MONITORING THE ELITE ATHLETE

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The application of sports medicine technology to the practical aspect of sport has led to the common belief that the scientific preparation of the athlete is the responsibility of a team - a coach, biomechanist, physician, exercise pysiologist, sport psychologist and others. The advent of sophisticated physiological equipment to determine specific objective measures of performance during activity has allowed the coach to perceive the athlete in precise scientific terms. This monitoring process is a contemporary yet controversial issue. To what extent does applied science impinge of this article is to review the different facets of monitoring with specific emphasis on the overtraining phenomena.

The monitoring process can generally be divided into three separate phases: medical, physiological and assessment of overtraining.

MEDICAL

The fact that the 1976 Canadian Olympic athletes, both male and female, had suboptimum hemoglobin concentrations in comparison to the 1975 Canadian general population and the 1968 Australian and Dutch Olympic teams (Clement et al., 1977) is testimony to the fact that medical monitoring is a necessity. These Olympic athletes did not have the basic hematological capabilities necessary to allow them to perform at maximal levels. This is not an isolated event and iron deficiency and anemia in elite competitive athletes is common place in sports medicine clinics (Clement and Sawchuk, 1984). The purpose of the medical monitoring is to ensure that all athletes approach competition free of disease or injury and have the necessary normal hematological values that will ensure optimum performance. The monitoring process includes a complete physical examination, the primary objective of which is to identify any serious medical problems that may indicate that vigorous physical activity is contraindicated in the athlete. The examination should also be particularly specific to the sport that the athlete is involved in. This may also identify weaknesses, muscle imbalance, incompletely rehabilitated injuries or biomechanical problems that may predispose the athlete to injury. Blood and urine tests should be done initially and 2 to 3 other times during the year depending on the intensity of training and the nature of the sport. Hemoglobin and serum ferritin are the most important parameters to be measured as they will indicate iron deficiency and anemia. These two disorders most definitely affect performance by affecting oxygen transport and muscle metabolism. Other screening tests can also be done to ensure that there is no disease process not yet identified. These tests represent the medical monitoring only; naturally, if the athlete develops an illness other specific tests may be necessary. It is imperative that the physician interpreting the monitoring tests be familiar with athletic medicine as there are several parameters that are recognized as normal in athletes that may be interpreted as manifestations of illness or injury in non-athletic patients.

The medical monitoring of athetes is fundamental to a sound training program. There is little to be gained by sophisticated physiological testing and assessments regarding overtraining if the athlete does not have the basic requirements that are necessary to allow him/her to participate at maximum.

PHYSIOLOGICAL MONITORING

This aspect of the monitoring process varies specifically with the sport and may require no evaluation or repetitive precise measurements of physiological function during maximal exercise. The requirements vary with the physiological demands of the sport. There are specific tests that can be used to quantify the various physiological parameters that have been identified as contributing to performance. Sophisticated measures of aerobic power, an aerobic capacity, strength, flexibility body composition are available and often can be determined with sport specific tasks. In depth physiological analysis can be useful in devising the exercise prescription (i.e. quantifying exercise intensity and duration) for each workout to allow an assessment of the effectiveness of the training program. They can also be used in certain circumstances to predict performance and therefore allow planning of race strategy. Each coach must be familiar with the physiological demands of his/her sport, the methods of quantification, the significance of the results of physiological testing and how to use the results to modify and direct the training program of each athlete.

OVERTRAINING

Although a considerable amount of research has been devoted to muscular fatigue, neither the exact sites nor the causes of fatigue, neither the exact sites nor the causes of fatigue are well understood. To the coach and athlete fatigue is perceived as a process leading to a decrease in performance and they believe that methods of training designed to postpone the onset of fatigue during competition will lead to improved physical performance. Thus, coaches, by necessity must monitor fatigue in their athletes and will often find themselves drawing a fine line between achieving the maximal attainable potential of the athlete and pushing the athlete into a state of overtraining with the consequential fall-off in performance.

With the onset of training, an increase in the training load will result in increased physiological benefits which correlate nicely with improved performance. As the training load increases, a zone of diminishing returns is approached; that is, for a large increase in training load only a small increase in performance results. Finally the precarious zone of maximal performance is reached - the athlete is balanced on a sometimes fine line between being precisely prepared for competition and overtrained. The purpose of monitoring for overtraining is to determine where each athlete falls on this curve with the aim of achieving maximal performance without overtraining. Unfortunately the early signs and symptoms of overtraining are vague and vary considerably between athletes. By the time an injury occurs the early and intermediate stages of overtraining are past and recovery to maximal performance levels will usually take several weeks if not months.

PHYSIOLOGICAL BASIS OF OVERTRAINING

Overtraining is a syndrome resulting from a failure to adapt to excessive stress. Hans Selye, who pioneered research in stress, is responsible for the general adaptation syndrome (G.A.S.) which states that the body responds to different forms of stress with the same adaptive-defense mechanism (Selye, 1956). Athletic training is but one kind of stress or aggression on the body. Overtraining is a relatively new problem; it was not until the 1920's when the Finnish runner Paavo Nurimi turned training from an occasional passtime to a serious time-consuming task that scientists/coaches/athletes began to recognize such conditions as staleness or overtraining.

The overload principle of increasing the quality and quantity of work has proven correct in many instances. There is, however, a point where the capacity to absorb stress is reached; exceeding this threshold will cause the negative effects of overtraining such as chronic fatigue, listlessness and an inability to make further fitness gains. Unfortunately at this time there are no precise criteria for evaluating the degree of fatigue/overtraining that athletes may be experiencing and history dictates that a subjective appreciation of the phenomena is not satisfactory. Training consists of placing the athlete in physiologically stressful situations on a repetitive basis with appropriately timed recovery and adaptive phases of the program. Further gains in performance will not be made simply by increasing the loading factor but by a precise prescrition of the recovery and adaptive periods. Understanding and recognizing the signs of failing adaptation will be the key to more efficient training.

GENERAL ADAPTATION SYNDROMES

The picture of stress expresses itself in the athlete as the General Adaptation Syndrome; there are three stages to this phenomena. In the initial alarm reaction resistance falls below normal. A large number of stressors such as physical exercise, trauma, hypo or hyperthermia, emotional stress, pain and others can set in motion a sterotyped response. Sympathetic nervous system arousal is increased and invariably the secretion of cortisol is elevated. This is mediated by stimulation of the hypothalamic-pituitary-adrenal axis. Catecholamine production is also stimulated which causes increases in the heart rate, stroke volume, metabolic rate, and frequency and depth of ventilation.

As the body can not be maintained in this state of alarm continuously, a second stage, adaptation, is necessary. During the stage of adaptation the simplest response that will effectively counter-act the stress is employed. The stress hormones, ACTH and cortisol, remain elevated, however if the stress is continued, plasma levels of FSH, LH, prolactin and growth hormone are significantly decreased. Gluconeogenesis is promoted at the expense of lipid reserves and if necessary, protein. The thymus, gonads, and lymph nodes involute; inflammatory reactions decrease and eosinopenia becomes evident (Tache et al., 1979). In general, adaptation occurs for immediate survival and secondary functions or lines of defense such as reproduction or resistance to inflammatory conditions are depressed.

In the final stage of exhaustion there is no further line of defense, cortisol levels fall as does the level of resistance. Diseases become manifest, not because of the direct results of some external agent but due to the consequences of the body's inability to meet these agents by adequate adaptive reactions. Chin and Evonuk (1971) have demonstrated that prolonged intensive exercise can lead to a significant decrease in plasma corticosterone thus it is possible that exhaustion of gluco corticoid stores plays a role in the overtraining syndrome.

SIGNS AND SYMPTOMS OF OVERTRAINING

The clinical expression of overtraining results in a miriad of symptoms. As the G.A.S. involves the entire body, symptoms can originate from any physiological system. It is the comprehensive nature of the G.A.S. that leads to the complex, yet non-specific, complaints of the overtrained phenomena. Table I summarizes the subjective symptoms that are most often encountered.

FATIGUE

A generalized fatigue state is perhaps the commonest complaint; this has been described as being tired, listless, stale, having low energy and a lack of iron. The fatigue is usually not localized to the major muscle groups involved in the sporting activity. It should be thought of as a warning mechanism to prevent overstrain and injury and has a physiological basis although the mechanisms involved in generalized fatigue are many and continue to be debated. Substrate availability may contribute to the state of fatigue and fits with the G.A.S. With prolonged repetitive exercise protein synthesis is inhibited, muscle and liver glycogen stores may be depleted and adrenal production of glucocorticoids and adrenalin may be decreased. The reduction in performance that accompanies the feeling of fatigue is an objective measurement that is most troublesome to the athlete and the coach and may trigger the concern regarding overtraining. There are several reasons for poor performance and certainly the physical and mental preparation for competition must be assessed. Nevertheless, a significant decrease in performance in spite of an optimal effort by the athlete, in combination with the subjective complaints of fatigue should indicate the possiblility of overtraining.

TABLE I

SYMPTOMS OF OVERTRAINING

Fatigue

- -lethargy, staleness
- -loss of enthusiasm for training
- -exhaustion
- -decreased performance
- -inability to train at previous levels

Increased systemic infections

- -frequent URI
- -sore throats
- -tender swollen lymph glands
- -skin rash

Gastrointestinal complaints

- -loss of appetite
- -disordered bowel habits
- -weight loss
- -decreased body fat

Neuropsychiatric disorders

- -depression
- -irritability
- -insomnia
- -poor attitude toward training
- -headache

Injury

- -generalized muscle and joint pain
- -overuse injuries to muscle, tendon, bone

Others

- -amenorrhea
- -dysmenorrhea

INCREASED SYSTEMIC INFECTION

The development of upper respiratory infections in athletes involved in strenuous training is, in our opinion, a reliable aid in confirming the diagnosis of overtraining. In the adaptive phases of the G.A.S. the glucocorticoid levels are increased and then become depleated if the stress is continued. Both of these conditions alter resistance to infective agents and the appearance of colds, sore throats, swollen tender lymph glands is increased in frequency. The immune/inflammatory response is altered by physical stress and the body loses its ability to maintain homeostasis. Eosinophenia is another response to stress and renders individuals with hay fever, asthma or other atopic diseases more succeptible to exacerbation of these conditions. Treatment with antihistamine/decongestant/bronchodilator agents may reduce symptoms but the fundamental problem is one of altered resistance secondary to overtraining: the training program must be reduced to allow compensation in the immune system.

GASTRO-INTESTINAL DISTURBANCES

Weight loss is another feature that accompanies overtraining and deserves regular monitoring. Although weight loss is common with increases in the volume of activity and therefore negative caloric balance, when encountered with overtraining it is often accompanied by other gastro intestinal symptoms such as loss of appetite, constipation, or diarrhea. A loss in body fat has been reported (Ryan 1983) and can be part of a comprehensive assessment of overtraining.

NEUROPSYCHIATRIC DISORDERS

A great many symptoms have been described that best fit under this classification. Depression is related quite naturally to the poor performance. It also may be related to overtraining through symptoms of insomnia, psychomotor agitation or retardation, loss of interest in usual activities, and complaints of altered ability to think or concentrate. These symptoms may be related at a psychologocal-endocrine mechanism possibly due to altered noradrenalin levels in the brain (Kopin, 1976).

INJURY

Overtraining may predispose the athlete to an acute injury, be the primary causes of an injury, and play a role in delaying the healing process. Overuse injuries are the result of chronic stress which exceeds the functional capacity of the tissue. Injuries are late symptoms of overtraining and often herald a lengthy absence from competition. Each training stimulus causes protein breakdown, but with rest re-synthesis and adaptation of the tissue occurs. Overuse injuries occurs when the training stimulus is applied before the body has recovered from the initial insult. Failing adaptation can apply to specific areas of the body or it can express itself with changes characteristic of the G.A.S.

MONITORING OF OVERTRAINING

Overtraining is a complex phenomena and unfortunately there is no single test that can be used reliably to evaluate precisely the degree of fatigue in an athlete. Understanding the G.A.S. is fundamental to the development of any monitoring system as there are tests that can assist the coach in this task.

BLOOD AND URINE TESTS

Simple measures such as hemoglobin and hematocrit have been used as indicators of stress. It has been demonstrated that with repetitive demanding work the hemoglobin and hematocrit are reduced in comparison to control values. This is due to the changes in hemodynamics of blood with a change in plasma volume as well as perhaps a reduction in erythropoiesis. Regretfully the individual variability in these measurements is high and these parameters can not be used to accurately reflect the overtrained state. Other changes in the peripheral blood smear that have been associated with overtraining are an increase in the white blood cell count with the differential count reflecting a lymphocytosis and/or eosinophilia.

Muscle enzymes such as creatine phosphokinase (CK) have also been measured in the blood and used to identify the overtrained state. These enzymes are not acceptable for this function because although they reflect the trauma induced through training, they are not specific for overtraining. For example, CPK levels will be elevated in blood of untrained subjects exposed to demanding work. Dressendorfer (1983) has implied that there is a relationship between elevated CK values and the presence of soreness. He suggests that runners with soreness often have poor performances and that a value of CK greater than 3 times baseline values may be a valuable indicator of overtraining, Other muscle enzymes such as lactate dehydrogenase and aspartase transaminase have also been used in attempts to monitor elite athletes but again lack the necessary specificity.

Gluco-corticoids and ACTH levels in the plasma or urine are thought to reflect the non-specific adaptation to stress. These variables consistently rise during exposure to stress, and may stay elevated for an extended period of time with prolonged stress (Chin & Evonuk, 1971). In the third stage of the G.A.S., adrenal exhaustion results in decreased levels of cortisol. Cortisol and ACTH exhibit diurnal variations and this introduces a variability to measurements of these parameters that limits their use in monitoring programs. Recently Barron et al (1985) have used an insulin-induced hypoglycemic stress to study the overtraining phenomena in five male runners. The plasma cortisol, ACTH, GH and PRL responses to this test were lower in the athletes with the clinical diagnosis of overtraining. The responses had returned to normal in four weeks of recovering. Other measures of central function that may prove to be valuable indicators of the overtrained state are plasma cortisol and testosterone (Dessypris et al, 1976; Kuoppasalmi et al, 1980) but further work is required to confirm their usefulness.

The level of plasma catecholamines increases with the duration and intensity of exercise. Urinary adrenaline and noradrenaline have been used as markers of the stress response and several researchers feel that both noradrenaline and adrenaline were reliable and sensitive barometers of stress. Thus urinary catecholamines may represent a valuable tool in the monitoring process. Chin & Evonuk, 1971 demonstrated an approximately 45% increase in noradrenaline and 50% decrease in adrenaline in plasma of rats who were exercised strenouously for six weeks. They also reported a 30% decrease in plasma corticosteriod levels indicating adrenal exhaustion. Regretfully there are methodological problems associated with the use of catecholamines. They are very labile and procedures such as venipuncture can result in a large increase. The sampling procedure requires an overnight fast, avoidance of tea, coffee, and medications that can affect the sympathetic nervous system. In addition, the assay for catecholamines is technically difficult. Catecholamine also display a circadian rhythm which confuses the stress response. Thus although catecholamines respond to stress with dramatic changes the nature and magnitude of the changes are such that this variable has limited practical value in monitoring overtraining.

The regular evaluation of iron status has been mentioned as an integral part of the medical monitoring process. More recently Banister and Hamilton (1985) used the iron profile to assess training and fatigue responses in five female distance runners over a period of 300 days. They suggest that serum iron and transferrin saturation varied in phase with training and a fatigue index, while serum ferritin varied out of phase. While this is a preliminary report it indicates that the iron profile may have some use in assessing the training status of elite athletes and warrants further investigation.

Blood lactate has been used in attempts to monitor overtraining as well as in the prescription of exercise intensity. The mystique surrounding the use of this parameter by Eastern Bloc countries is legendary and in the authors opinion without adequate scientific support. Lactic acid measurements from blood samples are simple and accurate; however, there are many factors that can influence the lactate level in blood and these must be rigorously controlled if the value is to have any meaning. Dressendrofer et al, (1985) has demonstrated that resting plasma lactate concentrations do not vary in response to strenuous repetitive exercise. Other physiologists have used lactate to assess training status as well as identify individuals with potential to compete internationally. The lactic acid response to a standarized training load should remain consistent; fitness improvements would result in a lower value for the task whereas a loss in aerobic capacity and or the overtrained state would be reflected in a higher lactate value for the same task. Although it would appear that lactate measurements have potential for use in overtraining assessment it should be emphasized that this parameter is influenced by many factors and caution must be taken in controlling for the variability.

Regretfully at present there is no definitive test for overtraining and these laboratory values should only be used to confirm or support the opinion of the coach gained by close personal observation.

OTHER MONITORING VARIABLES

The coach and athlete are in the best position to identify the symptoms and signs that can be associated with overtraining. The overworked phrase 'listen to your body' actually has some value. The coach and athlete can assist in this process by maintaining a comprehensive diary which includes specific comments on:

A. Training: volume, intensity, environmental factors, recovery time, performance times, injuries.
B. Subjective feelings: attitude toward training, effort at practice.
C. Lifestyle: social, financial, academic stresses, sleep pattern, nutrition, general feeling.
D. Pre-competition: travel, type of competition, accomodation, sleep, meals, social interactions.
E. Competition: performance, analysis of performance.

Objective measurements of variables such as morning heart rate, recovery heart rates, daily weight, percent body fat and hours of sleep, can be of value in contributing to the information on the overtraining phenomena. The heart rate recorded on waking has been used as the gold standard in monitoring training status and an increase of over 5 bpm should suggest that other signals should be evaluated. The slope of the heart rate/recovery curve from a standarized task is another useful measure. With increased sympathetic tone as in overstress, the heart rates will be elevated in the recovery period. This is monitored by simply recording the pulse rate at several periods during a standarized recovery. This gives much more information than the heart rate at the end of a performance task, which should be at or near a maximal value.

There are several possible monitoring programs depending on the physiological and psychological demands of the sport. All have the personal observation of the coach as the foundation, and in fact in many sports this may be all the monitoring that is necessary. The next level would involve non-invasive measurements such as morning heart rate, daily body weight, hours of sleep and frequent review of the training log. An additional log which includes all possible stressors would also be an important addition to the monitoring program. The heart rate response to a standardized task either on an ergometer or in a field situation would add valuable information but only if done on a regular basis under a controlled situation. Invasive measurements involve blood or urine sampling as well as laboratory facilities and represent another dimension in terms of sophistication and cost. Evaluation of hemoglobin, iron status, CK, lactate and measurements of hypothalmic-pituitary function can be done for athletes who are exposed to multiple stressors in physically demanding sports. These tests are experimental at present and further research is necessary before including them in a routine program of monitoring.

Further improvement in the performance of elite athletes will not be achieved by simply increasing the loading factor. A precise prescription of the training program that includes recovery and adaptation periods is necessary. Understanding and récognizing the signs and symptoms of failing adaptation is an important concept for each coach, athlete, and all support personel. Monitoring of the athlete in precise terms is a necessity if further gains in peformance are to be reached.

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