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Article *in* Sports Medicine · August 1998

Source: PubMed

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LEADING ARTICLE

Sports Med 1998 Jul; 26 (1): 1-16
0112-1642/98/0007-0001/$08.00/0

Overtraining and Recovery

A Conceptual Model

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Abstract

Fiercer competition between athletes and a wider knowledge of optimal training regimens dramatically influence current training methods. A single training bout per day was previously considered sufficient, whereas today athletes regularly train twice a day or more. Consequently, the number of athletes who are overtraining and have insufficient rest is increasing.

Positive overtraining can be regarded as a natural process when the end result is adaptation and improved performance; the supercompensation principle – which includes the breakdown process (training) followed by the recovery process (rest) – is well known in sports. However, negative overtraining, causing maladaptation and other negative consequences such as staleness, can occur. Physiological, psychological, biochemical and immunological symptoms must be considered, both independently and together, to fully understand the 'staleness' syndrome. However, psychological testing may reveal early-warning signs more readily than the various physiological or immunological markers.

The time frame of training and recovery is also important since the consequences of negative overtraining comprise an overtraining-response continuum from short to long term effects. An athlete failing to recover within 72 hours has presumably negatively overtrained and is in an overreached state. For an elite athlete to refrain from training for >72 hours is extremely undesirable, highlighting the importance of a carefully monitored recovery process.

There are many methods used to measure the training process but few with which to match the recovery process against it. One such framework for this is referred to as the total quality recovery (TQR) process. By using a TQR scale, structured around the scale developed for ratings of perceived exertion (RPE), the recovery process can be monitored and matched against the breakdown (training) process (TQR versus RPE). The TQR scale emphasises both the athlete's perception of recovery and the importance of active measures to improve the recovery process. Furthermore, directing attention to psychophysiological cues serves the same purpose as in RPE, i.e. increasing self-awareness.

This article reviews and conceptualises the whole overtraining process. In doing so, it (i) aims to differentiate between the types of stress affecting an athlete's performance; (ii) identifies factors influencing an athlete's ability to adapt to physical training; (iii) structures the recovery process. The TQR method to facilitate monitoring of the recovery process is then suggested and a conceptual model that incorporates all of the important parameters for performance gain (adaptation) and loss (maladaptation).

1. Definitions, Symptoms and Time Frame of Overtraining and its Effects

Modern-day sport, particularly at the elite level, is fiercely competitive. With more information now available from sports-related research, exercise scientists, coaches and athletes know more today about optimal training regimens than ever before. Consequently, training methods have changed dramatically.[1,2]

Training for success has increasingly become a balance between achieving peak performance and avoiding the negative consequences of overtraining. Training volumes *below* what can be considered optimal do not result in the desired adaptation (i.e. the greatest possible gain in performance), whereas training volumes *above* the optimum may, among other things, lead to a condition usually referred to as the 'overtraining syndrome', 'staleness' or 'burnout'. Hard training can apparently be the formula for both success and failure.

To date, rest (physical inactivity) is the best known treatment for athletes who have reached an undesirable state because of prolonged excessive training.[2-6] Rest, however, is avoided by most athletes since it is diametrically opposed to their instinctive response when a decline in performance occurs. Highly motivated athletes and coaches usually respond to a plateau or drop in performance with increases in the training load.[2,3] Consequently, it has been asserted that the greatest training-related factor leading to negative states is a failure to include enough recovery in the training programme.[1] It follows that an imbalance between training and recovery will have mild to severe negative consequences on performance.[4]

There are no generally accepted definitions for the terminology concerning the negative consequences associated with excessively hard physical training. Furthermore, the terms used have different meanings in different contexts. Terms used in connection with overtraining include overtraining syndrome, overtrained, overstrained, overused, overworked, overstressed, overreaching, stagnation, staleness, staleness syndrome, burnout and chronic fatigue syndrome.[2,4,5,7-9] In this article, the conditions overreached and staleness are used and are considered to be at opposite ends of an overtraining-response continuum. An athlete failing to recover within 72 hours has presumably negatively overtrained and is in an overreached state (a short term effect). The long term effect (staleness) results from more severe overtraining, is at the other end of this continuum.

Originally, 'burnout' was most often used in the literature in connection with studies of the human service and help professions.[10] More recently, Smith[11] extended the use of the term burnout to include athletes. There is, however, some disagreement about whether burnout really should include 'stale' athletes or not. Raglin[2] has argued that burnout should be distinguished and viewed separately from staleness. The main difference between the 2 related syndromes, according to Raglin,[2] is that loss of motivation (and withdrawal in severe cases) is a central characteristic of burnout but not of staleness. A stale athlete may still be highly motivated to continue training and may even increase the training load to compensate for a decrease in performance. Thus, it is important to consider them separately.

Taken together, the various terms used seem, nevertheless, to describe a single syndrome, most often referred to in the literature as the staleness (or overtraining) syndrome.[2-5,6,9,12,13] Many negative consequences have been associated with this syndrome, and some of those most commonly reported include:

- poorer performance
- severe fatigue
- muscle soreness
- overuse injuries
- reduced appetite
- disturbed sleep patterns
- mood disturbances
- immune system deficits
- concentration difficulties.[12,14,15]

In addition, decreased submaximum and maximum heart rates, decreased maximum oxygen uptake, as well as decreased submaximal and maximal lactate levels, have also been reported in connection with the negative consequences of too much training with too little recovery.[3,16] Many of the variations reported in the literature are, however, equivocal. That is, some studies associate staleness with increases in some specific variable, such as heart rate, whereas other studies associate staleness with decreases with that variable.[3,7,14] One possible explanation might be that different forms of staleness exist.

Two distinct and separate types of staleness have also been proposed, namely the sympathetic and parasympathetic overtraining syndromes.[3-5,7] The sympathetic form is characterised by increased sympathetic activity at rest while the parasympathetic form is characterised by decreased sympathetic activity with parasympathetic activity dominating at rest and during exercise. It is believed that the sympathetic overtraining syndrome is an intermediate stage before parasympathetic overtraining. Markers associated with parasympathetic overtraining are low resting heart rate and relatively low exercise heart rate, while markers associated with sympathetic overtraining are increased resting and exercise heart rates.[3,9,17]

Based on the aforementioned observations and the problems identified, the aim of the remainder of this article is to: (i) review and conceptualise the overtraining process; (ii) differentiate between the various types of stress that may affect an athlete's performance; (iii) identify factors that may affect the athlete's ability to adapt to physical training; and (iv) structure the recovery process. In addition, a new method called total quality recovery (TQR) is suggested to facilitate monitoring of the recovery process in order to reduce some of the negative effects associated with hard physical training. Finally, a conceptual model is presented which incorporates all of the parameters thought to be of importance for performance gains (i.e. adaptation) or performance losses (maladaptation).

1.1 Markers and Symptoms of the Negative Effects of Overtraining

The difference between *positive* and *negative* overtraining depends on the outcome of the training process. An athlete failing to recover within 72 hours of training has presumably worked too hard and thereby experiences negative overtraining and can be considered to be in an overreached state. This time frame is chosen from the elite athlete's perspective; if >72 hours are needed to recover, this is definitely regarded as a failure in the training programme. The fierce competition among elite athletes means that a loss of training days and disrupted training (i.e. forced rest for >72 hours) would be extremely undesirable. Thus, our definition of *positive* overtraining conforms to the definition of the overtraining process by Raglin.[2]

In addition, Morgan et al.[6] emphasised the need to view, define and separate the *cause* (process) and *consequence* (product) of overtraining. Raglin[2] later defined the training stimulus as ' . . . an overtraining process involving progressively increased training to a high absolute level that is in excess of more routine training undertaken to maintain performance'. Raglin's definition actually describes 3 degrees of training: (i) overtraining (in this case, positive overtraining) for eliciting gains in performance; (ii) maintenance training to remain at a certain level of performance; and (iii) undertraining when the stress is insufficient to maintain performance (resulting in a decrease in performance). Negative overtraining may result in the same decrease in performance capacity as undertraining, which is noteworthy. All training programmes will fall into one of these categories. Hence, the actual training performed (process) will determine the result (product).

Fry et al.[7] defined 4 major categories of symptoms associated with the staleness syndrome, namely:

- physiological symptoms
- psychological symptoms
- biochemical symptoms
- immunological symptoms.

To date, studies of the staleness syndrome have often tried to identify reliable early-warning signs (markers) to prevent the undesired negative outcome of hard physical training. Although observed physiological and biochemical symptoms have been effective in confirming the staleness syndrome, they have not been useful in preventing it.[18] Other reports corroborate these findings by stating that the value of physiological and biochemical markers is still unclear.[3,19] One reason for this is the inherent difficulty of distinguishing between adaptation, a result of thoughtfully devised training programmes, and maladaptation, the point at which the benefits of adaptive training begin to wane because of excessive training. This is particularly evident *during* the course of heavy training when some decrease in performance capacity is expected. In most athletes, it is only possible to determine whether a training cycle is adaptive or maladaptive *after* it has been concluded. In some extreme instances, this can be difficult even after the training cycle.

A recent example illustrates the difficulty in distinguishing between adaptation and maladaptation. A Swedish world class cross-country skier maintained heavy training for 20 years and never won a gold medal in the 50km event at the national level. He took 1 year off (only engaging in light training) and returned to competition in 1996, when he won his first gold medal at the age of 35. In this skier, it might have been difficult to clearly distinguish between adaptive and maladaptive training at any stage during the 20-year period.

A closely related problem seems to be the uncertainty of whether the symptoms noted precede staleness [or occur early in the development of the disorder (overreaching)] or are merely manifestations of the staleness syndrome.[2] To distinguish between preceding markers or early-warning signs with prognostic value and symptoms with diagnostic value (when the disorder has been verified) is extremely difficult in most applied situations. Hence, markers and symptoms are used synonymously throughout this article unless otherwise indicated.

Partly because of these aforementioned difficulties, Shephard and Shek[20] concluded that psychological testing provides both easier and more effective methods for detecting the staleness syndrome than methods dependent on various physiological or immunological markers.[21,22] Four advantages of using psychological markers to identify and monitor the overtraining process have been reported by O'Connor.[22]

(1) Psychological changes are more reliable, i.e. mood shifts coincide with increases and decreases in training and are also highly replicable.
(2) Some mood states are highly sensitive to increases in the training load (changes in these states occur early on and have large effects) while others are more sensitive to the staleness syndrome.
(3) Variations in measures of mood often correlate with those of physiological markers.
(4) The titration of training loads based on mood responses to overtraining appears to have good potential for preventing staleness.

It should be noted that a recent study reported that 1 out of 3 stale athletes did not show the anticipated mood response.[23] This suggests that mood inventories may not always differentiate between 'stale' and 'not stale' athletes. However, there are several limitations of this study that should be highlighted. For example, response distortion was not controlled for, no preseason mood assessment was made to obtain baseline scores and mood was only assessed 5 times. Nevertheless, this study emphasised the need for well designed, long term monitoring studies to determine how to prevent staleness.[24] The 4 major categories of symptoms mentioned at the start of section 1.1 all need to be considered since they are inter-related. This in turn lends support to the view that the staleness syndrome should be regarded as a psychobiological phenomenon.[2]

To summarise, there are various ways to classify the different staleness symptoms and markers (i.e. negative consequences). We suggest including all of the consequences of negative overtraining into the physiological, psychological, biochemical (or neuroendocrinological) and immunological categories defined by Fry et al.[7] This list could easily be extended to include behavioural and perceptual changes, for example, but even with more categories, it remains difficult to fit some symptoms into a single category. Some symptoms can show different characteristics, depending on how they are viewed. Appetite, for example, is primarily regulated physiologically but it also has some psychological dimensions. It seems that most of the symptoms overlap between 2 or more categories. Nevertheless, the 4 categories provide a good semantic overview of the different bodily symptoms that are associated with the staleness syndrome.

1.2 Long Term versus Short Term Aspects of the Overtraining-Response Continuum

The overtraining process and its associated symptoms may be viewed over a continuum from short term (acute) to long term (chronic), as described by Marion[14] and Kuipers.[17] It follows that some borderline athletes will be difficult to diagnose as being either ‘stale’ or ‘not stale’ when their condition is measured on a continuum.[8] Thus, the border between adaptation as a result of optimal training and the beginning stages of maladaptation due to excessive training is fluid, especially during a phase of heavy training, as discussed in section 1.1.[3] This is why optimal training can so easily lead to an overreached state. Because of the overtraining-response continuum it is also difficult to know whether observed symptoms are related to normal training fatigue, short term overreaching or long term staleness.[7] Some symptoms occur along the whole continuum while others only occur at a particular stage. Interestingly, a recent report asserts that fatigue and vigour are sensitive to short term conditions while depression is more sensitive to long term conditions.[22] Declines in performance, which are regarded as the hallmark of staleness,[2] occur together with increases in perceived effort during training along the whole continuum.[25,26] No consensus has been reached regarding the extent to which performance will decline at different stages along the continuum.[19] The decline in performance may also vary with overtraining across different sports, although published data on this are very scarce. If the comparison is extended to cover performance decline in, for example, all the distances for running events, the problem becomes even more complex. The effects of these confounding factors need to be addressed and related to the 4 different categories of symptoms.

Interindividual differences in recovery potential, exercise capacity, nontraining stressors and stress tolerance may explain the different degrees of staleness syndrome experienced by athletes under identical training stresses.[3] In athletes with less severe staleness, the markers are milder and athletes can still train at their usual level, but at the cost of greater difficulty to maintain any given submaximal performance (e.g. running speed) and increased perception of effort.[27] Hence, there is convincing evidence to support the view that the staleness syndrome exists on a continuum from short term to long term effects. Consequently, general and simplified guidelines for diagnosing staleness should allow for mild through to severe symptoms. Milder symptoms generally predict a shorter time for sufficient recovery from the staleness syndrome and more severe symptoms, following larger declines in performance, require a longer time for recovery. ‘Stale’ athletes, for example, do not respond well to reductions in training compared with overreached athletes. As well as the problem of setting diagnostic criteria for different degrees of the staleness syndrome, another difficult question is whether to look for qualitative or quantitative symptoms. To avoid oversimplified distinctions, the whole continuum will be defined in this article as the overtraining-response continuum.

As explained earlier in this article, overreached and staleness are regarded as opposite extremes of the overtraining-response continuum. This continuum excludes acute fatigue that occurs immediately after exercise, acute muscular overstrain, undertraining, maintenance training and all other prefatigued states considered normal training responses and which are always followed by a full recovery in the short term. The overreached state was chosen as the starting point on the overtraining-response continuum because it is beyond this point in the training process that negative overtraining (maladaptation) can occur if an athlete is not carefully monitored.

Staleness is thus regarded as a severe long term effect of an imbalance between the total stressors (training and nontraining) and total recovery, which is largely determined by the overall capacity (stress tolerance) of the individual. Overreaching is regarded as a far less severe, short term effect, also resulting from an imbalance between total stress and total recovery and determined by the overall capacity. Both conditions are regarded as possible products of *negative* overtraining.

1.3 Reasons for the Confusing Terminology

The lack of consensus regarding the terminology of overtraining is a factor of great concern. This was stressed by O'Connor,[22] who stated that perhaps the greatest barrier to further progress in this area of research is: (i) the existing confusion over terminology; and (ii) the lack of established diagnostic criteria for staleness. Other authors address this problem by proposing the development of an international standard with regard to terminology.[7,19]

The confusion in terminology is in part due to different theories and types of research. It is also caused, to a considerable extent, by language barriers and poor translation of reports. One reason for poor translation is the lack of equivalent terms. Other factors for confusion can be explained by tradition and different cultures. European authors have mainly used the terms overstrained, overtraining, overstrain and overtraining syndrome to indicate what some US researchers refer to as staleness or the staleness syndrome.[22]

When studies are performed within various disciplines, for example physiology and psychology, differences in terminology may occur. These differences could simply be due to the different perspectives in the deductive research on the psychophysiological overtraining phenomenon. Physiological studies by Fry et al.[7] and Kuipers and Keizer[4] use the term overload to describe the training process, whereas psychological studies by Morgan et al.[6] and Raglin[2] use the term overtraining. Physiologists and psychologists also differ in the use of terminology regarding the short term to intermediate stage of the staleness syndrome. The term overreaching is mainly used by physiologists,[4,7,9] whereas distress has been used by the psychologists[2,6] to describe a less severe state of staleness. Historically, it seems that once a term has been established, the related studies adopt it regardless of whether it is ultimately useful or confusing.

2. Structuring the Overtraining and Recovery Processes

It is evident from the studies referred to so far in this article that there is a need to formally structure both the overtraining and recovery processes. Only when the terminology and symptoms have been clearly defined and incorporated into a larger framework can a better understanding of how to avoid training methods that may lead to staleness be achieved. Five main areas need to be addressed to achieve this understanding of the staleness syndrome.

(1) The fact that most conditions on the overtraining-response continuum are associated with performance decrements and other negative consequences. That is, increased training is not always beneficial for enhanced performance.

(2) The lack of accepted tests and standard criteria available to accurately place an overtrained athlete on the overtraining-response continuum prohibits clearer diagnoses. It is *during* periods of heavy training (i.e. overtraining) that the most critical and difficult diagnoses have to be made.

(3) The obvious need to develop a reliable and easily managed method to monitor training (i.e. the breakdown process) is of the utmost concern. Such a method could then be matched with a similar method designed to measure recovery.

(4) The need to define the markers of recovery and thereby extend the monitoring system to cover the whole process of training and recovery.

(5) The need to integrate reliable markers into the training monitoring system to prevent negative overtraining (training that results in overreaching and staleness).

3. Factors Contributing to Staleness

The main factor leading to staleness is inadequate recovery (section 5). However, stress and an individual's capacity for training also contribute.

3.1 Categories of Stress

Lehman et al.[3] suggested yet another definition of the staleness syndrome which stated that '. . . staleness syndrome is an imbalance between training and recovery, exercise and exercise capacity, stress and stress tolerance. Stress is the sum of training and nontraining stress factors'. By this definition, different types of stress contribute to the total level of stress which may provoke, and result in, staleness. Hopefully, this notion will encourage researchers to consider a greater number of potential stressors in future overtraining studies. Knowledge of the process behind staleness would certainly benefit from identifying a larger number of stressors and examining their interactions and cumulative effects.

Morgan et al.[6] showed that the main contributor to staleness was the sport-specific stress created by training (physiological stress). It was later demonstrated that physiological stress alone can lead to staleness.[28] It is unclear, however, to what extent nontraining stress factors can provoke staleness. It has been suggested that the staleness syndrome can develop in an athlete who experiences relatively low physiological stress, provided that psychological and social stress factors are high.[7] Hence, occupational, educational and social stressors should not be disregarded as potential contributors to the staleness syndrome.[3] Budgett[5] also suggested that it is likely that only a small increase in the total stress might suddenly and unexpectedly elicit staleness. The onset of this staleness was caused by an increase in psychological and/or social stress which lead to an inability to recover from a previously well-tolerated training programme (physiological stress). It therefore appears to be important to evaluate the cumulative level of stress, and training stress might need to be adjusted while high levels of nontraining stressors (psychological problems or social conflicts) are present in an athlete. A preliminary study reported that perceived conflicts, occurring during the past 3 to 4 days (nights), had a substantial effect on recovery and thereby also affected performance.[29]

In conclusion, the different stressors that may to contribute to the staleness syndrome include psychological, social and physiological training stressors.

3.2 Capacity for Stress Tolerance

Athletes of comparable physical ability may have different responses to a given overtraining stimulus.[30] This indicates that athletes may differ in their vulnerability to developing staleness, which can be explained by individual differences in psychobiological characteristics or capacity. The same training stimulus may improve one athlete's performance, only maintain the performance by another and cause staleness in a third athlete.[2,31] Research findings among college swimmers indicate that athletes may indeed differ in their susceptibility to staleness.[27] For example, there is some evidence that, compared with individuals with normal anxiety, individuals with elevated anxiety perceive and rate the intensity of a given stressor as being greater.[18] Individuals who exhibit an elevated anxiety trait could therefore be regarded as having a lower capacity for tolerating stress and may be more likely to develop staleness.

This gives us 3 different capacities that determine vulnerability to developing the staleness syndrome: psychological, social and physiological capacity.

4. Mechanisms of the Breakdown (Training) Process

The main principle behind all physical training aimed at improving performance is known as the supercompensation principle.[32,33] This entails the breakdown (training) process followed by the recovery (rest) process, which results in an 'overshoot', or rebound, in performance and adaptation. The more intense the training, the greater the breakdown. High intensity training therefore demands higher quality recovery than low intensity training. Consequently, high intensity training also demands a longer recovery period than low intensity training. The athlete undertaking high intensity training would therefore benefit from high quality recovery more than an athlete undertaking low intensity training. Purposeful (positive) overtraining, in contrast to negative overtraining which may eventually lead to staleness, is a central feature of a well designed training programme to stimulate peak performance. It is important, however, that the overtraining period is followed by a period of sufficient tapering, usually through a combination of easier training and more rest units, to allow full supercompensation.[5] Thus, the physiological homeostasis must first be disturbed, whereupon sufficient recovery must be allowed for full supercompensation to occur. This explains why individuals with superior physical fitness need to exercise harder to improve performance than individuals who are less fit. It also explains why overtraining, on the one hand, can be regarded as positive when supercompensation is the end result or, on the other hand, negative when maladaptation occurs.

For the purposes of this review article, all single training bouts that are sufficiently intense and/or long enough to disturb the physiological homeostasis are regarded as an overload stimulus that will provoke and initiate the breakdown process. The recovery and restoration of homeostasis, and also the supercompensation that occurs if the allowed recovery period is sufficient, is regarded as a full recovery process. The breakdown and recovery processes could also be viewed as one isolated process initiated by an overload stimulus, the recovery process being the most important phase of this single process.[17] This process of breakdown and recovery, when initiated by a single training bout, is referred to as a training and recovery unit. A sequence of many repeated units creates the overtraining process. It is worth noting, however, that 1 unit alone should not cause negative consequences associated with any state of overreaching or staleness on the overtraining-response continuum.

Coaches and athletes can choose between the many methods of regulating and monitoring training intensity and volume. The well known methods include the use of: (i) percentage of maximum heart rate; (ii) percentage of 1 repetition maximum; (iii) objective speed measures; and (iv) subjective speed scales (1 = low speed, 3 = threshold and 5 = maximum speed). Subjective rating scales of perceived exertion,[34,35] for example, are frequently used to regulate and monitor the intensity with which the exercise is performed. Clearly, much research effort has been devoted to developing methods to monitor the breakdown process (i.e. through monitoring training intensity), compared with the lack of methods for measuring the recovery process.

5. The Recovery Process

5.1 Matching the Recovery Process to the Stress

The main factor responsible for the staleness syndrome is a lack of sufficient recovery after heavy physical training. This makes it important to select appropriate recovery methods that are matched against the training stimulus.[14] In contrast to the diversity of specific methods for measuring the breakdown process, very few methods to match the recovery process against the breakdown process have been reported. Some general and incomplete suggestions for implementing optimum recovery processes have been made but, in most cases, the suggested strategies were not related to the actual breakdown process.[7]

Another problem is that suggestions for the optimum recovery process are rarely differentiated as being proactive (preventing the occurrence of staleness) or reactive (rehabilitation from staleness). This distinction is a very important one because there are considerable advantages in preventing staleness rather than merely treating it with complete rest.

5.2 Different Types of Recovery

It has been suggested that the best way to treat overstress (which may comprise physical overtraining, psychosocial stresses or a combination of these) is by matching the treatment with the specific symptoms.[36] If somatic or cognitive overstress occurs, it should be treated by matched intervention methods. The same type of matching principle also applies to overtraining. It is suggested that overall recovery from overtraining and psychosocial stressors will benefit from appropriate, matched recovery methods aimed at the area that is in the greatest need.[17] Hence, it is logical to expect the greatest benefits to occur when overstress caused by social conflicts is addressed by treating the major cause of the particular stress, rather than treating other less important causes of stress.

A number of authors have emphasised the need to identify the probable causes of staleness and the need to match these with sufficient rest, sleep, relaxation, nutrition or other needed interventions.[4,37-39] Among the different approaches directed towards such recovery, 4 main categories have been identified: nutrition and hydration, sleep and rest, relaxation and emotional support, and stretching and active rest.

5.2.1 Nutrition and Hydration

Individuals failing to ingest sufficient carbohydrates to match the energy demand of heavy training have been shown to develop signs of staleness.[28,30] A poor diet with an insufficient caloric and fluid intake, particularly one lacking in carbohydrates, will decrease the capacity to tolerate physiological stress (training). It is well known that the replenishment of glycogen and fluid stores is necessary to tolerate frequent, intense bouts of training. This might be the most important factor in maintaining high intensity training. Fluid is necessary for more than maintaining performance capacity alone; each gram of carbohydrate requires 3g of water to bind to muscle glycogen. Insufficient fluid intake will thus inhibit performance by allowing less glycogen to be stored. To utilise an individual's carbohydrate storage limit (approximately 1000g), 3000g of water is needed for it to bind to muscle glycogen.[40]

5.2.2 Sleep and Rest

The most frequently mentioned factor for enhancing recovery is the most obvious one, rest. In this sense, rest means engaging in no physical activity (passive recovery during the daytime) and obtaining sufficient sleep.[41]

5.2.3 Relaxation and Emotional Support

A few studies have shown that mental training might help to prevent staleness.[42-44] This effect has been explained by an increased recovery capacity or increased stress tolerance.[42] Relaxation techniques, the use of flotation tanks, massages and saunas have also been suggested by Marion[14] as proactive recovery interventions. 'Time-out' periods from training are recommended for preventing athletes from becoming totally preoccupied with their sport. The learning and practice of relaxation and visualisation techniques by athletes is also recommended.[43,44]

Regeneration strategies have been widely used, particularly in the former eastern European countries. These involve a reduction of all nonspecific training stressors (i.e. occupational, educational, financial and social stressors) by incorporating rest, sleep, relaxation therapy, counselling, physiotherapy, saunas and massage into the routine of the athlete. Eliminating or minimising nontraining stressors is another strategy used by sport psychology consultants.[5]

5.2.4 Stretching and Active Rest

Active rest, meaning low volume and low intensity training, may accelerate the recovery process.[14] Budgett[5] highlights the fact that active rest should be provided through participation in a different sport in which no measure of the athlete's performance is available. In this way, exercise is used as a therapeutic tool to speed up recovery. Stretching has effects similar to massage and active rest, in that it increases the blood flow through the muscle.[45]

6. Proposed Method for Monitoring Training and Adequate Recovery

No model cited in the current literature presents a reliable method for monitoring both training and recovery.[7,46] Elite athletes and their coaches need a system to monitor training and recovery – a system that incorporates reliable markers which would be useful in preventing the staleness syndrome. The system must function on a daily basis and allow quick access to information about variations in selected markers. Such as system would present the possibility of immediately and simultaneously titrating the training load and the recovery and prevent negative overtraining.

A framework for the training and recovery process, henceforth referred to as the TQR process, has been developed for this purpose.[47] The TQR process is described in detail in section 6.2. To date, most investigations have been focused on structuring the recovery process. Some pilot research in elite Swedish kayakers has produced positive responses from the athletes.[47] The main purpose of developing this recovery system was to prevent the occurrence of the staleness syndrome (through proactive recovery) and thereby optimise the balance between training and recovery. This also reduces the risk of overuse injuries and infections which, in turn, helps to reduce the loss of available training days. In other words, helps athletes to remain healthy and capable of maintaining their training programme. To make the TQR process user-friendly and to relate it to the actual breakdown process, the scale for the recovery process was structured on the concept of the scale developed for ratings of perceived exertion (RPE) [fig. 1].[34,35] The RPE scale and the concept of perceived exertion have been used extensively since the scale was first described by Borg[34,35] and are described in reviews by Noble and Robertson[48] and Watt and Grove.[49]

Ratings of perceived exertion (RPE)	Total quality recovery (TQR)
6	6
7 Very, very light	7 Very, very poor recovery
8	8
9 Very light	9 Very poor recovery
10	10
11 Fairly light	11 Poor recovery
12	12
13 Somewhat hard	13 Reasonable recovery
14	14
15 Hard	15 Good recovery
16	16
17 Very hard	17 Very good recovery
18	18
19 Very, very hard	19 Very, very good recovery
20	20

Fig. 1. The ratings of perceived exertion (RPE) scale for athletic training and the total quality recovery (TQR) scale (reproduced from Borg[35] and Kenttä,[47] respectively, with permission).

6.1 Why Monitor Training Through Ratings of Perceived Exertion?

Studies[48,49] support the hypothesis that the sense of physical effort is best conceptualised as a complex psychobiological construct such as RPE, as originally proposed by Borg[34] (see also the model proposed by Hassmén[50]). RPE is usually accurate in estimating the intensity of an exercise stimulus.[18] Athletes have also demonstrated the ability to reproduce a certain described level of RPE, i.e. they can self-monitor the intensity of an exercise.[51] Together, these qualities facilitate a valid and reliable method for exercise prescription and monitoring.

Training intensity and exercise duration are the most critical factors which, together, determine the total physiological stress, i.e. the magnitude of the breakdown process.[20] The RPE technique can be used as a tool for accurately estimating exercise intensity. An additional benefit of using RPE is the resulting greater focus on the cognitive aspects (self-awareness) of the athletes, as opposed to relying on physiological cues alone. These cognitive aspects become relevant when the athletes are required to focus on overall psychophysiological cues to rate the perceived effort.[48]

Since the staleness syndrome is regarded as a psychobiological phenomenon, the method used for monitoring exercise intensity should also consider psychological aspects. A study demonstrated that RPE increases significantly at given workloads in athletes who experience staleness.[18] Another study found that changes in the RPE : blood lactate level ratio was a reliable predictor of staleness and was most suitable for field settings.[26] Since no reliable markers on the overtraining-response continuum have been established, the most sensitive instrument currently available for detecting the different degrees of staleness is the athlete's own body.[17] Consequently, the use of RPE in applied exercise settings could be a valuable tool in the detection of staleness.

6.2 Why Monitor Recovery Through the Total Quality Recovery Process?

To enable the measurement of the recovery process, the TQR scale, which is similar to the ordinary RPE scale, was developed.[47] The aim of developing the TQR scale was to provide a means to measure psychophysiological recovery (fig. 1).

The use of a TQR scale makes it possible to monitor, and potentially accelerate, the recovery process simply by providing a more complete understanding of the actions necessary for achieving a total recovery. The need to educate both athletes and coaches to enhance the recovery process has been clearly stated by other authors.[52] By using a predefined scale, users will not only be more aware of the complexities of the recovery process, they will also easily see how actions taken translate into an improved recovery after actual training.

The suggested TQR scale is divided into 2 subscales. The first, and easiest to use in applied settings, is termed the TQR perceived (TQRper) scale. The second, more complex subscale is referred to as the TQR action (TQRact) scale. The purpose of these subscales is to create one more subjective (TQRper) and one more objective (TQRact) scale, thereby integrating qualitative and quantitative aspects of the recovery process.

The TQRper scale emphasises the athlete's perception of recovery. The athlete is asked before bedtime to rate their recovery as an overall psychophysiological rating for the previous 24 hours, including the previous night's sleep. Directing the athletes attention to psychophysiological cues (mood states and bodily signals such as sensations of soreness, heaviness, etc.) serves the same purpose as in RPE, i.e. increasing self-awareness. Since this is a highly individualised measurement, it should be used primarily to detect intra-individual changes.

The TQRact scale grades and monitors actions (i.e. individual proactive recovery interventions) which, potentially, optimise and accelerate the recovery process. Athletes simply score their actions and accumulate recovery 'points' over a 24-hour period from the 4 main recovery categories described in section 5.2. Nutrition and hydration allows the accumulation of a maximum of 10 recovery points; sleep and rest a maximum of 4 points; relaxation and emotional support a maximum of 3 points; and stretching and active rest a maximum of 3 points. Thus, the maximum overall score of 20 points is equal to the highest ranking on the TQRact scale. Complete and accelerated recovery decreases the total time taken for the recovery process. Consequently, an athlete can tolerate more frequent and more intensive training. Theoretically, another athlete could eventually have a TQRact score which is beyond the lower limit of the actual scale (i.e <6). In practice, this would happen only in a case of badly mismanaged recovery.

Athletes accrue recovery points over a 24-hour period. The points are determined using standardised, individual calculations described in a specially designed TQR manual. The manual serves as a guideline to the athlete on how to earn recovery points. Recovery points are divided into the 4 different categories discussed above to direct the athlete's attention towards important recovery actions. Points are distributed among the recovery actions according to their degree of importance for the recovery process as well as accounting for the practical limitations that occur in field settings. It is easy to modify the criteria in the TQR manual so that they meet the demands of both the individual and the specific sport. The described manual was developed primarily to meet the needs of elite senior athletes (men and women) undertaking intense training for endurance sports. It can be adapted, however, for other groups also at risk for developing the staleness syndrome.

A general practical recommendation for ensuring that an athlete's recovery is adequate is that both the TQRact and TQRper ratings should, preferably, be at least equivalent to the actual training stress (RPE rating). This is particularly important when training becomes more intense because the recovery process is believed to be accelerated by proactive recovery actions. Proactive recovery actions are considered to provide a higher quality recovery compared with passive rest. A lower training intensity does not require the same high quality of recovery but, even after days of light training, there is a recommended minimum level of recovery [TQR 13 (reasonable recovery)] which athletes must attain.

Another practical implication to consider is the comparison of TQRact and TQRper. When an athlete has been taking full and complete measures for the recovery process and rates significantly lower on the TQRper compared with the TQRact scale, this is an early-warning sign that there is an imbalance between training and recovery. The report by Fry et al.[12] lends some support to the suggestion that an athlete's perception of recovery can be used as a potential marker for staleness: they observed that a group of athletes with the staleness syndrome experienced a decreased perception of recovery compared with 'nonstale' athletes. Further support is provided in other articles[4,17] which suggest that perceived insufficient recovery is a marker for detecting the staleness syndrome. This framework (TQR process) also allows the study of the associations between training intensity (RPE), recovery (TQR), variations in performance and other physiological markers such as immune function, muscle glycogen, cortisol, etc. The study of these associations might permit coaches and athletes to optimise the balance between training and recovery and achieve the best possible performances.

So far in this article, only the training and recovery processes have been structured. The next step is to integrate these 2 processes into the overall context of overtraining and recovery, rather than examining them separately. This will improve our understanding of the results of athlete monitoring and the correlation between training stress (process) and the result of training (product).

7. Conceptual Model for Overtraining and Recovery

One of the few questionnaires encountered in the literature that attempts to address the full complexities of stress and recovery was developed in Germany by Kallus.[29] The Recovery-Stress-Questionnaire (RESTQ) was developed to measure various areas of stress and various areas of recovery activities.[29] The stress and recovery activities are assessed simultaneously by the RESTQ. The result of the RESTQ provides an answer to the question 'How are you?', which is similar in nature to the actual state of stress determined by the stress-recovery balance. The RESTQ is based on the assumption that an accumulation of stress from various aspects of life leads to an altered overall state of stress, at least when there are insufficient opportunities for recovery. Although the RESTQ was developed to measure stress and recovery in a general sense, and not particularly in regard to staleness, it provides support for the conceptual model developed here for overtraining and recovery.

The conceptual model described below is an attempt to view the complex overtraining and recovery processes in their full context. It aims to increase understanding of the different parameters which interact and determine the full process underlying performance improvements (adaptation) and performance decrements (maladaptation). This is of great value for coaches, athletes and trainers alike because it can be used as a guideline for monitoring training and recovery, i.e. for tailoring the perfect training programme.

7.1 Process of Overtraining and Recovery

The total process of overtraining and recovery and the factors involved could be viewed as being controlled by forces which are both additive and interactive. The additive and interactive effects determine the final configuration of the total process. The total process is determined by 3 major subsystems, each consisting of 3 components: a specific stress, a specific capacity and a specific recovery. The sums of these components determine (1) the actual magnitude of total stress, (2) the actual overall capacity, and, finally, (3) the actual total recovery.

7.1.1 Actual Magnitude of Total Stress

Physiological stress (i.e. training) is the most central aspect of the staleness syndrome. Forms of stress such as illness and the use of drugs or medications are not of primary interest in the model. Psychological stress and social stress require more attention in the body-mind performance context. Psychological stress is defined here as intra-individual stress arising from internal stressors; this may, for example, stem from a perceived imbalance between athletic expectations and an athlete's performance capabilities. Social stress is defined as the result of interactions with other people. Social stressors may arise from home life, friends, colleagues at work, coaches and competitors, as described by Rushall.[53] Psychological and social stress, in conjunction with physiological stress, determine the actual magnitude of the total stress.

7.1.2 Actual Overall Capacities For Stress

The actual capacities for stress determine how much stress can be tolerated by an individual. Three major capacities have been identified which consist of various numbers of subcapacities. Aerobic and anaerobic capacities (both energy production capacities), and general strength, specific strength and technique together, are the neuromuscular capacities. The capacity for psychological stress comprises the level of self-confidence, capacity to cope with anxiety, attentional capacity, motivational level, attitude control, positive energy (positive mental health) and visualisation capacity. The capacity for social stress consists of the ability to create, handle and maintain relationships with others. All of the subcapacities within a specific category interact to determine the total capacity of an individual for that category of stress.

7.1.3 Actual Total Recovery From Stress

Recovery processes can also be differentiated into various subsystems and can be related to different types of stress.[29] The aim of each recovery activity should be to restore homeostasis and allow the adaptation of the individual to the stress(es). It is not possible to establish a full recovery until overall psychobiological homeostasis is attained. Therefore, all of the recovery processes need to be taken into account. Physiological recovery in relation to nutrition and hydration, sleep and rest, and stretching and active rest has been described in section 5.1. Psychological recovery is achieved through relaxation and emotional support. Finally, recovery from social stresses can be achieved only by interaction of the athlete with close friends or family members (social support).

Adequate *recovery* is dependent on the specific type of *stress* and the individual's *capacities*. The aim of monitoring training and adequate recovery in the elite athlete is to reach a balance in the zone where training yields optimal increases in performance. So far, this zone has been poorly defined.[17] Therefore, we suggest that this optimal zone be defined as the *adaptation threshold*. Theoretically, the adaptation threshold is the dynamic 'breaking point' where adaptation suddenly (i.e. within a short time frame for athletes near this threshold) becomes maladaptation. Together, recovery, stress and capacity can be viewed as 3 variables affecting the adaptation threshold. Thus, the need to identify the individual's dynamic threshold can be seen as the overall goal in monitoring training and recovery. As a consequence, discussions about which training regimens are good (adaptive) or bad (maladaptive) are incomplete without also considering the characteristics of the individual and the recovery process together with the psychosocial stressors.

To achieve the best results from each and every training session therefore demands consistent monitoring and intelligent decision-making. This occurs when the athlete responds to their day-to-day condition, or state, and as a consequence selects the most appropriate training session at that time. It is worth noting that a specific training stimulus may improve the athlete's performance at one point in time or merely maintain performance or cause staleness at other times. As discussed in this section, it is almost impossible to judge beforehand whether a given training schedule will have negative or positive consequences for all athletes. In this regard, optimal training can be regarded as an ongoing process of the 'total quality management' of training and recovery (RPE versus TQR).

8. Matching Stress, Capacity and Recovery to Improve the Adaptation Threshold

As mentioned earlier, optimising the recovery process enables the athlete to tolerate more frequent and more intense training and still respond positively. This corresponds to improving the adaptation threshold. Optimising the recovery and increasing the stress tolerance (i.e. capacity for stress) of an athlete are 2 different approaches, both of which should increase the dynamic adaptation threshold.

The matching principle can be applied in 3 different ways to prevent staleness (enhancing the adaptation threshold).

(1) Recovery must be matched with the specific stress or stressors.

(2) Training must be directed at improving specific capacities, which will in turn increase the specific (matched) stress tolerance. Improved coping skills will, for example, increase the overall psychological capacity and, eventually, this is believed to increase the overall stress tolerance.

(3) Psychological and social stressors must be minimised to better utilise the available resource of stress tolerance for adapting to the physiological stress.

For obvious reasons, the possible fourth option of reducing the training stress to a minimum is not feasible for competitive athletes.

The final assessment of all of the factors included in the model can be made when all of the available cues from the sociopsychophysiological process and the responses (symptoms and markers) have been evaluated (fig. 2). Individual baseline measurements for all of the considered overtraining markers are necessary for correct assessments of intra-individual changes. The final assessment should answer the most critical question for every athlete, 'Is it OK to continue my training schedule?' (i.e. will the result of my training lead to adaptation or maladaptation within my desired time frame?). By assessing individual differences in total stress, total capacity and total recovery, it is easier to understand why individuals respond differently to a particular training stimulus. This might even help to explain why some individuals seem to differ in their vulnerability to developing staleness. However, instead of discriminating between athletes on a basis of static vulnerability, it is better to use the term *individual adaptation threshold*, since this concept is dynamic and allows for change, or improvement by training.

9. Future Directions

Few studies have focused on self-assessments by athletes for monitoring training and recovery.[8] The conceptual model proposed here can be used as a framework for such studies. Empirical testing of the model, and all of the variables included, is of the utmost importance for the future development of improved or more sensitive monitoring of the whole training process, that is, with a focus on the relative contributions from different variables (physiological, psychological, biochemical and immunological). Interdisciplinary studies to incorporate knowledge from other related subdisciplines, such as sports medicine, education sciences and biochemical sciences, are also warranted. It is further suggested that the overtraining model described in this article will make it easier for endurance athletes to monitor and balance the total

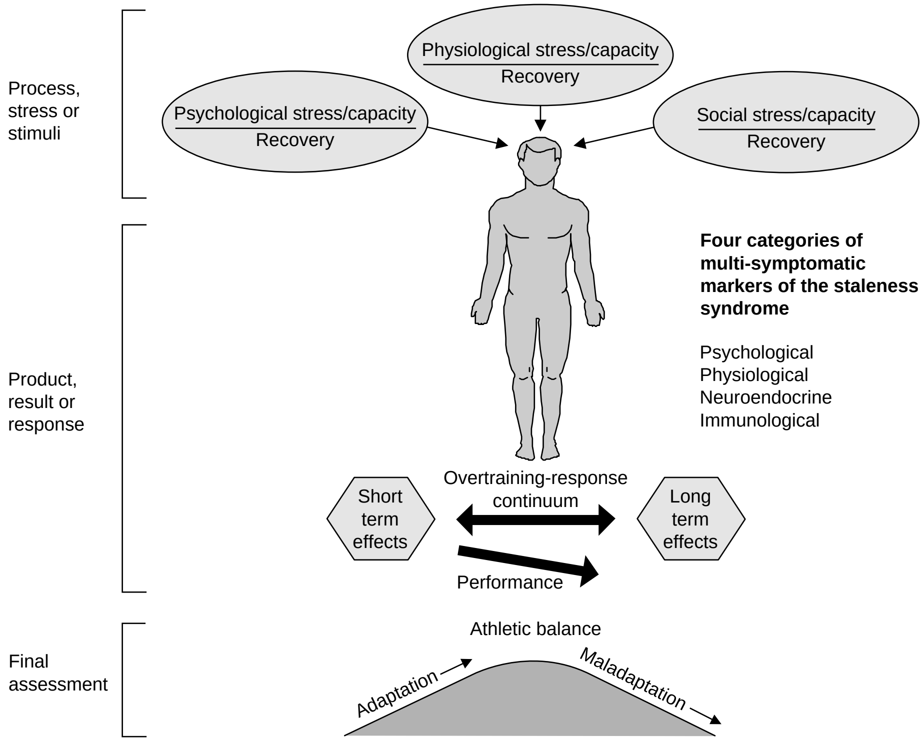

Fig. 2. An overview of the whole overtraining and recovery process.

training and recovery process. The model thereby enables the user to examine problems either separately (e.g. biochemical, physiological, psychological, nutritional, etc.) or by adopting a holistic perspective. It is suggested that the staleness syndrome can only be fully understood in this larger context. The proposed model also highlights the potential influence of factors primarily related to recovery, so far left uninvestigated by overtraining studies, and may encourage researchers to turn their attentions to these.

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