

REVIEW ARTICLE

Adaptation of exercise induced stress through scientific recovery techniques: a narrative review

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Abstract

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The modern sports are constantly challenging and needs a scientific individualized training protocol in order to be a record-breaking performer. Regular muscular graded exercise is prerequisite for better adaptation of training stimuli. Any physical or psychological stimuli that disrupt homeostasis result in a stress response. Muscular exercise is perhaps the most common form of stress that humans experience. Adaptation of Training stimuli largely depends upon the scientific optimum recovery protocol. Exercise physiology, in turn, is the study of how the body responds to this form of stress. Understanding exercise stress and how to impose it is the primary mission of the sports scientist. The purpose of narrative review-based study is to discuss the exercise induces stress and its management through recovery techniques to optimize sporting performance with specific emphasis on rest and recovery intervals.

Introduction

For optimizing performance in global sports scenario every athlete has to undergo scientific preparation through systematic training which induces adaptations in the muscle, and metabolic, cardiovascular and neurological systems (Borresen & Lambert, 2009; Issurin, 2009). The training load is a procedure to upsets the homeostasis through external stimuli and able to create dynamic internal state of equilibrium (Mukhopadhyay, 2022). Homeostasis, the dominant explanatory framework for physiological regulation, has undergone significant revision in recent years, with contemporary models differing significantly from the original formulation. Allostasis, an alternative view of physiological regulation, goes beyond its homeostatic roots, offering novel insights relevant to our understanding and treatment of several chronic health conditions. Despite growing enthusiasm for allostasis, the concept remains diffuse, due in part to ambiguity as to how the term is understood and used (Douglas & Woods, 2014). Bernard (1929) first described the processes of physiologic control as the *milieu interieur* in his book "An Introduction to the Study of Experimental Medicine". The term homeostasis was later coined by Walter Bradford Cannon in his book "Organization for Physiological Homeostasis" (Cannon, 1929), Waddington (1957) preferred the more dynamic term homeostasis.

Homeostasis referred to a balance or harmony of systems and physiological parameters that allow a little variation such as body temperature, pH, and arterial oxygen tension, glucose, protein, sodium, and calcium. On it, the physiology is regulated around strict values of a "set point" precisely determined. Therefore, the stability of the internal environment is maintained by constancy in maintaining the set values or "set point" of their different systems and parameters. For these values to be remained settled it is needed to maintain their internal elements balance. These elements maintain homeostasis and they are able to make the body react properly to different focal of aggression such as sports training, form the basis of the allostasis (García-García et al., 2016).

Any internal as well as external factors can disturbed the "set point" of an individual, which can be termed as stress and the responsible factor is termed as stressor. Exercise is a stressor, which upsets the homeostasis of a sportsperson at the time of tackling the training load. The term "stress" is widely used, and its significant contribution to human disease and suffering is well recognized (Kemeny & Schedlowski, 2007; Chida et al., 2008; McEwen, 2008; Fagundes et al., 2012; Van der Kolk et al., 2012; Everly & Lating, 2013). However, the term is often poorly defined. It has been used to refer to a subjective state, a physiological reaction, a neurochemical response, or the presence of a certain kind of external situation.

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A textbook definition of 'exercise stress' does not exist, largely because 'stress' is used as a catch-all term for anything that results in a physiological response to muscular activity. It can be defined as "Any muscular activity that challenges homeostasis and produces a measurable physiological response". To begin to understand exercise stress, one has to understand first the stimulus causing it before considering the resulting physiological responses (Coffey & Hawley, 2017). Although exercise intensity is the most important component of exercise stress, a complete definition would require considering the duration of exercise or volume of exercise. This is important because even mild exercise can result in significant levels of stress if continued for long enough. A distinction also needs to be made between the absolute and relative stress that exercise produces (Coffey & Hawley, 2017).

The well-documented effects of physical training are a manifestation of the chronic adaptation to exercise stress. Selye (1936) considered muscular exercise to be a form of his 'general adaptation syndrome', although in later writings he made a distinction between muscular adaptations to exercise and the non-specific stress reaction he was describing. A key feature of exercise stress is that adaptations to it are positive in all but the most extreme cases (overreaching or overtraining). In other words, application of training stress that does not cause injury will maintain or improve physiological function, in contrast to the so-called 'exhaustion phase' of the general adaptation syndrome.

The molecular basis of 'strength' or 'resistance' training and 'endurance' training has so far been convincingly differentiated. Even in these cases our understanding of the processes leading to training adaptations is far from complete. To observe the clearest distinction between strength and endurance training usually requires a sample of trained participants. This is because even relatively low-intensity exercise in untrained individuals results in both mitochondrial and myofibrillar protein synthesis (Coffey & Hawley, 2017; Burnley, 2017). Resistance exercise and endurance exercise put stress on organic system and upset the homeostasis and in the long run, chronic exposure of such kind of stimulus effects difference in adaptation of

athlete. Training with over load and adequate recovery is prerequisite for better sporting adaptation.

Training overload occurs when the balance between external load and internal load is altered so that the body's adaptive capacity is inadequate, resulting in manifestations of altered performance and injury and/or illness. Current concepts explain more accurately the features related to loading, overload, and recovery. Athletes respond individually with an internal and external load; it, therefore, determines the magnitude of the stimulus of load (Stanley et al., 2019; Herring et al., 2016; Mukhopadhyay, 2021).

The purpose of the review article was to discuss the traditional and modern recovery modalities and strategy to maximise the adaptation in shortest possible time depending upon the different component of training i.e. strength and endurance.

Homeostasis

Any system in dynamic equilibrium tends to reach a steady state, a balance that resists outside forces of change. When such a system is disturbed, built-in regulatory devices respond to the departures to establish a new balance; such a process is one of feedback control. All processes of integration and coordination of function, whether mediated by electrical circuits or by nervous and hormonal systems, are examples of homeostatic regulation (Homeostasis and Cellular Function; Kahn Academy, 2019; Lumen Learning, 2019).

Homeostasis can be influenced by either internal or existing conditions (*intrinsic factors*) or external or environmental conditions (*extrinsic factors*) and is maintained by many different mechanisms. All homeostatic control mechanisms have at least three interdependent components for the variable being regulated (Cohen, 2012).

A *sensor* or receptor that is responsible to detects changes in the internal or external environment. The *integrating center* or control center receives information from the sensors and initiates the response to maintain homeostasis. An *effector* is any organ or tissue that receives information from the integrating center and acts to bring about the changes needed to maintain homeostasis (Mukhopadhyay, 2021).

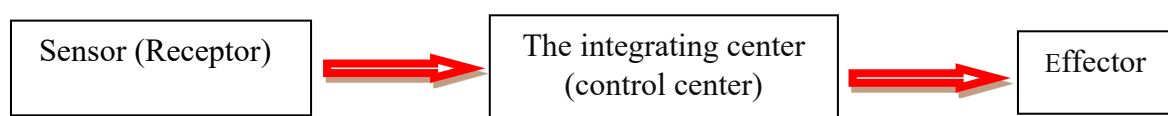


Figure 1. Conceptual diagram illustrating homeostasis.

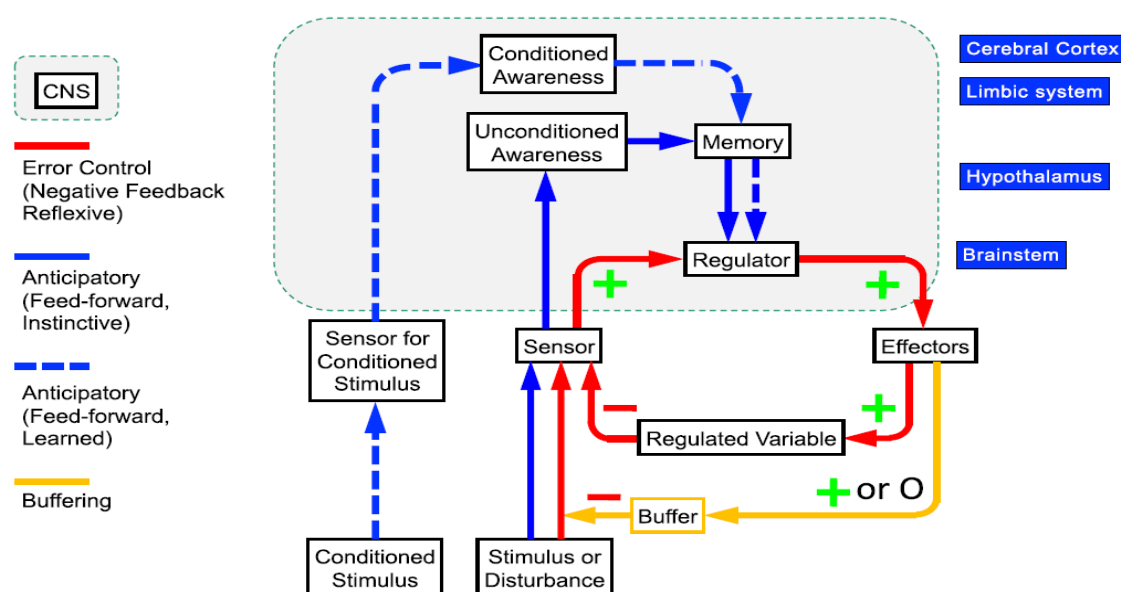


Figure 2. Concept diagram illustrating 3 ways homeostasis happens: negative feedback regulation via internal reflexes, anticipatory regulation via conditioning or instinct, and buffering.

In the model, the effectors are both autonomic and no autonomic. Effector responses to a disturbance are determined by 3 forms of regulation. First, effector activities are determined from input-output (afferent-efferent) curves relating sensory input to effector output (error control by negative feedback). Second, via exteroceptive or interoceptive input, effector activities are altered by instinct or imprinting in advance of a change in the level of the regulated variable. Third, via exteroceptive input, effector activities are altered by associative learning (classical or instrumental conditioning), also in advance of a change in the level of the regulated variable. The extent of sensor activation in response to a disturbance is modulated by buffering. Buffering is a means of diminishing the intensity of an external disturbance, thereby reducing the required use of reflexive homeostatic mechanisms. Effector responses can also modify buffering in advance of a disturbance, via instinct or learned behaviours (Goldstein, 2019).

Stress

Stress is a threat to maintain consistency of our internal environment. Stress is an essential adaptation necessary for homeostasis, performance and survival (Galley et al., 2014). In a general sense, stress refers to a collection of physiological, emotional, behavioural and cognitive reactions that occur in response to environmental demands. Lazarus and Folkman (1984) suggested that stress results when the demands of the environment are

greater than the individual's perceived coping resources. Intense exercise implies adaptive processes involving affective, physiological, biochemical, and cognitive-behavioral response in an attempt to regain homeostasis (reviewed by Morgan et al., 2015). Therefore, it is difficult to differentiate between the effects of the physical stress of exercise and the effects of the psychological stress during exercise (Lin et al., 2012). Therefore, both the physical and psychological demands during intense exercise are referred to here as "stress". Stress may be acute, episodic or chronic, which varies in characteristics, symptoms, duration and management approaches. The most commonly experienced stress is acute stress (Kumar & Srilatha, 2019).

Two main distinct but interrelated systems that affect the stress response during exercise are: the sympatho-adreno-medullary (SAM) and hypothalamus-pituitary-adrenal (HPA) axes. The activation of these axes results in the release of catecholamines (norepinephrine (NE) and epinephrine) and glucocorticoids into circulatory system (reviewed by Ulrich-Lai & Herman (2009). Stress during exercise also activates the autonomic nervous system (ANS) (Matins et al., 2005), which provides the most immediate response to stressor stimulus through its sympathetic and parasympathetic arms, and increases the neuronal release of NE and other neurotransmitters in peripheral tissues (extensively reviewed by Ulrich-Lai & Herman, 2009).

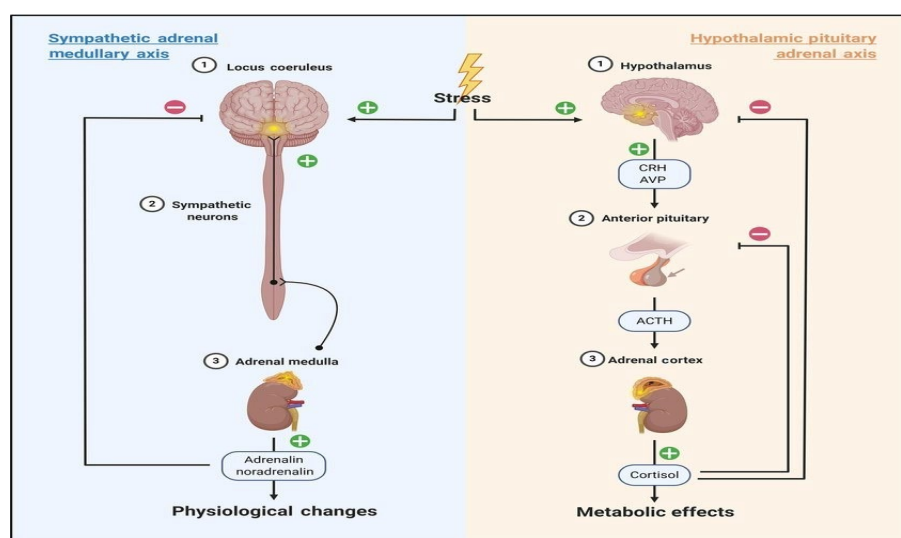


Figure 3. The sympathetic adrenal medullary axis and the hypothalamic pituitary adrenal axis are both altered due to stress. +: Indicates stimulatory pathways; -: Indicates inhibitory pathways. ACTH: Adrenocorticotrophic hormone; CRH: Corticotrophin-releasing hormone; AVP: Arginine vasopressin Cited from Carlton *et al.* (2021).

Exercise represents a potent physiological stimulus upon the hypothalamo-pituitary adrenal (HPA) axis. Two major factors modulate the HPA axis response to exercise: Intensity and duration. Endurance training does not induce permanent hypercortisolism as endurance-trained subjects have similar biological markers of HPA axis activity in resting condition. However, during a challenge of the HPA axis, endurance-trained subjects demonstrate an adaptation of the HPA axis activity to repeated exercise resulting from decreased tissular sensitivity to glucocorticoids. A great diversity of other mechanisms is involved in this adaptation, acting potentially at all levels in the cascade and leading to the biological effects of cortisol (St-Pierre & Richard, 2020).

The identification of a stressor leads to activation of two major constituents of the stress system and the release of its final mediating molecules. The sympathetic-adreno-medullar (SAM) axis, secretes noradrenaline and norepinephrine and the hypothalamus-pituitary-adrenal (HPA) axis, secretes glucocorticoids. Once these axes are activated in response to a given stressor, they will generate a coordinated response that starts within seconds this is term as fight or flight action. To accomplish this, the stress response systemically promotes energy mobilization, metabolic changes, activation of the immune system and suppression of the digestive and reproductive systems (Dayas, 2001).

Physical stressors are mainly processed by brainstem and hypothalamic regions (Ulrich-Lai & Herman, 2009; Dayas, 2001; de Kloet *et al.*, 2005a; Fenoglio *et al.*, 2006; Joëls &

Baram, 2009), they usually require immediate systemic reaction, which might be considered reflexive (Ulrich-Lai & Herman, 2009). Thus, the first phase of the stress response (sympathetic adrenomedullar system—SAM), provides a rapid physiological adaptation, resulting in short-lasting responses, such as alertness, vigilance and appraisal of the situation, enabling a strategic decision to face the challenge in the initial phase of a stressful event (de Kloet *et al.*, 2005a; Fenoglio *et al.*, 2006). Whereas, the secondary phase involves the hormonal mechanism (Hypothalamic Pituitary adrenal axis—HPA) considered sluggish compared to the synaptic mechanisms that activate the SAM, but resulting in an amplified and protracted secretory response (long-lasting responses). The limbic forebrain regions may contribute to physical stressors processing as well, influencing the functions in the autonomic responses to stress and the activation of the HPA-axis (Ulrich-Lai & Herman, 2009). These limbic stress circuits involve the amygdala, hippocampus and prefrontal cortex (PFC) that receive associational information from subcortical and cortical areas (Lívea *et al.*, 2018). Chronic exposure to physical exercise may improve the functional capacity of brain and recover quickly from allostasis state to homeostasis state.

Allostasis

In the last few decades, the initial concepts of stress have been revised. Sterling & Eyer (1988) as well as others (McEwen & Stellar, 1993; Schulkin *et al.*, 1994) proposed the new concept of allostasis, allostatic load and allostatic overload. These concepts would take into account the

findings of the 60s, 70s and 80s from stress research, such as physiological variations in normal states and the presence of anticipatory responses to stressors (Dallman, 2003; Schulkin, 2003). In the definition of allostasis, the set-point to maintain a physiological equilibrium is constantly changed, so what is ideal for baseline situations is not necessarily ideal in stressful situations (Koolhaas et al., 2010). Moreover, the set-point to maintain physiological balance in allostasis does not work in a linear fashion, but it can be regulated in several ways (McEwen & Stellar, 1993). Finally, the terms “allostatic load” and “allostatic overload” consider the cumulative effects of stressors on the body in normal physiological and pathological situations, respectively (McEwen & Stellar, 1993). The concepts of stress, stressor and stress response are still widely used and accepted by the scientific community, as it considers an unusual parameter value not as a failure to defend a set point, but as a response to some prediction. Homeostasis describes the mechanisms that hold a constant controlled variables by sensing its deviation from a “set point” and feeding back to correct the error. Allostasis describe the mechanisms that change the controlled variable by predicting what level what level will be needed and then overriding local feedback to meet anticipated demands. Figure 4 represents the alternate model of regulation.

Adaptation

Exercise and physical training are biological stressors. The body reacts similarly to exercise as it does to other

stressors (Kiely, 2016). Stress disrupts homeostasis and this leads to an adaptive response (Chu et al., 2021). The body's responses to a single bout of exercise are regulated by the principles of homeostasis. Homeostasis is defined as the ability of the body to maintain a stable internal environment for cells by closely regulating various critical variables such as pH, acid-base balance, oxygen tension, blood glucose concentration and body temperature (Powers & Howley, 2014). Specifically, in exercise – muscle contractions disturb homeostasis resulting in various responses. The type of adaptation is dependent on the overload stimulus. It is important for clinicians using exercise as a modality to understand the biological process of adaptation (Lambert, 2022).

General Adaptation Syndrome (GAS)

Athletes respond to stress by reacting and then adapting. Stress response causes the activation of well-known and systematic biological mechanisms. Physiological and psychological/behavioural responses covary with reactions and adaptations to stress (Sterling & Eyer, 1988). The body mounts a defence involving nearly all systems of the body (53).

The general adaptation syndrome (GAS) provides a mechanistic model to understand the relationship between stress, adaptation, and fatigue. Selye first proposed the GAS to describe his observations of a systemic three-phase response consisting of the alarm reaction, stage of resistance, and stage of exhaustion to ‘diverse nocuous agents’ (Selye, 1936).

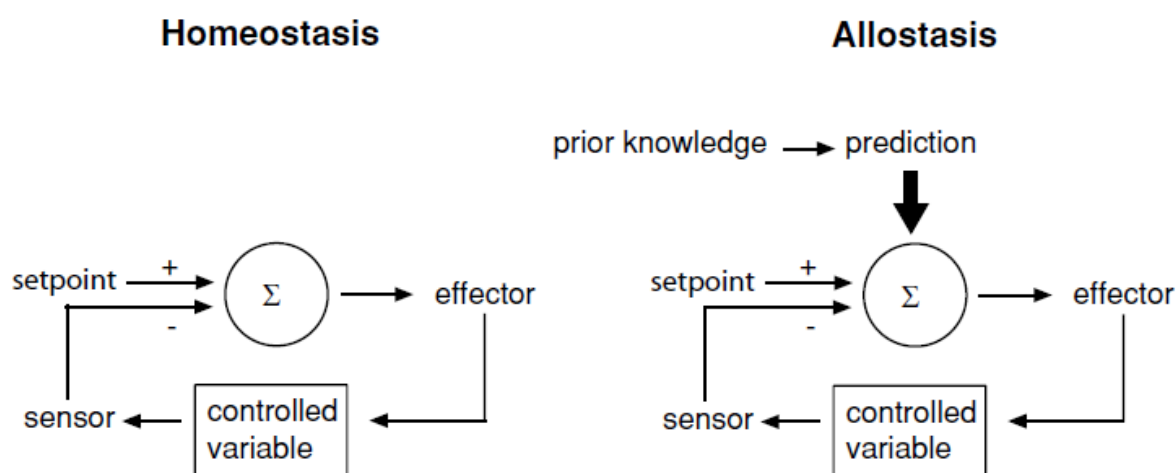


Figure 4. Represents the alternate model of regulation Cited from Starlling (2004).

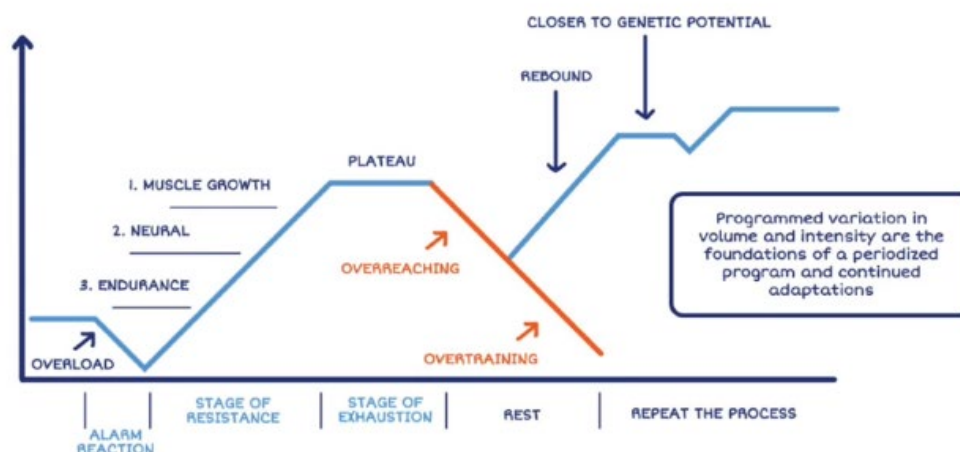


Figure 5. Graphical representation of GAS (Cunanan et al., 2018; Personal Trainer Collective, 2023).

The initial phase or the first phase starts with the initiation of physical exercise; this stage is termed as “Alarm Reaction”. The performance capacity is decreasing gradually and after appropriate rest, the athlete regains the capacity, this phase is termed as stage of resistance and due to the effect of supercompensation the baseline performance is increased. If enough recovery is not administered or excessive overload is given, the stage of overreaching appears. So adaptation of training load basically depends upon appropriate ratio of load and recovery. The GAS has proven to be an instructive framework for understanding the mechanistic process of providing a training stimulus to induce specific adaptations that result in functional enhancements.

Recovery

The improvement of athletes' training level is gradually realized through the cycle of training-fatigue-recovery-training-fatigue-recovery-cycle (Bradley & Noakes, 2013). Therefore, training without fatigue is meaningless, and training without recovery from fatigue is harmful. If fatigue is not eliminated in time, it will accumulate into injuries, and injuries will become ill for a long time. This will not only do no good to the improvement of athletes' training level, but also may seriously ruin an athlete's sports career (García-Pérez et al., 2013).

Recovery is a multidimensional process involving a number of systems (Jeffreys, 2005). More specifically, recovery is defined as an inter- and intra-individual multi-level process for the re-establishment of performance abilities that can be systematically used to optimize situational conditions, to build up and refill personal resources, and buffers (Kellmann & Kallus, 2001). This

definition demonstrates the complexity and multidisciplinary nature of the recovery process. Recovery strategies can be divided into active and passive methods (Kellmann, 2002); each strategy addresses either regenerative (the physiological aspect of recovery) or psychological components of recovery (mental and emotional stress) (Kellmann et al., 2018).

“Recovery is an inter-individual and intra-individual multi-level (e.g., psychological, physiological, and social) process in time for the re-establishment of performance abilities. Recovery includes an action-oriented component, and those self-initiated activities (proactive recovery) can be systemically used to optimize situational conditions and to build up and refill personal resources and buffers.”

Exercise and stress

In general, exercise causes two types of stress on muscle tissue: mechanical and metabolic.

- Mechanical stress refers to damage to protein structures of individual muscle fibers, while
- Metabolic fatigue means depletion of available energy stores in muscle cells. Every workout applies different levels of mechanical damage or metabolic fatigue and requires appropriate time for the body to repair and adapt.

In the recovery phase, the body expends energy to replace the energy spent during exercise, repair damaged tissues and remove metabolic by-products. This phase can be identified by an increase in oxygen use, known as excess post-exercise oxygen consumption (Bompa & Haff, 2009).

The process of recovery can be classified as follows:

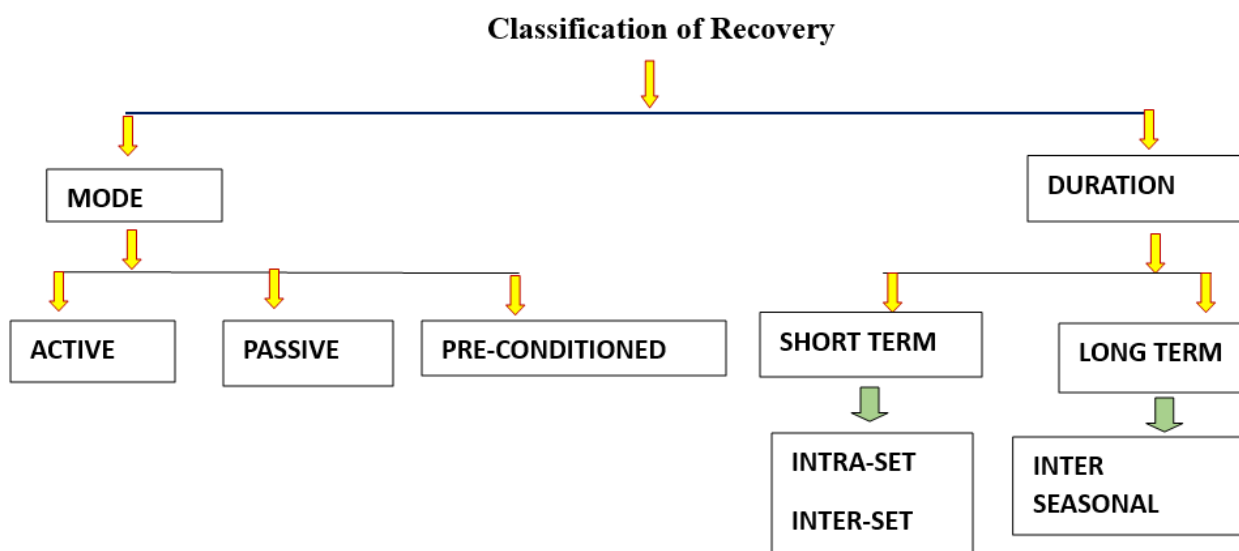


Figure 6. The process of recovery.

- It involves moderate exercise during the recovery process to eliminate the results of fatigue through a target oriented physical activity (e.g., a cool-down programme directly after a match or on the following morning)
- A passive approach could consist of sauna, massages, or just sitting or lying quietly.
- Dynamic stretching or systematically breathing for just a few minutes during a half-time break, recovery is tightly linked to environmental circumstances.
- The time interval between training bouts that allows an athlete to meet or exceed previous performance. Between Set Recovery.
- Long-term recovery involves rest and recovery periods that are built into a seasonal training schedule. It also may include days or weeks of rest and recovery incorporated into an annual athletic program.

Recovery Strategy

There are three levels of recovery: Level-1) Passive Recovery, Level-2) Active Recovery, Level-3) Enhance recovery through Training.

Level-1: Passive recovery can be formulated through improving the quality of sleep, providing recovery nutrition (the purpose of recovery nutrition, is to remember the 3 R's: *"Replenish, Rehydrate, Rebuild"*) and promoting psychological wellbeing through self-talk, mental imagery and rebuild mental toughness through psychological skill training.

Level-2: Active recovery is the best way to optimize recovery process within a shortest span of time. Active rest (low intensity work out) may be prescribed along with Hydrotherapy (contrast bath and or cold-water immersion in order to removal of metabolic waste) and common physical therapy (massage, foam rolling, vibration etc.).

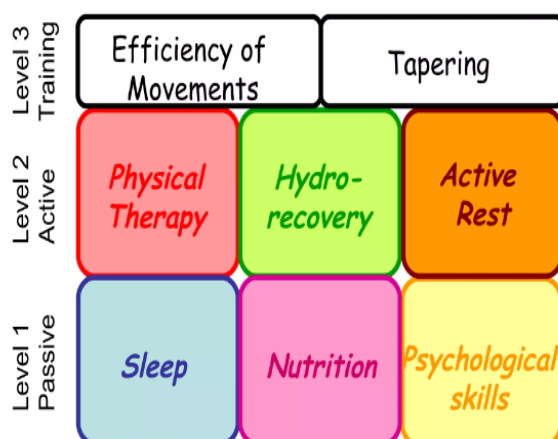


Figure 7. Schematic diagram of recovery strategy.

Level-3: Efficacy of movement (an ability to achieve a given performance repeatedly is referred to as efficiency) is an important skill related practice which can be helpful to promote recovery process as movement efficacy is largely depended upon movement economy. Movement efficacy reflects the economy of energy expenditure for skill related performance. On the other hand, tapering of training load (A progressive nonlinear reduction of training load during a variable period of time in order to reduce the physiological and psychological stress) is an important aspect to breaking the load barrier and foster recovery through reduced intensity work outs.

Physiology of Recovery

At the end of the post exercise and beginning of next set of work outs four main task need to be completed before the exhausted muscle can operate at full efficiency again. If the working muscle is not fully recovered the athlete may not able to tackle the workload with full potentiality. The important task is listed below (Powers & Howley, 2009; Ivy, 2004; Baker et al., 2010):

- Replacement of loss of ATP and Phosphocreatine
- Removal of Lactic Acid
- Replacement of Oxygen to myoglobin
- Replacement of lost Glycogen

This can be overcome through two important phases:

- First Replenishment Stage (Alactacid Component)
- Second Replenishment Stage (Lactic acid Component)

Lactic Acid can be removed in the following ways:

- Oxidized into carbon-dioxide and water in the active muscle organ
- Converted into glycogen then stored into muscle and/or liver through Cori Cycle.

- Converted into Glucose (Cori Cycle)
- Converted into Protein in liver and kidneys (Gluconeogenesis)
- Extracted in Sweat and Urine

Keeping the physiological and physical consideration about the recovery process the appropriate recovery modalities can be administered.

Types of Recovery depending upon types of activity

Two different types of recovery can be given to the clients depended upon the nature and types activity, actually the process of recovery must be in agreement with the major energy source require to carry out the load.

The athletes who are performing short duration high intensity and repetitive types of exercise passive recovery is more helpful as passive recovery does not reduce phosphocreatine levels, which may affect the performance of these types of workouts (Rabelo, 2017).

On the other hand, active recovery may be more useful for the athletes who are performing long duration moderate intensity work out or aerobic activity, as it quickly decreases the amount of lactic acid in the muscles, which restores the pH balance in the body (Rabelo, 2017).

Recovery Techniques

Recovery from training and competition is complex and typically dependent on the nature of the exercise performed and any other outside stressors. There are a number of popular methods used by athletes to enhance recovery. Some of the most popular recovery techniques for athletes include hydrotherapy, active recovery, stretching, compression garments, massage, sleep and nutrition (Shona, 2013)

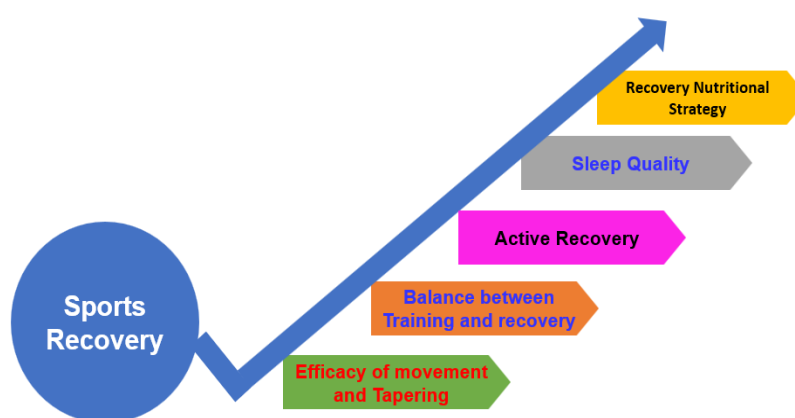


Figure 6. Schematic representation of recover modalities.

a) Efficacy of Movement: Efficacy of movement is a responsible factor to enhance recovery as it is related with economical expenditure of energy for performing any skill movement. By improving the efficacy of movement unnecessary loss of energy can be prevented whereas, tapering of training load is related with decrease of training intensity, as a result of that athlete can perform activities with lower intensities which can be a part of active recovery.

b) Balance between Training and Recovery: The greater the stress of the workout, the greater the overall muscle recruitment, and the greater the potential for muscle damage and soreness, therefore the need for longer recovery time. There must be balance between recovery and load otherwise over reaching syndrome may arise which hamper the performance and health of an athlete. The longer recovery period between workouts allows more time for repairing damaged muscle fibers and rest for the nervous system responsible for initiating muscles contractions. It also gives muscles a chance to remove metabolic waste and fully replenish all fuel stores. An athlete could have a specific goal requiring shorter recovery periods between workouts to help that individual adapt to exercising in a slightly fatigued state, but overall, the optimal recovery time between strength-endurance workouts is approximately 24 to 36 hours. The recommended recovery time between high-intensity strength and power workouts is anywhere from 48 to 72 hours.

The athlete who performed strength type exercise for building strength for weight lifting can train specific body parts and follows segmental workout plan.

Exercise for lower part of muscles one day and upper part of muscle next day. A bodybuilder can perform high volume of chest training on a Monday, back training on a Tuesday and leg training on a Wednesday, as a result of that each group of muscle can get 72 hours of complete rest. Depending upon the purpose of the training the recovery time intervals vary, which can be summarized in the Table 1 and Table 2 (Robinson et al., 1995; de Salles et al., 2009).

Several factors should be taken into consideration before providing optimal recovery plan of an athlete. The individuality of athlete (no two individuals are alike), environmental condition, Training experience, health status, psychological makeup, training schedule, mutual effect of different task, gap between consecutive training sessions etc.

c) Active Recovery: Active recovery combining with jogging, running, swimming, cycling etc. With low intensity and moderate duration can be proven beneficial than passive recovery. It is the best way of recovery.

d) Sleep Cycle: Sleep cycle of an individual can be divided into four stages, viz:

- Stage-1, non-REM-1 (Rapid Eye Movement) Sleep: 2-5% of total sleep time
- Stage-2, non-REM-2: 45-55% of total sleep time
- Stage-3 non-REM-3: 10-20 % of total sleep time
- Stage-4 REM: 20-25% of total sleep time.

Table 1

Represents the rest intervals and recovery time as determined by intensity.

Training Goal	Rest Interval Length	Recovery Between Workouts
Muscular Endurance < 70% 1RM, 12-15+ reps	≤ 30 seconds	24 hours
Hypertrophy 70-85 % 1RM, 6-12 reps	30-90 seconds	24-72 hours
Strength >85% 1RM, 1-5 reps	2-5 minutes	48-72 hours
Power >85% 1RM, 1-5 reps	2-5 minutes	48-72 hours

Source: NSCA Essentials of Strength Training and Conditioning (3rd Ed.) 2008.

Table 2

Rest intervals between each set.

	Reps per set	Rest between sets
Strength	≤ 6	2-5 minutes
Power	≤ 6	2-5 minutes
Hypertrophy	6-12	1-2 minutes
Muscular Endurance	> 12	< 30 seconds

There are 4-6 cycles per night and most of healing and tissue repairment takes place in the 3rd phase of the sleep cycle. Athletes require 7-8 hours of complete sleep, in order boost physiological and psychological recovery (De la Serna, 2018; Schupp & Hanning, 2003).

e) Recovery Nutrition: Over the years, recovery nutrition has become one of the most common terms and practices in the sports nutrition world. Post-exercise nutrition is extremely important for competitive athletes, but not all active people need a recovery snack or meal.

The goals of the recovery nutrition are to:

- Appropriately refuel and rehydrate the body
- Promote muscle repair and growth
- Boost adaptation from the training session
- Support immune function

Consuming frequent meals throughout the day containing adequate carbohydrate (according to training intensity) and protein (approximately 0.25 g/kg) will help fully restore muscle glycogen and sustain maximal daily rates of MPS over prolonged (8 to 24 h) recovery periods (More, 2015; Clyde, 2004).

The average athlete loses 1-3L sweat/hour. Sweat is primarily made up of water, but it also contains electrolytes that have abundant roles in the body. Sodium and chloride are the most abundant electrolytes in the sweat with potassium, magnesium, and calcium present in lower amounts. So, in the recovery the loss of minerals and electrolytes should be replenished through food or sports drinks. Athlete should hydrate 150 -200 ml every 15-20 minutes (Casa et al., 2000).

Conclusions

Although there is no consensus on a central strategy for recovery, monitoring and observing a client's exercise performance will always be most insightful in adjusting and planning for this essential ingredient of training. In addition, educating athletes about the importance of recovery may empower them to complete suitable interventions to enhance the process. Focus on the four 'BIG R' of Recovery.

The 4 "R's" of Recovery:

1. Rehydrate: Replace fluid loss and fix electrolyte imbalance (sodium). Aim to replace 150% of the fluid you have lost in the first 4 h after exercise e.g., 1 kg fluid lost = 1.5 L fluid.

2. Refuel: Replenish your muscles energy stores with adequate carbohydrate intake (0.8-1.2g/kg of body weight)

in first 4 h post-exercise e.g., 75 kg = 60-90 g of carbohydrate.

3. Rebuild: Repair your muscles with adequate protein intake – 1.2-2.0g/kg/day e.g., 75 kg = 90-150g of protein.

4. Rest: Make sure your body gets adequate rest by aiming to sleep 7-9h per day (athletes may require more) and include other types of rest e.g., napping, meditation, yoga, etc.

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