in training do not yield improved performance anymore, but deterioration ensues instead [1].

Case 1
JPL is a strong amateur athlete. He has always been very active in sports like running, cross-country skiing and mountain biking. During the late 90s and early 2000s, he participated in many long (ultra) endurance competitions, and sometimes competed twice during the same week-end (e.g. 100 km of Biel and a mountain race; or two editions of the Jungfrau Marathon the same week-end). End of August 2002, after another new week-end of running competitions (Defi du Val de Travers, 72 km, 2000 m climb and Matterhornlauf, 14 km, 850 m climb), something changed. He felt more physically fatigued as usual, and in the following weeks he was no longer able to train and race at his previous levels. His sleep deteriorated, he suffered several respiratory infections and he felt increasingly depressed. It ultimately impacted on every facet of his professional and family life. He underwent numerous physiologic and blood tests and took multivitamin therapy, without success. In the end he stopped competition for a full year, only remained active for base training and did not participate in many races anymore. After a years' rest he took up leisure racing again, but at a more modest pace. This athlete had suffered classic symptoms of an overtraining syndrome and his experience highlights many of the principles discussed in the following paragraphs.

Case 2
MT is 42 years old and has a history of regular participation in various sports activities. In his youth he was member of an athletics club and had competed in local events specializing in 3 and 5 km races. After giving up competition he has been a recreational runner for the last 15 years, running once to twice a week for a cumulated distance of 15 to 25 km. He works as a manager in a medium-size company and has an A-type personality and lifestyle. He is married and has two children, 9 and 11 yrs. His BMI is 24. With some friends who have run several marathons in the past years he has decided to run his first marathon. After asking his friends how much they run every week he increases his running sessions from 2 to 6 every week, and cumulated distance run per week is about 70–80 km. He was always used to run at a continuous pace, but now also has included interval sessions where he runs at higher pace for periods of about 10 minutes interspaced with resting periods of 5 minutes. He has been doing this since three months now. In the beginning it was a bit hard to comply with but then it seemed that it had effect and that his training session speeds increased. However, since the last 4 weeks his performance has been declining. He has had a cold that would not go away as usual and he is increasingly feeling tired. His sleep has deteriorated and he has lost 6 kg of body weight. He also complains of soreness in his leg muscles. There have been no changes in his work environment or at home, but he mentions a decreased libido. His physician does a general physical examination and check-up and advises MT to refrain from training for two weeks while staying physically active (walking, stair-climbing). He also advises MT to consult with a professional coach to develop a new training regime adapted to his abilities. The coach proposes a training program and suggests MT to keep a runners diary, to skip this year's marathon and to aim at next year's.

Overtraining or unexplained underperformance: a syndrome

A generally accepted definition of overtraining is a persistent decrement in athletic performance capacity, despite 2 weeks of relative rest. Since the aetiology appears to be multifactorial and excess exercise is not the sole causative factor the syndrome has recently been redefined as unexplained underperformance syndrome [2, 3]. However, for the sake of clarity we adhere in this short review to the usual terminology: overtraining syndrome, also known as staleness of burnout.

The typical symptoms and signs of overtraining are a decrement in performance, a reduction in the ability to perform high intensity exercise, persistent high perceived exertion and fatigue ratings, a drop in maximal heart rate and peak blood lactate, and changes in the athletes' self-reported indicators of well-being such as fatigue and quality of sleep. Increases in upper respiratory infections may accompany the overtraining syndrome. Several of these symptoms and signs may also be present after a period of intense training or an especially hard competitive event; however in this case the situation will normalize within at most two weeks of reduced training activity. If in spite of two weeks relative rest the symptoms persist one can diagnose overtraining syndrome. Several symptoms like generalized fatigue, depression, muscle and joint-pain and loss of appetite may already present before a clear drop in performance shows.

Contributing factors to the advent of an overtraining state include a sudden increase in training volume and/or intensity, a heavy competition schedule, lack of periodization, lack of recovery time, monotonous training schedules, and high levels of reported stress regardless whether related to training.

The prevalence of overtraining is not well not known but could be quite high. Up to 60% of long distance runners, 21% of Australian swimmers and 50% of soccer players have been classified as overtrained [4]. Overtraining in recreational athletes is not well described but is probably frequent also.

Diagnosis: history rather than tests

The diagnosis of overtraining is primarily based on the patient's history carefully ruling other diseases, completing history with a physical exam, an incremental exercise test and laboratory tests. History taking should be done carefully specifically probing for changes in training regime and general subjective feelings of stress whether or not related to training and competition. Many factors can contribute to an overtraining state. One can make distinction between internal and external factors that can increase vulnerability to overtraining. Internal factors include general health, nutrition state, mood state, personality (A-type), age, sex, menstrual cycle; external factors include intensity and volume of training, private life stress, training history, environmental conditions and time of the year, food intake, sleep, other illness, medication and other substance intake, travel in general and jetlag. Differential

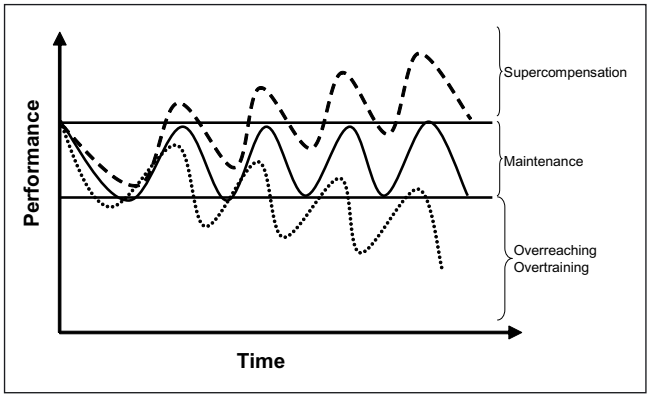

Figure 1: Training is invariably accompanied by a temporary decrease in performance. Then after an appropriate resting period performance is normalized again. An increase in the training intensity can lead to training effect by overreaching, but if the intensity is too high or insufficient rest is allowed performance may actually drop and a situation of overtraining may ensue.

diagnosis includes primary depression, anaemia, Addison's disease, nutritional deficiencies, hypo- or hyperthyroidism, infections, and muscle disease.

Musculoskeletal
Myalgia
Arthralgia
Overuse injury
Decreased strength
Decreased efficiency in sports activity
Decreased economy of locomotion
Increased recruitment

Physiology
Increased basal metabolic rate
Negative nitrogen balance
Decreased maximal lactate production
Increased heart rate at submaximal loads
Decreased maximal heart rate and VO_2max
Decreased muscle glycogen stores

Immunologic
Frequent infections
Poor healing of wounds

Endocrine
Delayed menarche
Oligomenorrhea
Amenorrhea
Decreased libido (for men only)
Decreased sperm count

Psychologic
Depressed mood
General malaise
Disordered sleep
Poor concentration
Anorexia

Table 1: Clinical presentation.

Tests

To date not one single lab test, nor a combination has been shown to be reliably able to identify an overtrained athlete. Here follow a number of testing results that have been reported in the literature. We believe that a proper history and physical examination excluding other pathologies in combination with a simple standardized incremental exercise test measuring heart-rate, blood lactate, perceived exertion and gas exchange is sufficient to diagnose overtraining.

Blood lactate: sub-maximal blood lactate measurements may be the same or reduced (especially when glycogen stores are low) but are not discriminating. However, peak exercise test blood lactate is often decreased in overtraining and may thus be useful for monitoring purposes [5]. The rate of perceived exertion (RPE) during exercise has been repeatedly reported to be increased in overtraining and is very useful. However, the relationship between RPE and blood lactate proved not to be very useful [5].

Heart rate: resting heart rate on arousal may be increased, but may also be decreased and is thus not very discriminatory; night time heart rate is increased, and appears useful as a measure but is not very practical. Maximum heart rate is generally decreased and can be obtained during incremental exercise testing [6]. Heart rate variability, usually using an approach of frequency domain analysis seems promising but has so far not been shown to be a reliable tool to diagnose overtraining [6]. However, further research is necessary before strong conclusions can be made. A recent report using another approach of heart rate variability analysis (Poincare plots) may present an alternative way for monitoring heart rate variability [7].

A two-bout exercise protocol may be more sensitive than a single exercise protocol [8]. Trained athletes in good condition can do an identical second incremental exercise test after 4 hours, by contrast athletes approaching or being in the overtrained state show decreased performance as well as hormonal disturbances during the second test [8].

Changes in the length of sugar strings of certain blood glycoprotein and of the length of the chains of free fatty acids in blood have recently been proposed to be useful monitoring tools but further research and simplification of the method are still necessary [9]. Interesting is the recent observation that increased carbohydrate intake (65% vs 40% of energy intake) during an overload period leading to overreaching in cyclists attenuated the extent of overreaching as compared to control [10].

Recent publications on neuroendocrine balance, and cytokines, especially IL-6, TNF-alpha and IL-1beta, are of interest. Increased levels of cortisol together with decreased levels of testosterone have also been reported. It is perhaps possible in the future to use combinations of circulating hormones and cytokines during or after an exercise challenge to monitor training status and to identify impending overtraining syndrome in athletes [3, 4, 11]. Recent studies on overreaching in cyclists could not confirm these changes in plasma cytokines [12]. On the other hand, the ratio between plasma glutamine and glutamate had dropped, and may be a useful and relatively simple laboratory parameter that can be monitored [12].

Overall it therefore seems that there is no simple test yet that can reliably identify overreaching or overtraining. The diagnosis remains largely based on history, symptoms and signs. Lab results and test results, especially when longitudinal data are available can be useful but only as corroborating evidence.

Sympathic	**Parasympathic**
Increased resting pulse	Decreased resting pulse
Prolonged pulse recovery	Rapid pulse recovery
Disordered sleep	Poor digestion
Increased sweating	Decreased blood pressure
Emotional instability	Early fatigue

Table 2: Neurophysiologic expression.

Decreased iron and ferritin with normal haematocrit
Increased resting cortisol
Elevated sex hormone-binding globulin
Decreased pulsatile FSH/LH secretion
Depressed profile of mood state

Table 3: Laboratory abnormalities.

Aetiology

Various hypotheses have been proposed to explain the different observations made on athletes suffering from overtraining. Presently the preferred model is the so-called cytokine hypothesis of overtraining since it can encompass most observations made and takes into account the other models [4, 11], however other models remain of interest, especially the metabolic hypothesis of sugar-chain and fatty acid chain lengths mentioned before [9]. In the cytokine model overtraining syndrome is the response to excessive musculoskeletal stress which induces local acute inflammatory reactions that may, if sufficiently solicited by frequent and intense muscle use, evolve into chronic inflammation and systemic

Parameter in the field	Sign of risk of overtraining
Subjective	
Subjective fatigue ratings	Increased feeling of fatigue despite adequate recovery time (easier training of 1 day to 2 wk)
Mood state	Decreased positive and increased negative feelings
Muscle fatigue ratings	Increased despite recovery time (easier training of 1 day to 2 wk)
Perceived exertion during constant exercise load	Increased
Physical performance capacity	
Heart rate during constant submaximal load	Increased
Time for a given distance with constant submaximal heart rate	Increased
Time for a given distance during maximal effort +HRmax	Increased; HRmax decreased
Time to exhaustion during constant velocity	Decreased
Power during maximal effort	Decreased
Cardiovascular factors	
Resting morning heart rate	Increased, or decreased more than normal individual variation
Heart rate to orthostatic test in connection with decreased heart rate variability during standing after standing up	Increased, or decreased more than normal individual variation
Other	
Weight and nutrition	Increased, or decreased more than normal individual variation
Log of external and internal stress factors (other than exercise training)	Increased
Lab parameters	
Mechanical efficiency during submaximal load	Decreased
Maximal performance capacity (Wmax, VO_2max, time to exhaustion, time-trial)	Stagnant or decreased
Nutrition and health status	

Table 4: Prevention of overtraining: useful parameters to monitor (adapted after Uusitalo [15]).

inflammation. Systemic inflammation is the result of the release from circulating monocytes of large quantities of inflammatory cytokines such as IL-1beta, IL-6 and TNF-alpha. These cytokines act on the central nervous system and induce changes in behaviour referred to as «sickness», which is believed to promote repair and recuperation. These cytokines also act on the hypothalamus by activating the hypothalamo-pituitary-adrenal axis (increased catacholamines, glucocorticoids) and inhibiting the hypothalamo-pituitary-gonadal axis (decreased gonadal hormone release). Pro-inflammatory cytokines also stimulate liver gluconeogenesis and acute phase protein synthesis. Anti-inflammatory factors that accompany prolonged systemic inflammatory reactions may account for the alleged immune suppression observed in overtraining. For recent reviews see Smith [4] and also Steinacker [11] and Robson [3]. As stated above, some recent observations in overreached cyclists failed to confirm increased levels of plasma cytokines and the search for the exact mechanisms underlying overtraining remains open [12].

Prevention

Prevention remains the best cure to overtraining. Early warning signs are therefore of use for the athlete and the trainer. One of the best parameters is the subjective sensation of the athlete [13, 14]. Changes in the perception of general well-being and in the subjective appreciation of training sessions has repeatedly been shown to be related to the advent of the overtraining syndrome. Regular assessment of mood state using validated questionnaires and the use of training diaries with entries for the subjective appreciation of the training sessions are of great value for both the athlete and the trainer/coach. Also non-training related factors should be taken into account. General levels of stress, illness, and travel, may precipitate towards an overtraining syndrome.

Treatment

As mentioned before, the frontier between training induced increases in performance and deterioration is a fine line. If a well-dosed temporary increase in training volume and/or intensity ultimately may lead to an increase in performance, the direct effect of the increase in training will initially be fatigue. Proper rest (a temporary decrease in training or tapering) will then allow recuperation and possibly super-compensation. However, in case of an overtraining syndrome a relative rest of more than two weeks will be necessary before a very gradual increase in physical activity can be planned. Indeed, a full blown overtraining syndrome will

not heal within weeks, but is rather matter of careful monitoring and slow recuperation over several months. Depression is often a secondary pathology accompanying full-blown overtraining syndrome. In certain advanced cases anti-depressive treatment including pharmacological treatment and psychotherapy may therefore be necessary. There are no other pharmacological treatments that have been proven to be of any use. The present direction of research of the cytokine hypothesis with an important role for IL-6 and related molecules indicates that anti-IL6 treatment may be a possible pharmacological treatment option in the future. However, the main treatment of overtraining syndrome is sufficient rest. A full blown overtraining syndrome necessitates up to several months of reduced physical activity. A slow increase in physical activity and training is mandatory. It is important to initially refrain from the training mode that was used just before the advent of the overtraining syndrome. Relapse is frequent, and there are some indications that a first overtraining syndrome may sensitise for future overtraining episodes.

Conclusions

Overtraining, a decrement in performance despite training that does not disappear after 2 weeks of relative rest, accompanied by symptoms like fatigue, anorexia, and muscle and joint pain, is a frequent syndrome in endurance athletes. It is most often the result of excessive activity from training and competition and can be exacerbated and/or triggered by other stresses. Its diagnosis is made on history and serial exercise test data, no simple discriminative laboratory tests exist. Treatment is rest and gradual reintroduction of training. Prevention is possible and can be done by carefully monitoring subjective exertion from training and general mood combined with simple exercise test results. The cytokine model of excessive stress leading to a generalized inflammatory state can explain the overtraining syndrome and represents a promising avenue of further research to improve the diagnosis and management of this frequent and debilitating health problem in athletes.

Address for correspondence:

Prof. Bengt Kayser, MD, PhD, Faculty of medicine, Centre médical universitaire, 1211 Genève 4, bengt.kayser@medecine.unige.ch

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