RECOVERY

Rest, Recovery, and Regeneration

A. Introduction and definitions

An important component of the process leading to a peak performance at a given moment in time is the aspect of 'recovery'. In this discussion, 'recovery' is the multifaceted element that constitutes a return of homeostatic equilibriums and the potential for an increased level of 'readiness' or 'preparedness' for some imminent or future performance.

It is immediately important to realize that although recovery is typically used as some 'all-encompassing' term, it does in fact refer to many different elements and that the process of recovery may well be highly specific to each. Figure 1 illustrates an overview of the main components that influence performance, each of which may be broken down into smaller and more specific elements and be associated with their own recovery characteristics. Additionally, the issue of 'individualization' should also be taken into account when discussing any facet of the response to exercise, training, and performance (see *'Exercise Physiology'* section).

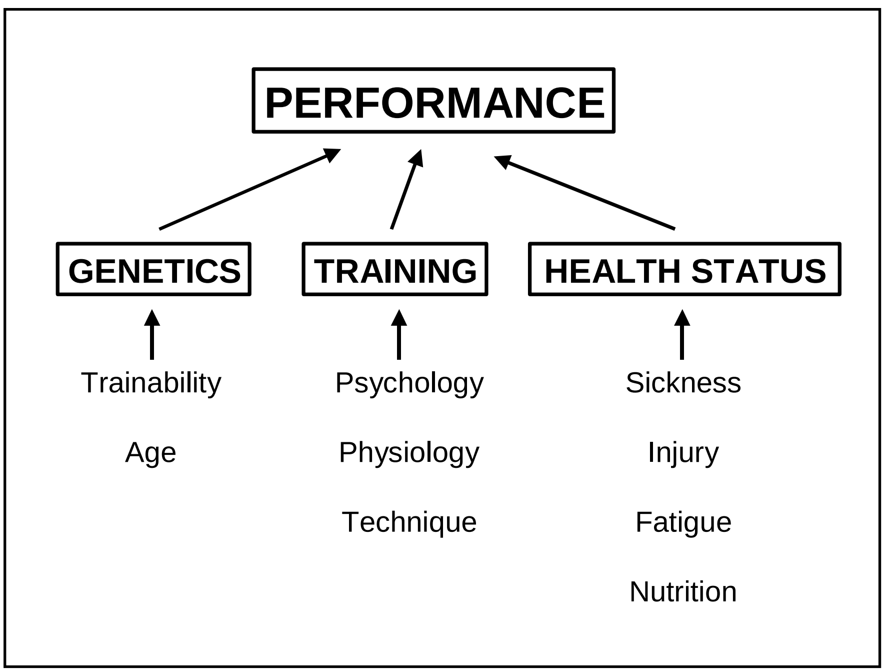

Figure 1. Factors in athletic performance
(*Adapted from MacDougall & Wenger, 1991*)

B. The complex interrelationship of variables

These factors (Figure 1) may be further examined via the following diagram (Figure 2) which expands these points and suggests the format of a flowing continuum for each, while still recognizing the interrelationship between these factors and their cumulative impact upon performance.

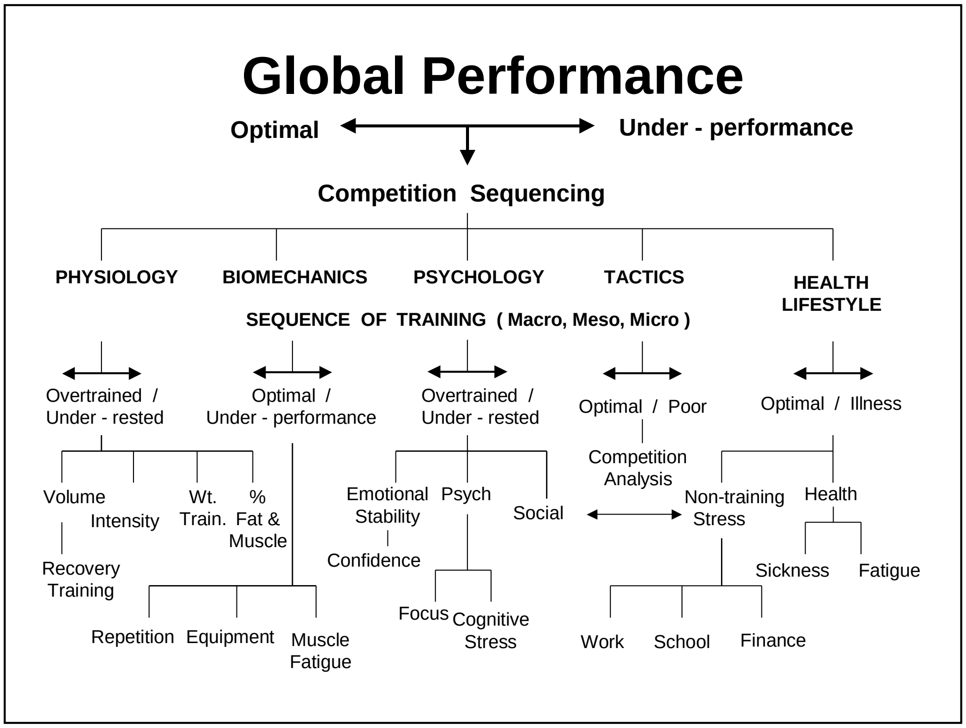

Figure 2. Continuum of factors involved in 'Global Performance'
(*Smith & Norris, 2000*)

The schematic model presented in Figure 2 illustrates that performance is not simply isolated to physiological or biomechanical or psychological elements, but involves a complex matrix of all the 'stressors' acting upon the individual (or team), including components that would be viewed as 'non-training' stressors. That is, the 'stress' placed upon an athlete at any one moment or over a particular period is made up of many factors and that this is a cumulative process. All of which have an implication for the recovery of an athlete and their readiness for further training loads or competitive performance.

C. Physical recovery

Viru (1995) states that the main functions of the recovery period are as follows:

- 'A normalization of functions' (essentially the transition from some exercising level back to the pre-exercise state)
- 'Replenishment of energy resources together with temporary supercompensation for them'
- 'Normalization of homeostatic equilibriums'
- 'Reconstructive function, particularly in regard to cellular structures and enzymes systems.

Further, it should be understood that the above components follow different time spans, that is, the first and third components are likely to be achieved within a relatively short period of time (minutes to some hours). Whereas, the other two components tend to require much longer periods of time to return to what would be characterized as their pre-exercise condition. Viru (1995) also suggests that the time element follows a basically two-stage path, *a stage of rapid recovery* and *a stage of delayed restitution of bodily resources and working capacity*, although both stages are not necessarily exclusive of each other (see *'Exercise Physiology'* and *'Nutrition'* sections).

In practical terms, all of the preceding information points clearly to the need to incorporate recovery periods ('rest, recovery, and regeneration') into the training process. Basically, the message is that such periods are an integral part of the format of training design and that unless those individuals involved in the design of training regimes understand this aspect, the final performance outcome is likely to be compromised.

1. Forms of physical recovery

The usual breakdown for physical recovery involves either *active* or *passive* forms, or a combination of the two.

Active recovery typically follows a pattern of low intensity and low volume in relation to the current capacity and training load of the individual athlete. Such recovery may be used in the immediate period following sustained high intensity training or competition, particularly where the anaerobic glycolytic energy pathway has been substantially involved (see '*Exercise Physiology*' Section). In addition, this level of activity may also be incorporated into a longer period of time (perhaps several days) to aid recovery from an extended period of intense training, competition or other non-training stressors (e.g., travel).

One of the major uses of an active recovery is to remove lactic acid and other associated metabolic products. It has been clearly demonstrated that low intensity exercise accelerates blood lactate removal (see Figure 3) as compared to passive recovery. This is due to a number of processes acting to restore pre-exercise conditions that operate more effectively during light exercise. Essentially, it should be emphasized that well-trained individuals will normally demonstrate rapidly falling heart rates after high intensity exercise, which is synonymous with decreased blood flow to the previously working muscles. Obviously then, it would be more advantageous to maintain an optimal level of blood flow and, hence, delivery of oxygen and other nutrients, as well as an enhanced physical removal of potentially disruptive elements (e.g., hydrogen and ammonia ions). In practical terms, for well-trained individuals with a sound aerobic 'background', an active recovery from a performance producing peak post-exercise blood lactate levels of approximately 14-18 $mmol \cdot L^{-1}$ typically has to last 20-40 minutes to even begin to approach pre-exercise levels. An example intensity for this active recovery would be exercise resulting in a heart rate of around 135-140 $b \cdot min^{-1}$ for an athlete with a maximal heart rate of 195-200 $b \cdot min^{-1}$ and a resting heart rate of 40-60 $b \cdot min^{-1}$.

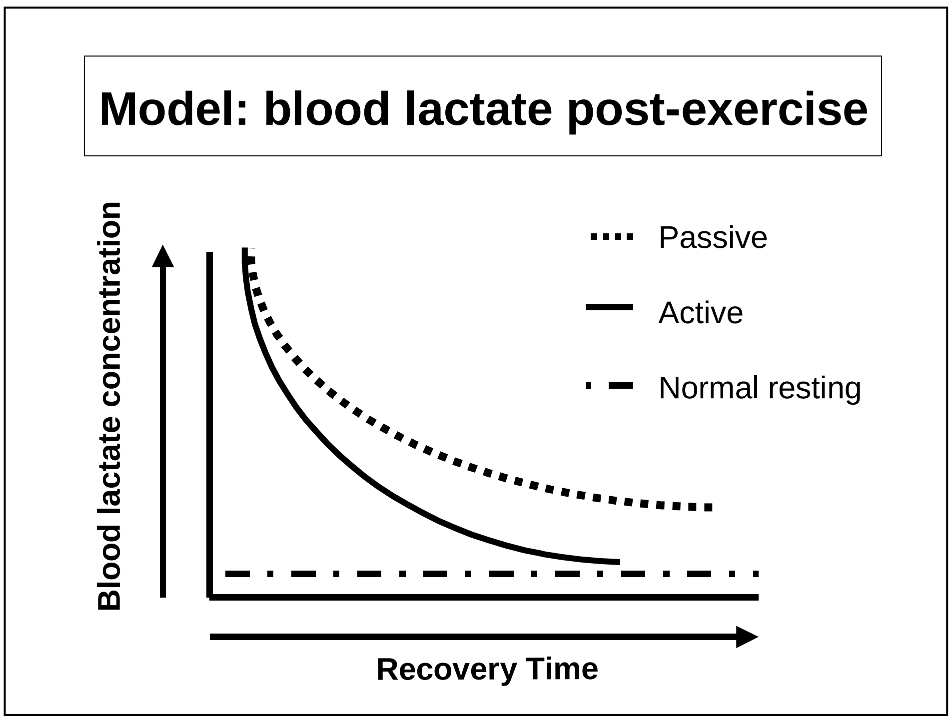

Figure 3. Schematic of post-exercise blood lactate kinetics

Passive (or static) recovery, on the other hand, refers to periods that do not involve any form of activity. These may be of short duration (e.g., a few minutes) through to several days (e.g., 1-10 days) after the completion of extended periods of arduous training and competition, or as part of the preparation for peak performance. This form of recovery is preferred when there is a priority to restore adenosine triphosphate (ATP) and the high energy phosphagens after short duration, high intensity efforts (typically less than 15 seconds in duration; see '*Exercise Physiology*' section). It may also be used when there is a priority to restore macronutrients and essential substances, such as water, carbohydrate, protein and fat (see '*Nutrition*' section).

Additionally, passive recovery measures may also be used to allow for neuromuscular recovery and a restoration of neural movement pattern execution after intense exercise or loading. Massage and other physical manipulative techniques are often cited as being of benefit in terms of aiding recovery from training and competition. Such methods are commonplace in elite sport, although there is conflicting information from controlled studies as to their real effectiveness.

2. Specific aspects of physical recovery

As has been previously stated, there is an obvious relationship between the form of fatigue induced and the exercise or activity that brought about the fatigue in the first place. Aside from the elements, structures or mechanisms that are identified as being 'fatigued', it should also be understood that the time sequence of the restoration of components affected by the exercise or activity is also related to the nature of the exercise challenge (see Figure 4). Platenov (1988) remarks that the greatest delay in a return to a 'resting' state occurs in those components most affected by the exercise form.

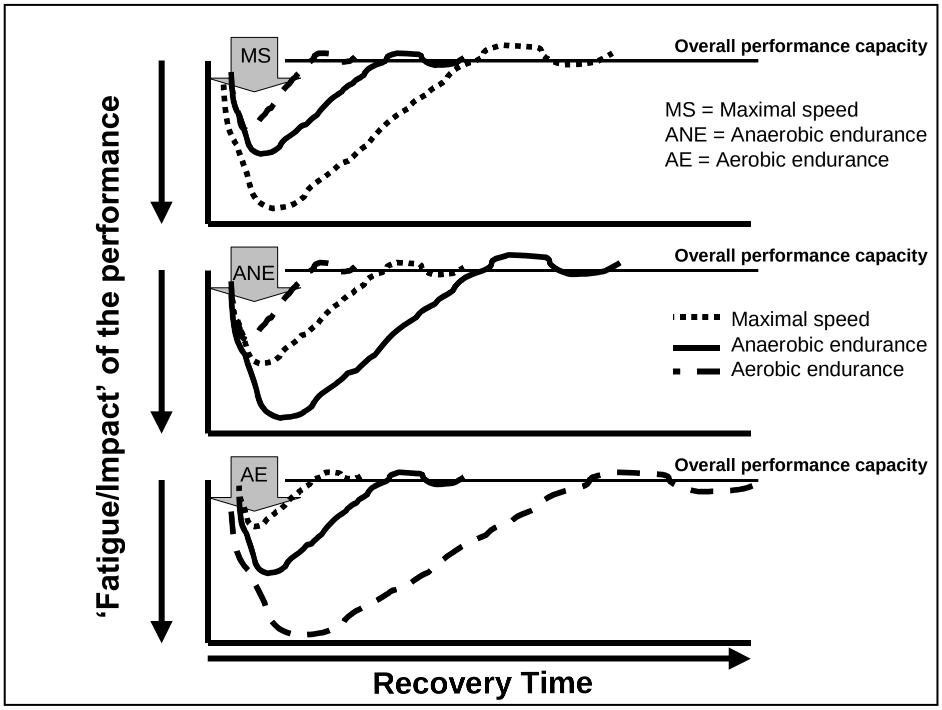

Figure 4. Schematic representation of the specific impact of various forms of representative training upon those elements and their subsequent recovery and performance level.
(*Adapted from Platenov, 1988*)

Energy stores typically follow a temporal pattern of rapid restoration of the high energy phosphates followed by glycogen. Usually it is observed that ATP levels return to normal prior to phosphocreatine (PCr) levels and glycogen, however, there is some evidence to suggest that this may not always be the case. Such findings would also hint further at the 'individualization' aspect of the response to exercise and that, although, the restoration of energy stores are interrelated there is some 'uncoupling' of these pathways dependent upon the specifics of the situation. One aspect that does seem to be strongly evident is the occurrence of a transitory 'supercompensation' phase for skeletal glycogen and phosphocreatine stores, something that has also been reported for liver and myocardial glycogen content, assuming that an adequate dietary source is available in the hours and days after exercise.

Protein synthesis and degradation during post-exercise recovery is also specific to the exercise stress imposed. Therefore, it has been shown that after endurance training the directional trend for the protein adaptive response is towards the mitochondrial proteins of the oxidatively-biased muscle fibres, whereas after intensely stressful strength or resistance training the bias is towards the myofibrillar proteins of the glycolytically-oriented fibres. Similarly, disruptive transitory states are documented for the endocrine, immune and central nervous systems, which together with the aforementioned points, again emphasize the fact that there are several processes at work when in some 'post-exercise recovery and regeneration' phase.

D. Psychological recovery

It is well documented that the 'psychological profile' and, or, subjective evaluation of intensity (e.g., 'Rating of Perceived Exertion', RPE) is altered during phases of intense training and high fatigue. Indices such as the '*Profile of Mood States*' (POMS) have been used to characterize the psychological condition of athletes during various parts of their training and competitive programs. A common finding from such evaluation is the deterioration of an athlete's profile from one of relatively positive mental health during 'early' season or low training demands to a more disrupted level when undergoing or having completed a phase of intense training (Kellman & Kallus, 1999). Such disruptions are alleviated with a reduction in the overall training stress, particularly by removing highly intensive elements and reducing the overall training volume. Several 'paper and pencil' questionnaires have been evaluated in the literature and many demonstrate the ability to be utilized in an ongoing manner as monitoring tools of an athlete's psychological well-being, whereby training demands could be manipulated so as to allow for sufficient recovery from the training or competitive stress.

Earlier in this section and via figure 2, it was suggested that both training and non-training stressors contribute cumulatively to the overall psychological state of the athlete. As with the 'physical' stressors, this aspect also emphasizes the need for systematic recovery periods to be built into the training and competition calendar. It may be stated that '*stress summarizes all individual training, non-training, and competition-dependent stress factors*' (Lehmann, Foster, Gastmann, Keizer, & Steinaker, 1999) and that these may increase the potential for a serious fatigue manifestation or possible 'overtraining' situation.

E. 'Overtraining'

The concept of 'overtraining' has received a great deal of attention in recent years, both from an academic research-oriented point of view and by the general public and mass media. Unfortunately, the proliferation of material on the topic has led to an unnecessarily large and muddled associated jargon that has further added to the overall confusion concerning this inherently complex topic.

Lehmann et al. (1999) define 'overtraining' as '*stress > recovery (regeneration) imbalance, that is, too much stress combined with too little time for regeneration*' and that 'overtraining syndrome' concerns '*an impaired state of health which is caused by* *overtraining and characterized by particular findings*'. The published literature on the characteristics of 'overtrained' athletes provides an extensive and bewildering array of physical and psychological symptoms that may or may not appear for a particular individual. These characteristics or symptoms include, but are by no means limited to, the following:

Underperformance
Depression
Sleep disturbance
Increased resting heart rate
Increased susceptibility to upper respiratory tract (URT) infections and other minor ailments
Irritability and altered mood states
Loss of appetite
Weight loss
Disrupted menstrual cycle
General feeling of fatigue
Lowered resting heart rate
Cardiac arrhythmia

Although this concept has been continually labeled as 'overtraining', more recent thought has led to a re-evaluation and the introduction of the view that what is actually consistently seen is an 'underperformance' by athletes and that this may have different etiologies dependent upon the individual and their specific circumstances. Furthermore, the elements that may or may not be involved are viewed as being on some form of continuum (optimal to sub-optimal; see Figure 2) and that there is also an over-riding time or sequence continuum suggesting that athletes may shift from typical short-term training fatigue states, through mild or extensive 'overreaching', to some long-term performance incompetence dependent upon the appropriateness of the recovery and regeneration periods to the training load (Fry, Morton, & Keast;, 1991).

A practical basis has led Smith (1999) to state that there are five stages to the fatigue continuum and that these are as follows:

1. The 'normal' training stress
2. Overstraining
3. A training overload
4. Overreaching
5. Overtraining

Smith (1999), while fully recognizing that these stages actually 'flow' into one another somewhat seamlessly, then goes on to provide a framework for expected recovery timelines associated with each of these stages and these are shown in Figure 5.

Time Frame of Recovery for the 5 Stages of Fatigue

1. Training Stress	< 24 hrs
2. Overstrain	3-5 days*
3. Training Overload	5-7 days
4. Over-reaching	10-14 days
5. Overtraining	> 28 days

*peak soreness ('delayed onset'), 24-48 hrs

Figure 5. Practical guide to expected recovery timelines.
(*Smith, 1999*)

F. Practical guidelines and the 'supplement' issue

The fundamental task of this section is to ultimately provide the basis for a rationale for a systematic recovery component within a training and competition program and a practical set of guidelines for those dealing with high performance athletes. The following points are listed in order to provide a framework for the establishment of just such a rationale and guide.

1. Always strive to maintain a basic level of health
2. Eat wisely, eat enough and ensure adequate hydration
3. Restoration of energy and water stores before and after training and competition should be a major priority for those engaged in endurance activities
4. Despite the forceful advertising and strong claims made by nutritional supplement companies, there is little controlled work to support the vast majority of the purported 'ergogenic' substances
5. Supplementation is not an excuse for a poor diet or unwise nutritional practices
6. Rest, recovery and regeneration periods should be planned as integral parts of the training and competition program

7. At least one full day per week should be assigned to passive recovery
8. Try to allow for full recovery every 2 weeks
9. Every 4-6 weeks allow for a systematic regeneration period of approximately 1-3 days, in addition to the normal day per week guide
10. Every 16-22 weeks there should be a more extended period of planned regeneration. This will be in the order of 5-10 days of appropriate measures, some of which will be of a passive nature.
11. Keep a training diary that tracks both training volume (e.g., in minutes or hours, metres or kilometers), some attempt to examine intensity (e.g., heart rate, RPE, arbitrary scale), and indices of the athlete's level of well-being and 'readiness' or 'preparedness' for continued training and competition (e.g., resting heart rate, POMS, criterion performance, body mass, fat and fat-free mass)
12. Attempt to 'individualize' the training schedule and load (i.e., do not 'blindly' follow some famous athlete's training regime)
13. Establish a sound 'history' of basic training (Smith, 1999) or 'background training' (Foster, Daniels, & Seiler, 1999) involving a critical mass of low intensity prior to attempting to increase the percentage of high intensity interval training within a given program
14. Monitor the 'easy/light' training sessions or days as carefully as you would the 'hard/intense' ones
15. Most 'experts' suggest limiting the number of really intense training sessions to 2-3 per 7 day cycle

Figure 6 shows the 'basic rule' of a commitment to ongoing monitoring when engaged in longitudinal training and competition programs. This basic rule embraces the concept of 'entry and exit' testing or monitoring, whereby particular variables are examined upon entry into, and exit from, a particular phase of training or competition. The variables measured will be largely dictated by the event and training format in question, however, there are likely to be common factors amongst all sports activities. It should also be noted that the competitive event itself is not only 'the highest form of training' (Smith, 1999), it is also 'the highest form of monitoring' (Norris, 1999).

The diagram also emphasizes the need for a planned and executed 'recovery period' after the training or intervention period and prior to the next evaluation or competition period/event. This is to ensure that the next evaluation or competitive event is not influenced negatively by some 'residual fatigue' that is still present as a consequence of the training/intervention period. Such a format allows for the evaluation of the effectiveness of the training or intervention program and is one of the determinants in the process of establishing the strengths and weaknesses of a particular athlete, group of athletes, or team. It may also be seen that the 'exit' point is in fact the 'entry' point for the next chronological phase.

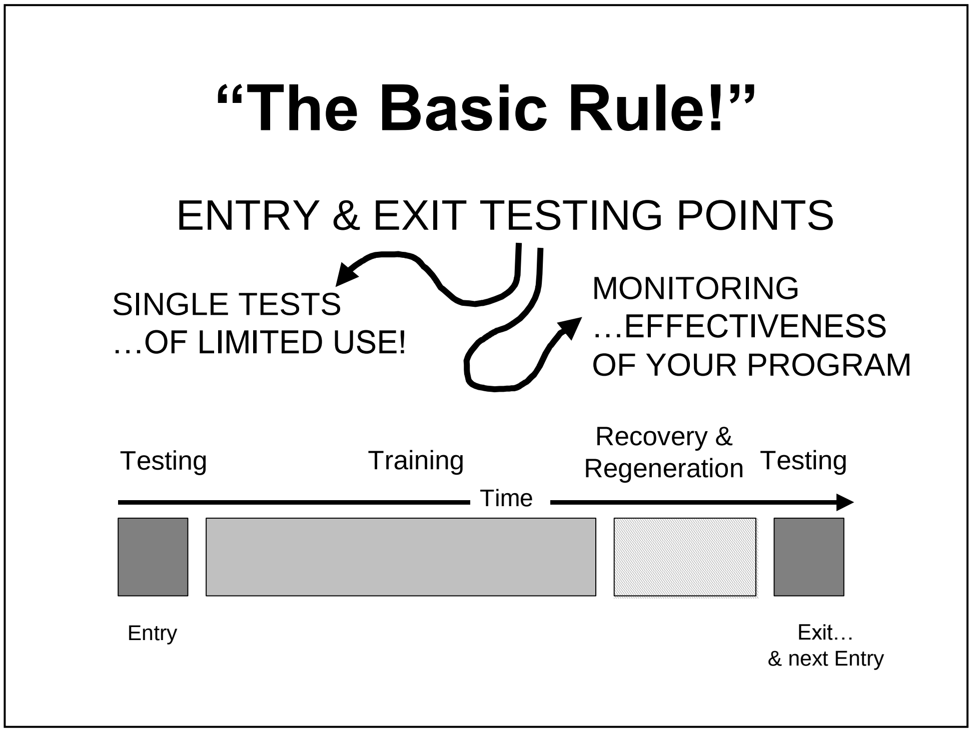

Figure 6. The 'basic rule' of a commitment to 'entry and exit' testing or monitoring.
(*Norris, 1999*)

Finally, attention should be returned to the Figures 1 and 2. Both these models emphasize the need for the maintenance of a base level of health. Since the systematic training and competition programs of modern athletes may actually be viewed as severe challenges to the health and well-being of an individual athlete, the fact that these models highlight the importance of health and related factors is not to be taken for granted. Indeed, without a sound basis of health, training and competition performance is likely to be compromised.

At the root of basic health is sound nutrition (see '*Nutrition*' section). As has been previously commented in the 'practical guidelines' section, nutritional supplements and so-called ergogenic aids is an extremely volatile aspect of the athlete-of-today's life. The constant advertising barrage and pressure from influential persons, together with the persistent arrival almost weekly of new 'wonder' substances, is likely to challenge the resolve of any individual otherwise trying to maintain sound dietary practices. It is beyond the scope of this section to do justice to this massive and complex issue, therefore, a resource list of reliable and credible sources is provided in the bibliographic/reference portion following this section.

Finally, Figure 7 is presented to leave the reader with a summarizing concept. This model compliments the other aspects introduced in this section by illustrating the concept that the potential performance gain from a given training or intervention load acts in summation with the level of fatigue or homeostatic disruption associated with that load to establish a pathway for the level of 'preparedness' (or readiness) of the athlete to perform at any moment in time.

It is easy to see that in the immediate period after completing the training load, the level of fatigue tends to outweigh the ability to actually attain the performance potential gained. This is clearly shown by the line of 'preparedness'. As time progresses however, the level of fatigue diminishes such that the level of preparedness rises. This occurs despite a loss in the potential gain from having done the particular training load in the first place. In fact, the available literature tends to suggest that the rate of decay when comparing the fitness component with the fatigue component is 3:1 in favour of the fitness component. That is, the fitness component will take three times as long to decay back to the previous level than the fatigue component. This illustration alone should summarize the concept of the need for systematic and appropriate recovery practices.

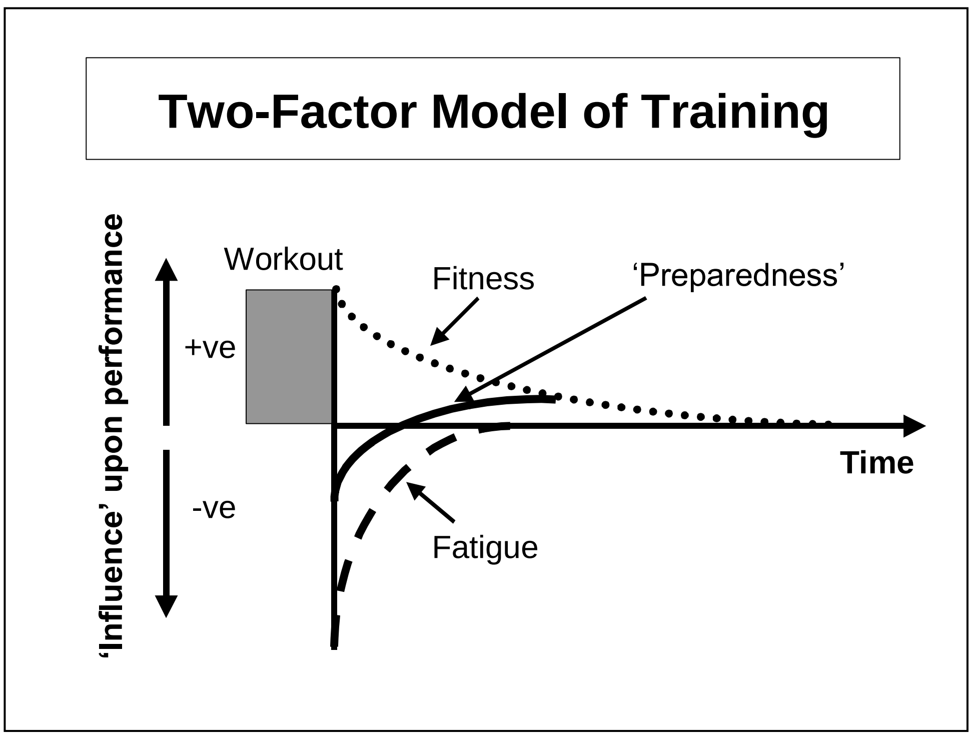

Figure 8. Two-factor model of training.
(*Modified from Zatsiorsky, 1995*)

SUGGESTED READINGS.

Lehmann, M., Foster, C., Gastmann, U., Keizer, H., & Steinacker, J.M. (Eds.). 1999. Overload, Performance, Incompetence and Regeneration in Sport. Kluwer Academic/Plenum Publishers, New York, NY.

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