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Unit -IV

BIOCHEMISTRY OF EXERCISE

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Unit - IV

Biochemistry of Exercise

Definition

The human body responds rapidly to the increased energy demands of exercise, in particular, the utilization of carbohydrates (sugars) and lipids (fats) as substrates that are oxidized to provide energy to muscle cells.

Energy turnover in muscle increases more than 100-fold during exercise. Oxidation of glucose and fatty acids for muscle energy increases in proportion to the intensity of the exercise. The metabolic pathways that provide the energy for muscle contraction are controlled by complex interrelationships among hormones and other signaling molecules.

During moderate-to-hard endurance exercise, carbohydrates supply about 50% of energy requirements, primarily from glycogen stored in muscle tissue. Glycogen is the storage form of glucose, the primary carbohydrate utilized by the human body. Glycogen is broken down to glucose. Glycolysis is the breakdown of glycogen and glucose to supply cellular energy. As muscle glycogen stores become depleted, the liver releases more glucose into the bloodstream to fuel glycolysis in muscle.

The remaining energy is derived from the oxidation of fatty acids, including those already in the bloodstream as well as those mobilized from fat stores. As the intensity of the exercise decreases, for example, to a pace where a conversation could be held, less carbohydrate is used, and fat becomes the principal energy source.

When carbohydrates are limited, certain amino acids from muscle protein can be converted to glucose to be consumed as fuel. Although their energy contribution during short-term intense exercise is negligible, during prolonged exercise, amino acids provide 3–6% of the body's energy requirements. When carbohydrate availability is limited, amino acids may provide as much as 10% of the body's fuel.

Function

1. **Glycolysis**

The energy for muscle contraction comes from ATP (adenosine triphosphate). ATP is formed by aerobic (oxygen-dependent) respiration in the mitochondria of muscle cells, using energy released by glycolysis. Breaking of a high-energy bond in ATP releases ADP (adenosine diphosphate), inorganic phosphate (Pi), and one proton or hydrogen ion (Hþ). The protons are utilized by the mitochondria.

The final step of glycolysis yields two molecules of pyruvate along with protons from the splitting of ATP. Under conditions of sufficient oxygen, pyruvate is further metabolized in the mitochondria; however, under conditions of insufficient oxygen availability, as is common during intense exercise, lactate (lactic acid) builds up in muscle. Until recently, it was thought that this buildup of lactic acid caused acidosis, characterized by muscle soreness and fatigue, but it is now recognized that acidosis or muscle burn results from the release of more protons than can be utilized by the mitochondria. Pyruvate absorbs the protons to form lactate, temporarily slowing the development of acidosis and muscle fatigue. Lactate is metabolized within 15–30 minutes after exercise. Muscle cells also store energy in phosphate bonds in compounds such as phosphocreatine, which is known as the phosphagen system. Release of phosphate from these compounds to provide energy also produces protons that contribute to acidosis.

2. Fat and protein metabolism

Synthesis of new protein decreases during exercise; however, both glycogen synthesis and protein synthesis typically increase following exercise. Post-exercise protein synthesis in trained muscle tends to be specifically directed toward making more muscle fiber proteins, leading to muscle growth or hypertrophy. This response lasts for 24–48 hours after resistance exercise. However, protein synthesis decreases with age, leading to muscle loss, especially in women.

3. AMPK (adenosine monophosphate-activated protein kinase)

Although many different signaling molecules and pathways are involved in exercise biochemistry, AMPK (adenosine monophosphate-activated protein kinase) is considered to be a particularly important regulator of energy pathways in skeletal muscle. AMPK is an enzyme that senses fuel requirements and is highly activated in skeletal muscle during exercise.

4. Hormones

Hormones play major roles in the biochemistry of exercise.

1. Cortisol, the major glucocorticoid steroid and a stress hormone, is released from the adrenal glands during exercise and affects cell metabolism throughout the body. Cortisol increases the metabolic rate and mobilizes glucose stores to provide energy.
2. Activation of the hormone norepinephrine early in exercise and increased blood levels of epinephrine later in exercise stimulate the release of glucose from the liver and fatty acids from adipose tissue.
3. Glucagon is a hormone that increases blood sugar levels during exercise by stimulating glycogen breakdown in the liver.
4. Several metabolic pathways—including glucose uptake, amino acid transport, and protein and glycogen synthesis—become increasingly sensitive to insulin during and after exercise.

5. Insulin and the sex hormone testosterone help regulate protein synthesis in muscle and affect muscle hypertrophy. Insulin may slow any increase in the breakdown of muscle protein following exercise, especially in younger people.
6. Energy-regulating hormones, such as leptin, affect AMPK activity.
7. Interleukin-6 (IL-6) is released by muscle during exercise and appears to stimulate the hydrolysis of stored fuel in muscle, liver, and fat tissues, as well as activating AMPK in these tissues.
8. Various hormones that are stimulated by exercise affect digestion and may speed it up.
9. Exercise has both acute and delayed effects on melatonin secretion, which is involved in regulating biological or circadian rhythms.
10. Exercise significantly increases secretion of growth hormone.

What is Metabolism?

Metabolism is a term that is used to describe all chemical reactions involved in maintaining the living state of the cells and the organism.

Metabolism can be conveniently divided into two categories:

- **Catabolism -** the breakdown of molecules to obtain energy
- **Anabolism -** the synthesis of all compounds needed by the cells

Metabolism is closely linked to nutrition and the availability of nutrients. Bioenergetics is a term that describes the biochemical or metabolic pathways by which the cell ultimately obtains energy. Energy formation is one of the vital components of metabolism.

Nutrition, Metabolism and Energy

Nutrition is the key to metabolism. The pathways of metabolism rely upon nutrients that they breakdown in order to produce energy. This energy in turn is required by the body to synthesize molecules like new proteins and nucleic acids (DNA, RNA).

Nutrients in relation to metabolism encompass factors like bodily requirements for various substances, individual functions in the body, the amount needed, and the level below which poor health results.

Essential nutrients supply energy (calories) and supply the necessary chemicals which the body itself cannot synthesize. Food provides a variety of substances that are essential for the building, upkeep, and repair of body tissues, and for the efficient functioning of the body.

Carbohydrates in Metabolism

Foods supply carbohydrates in three forms: starch, sugar, and cellulose (fiber). Starches and sugars form major and essential sources of energy for humans. Fibers contribute to bulk in diet.

Body tissues depend on glucose for all activities. Carbohydrates and sugars yield glucose by digestion or metabolism.

The overall reaction for the combustion of glucose is written as:

$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O + \text{energy}$$

Most people consume around half of their diet as carbohydrates. This comes from foods such as rice, wheat, bread, potatoes and pasta.

Proteins in metabolism

Proteins are the main tissue builders in the body. They are part of every cell in the body. Proteins help in cell structure, functions, hemoglobin formation to carry oxygen, enzymes to carry out vital reactions and a myriad of other functions in the body. Proteins are also vital in supplying nitrogen for DNA and RNA genetic material and energy production.

Proteins are necessary for nutrition because they contain amino acids. Among the 20 or more amino acids, the human body is unable to synthesize 8 and these are called essential amino acids.

The essential amino acids include:

- Lysine
- Tryptophan
- Methionine
- Leucine
- Isoleucine
- Phenylalanine
- Valine

- Threonine

Foods with the best quality protein are eggs, milk, soybeans, meats, vegetables, and grains.

Fat in Metabolism

Fats are concentrated sources of energy. They produce twice as much energy as either carbohydrates or protein on a weight basis.

The functions of fats include:

- Helping to form the cellular structure;
- Forming a protective cushion and insulation around vital organs;
- Helping absorb fat-soluble vitamins,
- Providing a reserve storage for energy

Essential fatty acids include unsaturated fatty acids like linoleic, linolenic, and arachidonic acids. These need to be taken in diet. Saturated fats, along with cholesterol, have been implicated in arteriosclerosis and heart disease.

Minerals and Vitamins in Metabolism

The minerals in foods do not contribute directly to energy needs but are important as body regulators and play a role in metabolic pathways of the body. More than 50 elements are found in the human body. About 25 elements have been found to be essential, meaning a deficiency produces specific deficiency symptoms.

Important minerals include:

- Calcium
- Phosphorus
- Iron
- Sodium
- Potassium
- Chloride ions
- Copper
- Cobalt
- Manganese

- Zinc
- Magnesium
- Fluorine
- Iodine

Aerobic Metabolism

Aerobic means *oxygen dependent* and aerobic metabolism refers to an energy-generating system under the presence of oxygen as opposed to anaerobic, i.e., oxygen independent metabolism. Aerobic metabolism uses oxygen as the final electron acceptor in the electron transport chain and combines with hydrogen to form water.

Aerobic metabolism is the way your body creates energy through the combustion of carbohydrates, amino acids, and fats in the presence of oxygen. ... Examples of exercises that use aerobic metabolism include walking, running, or cycling with sustained effort.

Anaerobic metabolism

Anaerobic metabolism, which can be defined as ATP production without oxygen (or in the absence of oxygen), occurs by direct phosphate transfer from phosphorylated intermediates, such as glycolytic intermediates or creatine phosphate (CrP), to ADP forming ATP.

Aerobic and Anaerobic systems during rest and Exercise

- **Aerobic exercise** is any type of cardiovascular conditioning or "cardio." During cardiovascular conditioning, your breathing and heart rate increase for a sustained period of time. Examples of aerobic exercise include swimming laps, running, or cycling.
- **Anaerobic exercises** involve quick bursts of energy and are performed at maximum effort for a short time. Examples include jumping, sprinting, or heavy weight lifting.
- Your respiration and heart rate differ in aerobic activities versus anaerobic ones. Oxygen is your main energy source during aerobic workouts.

- **During aerobic exercise**, you breathe faster and deeper than when your heart rate is at rest. You're maximizing the amount of oxygen in the blood. Your heart rate goes up, increasing blood flow to the muscles and back to the lungs.
- **During anaerobic exercise**, your body requires immediate energy. Your body relies on stored energy sources, rather than oxygen, to fuel itself. That includes breaking down glucose.

Benefits of aerobic exercise

- Can help you lose weight and keep it off
- May help lower and control blood pressure
- May increase your stamina and reduce fatigue during exercise
- Activates immune systems, making you less likely to get colds or the flu
- Strengthens your heart
- Boosts mood
- May help you live longer than those who don't exercise
- Adenosine Triphosphate

Benefits of anaerobic exercise

Anaerobic exercise can be beneficial if you're looking to build muscle or lose weight. It can also be beneficial if you've been exercising for a long time, and are looking to push through an exercise plateau and meet a new goal. It may also help you maintain muscle mass as you age.

Other benefits include:

- Strengthens bones
- Burns fat
- Builds muscle
- Increases stamina for daily activities like hiking, dancing, or playing with kids

AEROBIC EXERCISE VERSUS ANAEROBIC EXERCISE

AEROBIC

With aerobic exercise, oxygen supplies energy for continuous movement.

Slow-twitch muscle fibers contract repeatedly without fast fatigue.

Aerobic exercises include running, biking, swimming, and any activity that

ANAEROBIC

Anaerobic exercises take place without oxygen. Energy comes muscle stores.

Fast-twitch muscle fibers carry out short bursts of high-powered exercises.

Anaerobic exercises include sprints, weightlifting, and high-intensity

High Intensity Exercises

This type of workout calls for repeated bursts of intense, often difficult, exercise alternated with slower recovery periods. The benefit of these workouts is not only that it takes much less time to complete, but it also increases your body's VO2 max (your body's ability to sustain physical activity) and is an indicator of your level of aerobic fitness. However, because of the intensity of these sessions, aim to do not more than two per week to give your body time to recover. HIIT can be done not only on the treadmill, but also on the bicycle and elliptical trainer.

Short-duration exercises interspersed with brief periods of lower-intensity movement. Clients train as intensely as possible for intervals of 30–60 seconds – depending on the intensity level and the equipment/apparatus used for training – before entering the recovery phase. This pattern repeats throughout the workout. The intent is to utilize the anaerobic energy system, long thought to be the exclusive realm of sprinters and court athletes whose movements are too brief and powerful to engage the oxygen pathways of the cardiovascular system (Smith, 2002). During short-burst exercise, the body produces metabolic byproducts (hydrogen ions) that have been identified as the cause of acidosis (“the burn”). The cardiovascular exercise following the short burst of anaerobic exercise helps to neutralize or buffer this acidosis. The primary fuel used is carbohydrate (Smith, 2002), with stored fat kicking in later.

By contrast, traditional endurance training keeps the body moving longer at more moderate intensity levels, with the aerobic system maintaining function. The primary energy sources are carbohydrate and fat (Smith, 2002). There is abundant research verifying the physiological adaptations attributed to endurance training, especially improved exercise capacity—the body’s ability to sustain a given sub-maximal amount of work for a longer of time (Gibala et al., 2006). For many exercisers, the rewards include improved cardiovascular function, decreased incidence of diabetes, high cholesterol and hypertension, weight loss, and reduction of body fat. Those training for competitive sports count on aerobic training to gain needed stamina.

Treadmill

First things first: Start every workout, particularly HIITs, with a solid five- to 10-minute warmup. Then, pick your ratios. Beginners should start with a short intensity period and a longer recovery period, such as 60 seconds of activity to two minutes of recovery. The recovery doesn't mean stopping entirely, though; it means that you sprint for the activity period and walk or slowly jog during the recovery period. On a treadmill, you could set the speed to 8 to 10 mph for the high-intensity portion and around 3.5 mph for the recovery portion. However, play around with settings to see what feels appropriate for you. Repeat the the pattern for a total of eight cycles, and then end with a five-minute cool-down walk.

A similar HIIT workout session can be done on a bicycle by following this workout:

- Warm up with a five- to 10-minute easy ride.
- Pedal as fast as you can for 30 to 60 seconds.
- Slow down for an easy ride of one to two minutes.
- Repeat the cycle eight times, if possible.

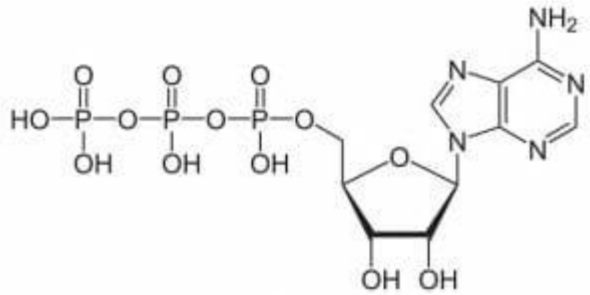
- Complete an easy five-minute cool down.

If you have access to a stationary bike, you can complete this same HIIT workout indoors when the weather is bad or when you simply feel like staying out of the sun.

Definition ATP

Adenosine triphosphate, also known as ATP, is a molecule that carries energy within cells. It is the main energy currency of the cell, and it is an end product of the processes of photophosphorylation (adding a phosphate group to a molecule using energy from light), cellular respiration, and fermentation. All living things use ATP. In addition to being used as an energy source, it is also used in signal transduction pathways for cell communication and is incorporated into deoxyribonucleic acid (DNA) during DNA synthesis.

Structure of ATP



This is a structural diagram of ATP. It is made up of the molecule adenosine (which itself is made up of adenine and a ribose sugar) and three phosphate groups. It is soluble in water and has high energy content due to having two phosphoanhydride bonds connecting the three phosphate groups.

Functions of ATP

1. Energy Source

ATP is the main carrier of energy that is used for all cellular activities. When ATP is hydrolyzed and converted to adenosine diphosphate (ADP), energy is released. The removal of one phosphate group releases 7.3 kilocalories per mole, or 30.6 kilojoules per mole, under standard conditions. This energy powers all reactions that take place inside the cell. ADP can also be converted back into ATP so that the energy is available for other cellular reactions.

2. Signal Transduction

ATP is a signaling molecule used for cell communication. Kinases, which are enzymes that phosphorylate molecules, use ATP as a source of phosphate groups. Kinases are important for signal transduction, which is how a physical or chemical signal is transmitted from receptors on the outside of the cell to the inside of the cell. Once the signal is inside the cell, the cell can respond appropriately. Cells may be given signals to grow, metabolize, differentiate into specific types, or even die.

3. DNA Synthesis

The nucleobase adenine is part of adenosine, a molecule that is formed from ATP and put directly into RNA. The other nucleobases in RNA, cytosine, guanine, and uracil, are similarly formed from CTP, GTP, and UTP. Adenine is also found in DNA, and its incorporation is very similar, except

ATP is converted into the form deoxyadenosine triphosphate (dATP) before becoming part of a DNA strand.

Phosphagen System.

Introduction

Human energy production is based on complex interconnected pathways that break down nutrients derived from food into usable energy, adenosine triphosphate (ATP). It can be divided into three main systems; aerobic respiration, anaerobic respiration, and the phosphagen system.

Each of these has a specific function and relies on varying metabolic processes to generate ATP. This energy is used for exercise and maintaining regular body functions like breathing, heartbeat, cell repair, hormone activity, etc.

The phosphagen system is the fastest of the energy systems. It provides energy rapidly during quick and intense exercises that last 10 seconds. Therefore, it is especially important in short and explosive sports like weightlifting, javelin and discus throwing, shot putting, as well as various sports that rely on quick sprints.

The basics of the phosphagen system

The phosphagen system, also called the ATP-PC system, utilizes stored adenosine triphosphate (ATP) and creatine phosphate (CP) during the first few seconds of an exercise. This process relies on the hydrolysis of an ATP molecule, where the bond is split by adding a water molecule, as well as breaking down a high-energy phosphate called creatine phosphate. This process of regenerating ATP via the transfer of phosphate groups occurs through either of two reactions;

1. Creatine kinase
2. Adenylate kinase

Although the phosphagen system is anaerobic and does not require oxygen to work, it provides so little energy that it does not produce lactic acid. Hence, the phosphagen system is also known as the anaerobic alactic system.

During the first 2-3 seconds of an exercise, ATP is broken down to produce adenosine diphosphate (ADP) and inorganic phosphate (Pi) in a process called ATPase. Since muscle fibers have such a limited amount of free ATP, your body needs to constantly produce more energy to meet the demands of physical activity. This is done by breaking down creatine phosphate into creatine (Cr) and phosphate. This process is catalyzed by an enzyme called creatine kinase. The resulting energy of this process also fuels the resynthesis of ADP and CP into ATP. Thus, generating more energy for muscle contraction.

During a maximal exercise, the energy received from the phosphagen system is fully depleted in 10-15s. However, it also recovers very quickly. In fact, it is nearly 70% regenerated in just 30 seconds and fully recovered in 3-5 minutes. However, this also depends on the acidity inside the muscles (slower if more acidic) and the extent of CP depletion.

Duration	**Classification**	**Energy Source**
1-3s	Anaerobic	Stored ATP
3-10s	Anaerobic	ATP + CP
10-45s	Anaerobic	ATP + CP + Muscle Glycogen
45s-2mins	Anaerobic, Lactic	Muscle Glycogen
2-4mins	Aerobic + Anaerobic	Muscle Glycogen + Lactic Acid
>4mins	Aerobic	Muscle Glycogen + Fatty Acids

Physiological Aspects of Fatigue

Introduction

Fatigue is defined as a physiological state of reduced mental or physical capability, which may develop as a result of sleep loss or extended wakefulness, disrupted circadian rhythm or increased workload.

Fatigue can be separated into three distinct types;

1. Acute,
2. Cumulative
3. Circadian Fatigue.

Acute Fatigue typically results from an extended period of wakefulness exceeding 16 h.

Cumulative fatigue, also known as sleep debt, results from an accumulation of suboptimal sleep times, which may be for days, weeks or months.

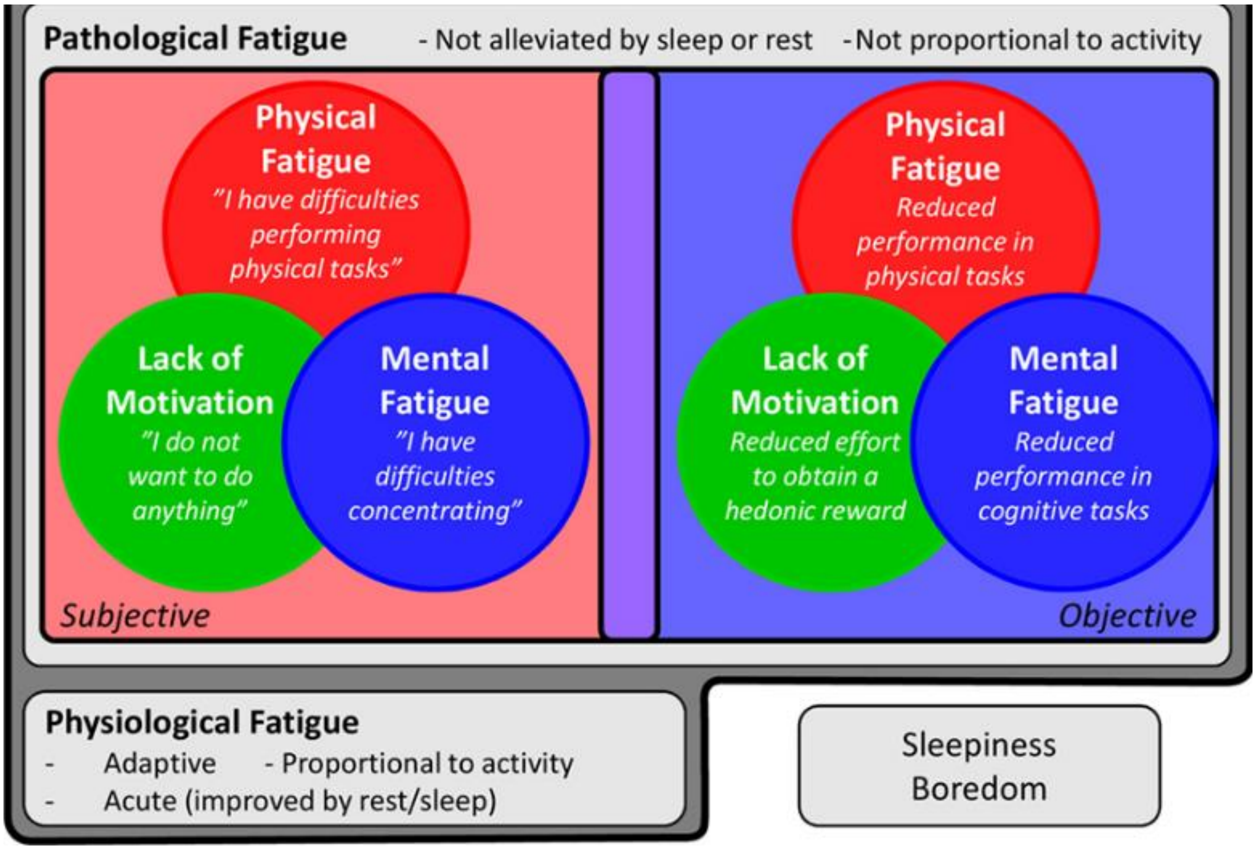
Circadian fatigue, or chronodisruption, is a form of fatigue that results from shifting the sleep/wake cycle, either due to changes in working hours, or following trans-meridian travel.

Sleep is essential to human life, serving various physiological and endocrine roles, which contribute towards restoring optimal physical and emotional health and well-being. Sleep can be separated into five stages.

Stages 1–4 are termed non-rapid eye movement (NREM) sleep. Typically, 25–30 min is spent in stages 1–2, where body temperature and heart rate decrease. Slow-wave sleep (SWS) or deep sleep occurs during stages 3 and 4. It is the most restorative stage, where heart rate, blood pressure, brain glucose metabolism and sympathetic nervous system activity all decrease, while vagal tone and parasympathetic nervous system activity increase. SWS also facilitate several important endocrine functions including inhibition of the hypothalamic–pituitary–adrenocortical (HPA) system and release of growth hormone.

Stage 5 is termed rapid eye movement (REM) sleep. Sympathetic activity is promoted with increased respiration and heart rate. REM sleep is reached 90 min after falling asleep, with the first cycle lasting for 10 min. Time in REM sleep increases with additional cycles until the final sleep cycle, where REM sleep lasts approximately an hour. A typical sleep period will include 4–5 sleep cycles, with waking occurring in stage 1–2 post-REM.

In terms of optimizing physical performance, it has been demonstrated that daily sleep extension for periods of 1.5–2 h can improve accuracy, reaction time and subjective feelings of mood, vigor and fatigue. While there is less scientific evidence, enhancing sleep quality has further been demonstrated to normalize cognitive performance in patients with sleep apnoea who receive continuous positive airway pressure (CPAP) treatment. Therefore, enhanced sleep quality may be associated with improvement in cognitive performance of healthy individuals.


Pathological Fatigue
- Not alleviated by sleep or rest
-Not proportional to activity
Physical Fatigue
"I have difficulties performing physical tasks"
Lack of Motivation
"I do not want to do anything"
Mental Fatigue
"I have difficulties concentrating"
Subjective
Physical Fatigue
Reduced performance in physical tasks
Lack of Motivation
Reduced effort to obtain a hedonic reward
Mental Fatigue
Reduced performance in cognitive tasks
Objective
Physiological Fatigue
- Adaptive
- Proportional to activity
- Acute (improved by rest/sleep)
Sleepiness
Boredom

Another important aspect to take into account regarding central fatigue is the distinction between *physiological* and *pathological* fatigue. Biologically, fatigue is first and foremost an adaptive physiological process. It is the reduction of effort, resulting from perceived exertion (appraised by motor and sensory inputs) and motivational factors. Fatigue is a signal to rest, and it encourages energy preservation to prevent injuries, which may be beneficial after intense work or sleep loss, or when the bodily resources need to be redirected toward fighting pathogens during an infection. Fatigue also helps focus on more energy-efficient actions. As such, healthy, normal physiological processes of fatigue are denoted *physiological fatigue* in this review, as opposed to *pathological fatigue*, which is a state where the adaptive function has been lost. Although central fatigue is primarily a feeling, and usually assessed through subjective measurements (e.g., self-report questionnaires), it can also be measured objectively, using physical, cognitive, or motivational tasks.

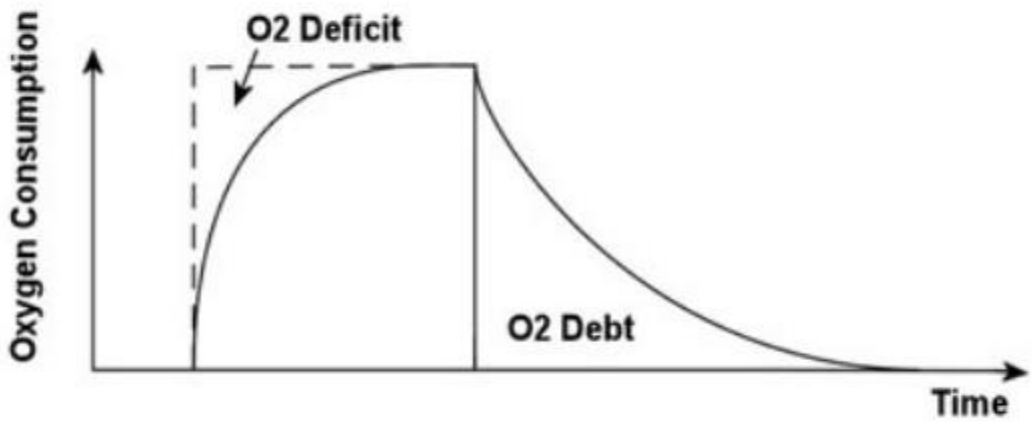
Taken together, central fatigue appears to be not just “fatigue,” but a complex symptom that comprises several dimensions and concepts. In this review, we will focus on the effects of inflammation on central fatigue and illustrate the importance of multidimensional assessments in understanding the pathophysiology of inflammation-induced central fatigue.

Oxygen Debt & Recovery

What is oxygen debt and Recovery

When you have a short intense burst of exercise such as sprinting you generate energy for this anaerobically or without oxygen. When you stop exercising you are still breathing heavily. This is your body taking in extra oxygen to ‘repay’ the debt. Well, that is the simple solution but there is a little more to it if you want to look a bit deeper.

True, your body has worked anaerobically and will have produced energy without some of the oxygen it would normally have used performing a low-intensity exercise such as slow steady running. The difference between the oxygen the body required and what it actually managed to take in during the sudden sprint is called oxygen deficit.



When you stop sprinting and start to recover you will actually need more oxygen to recover than your body would have liked to use had enough been available. This is called Excess Post Exercise Oxygen Consumption.

Why does it take more oxygen to recover?

- You needed to replace the oxygen the body needed but couldn't get (oxygen deficit).

- Breathing rate and heart rate are elevated (to remove CO_2) and this needs more oxygen.
- Body temperature and the metabolic rate are increased and this needs more oxygen.
- Adrenaline and Noradrenaline are increased which increases oxygen consumption.

So after exercise, there are other factors causing an increase in oxygen needs as well as repaying the lack of oxygen during exercise.

What has lactic acid got to do with oxygen debt?

Lactic acid is a by-product of exercising without using oxygen (anaerobically). It is essential this is removed but it is not necessarily a waste product. It is recycled into other useful chemicals:

- During prolonged intensive exercise (e.g. 800m race) the heart may get half its energy from lactic acid. It is converted back to pyruvic acid and used as energy by the heart and other muscles.
- It is thought that 70% of lactic acid produced is oxidized, 20% is converted to glucose (energy) in the liver.
- 10% is converted to protein.

What is Recovery?

Bishop et al. (2007) define recovery as the ability to meet or exceed performance in a particular activity.

Jeffreys (2005) continues that factors of recovery include 1) normalization of physiological functions (e.g., blood pressure, cardiac cycle), 2) return to homeostasis (resting cell environment), 3) restoration of energy stores (blood glucose and muscle glycogen), and 4) replenishment of cellular energy enzymes (i.e., phosphofructokinase a key enzyme in carbohydrate metabolism). In addition, the recovery is very dependent on specific types of training (see question #1 in the Pertinent Recovery Questions for the Personal Trainer section). Recovery may include an active component (such as a post-workout walk) and/or a passive component (such as a post-workout hydrotherary treatment).

Types of Recovery

The most rapid form of recovery, termed **"immediate recovery"** occurs during exercise itself. Bishop and colleagues (2007) give an example of a race walker with 1 leg in immediate recovery during each stride. With this phase of recovery, energy regeneration occurs with the lower extremities between strides. As each leg recovers more quickly, the walker will be able to complete the striding task more efficiently.

"Short term recovery" involves recovery between sets of a given exercise or between interval work bouts. Short-term recovery is the most common form of recovery in training (Seiler, 2005). Lastly.

Training recovery is used to describe the recovery between workout sessions or athletic competitions (Bishop et al., 2007). If consecutive workouts occur (such as within the same day) without appropriate recovery time, the individual may be improperly prepared for the next training session.

Nutritional aspects of Performance

Athletes and professional coaches are more aware than ever before of the importance of nutrition in sport. While there is an array of factors that contribute to an athlete's overall performance in their chosen sport, food is a critical piece to the puzzle, providing the energy needed. The approach to nutrition in sports is different from that of nutrition for overall health. This blog post helps to shed some light. If you'd like to know more about our course, Sports Nutrition Course for Weight Control & Performance

Nutrition in Sports vs Health

Sports nutrition is the study and practice of hydrating and fuelling your body with the aim of improving athletic performance. The ultimate goal is improving performance, realising true potential and when executed properly, a scientific, person-centred nutrition plan can help you do just that. Over the years, sports nutrition has changed and morphed in parallel with the growing awareness of the role that exercise plays in overall health and awareness. Today, with the help of more science and research, nutrition in sport is now rapidly growing, developing ever more new ways to help people run longer, lift more, swim further or do whatever sport they want to do just that bit better.

Benefits of sports nutrition

The ideal diet for an athlete is not very different from the diet recommended for any healthy person. And while certain sports require the athlete to fit a certain weight group or body fat, the benefits to nutrition in sports spans beyond just aesthetics.

- Enables you to train longer and harder
- Delays onset of fatigue
- Maintains a healthy immune system
- Enhances performance
- Improves recovery
- Improves body composition
- Reduces potential of injury
- Helps with focus and concentration

Nutrition in Sports – Basic Overview

It is well established that what an athlete eats can affect his/her ability to train, recover and compete. What we eat and drink provides us with energy. How we train and the type of sport we choose to compete in places certain energy demands on the body. The amount, composition and timing of food intake can profoundly affect sports performance.

An individual's needs will vary depending on a multitude of factors – age, genetics, gender, sport, lifestyle. This is where combining bespoke training for weight-loss/performance with a ***personalised*** nutrition and lifestyle plan vastly improves client outcomes and satisfaction.

Nutrition in Sports – the foundation is behavior & lifestyle

The core, the root and foundation of any nutrition and training programme is what happens outside of the gym/pitch/court etc. Balancing stress and sleep, mobility, social relationships, recovery and lifestyle to match your sports goals lays the groundwork and sets you up for success in all subsequent elements. Yet, it's often the most under-appreciated or neglected. Think about it – the average amateur athlete might spend 1-2 hours in the gym at 5x per week.

Nutrition in Sports – Macronutrients & hydration

Food is made up of three macronutrients – fat, carbohydrate and protein. The ultimate goal of nutrition in sport is to balance these macro and micronutrients to achieve optimal energy output and at times body composition for the intended sport. The split of how many of each a person needs will depend on personal and sports-specific factors. For example, the ketogenic is probably not the best approach for a Cross Fitter but there are anomalies in the sport that thrive on a higher fat diet. Not only that, but the macronutrient requirements will also shift with the phases of training – a conditioning phase may require more carbohydrate compared to a structural rebuild and so on.

The average sedentary person needs about 2-3 litres per day. However, for the athlete, hydration needs can increase significantly depending on sweat and training demands. Specific fluid needs will vary from athlete to athlete depending on body weight, exercise and environmental conditions. However, hydration becomes not only just water intake but also electrolyte balance.

Nutrition in Sports – Micronutrients

In addition to balancing these macros, the goal is to also obtain optimal micronutrient intake i.e. vitamins, minerals, phytonutrients etc. This is of critical importance to mention and again far too often neglected. Micronutrients help support a healthy body, managing a host of factors such as injury prevention, muscle building, immune support, recovery and more. Again, it's not uncommon to see individuals neglect this in favour of empty calories – whether for simply getting in enough calories (remember some might require quite a lot of food over the course of a day) or the opposite cutting calories (to make weight).

Nutrition in Sports – Nutrient Timing

When it comes to nutrition in sports, nutrient timing begins to play a role for the purpose of performance. To maximise the training session, it’s important to look at pre, during and post nutrition. Not only that, there might be other nutrient timing demands to align in time for game day/competition. Again the requirement will depend on the individual and the sport. This is also where at times, it might result in having to look at packaged sources of energy i.e. energy gels, protein shake etc. While this ***should be avoided where possible***, at the end of the day training for sport is different than training for health. You want to isolate and maximise nutrients at certain specific times which isn’t always possible with whole food.

Nutrition in Sports – Supplements

The basis of a good diet is rooted in whole food and proper hydration. However, when it comes to sports nutrition, the physical demands of training may require additional support. Again the specific detail around this will depend on individual needs and requirements. A note to remember to always check what’s allowed/banned in your particular sport. As a final note, you get what you pay for. The supplement industry is a huge multi-billion dollar enterprise but it’s also highly unregulated.

Recovery Process

Introduction

Recovery from exercise training is an integral component of the overall training program and is essential for optimal performance and improvement. If rate of recovery is improved, higher training volumes and intensities are possible without the detrimental effects of overtraining (Bishop et al., 2007). While recovery from exercise is significant, personal trainers and coaches use different approaches for the recovery process for clients and athletes. Understanding the physiological concept of recovery is essential for designing optimal training programs. As well, individual variability exists within the recovery process due to training status (trained vs. untrained), factors of fatigue, and a person's ability to deal with physical, emotional, and psychological stressors (Jeffreys, 2005). This article will provide evidence-based research and practical applications on recovery for personal trainers and fitness professionals.

What is Recovery?

Bishop et al. (2007) define recovery as the ability to meet or exceed performance in a particular activity. Jeffreys (2005) continues that factors of recovery include 1) normalization of physiological functions (e.g., blood pressure, cardiac cycle), 2) return to homeostasis (resting cell environment), 3) restoration of energy stores (blood glucose and muscle glycogen), and 4) replenishment of cellular energy enzymes (i.e., phosphofructokinase a key enzyme in carbohydrate metabolism). In addition, the recovery is very dependent on specific types of training (see question #1 in the Pertinent Recovery Questions for the Personal Trainer section). Recovery may include an active component (such as a post-workout walk) and/or a passive component (such as a post-workout hydrotherary treatment).

Physiology of Recovery

Muscle recovery occurs during and primarily after exercise and is characterized by continued removal of metabolic end products (e.g., lactate and hydrogen ions). During exercise, recovery is needed to reestablish intramuscular blood flow for oxygen delivery, which promotes replenishment of phosphocreatine stores (used to resynthesize ATP), restoration of intramuscular pH (acid/base balance), and regaining of muscle membrane potential (balance between sodium and potassium exchanges inside and outside of cell) (Weiss, 1991). During post-exercise recovery, there is also an increase in 'excess post-exercise oxygen consumption' (or EPOC). Other physiological functions of recovery during this phase include the return of ventilation, blood circulation and body temperature to pre-exercise levels (Borsheim and Bahr, 2003).

Types of Recovery

The most rapid form of recovery, termed “immediate recovery” occurs during exercise itself. Bishop and colleagues (2007) give an example of a race walker with 1 leg in immediate recovery during each stride. With this phase of recovery, energy regeneration occurs with the lower extremities between strides. As each leg recovers more quickly, the walker will be able to complete the striding task more efficiently.

“Short term recovery” involves recovery between sets of a given exercise or between interval work bouts. Short-term recovery is the most common form of recovery in training (Seiler, 2005). Lastly, the term “training recovery” is used to describe the recovery between workout sessions or athletic competitions (Bishop et al., 2007). If consecutive workouts occur (such as within the same day) without appropriate recovery time, the individual may be improperly prepared for the next training session.

Factors of Recovery

Gleeson (2002) elucidates the following related factors involved in the ability of a person to recover.

1) Muscle soreness and weakness
2) Poor exercise performance
3) Decrease in appetite
4) Increased infection
5) Quality and quantity of sleep
6) Gastrointestinal abnormalities

Personal trainers should be aware that these conditions may have an adverse influence on client recovery from exercise.

Pertinent Recovery Questions for the Personal Trainer

1) How Much Rest between Sets?

Willardson (2008) describes rest between sets as a multifactorial phenomenon that is affected by several factors. However, summarizing previous research, he purposes some specific rest periods (between multiple set training) for the following training protocols.

- Muscular endurance training: 30 to 90 seconds
- Hypertrophy training: 1 to 2 minutes
- Power training: 3 minutes
- Muscular strength (for clients less adapted to strength training): 4 to 5 minutes
- Muscular strength (for clients well-adapted to strength training): 3 minutes

2) How much rest between sessions?

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. Muscle recovery between resistance training sessions for most individuals is also influenced by other types of training performed, such as cardiovascular training, interval sprints and sports conditioning sessions. Rhea (2003) concluded that for untrained individuals and trained individuals a frequency of 3 and 2 days, respectively, per week per muscle group is optimal, which translates to 1-2 days rest between sessions. However, this will vary depending on total volume of resistance training, individual training status, and overall goals (e.g., training for hypertrophy, strength, endurance, etc.).

3) Is there a gender difference in recovery?

A gender difference has been shown in fatigue, a factor influencing recovery. Numerous studies have shown fit women have a greater resistance to fatigue than their male counterparts; therefore, fit women are able to sustain continuous and intermittent muscle contractions at low to moderate intensities longer than physically active men (Critchfield and Kravitz, 2008).

4) Do different muscle groups need more rest?

Ground based movements such as the deadlift, squat, and overhead press require more rest than smaller muscle groups such biceps, triceps, and forearm flexors. This is due to the increase in motor unit recruitment and larger muscle mass involved with these multi-joint exercises.

5) Can certain supplements aid in the recovery of training?

Many supplements have been used to assist in recovery of training. Bloomer (2007) provides evidence on certain antioxidants such as Vitamin C and Vitamin E and their purported affect on attenuating muscle damage, thus enhancing the recovery of training. However, he confirms that these supplements do not eliminate muscle trauma from exercise, only minimize some of the signs and symptoms (e.g., delayed onset damage, inflammation).

6) Does massage therapy affect the recovery process?

Weerapong (2005) reported that some studies have shown that massage did in fact reduce delayed onset muscle soreness, while other studies have not realized this effect. However, it should be pointed out that the psychological benefits of massage toward recovery are often quite meaningful to the exercisers.

Methods to Speed up Recovery Process

a. Cool down.

By cooling down and exercising at a low intensity (jogging etc) then more oxygen is getting taken in to the muscles. This means creatine phosphate stores will replenish at a faster rate. The more oxygen that is present then the quicker the body can remove lactic acid and turn it back into energy and re-saturate the myoglobin stores

b. Eating a high carbohydrate meal within 30 mins post exercise

The optimum time for the body to take up carbohydrate is within 30 minutes of finishing exercise. By eating High Glycaemic Index carbohydrate (carbohydrate that release energy quickly e.g. sugary foods) and Low Glycaemic Index (Carbohydrate that release energy at a slower rate e.g. fruit, wholemeal bread, wholemeal pasta and rice) Then the body is able to begin restore the glycogen used over exercise period. (See nutrition)

c. Recovery supplements

The use of recovery supplements is widely used in sport for recovery purposes. They often contain a mix of carbohydrate (to re-supply the glycogen stores), protein and amino acids, (for growth and repair of the muscle) and creatine (Help restore CP stores)

d. Ice baths

The theory behind ice baths is that when we exercise at a high intensity small micro-tears occur in the muscles. Some research believes that it is these micro-tears that cause Delayed Onset of Muscle Soreness (DOMS) or at least the swelling that takes place around the micro-tears. It is believed that Ice Baths reduce the swelling around the muscle micro-tears and reduce the pain that they cause, this means that the performer is able to train at a higher level the next day. It must be noted that research on this is not conclusive.

e. Massage

Massage can serve two purposes; the first is psychological benefits e.g. relaxing feeling of the massage and the fact that it can be invigorating, (providing it is not a deep muscle massage).

Secondly it can help physically by returning de-oxygenated blood from the muscle tissue to the heart to be re-oxygenated.

f. Compression Clothing

Recent studies have concluded that compression clothing can help recovery by maximising the pumping action of the muscles in returning blood to the heart and help with subsequent removal of lactic acid and blood lactate.

There must be an understanding in the difference between alactic and lactacid oxygen debt and specifically what each system repays/removes. The candidate must also be able to provide specific examples of how the methods to speed up recovery and why each are used.