How Much Is Too Much?
Performance Aspects of Overtraining

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The primary goal of athletic training is to enhance performance as much as possible. This is accomplished via a training program, which should eventually lead to peaking at the right moment. To push the performance capacity to its upper limit, relatively high amounts of intensive exercise have to be done. Therefore, the athlete is continuously challenging the delicate balance between training and overtraining. The most difficult part of the training process is to find this optimal balance, and since most athletes are inclined to do too much training, overtraining is frequently encountered in elite athletes. The delicacy of the balance between training and overtraining is clearly illustrated by the difference between winning and losing. Snyder and Foster (1994) reported that in the 1988 Olympic speedskating event in Calgary the difference in average velocity between all gold and silver medal performances was 0.3%, while the mean difference between all the gold medalists and the 4th places was 1.3%. In the 1991 World canoe championships a performance decrement of 2.5% would have left the gold medallist ineligible for participation (Fry, Morton, Garcia-Webb, Crawford, & Keast, 1992).

Unfortunately few scientific data exist about the optimal training for peak performance. From the literature some data can be obtained about the relationship between training characteristics and effects on performance capacity. Based on the relatively scarce data there appears to be a non-linear relationship between training volume and increase in performance. As nicely documented by Noakes (1991) a classic example of the non-linear relationship between training load and performance is provided by the former long distance runner Ron Hill. Hill used to be very consistent in his training and when his training mileage is plotted against running performance there appears to be an optimum in performance when the training mileage ranges between 150-170 km per week (Noakes, 1991). A similar observation is made by the author of this paper, who was a world class speed skater from 1972-1975. The training characteristics and competitive results were accurately recorded daily for several years. The training consisted of a rather consistent mix of endurance exercise and intermittent exercise at near competitive intensity. In retrospect, it was observed that when the total training duration was beyond 15 hours a week there was a consistent decrement in competitive performance (Kuipers, unpublished observations). Twice an overtraining syndrome or staleness (Kuipers & Keizer, 1988) was encountered when the training load exceeded approximately 20 hours a week (Kuipers, unpublished observations). Some more recent studies provide a similar general picture. Costill et al. (1991) studied the effect of increasing the training volume on performance capacity in swimmers. Doubling the training volume for 6 weeks failed to induce a further increase in performance indices. Flynn et al. (1994) studied the relationship between training stress and hormonal and blood chemical markers for training stress. One of the findings of this study was that during the period of the highest training load, a decrement in performance was observed. O’Toole (1989) studied the relationship between training indices and performance in triathletes. The general conclusion in this study was that better triathletes used higher training volumes. It must be assumed that these athletes remained within the optimal zone, because it is known from experimental studies on overtraining that when athletes push the training volume too far they may end up with overtraining (Fry, Morton, & Keast, 1991; Lehmann, Foster, & Keul, 1993). These studies indicate that there appears to be an optimal zone for the amount of training yielding optimal increase in performance. However, this optimal zone is poorly defined, and passing this gray area may lead to overtraining syndrome (Lehmann et al., 1993). Several studies have shown that at present there is not a specific, and reliable indicator neither for training in the optimal zone nor for early overtraining (Bruin, Kuipers, Keizer, & VanderVusse, 1994). Unfortunately, at present there is no satisfactory indicator for early overtraining. Therefore, the most sensitive instrument for detecting overtraining is the athlete’s body (Hooper,
Mackinnon, Howard, Gordon, & Bachmann, 1995). Signs of increased fatigability, local or generalized hardening of muscles, should be interpreted as incomplete recovery, and should lead to training adjustment.

To obtain optimal training results on the one hand, but avoid overtraining on the other, a good understanding of the basics of training physiology is necessary. Physical exercise leads to a disturbance in cellular homeostasis. These exercise-induced changes are the stimulus for initiating physiological responses to restore homeostasis. However, recovery processes do not stop when homeostasis is restored, but continue until a small overcompensation is attained (Viru, 1984, 1994). The training adaptations are specific and reversible, which implies that the training stimulus should be as specific as possible, and should be repeated on a regular basis. The optimal moment for the next training is when the overcompensation (supercompensation) is at its highest level. However, relatively little is known about the rate and state of recovery, and unfortunately no simple and easily obtainable variables are available to obtain insight into the recovery process.

Since the actual adaptation takes place in the recovery phase, recovery is the most important component of the training process. Too many athletes and coaches lay too much emphasis on the training but pay too little attention to recovery. Although little is known about recovery, it appears that the duration of the recovery phase is not always the same and depends among other things on several factors (e.g., the volume of training, individual factors, etc.). In addition, it is known that the recovery rate is not the same in different organ systems (McArdle, Katch, & Katch, 1991).

As mentioned before, recovery is initiated by the disturbance of homeostasis. There is evidence that recovery processes are modulated by the endocrine environment (Viru, 1985). The endocrine system and the autonomic nervous system play an important role both for performance, as well as for recovery and adaptation. During exercise, the neuro-endocrine system supports catabolic processes. During the recovery phase anabolic processes are most important. The endocrine environment can modify and amplify the recovery and adaptation process. It is not one single hormone which modifies recovery, but the hormonal system works in a concerted action (Viru, 1985). Cortisol seems to have a dual role. In low concentrations it enhances the effect of anabolic hormones, but when present in high concentrations it enhances catabolism (Viru, 1985). For a fine tuning of the endocrine system and the autonomic nervous system, a proper integration and control is necessary, which is localized in the hypothalamus. All external and internal stimuli are integrated in the hypothalamus and an adequate answer is prepared enabling the body to cope with each situation and threat to the integrity of the organism. The answer from the hypothalamus can be expressed via the endocrine system, via the autonomic nervous system, and via behavior (Viru, 1985).

When exercise and the concomitant disturbance in homeostasis are not matched by adequate recovery (i.e., at the time of the next training), the athlete is actually overdoing or overtraining, and may become overloaded or overtrained. In order to obtain optimal results in sports, it is important to detect too much training or incomplete recovery as soon as possible. Overtraining is a general term and may include different entities. Based on the pathogenesis and affected organ systems, three different types of overtraining can be distinguished:

1) mechanical overtraining,
2) metabolic overtraining or overreaching, and
3) overtraining syndrome or staleness.

**Mechanical Overtraining**

Mechanical overload involves the locomotor system. Connective tissue and connective tissue-derived tissues, such as cartilage and bone, have a relatively poor vascularization, and consequently a low metabolic rate and a slow recovery (Puddu et al., 1994). Therefore, the balance between exercise and recovery is a brittle one and can easily be disturbed. Too much training, too quick increases in training loads, and inappropriate material, such as insufficient footwear, may tip the balance toward overtraining (Keizer & Kuipers, 1993). Local cooling of exposed parts may contribute to a disturbance of the balance because cooling decreases the perfusion and metabolic rate of these tissues and may tip the delicate balance (Puddu et al., 1994). A dysbalance between exercise and recovery is usually local and is most frequently expressed as overuse sport injuries, which may be encountered in any part of the locomotor system.

**Metabolic Overtraining or Overreaching**

Nowadays athletic training includes a high volume of intensive exercise. Intensive exercise relies on carbohydrate supply, resulting in a quick depletion of glycogen stores. When high intensity exercise is done in association with low glycogen levels this may lead to a dysbalance between ATP splitting and ATP generation. This in turn will lead to an accumulation of ADP. In order to restore the ADP/ATP ratio, 2 ADP form 1 ATP and 1 AMP, which is further broken down to IMP and eventually to uric acid, while ammonia is also formed (DeHaan, 1993; Sahlín, Broberg, & Ren, 1989; Sahlín & Katz, 1993). When insufficient time for recovery is allowed, this may lead to a decline of the energy rich phosphate pool (Bruin et al., 1994). The metabolic type of overtraining is probably associated with overreaching (Lehmann et al., 1993; Stone et al., 1991).
Theoretical parameters for detecting metabolic overtraining are ammonia and uric acid. However, ammonia is a volatile substance requiring special care during blood sampling and storage, while plasma uric acid concentration is influenced by several factors making its sensitivity and specificity for detecting metabolic overtraining rather low.

**Overtraining Syndrome or Staleness**

When the hypothalamus cannot cope with the total amount of stress, dysfunction of the neuroendocrine system and changes in behavior may be encountered (Barron, Noakes, Levy, Smith, & Millar, 1985). This generalized form of overstress in athletes is generally referred to as overtraining syndrome or staleness (Kuipers & Keizer, 1988). The overtraining syndrome is featured by premature fatigue during exercise, decline in performance, mood changes, emotional instability, and decreased motivation (Stone et al., 1991). In addition, overtraining and staleness may be associated with changes in immune function (Fry, Morton, Garcia-Webb, Crawford, & Keast, 1992). The proneness for infections has been attributed to changes in glutamine metabolism by Newsholme, Parry-Billings, McAndrew, and Budgrett (1991) who suggested that intensive exercise may cause a decrease in plasma glutamine. Since glutamine is thought essential for immune cell functioning, decreased plasma glutamine levels may lead to decreased immune function. Although there is some experimental support for this hypothesis, more research is needed to give this hypothesis a more solid basis.

There is a gradual transition from adequate recovery via short term overstress to an overtraining syndrome. Training alone is seldom the primary cause when encountering an overtraining syndrome or staleness. Rather it is the total amount of stress which exceeds the capacity of the organism to cope. Contributing factors for an overtraining syndrome include too many competitions, too much training, infectious diseases, allergic reactions, mental stress, nutritional deficiencies, jet lag, etc. (Kuipers & Keizer, 1988). Newsholme et al. (1991) attributed the overtraining syndrome to an increased uptake of branched chain amino acids by muscle tissue during exhaustive exercise, leading to a changed balance of the ratio aromatic/branched chain amino acids. This in turn, would lead to an increased uptake of tryptophane in the brain and an increased formation of the neurotransmitter 5-hydroxytryptamine (5-HT). This is thought to be associated with central fatigue and symptoms of overtraining syndrome. However, there is no solid scientific evidence supporting this hypothesis (Lehmann et al., 1992, 1994; Rowbottom, Keast, Goodman, & Morton, 1995).

Originating from German literature, two types of overtraining can be distinguished: 1) the sympathetic type, and 2) parasympathetic type (Israel, 1958). The sympathetic, or Basedowian type, is characterized by increased sympathetic tone in the resting state, while in the parasympathetic, or Addisonoid type, the parasympathetic tone dominates in the resting state as well as during exercise. The main characteristics of both types of overtraining are summarized in Table 1.

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<tr>
<th>Table 1. The main symptoms of sympathetic and parasympathetic types of staleness or overtraining syndrome.</th>
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<tr>
<td><strong>Sympathetic type of overtraining</strong></td>
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<tr>
<td>increased heart rate at rest and during exercise slow recovery after exercise</td>
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<tr>
<td>poor appetite, weight loss</td>
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<tr>
<td>mental instability and irritability</td>
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<tr>
<td>increased blood pressure in the resting state</td>
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<tr>
<td>menstrual irregularities, oligomenorrhea or amenorrhea in females</td>
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<tr>
<td>disturbed sleep (e.g., difficulties in falling asleep and early waking)</td>
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<tr>
<td>increased resting diastolic and systolic blood pressure</td>
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<td><strong>Parasympathetic type of overtraining</strong></td>
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<tr>
<td>low or normal resting pulse rate</td>
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<tr>
<td>relatively low exercise heart rate</td>
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<tr>
<td>fast recovery of heart rate after exercise</td>
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<tr>
<td>hypoglycemia during exercise, good appetite</td>
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<tr>
<td>normal sleep, lethargy, depression</td>
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<tr>
<td>low resting blood pressure</td>
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<tr>
<td>low plasma lactates during submaximal and maximal exercise (lactate paradox)</td>
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The sympathetic type of overtraining syndrome is most often observed in team sports and sprint events, while the parasympathetic type is typically observed in endurance athletes (Lehmann et al., 1993). The characteristics of the parasympathetic type of the overtraining syndrome are misleading to athletes and coaches, because the symptoms are suggestive of excellent health. Although the patho-physiological mechanism of both types of overtraining are virtually unknown yet, it is hypothesized that both types reflect different stages of the overtraining syndrome. It is hypothesized that during the early stage of the overtraining syndrome, the sympathetic system is continuously alerted, while during advanced overtraining the activity of the sympathetic system is inhibited, resulting in a dominance of the parasympathetic system. This would also explain the increased proneness for hypoglycemia during exercise, because the glucose counterregulation is mediated via the sympathetic system.

**Diagnosis of Overtraining**

Because the transition from adequate training to overtraining is a gradual one, it is rather difficult to diagnose...
an overtraining syndrome in its earliest stage. Several attempts have been made. Several blood chemical variables have been suggested as indicators for detecting early overtraining (Bruin et al., 1994; Rowbottom et al., 1995). Since staleness is associated with hormonal changes, hormones have also been suggested as early markers. Adlercreutz and co-workers (1986) have suggested that the ratio of free testosterone and cortisol would be indicative of the balance between anabolic and catabolic processes. Other investigators, however, have found evidence that the free testosterone/cortisol ratio is not a reliable marker for early staleness (Lehmann et al., 1992; Urhausen, Gabriel, & Kindermann, 1995; Vermulst, Vervoorn, Boelens-Quist, Koppeschaar, & Erich, 1991). Bruin et al. (1994) conducted an overtraining study in race horses in an attempt to find markers for early overtraining. Unfortunately, all attempts to identify a reliable, specific, and sensitive parameter for early staleness, have failed. Usually, an overtraining syndrome is diagnosed by excluding other causes for underperformance. This can be done by a stepwise examination. The first step should be to consult the training log in order to identify possible factors which could explain increased fatigue. If this does not lead to a clear explanation for decreased performance routine blood tests can be conducted (e.g., hemoglobin concentration, hematocrit, ferritin concentration, red blood cell sedimentation rate, white blood cell count, white blood cell differentiation, liver functions).

If no abnormal findings are obtained with these tests, exercise testing can be done. In an overtraining syndrome the maximal workload attained is decreased, while at submaximal exercise intensity the lactate concentration is decreased as well. In addition to a lower peak power output, also peak lactate levels are decreased. This "lactate paradox" has been reported by some investigators (Foster, Snyder, Thompson, & Kuetel, 1988; Jeukendrup, Hesselink, Snyder, Kuipers, & Keizer, 1992; Jeukendrup & Hesselink, 1994).

Because overtraining is difficult to diagnose, it is most important to prevent overtraining. The following rules and guidelines can be helpful in avoiding overtraining:

1) develop a well balanced training program, with individual adjustment,
2) have field or laboratory performance tests at regular intervals,
3) emphasize proper diet (>55% carbohydrate), and
4) have the athletes keep a training log in which resting heart rate and body weight are registered.

It can be helpful to use the profile of mood states scale (POMS) as described by Morgan, Brown, Raglin, O'Connor, and Elicickson (1987). The POMS yields information about the global measure of mood, tension, depression, anger, vigor, fatigue and confusion. Overtraining can be detected at an early stage by monitoring the mood state with the POMS. A comparable approach is to have the athletes complete a self-designed questionnaire on a visual analog scale which contains questions about fatigability, recovery, motivation, irritability, and sleep. The disadvantage of self-designed questionnaires is that validation is lacking.

**Treatment of Overtraining**

The treatment of overtraining depends on the type and cause of overtraining. In the case of mechanical overtraining a number of measures have to be considered. Wearing proper clothing (e.g., proper footwear, cooling, etc.). Training should be adjusted, yet attention needs to be focused to not make rapid increases in training load which could cause mechanical overtraining. Gradual increase in training load should prevent recidivism.

With metabolic overtraining a decrease in training volume is the most important step to be taken. Most emphasis should be placed on sufficient rest, recovery, and a carbohydrate diet (Kuipers & Keizer, 1988). Usually metabolic overtraining is reversible within a few days.

Systemic overtraining usually requires one to several weeks for recovery. The contributing factors should be identified and counseling provided if necessary. Specific drugs or treatments are unknown. Therefore the most important thing is to prevent overtraining.

**References**


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