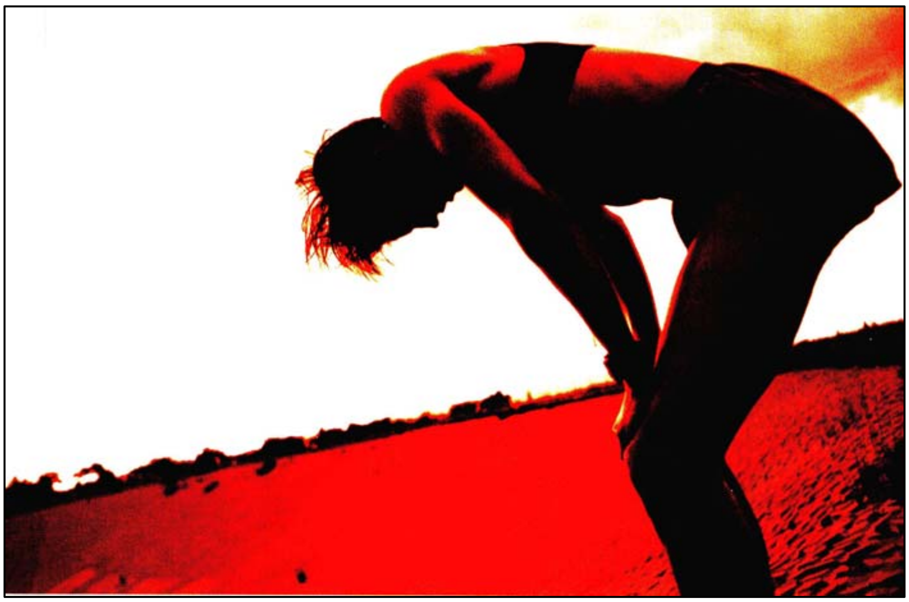
OVERTRAINING:
Causes, Recognition and Prevention



M. Allison Williams, PhD.
Visiting Scholar
United States Olympic Committee
Colorado Springs, CO

Randall L. Wilber, Ph.D., FACSM
Senior Sport Physiologist
United States Olympic Committee
Colorado Springs, CO

OVERTRAINING: CAUSES, RECOGNITON AND PREVENTION

> "More performances are spoiled by slight overtraining than by slight lack of fitness. An athlete who is 50% conditioned for an event will do better than an athlete who is 0.5% overtrained."
>
> **Bobby McGee**
>
> **Coach of multiple Olympic athletes**

Unfortunately, when training does not go as planned, an athlete may reach a point of overtraining. It is not uncommon for Olympic athletes to experience overtraining at some point in their career. A survey conducted by the USOC Sport Psychology staff after the 1996 Atlanta Olympics revealed that an astonishing 28% of Team USA athletes indicated that they had overtrained for the Games, and that this overtraining had a negative impact on their performance. These U.S. Olympians also identified the need to taper, rest, travel less, and stay healthy as changes they would make if they could prepare again for the Olympics. Overtraining is not limited to elite athletes. In fact, it may be just as prevalent among sub-elite and recreational athletes, especially endurance athletes.

This manual is written for the purpose of providing Team USA athletes and coaches with scientifically-based information on overtraining. Specific sections include:

- Terminology: Overreaching vs. Overtraining
- Symptoms of Overtraining
- Physiological Models of Overtraining
- Prevention of Overtraining
- Sources for Additional Reading

It is our hope that the information provided in this manual will help Team USA athletes and coaches better understand overtraining, and therefore, be better equipped to avoid overtraining.

Terminology: Overreaching vs. Overtraining

It is important to distinguish between overreaching and overtraining. Whereas overreaching is necessary for an athlete to improve performance, overtraining results in a decrement in performance. In general, overreaching and overtraining can be distinguished by the following characteristics:

Overreaching:

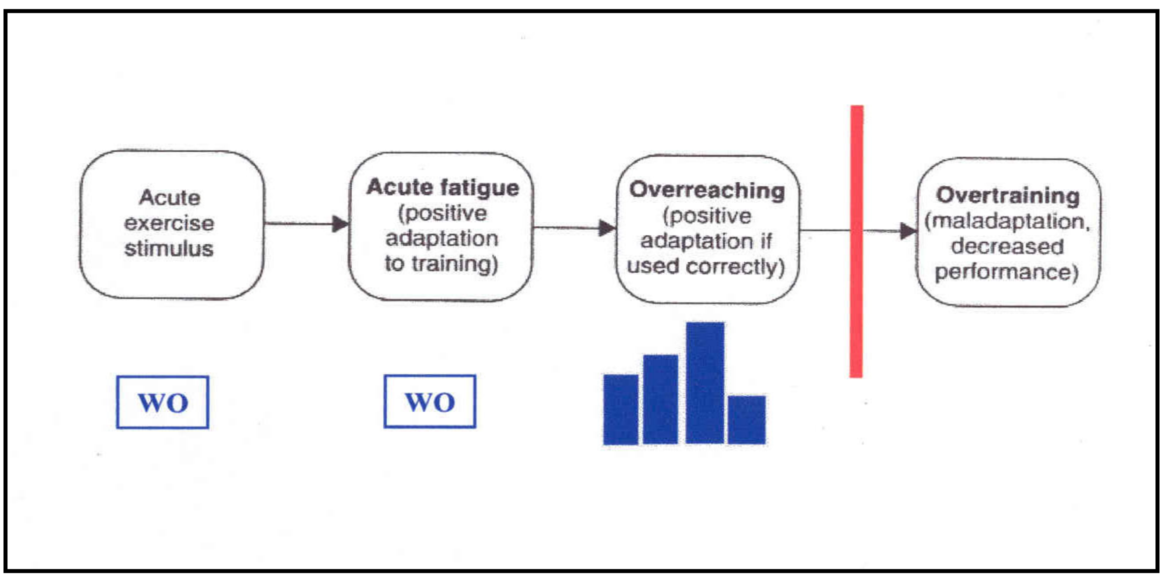
- Short-term (days)
- Reversible with recovery
- Positive training adaptation – necessary to improve performance

Overtraining:

- Long-term (weeks, months)
- Irreversible with recovery
- Negative training adaptation – performance suffers chronically

Perhaps the best way to think of overtraining is as the extreme point on a continuum. As shown in Figure 1, a single training session will produce an acute physiological stimulus and accompanying fatigue. A series of several high-intensity workouts may result in overreaching. For example, a 4-week macrocycle comprised of 3 progressively harder weeks followed by a week of recovery is classified as overreaching. In other words, the initial 3 weeks of hard training provide a progressive overload and produce abnormal fatigue, but the fourth week provides time for the athlete to recover and regenerate. This allows positive physiological and psychological adaptations to take place and performance to improve. Without the recovery week, however, the athlete may become overtrained. Of course, the challenge is knowing how to overreach *without* overtraining.

Figure 1. The overtraining continuum showing the difference between *overreaching* and *overtraining*. WO means "workout". (Adapted from: Fry and Kraemer, *Sports Medicine* 23:106-129, 1997.)



Symptoms of Overtraining

There are over 100 documented symptoms of overtraining in the scientific literature. Therefore, it is not possible to identify an overtrained athlete using only one or two symptoms. Perhaps a better way to think of the symptoms of overtraining is as a picture puzzle containing hundreds of individual pieces. The individual pieces can be compared to the many symptoms of overtraining. Therefore, the more "pieces of the puzzle" that we have, the better we are able to make an accurate assessment of overtraining. Several physiological, biochemical, immunological and psychological symptoms have been used to describe the overtrained athlete (Table 1). However, the most obvious symptom is a consistent decrease in an athlete's ability to train and compete.

Table 1. Symptoms of overtraining.

Performance	Consistent decrease in performance compared with: ➢ earlier in the current season ➢ at the same point in the previous season Prolonged recovery after workouts and competition Reduced toleration of training load – inability to complete workouts Decreased muscular strength Loss of coordination Deterioration of technical skills
Physiological	Increased heart rate at rest, during submaximal exercise and during recovery Increased O_2 consumption during exercise Reduced maximal exercise capacity Decreased blood lactate level during submaximal and maximal exercise Decrease in "normal/healthy" total body weight and body fat Poor sleep and chronic fatigue Loss of appetite and gastrointestinal disturbances Chronic muscle soreness Increased muscle and joint injury
Immunological	Increased susceptibility to colds, flu and allergies Swelling of the lymph glands Bacterial infection Minor cuts heal slowly Abnormal white blood cell (WBC) profile on blood test

Biochemical	Reduced muscle glycogen level Elevated serum cortisol Decreased serum ferritin (iron deficiency) Mineral depletion Menstrual dysfunction ➢ oligomenorrhea: irregular menstrual period ➢ amenorrhea: lack of menstrual period Decreased bone mineral density
Psychological	General apathy and lethargy Lack of concentration Mood changes Decreased self-esteem Fear of competition

Physiological Models of Overtraining

Several physiological models have been proposed to explain how an athlete becomes overtrained. Each of these models is summarized below.

1. Glycogen Depletion. The glycogen depletion model of overtraining says that extensive training combined with inadequate carbohydrate replacement following workouts and competition leads to low muscle glycogen stores. In turn, low muscle glycogen stores produce chronic muscular fatigue, which eventually results in overtraining.

2. Immunosuppression. The immunosuppression model of overtraining states that extensive training and psychological stress produce chronically elevated levels of the stress hormone, cortisol. Research has shown that abnormally elevated cortisol can impair the immune system's normal function. This can lead to illnesses such as upper respiratory tract infection (URTI) as well as injury, which may eventually lead to an overtraining scenario.

3. Autonomic Nervous System (ANS) Imbalance. The ANS imbalance model of overtraining suggests that extensive training and psychological stress lead to impaired function of the hypothalamus. The hypothalamus is located in the brain and controls the ANS, which is comprised of the sympathetic (SNS) and parasympathetic (PSNS) nervous systems. According to this model, impairment of the SNS ("sympathetic overtraining") is typically seen in team sports and sprint/power athletes, whereas impairment of the PSNS ("parasympathetic overtraining") is more common among endurance athletes. In addition, sympathetic overtraining is considered to

be "early" overtraining, while parasympathetic overtraining is viewed as "advanced" overtraining.

> The SNS is often referred to as the "fight-or-flight" system. Its activity is evident during times of excitement, danger, or emergency. Characteristics of an activated SNS include a rapidly beating heart; rapid, deep breathing; cold, sweaty skin; and dilated eye pupils. The PSNS is sometimes called the "resting and digesting" system. It is most active in non-stressful situations. When the PNS is activated, blood pressure, heart rate and respiratory rate are regulated at low normal levels.

4. <u>Central</u> <u>Fatigue</u>. The central fatigue model of overtraining states that extensive training combined with inadequate carbohydrate replacement results in low muscle glycogen stores. As a result of low muscle glycogen, there is a greater reliance on branched-chain amino acids (BCAAs) for energy during endurance exercise. This increased utilization of BCAAs affects the amount of 5-hydroxytryptamine (5-HT) that enters the brain, which ultimately results in a greater production of serotonin. Serotonin is a chemical neurotransmitter that produces lethargy, sleepiness and mood depression. It is believed that increased levels of serotonin in the brain lead to chronic central fatigue and overtraining.

5. <u>Elevated</u> <u>Cytokines</u>. Extensive training and inadequate recovery produce muscle and/or joint trauma, which leads to an increase in the amount of specific white blood cells, called pro-inflammatory cytokines. Elevated circulating cytokines then: a) affect the central nervous system resulting in loss of appetite, sleep disturbances and negative mood changes; b) affect the hypothalamic-pituitary axis (HPA) resulting in increased levels of stress hormones (cortisol, epinephrine, norepinephrine) leading to immunosuppression; and c) affect the hypothalamic-gonadal axis (HGA) resulting in decreased levels of testosterone and luteinizing hormone, decreased skeletal muscle anabolism, and impaired reproductive function. Thus according to this model, overtraining is caused by excessive amounts of circulating pro-inflammatory cytokines, which in turn produce negative psychological and physiological effects that prevent the athlete from training effectively and competing optimally.

Prevention of Overtraining

As previously mentioned, it is a challenge for athletes and coaches to know when they have crossed the boundary between overreaching and overtraining. The following practical strategies are offered as ways to prevent overtraining.

1. Recognition of Overtraining Risk Factors. In general, overtraining risk factors can be organized into three categories based on athlete, sport and training. Table 2 outlines several risk factors for overtraining.

Table 2. Risk factors for overtraining.

Athlete	Perfectionist or Obsessive-Compulsive personality Excessive level of motivation "More is better" training approach . . . based on both bad or good performance Resistant to taking time off from training . . . during injury/illness or non-injury/illness Sport specialization at an early age Eating disorders or disordered eating Competitive schedule designed to chase "points" or money. External stressors . . . home, school/job, relationships, financial.
Sport	Ultra sport (e.g., Ironman events, multi-day cycling events) Multi sport (e.g., triathlon, pentathlon) Endurance sport (e.g., marathon) Sport that allows for little or no individualized training "Meat grinder" sports (e.g., distance running in Kenya, soccer in Brazil)
Training	Overloading adolescent athletes during growth spurts Transition from junior/developmental level to senior level . . . and accompanying increase in training load. Lack of scientifically-based periodization leading to stress-recovery imbalances and overtraining. "Knee jerk" response to under-performance leading to an excessive increase in training load. Training individually with minimal or no 'face-to-face" coaching and objective monitoring Training with significantly more skilled/fit athletes Poor monitoring of "recovery" workouts Olympic / World Championship season Lack of scientifically-based taper Coaching of athlete by a former successful elite athlete Change in training environment (e.g., heat + humidity, altitude)

2. Scientifically-Based Training Program. The best way to prevent overtraining is to use a scientifically-based training plan that includes periods of progressive overload in combination with adequate recovery and regeneration. This type of training program will result in optimal performance at the "peak" of the competitive season. The training program should be organized and periodized to ensure a logical and systematic progression in the training load based on the four physiological principles of training.

- Sport Specificity – the program should be designed to train the body for a specific sport or activity.
- Progressive Overload – the stress or overload applied to the human body must be progressive and gradual, being careful not to alter too many training variables at the same time (volume, duration, intensity and recovery).
- Individualization – the program should be designed to meet the physical capabilities, limitations and goals of each individual athlete.
- Tapering/Peaking – the final days of training prior to a major athletic event should decrease training load to allow increased recovery and peak physical performance.

Dr. Inigo Mujika has conducted extensive research on tapering in elite athletes. His book on tapering can found in the "Sources for Additional Reading" section at the end of this manual. Dr. Mujika makes the following recommendations for an effective taper: a) training intensity should be either maintained or increased during the taper period in order to prevent detraining; b) training volume should be reduced by 40% to 60%; c) training frequency should be maintained in order to prevent detraining; d)positive physiological and performance adaptations can be expected as a result of a taper lasting about 2 weeks; and e) progressive, nonlinear tapers seem to produce better performances than step-wise or linear tapers.

3. Detailed Monitoring of Training Response. Systematic and detailed monitoring of the athlete's response to training is critical to the prevention of overtraining. This can be done via open communication between the athlete and coach, and/or by keeping a detailed training diary. The training diary should include several of the following physical and psychological responses to training: heart rate, weight, length of sleep, quality of sleep, tiredness sensation, training willingness, appetite, competitive willingness, muscle soreness. These training responses should be tracked on a daily basis. The "Recovery-Stress Questionnaire" (RESTQ) developed by Kellman and Kallus is a very good, PC-based instrument designed for the daily monitoring of an athlete's training response; information on the RESTQ is provided in the "Sources for Additional Reading" section at the end of this manual. The coach should be looking for any patterns that

might suggest the athlete is moving from the overreaching stage to the overtraining stage. In addition, laboratory and/or field tests can provide valuable information regarding the athlete's response to training and the potential for overtraining. Laboratory tests used to monitor training response include:

- Maximal oxygen consumption (VO_2max)
- Lactate threshold velocity (swim, run) Lactate threshold power output (bike)
- Economy (doing the same work with less effort)
- Maximal velocity (swim, run) Maximal power output (bike)

Field tests used to monitor training response include:

- Time Trials (whole or partial competition distance)
- Any workout designed to mimic the protocol of a laboratory test

4. Nutritional Intervention. Carbohydrate supplementation is very important for long-term training progression. Muscle and liver glycogen stores can be depleted during daily workouts. Inattention to glycogen replacement could result in overtraining, as suggested in the Carbohydrate Depletion and Central Fatigue models of overtraining. In addition, research has shown that commercial carbohydrate drinks (Gatorade™, Powerade™) help reduce abnormally high levels of the stress hormone cortisol, which can impair normal function of the immune system (see "Immunosuppression" model of overtraining). An effective carbohydrate supplementation regimen is one in which the athlete consumes:

- A high glycemic index (GI) drink or food 3 to 4 hours prior to a workout/competition (Gatorade™, Powerade™, bagel, baked potato), or a *low* GI food 30 to 60 minutes prior to a workout/competition (apple, banana, flavored yogurt),
- A moderate-high GI drink or food during the workout/competition (Gatorade™, Powerade™, PowerBar™),
- A high GI drink and/or food immediately and for up to 2 hours after the workout/competition (e.g., Powerade™, Gatorade™, bagel, watermelon, baked potato). Use of a protein additive containing essential amino acids may also be beneficial in the post-workout/competition period because it may stimulate the insulin response and ultimately enhance glycogen replacement, and also aid in the repair of skeletal muscle damage.

Although most athletes are probably very attentive to replenishing carbohydrate stores after a competition, there is a tendency to neglect carbohydrate supplementation prior to, during and following the daily training sessions. Athletes in training should be aware of this fact and make sure that carbohydrate supplementation and replacement are as much a part of their daily workout as the warmup and warmdown.

It is also recommended that athletes in training add some protein to their diet. Protein is essential for the maintenance, growth and repair of all the body's tissues, particularly skeletal muscle. In addition to skeletal muscle growth and repair, the human body also uses protein to regulate hormone activity, maintain water balance, protect against disease, transport nutrients, carry oxygen and regulate blood clotting. Individual protein needs can be determined by an athlete's activity level and body size. Table 3 lists the protein recommendations for individuals in training. Good protein sources include fish, soy products, eggs, fat-free and reduced fat dairy products, legumes, nuts, whey or soy protein powder and lean meats (poultry, beef, pork).

Table 3. Recommendations for dietary protein intake based on exercise time and body size.

Exercise Time (hr/day)	**Protein Needs per Day**
< 1 hr	0.5 g x total body weight (lb)
1-2 hr	0.6-0.7 g x total body weight (lb)
> 2 hr	0.8-0.9 g x total body weight (lb)

In terms of vitamins and minerals, triathletes in training may want to consider the following:

- Beta-carotene, vitamin C and vitamin E for their antioxidant properties.
- Folate, vitamin B_6 and vitamin B_{12} for their positive effects on the immune system.
- Zinc, selenium and copper for their positive effects on the immune system.
- Iron for its positive effect on red blood cell production.

It is recommended that these vitamins and minerals be obtained via a well-balanced diet and a good multiple vitamin. Additional supplements containing these vitamins and minerals may not be necessary and, in fact, over-supplementation may be unhealthy.

5. Blood Chemistry. If possible, blood chemistry tests should be conducted periodically (4-5 per year) for the purpose of monitoring red blood cell status and iron status. This will help prevent the athlete, particularly the female athlete, from developing iron deficiency and anemia. In addition, a white blood cell count can be used to evaluate general immune response. Other biochemical markers, such as cortisol and creatine kinase, can be useful in monitoring overall health and the athlete's response to training. A standard blood chemistry panel is recommended, which can probably be done at minimal cost at a local clinic or hospital.

6. Training during Illness? A commonly asked question among athletes in training is, “Can I train when I’m sick?” In general, if the sickness is in the throat or below, the answer is “no”. However, if the sickness is above the throat, the answer is “yes, if you want to”. Guidelines for training during illness are summarized as follows:

NO

- If the athlete is experiencing symptoms of systemic involvement (fever, extreme fatigue, muscle aches, swollen lymph glands).
- Submaximal and maximal exercise should not be attempted.
- Allow 2 to 4 weeks of recovery before gradual resumption of training.

YES

- If the athlete is experiencing symptoms of a common cold with no systemic involvement.
- Submaximal exercise is OK.
- Short duration maximal exercise is OK.

7. Recovery Techniques. Several recovery techniques can be used by the athlete to reduce the risk of overtraining. One recovery technique that is easy to do but often overlooked or compromised is passive recovery, or sleep. Athletes engaged in daily training should get a minimum of seven to nine hours of sleep per night. An athlete “plants the seeds” of improved fitness during the daily workout, but it is at night when s/he is sound asleep that the “garden grows”. In other words, it is during the time of sound sleep that your body adapts to the physiological stress of the daily workout and allows your skeletal muscles, cardiopulmonary system, enzymatic profile, etc. to “grow” thereby enhancing your ability to perform physically. These positive adaptations are due to increased levels of human growth hormone (increased anabolic effect) and decreased levels of cortisol (decreased catabolic effect) that occur during deep, uninterrupted sleep. Afternoon naps can also be beneficial but we realize that this is not possible for some athletes due to school, job and family commitments.

Another recovery technique is hydrotherapy, which can take the form of low-intensity swimming or water running, sauna, cold water immersion, and contrast baths. A “poor man’s” contrast bath can be done by simply standing in the shower and alternating cold and hot water every few minutes for approximately 20 minutes. A very effective neuromuscular recovery technique is massage, which can be done following workouts or competitions. Another simple but effective recovery technique is monitoring hydration status. This can be done by monitoring total body mass, or scale weight, making sure to use the same accurate scale each time and “weigh in” and “weigh out” at the same time of day. Fluid replacement should equal 16 ounces for each pound of body weight loss. Other effective and practical recovery techniques include pneumatic massage (e.g., Normatec®) and low-frequency vibration of specific muscle groups.

Summary

Overtraining is common among athletes engaged in regular training that involves high volume and/or high intensity workouts, and is particularly prevalent in Olympic athletes. It is often difficult to distinguish between overreaching and overtraining. Because overtraining appears to be due to a complex combination of physiological, immunological and psychological factors, there is no single marker that serves to quickly and clearly identify overtraining. Recommendations to prevent overtraining include: a) recognition of overtraining risk factors; b) adherence to a scientifically-based training program that includes strategically placed recovery phases and a well-designed taper, c) detailed monitoring and documentation of the training response, d) nutritional intervention, with emphasize on carbohydrate replacement, e) periodic blood testing, with focus on iron status, f) wise decisions about training when sick, and f) daily utilization of recovery techniques, including passive rest.

Sources for Additional Reading

Tapering and Peaking for Optimal Performance
Author: Inigo Mujika
Publisher: Human Kinetics, Champaign, IL, 2009.

Overtraining Athletes: Personal Journeys in Sport
Authors: Sean O. Richardson, Mark B. Anderson, and Tony Morris
Publisher: Human Kinetics, Champaign, IL, 2009.

Sport Physiology for Coaches
Authors: Brian J. Sharkey and Stephen E. Gaskill
Publisher: Human Kinetics, Champaign, IL, 2006.

Enhancing Recovery: Preventing Underperformance in Athletes
Author: Michael Kellmann (Ed.)
Publisher: Human Kinetics, Champaign, IL, 2002.

Physiological Aspects of Sport Training and Performance
Author: Jay R. Hoffman
Publisher: Human Kinetics, Champaign, IL, 2002.

Recovery-Stress Questionnaire for Athletes (User manual and CD-ROM)
Authors: Michael Kellman and K. Wolfgang Kallus
Publisher: Human Kinetics, Champaign, IL, 2001.

Physiological Tests for Elite Athletes
Author: Australian Sport Commission; Christopher J. Gore (Ed.)
Publisher: Human Kinetics, Champaign, IL, 2000.

Sport Nutrition for Health and Performance
Author: Melinda Manore and Janice Thompson
Publisher: Human Kinetics, Champaign, IL, 2000.

Periodization: Theory and Methodology of Training
Author: Tudor O. Bompa
Publisher: Human Kinetics, Champaign, IL, 1999.

Periodization Training for Sports
Author: Tudor O. Bompa
Publisher: Human Kinetics, Champaign, IL, 1999.

Overtraining in Sport
Authors: Richard B. Kreider, Andrew C. Frey, and Mary L. O'Toole (Eds.)
Publisher: Human Kinetics, Champaign, IL, 1998.

Physiological Assessment of Human Fitness
Authors: Peter J. Maud and Carl Foster (Eds.)
Publisher: Human Kinetics, Champaign, IL, 1995.