19.1 Fitness and Nutrition

http://www.oercommons.org/courses/nutrition-and-medicine/view

Nutrition for fitness and athletes will be similar to that of the normal, balanced person, but there are going to be a few changes. Athletes need a balanced diet to perform at their highest potential.

Fitness:

According to the American College of Sports Medicine (ACSM) fitness is defined through four variables F (frequency), I (intensity), T (time), and T (type). These exercise principles are then applied to the three types of physical fitness, Cardiorespiratory Endurance, Muscular Strength/Endurance and Flexibility. In each of the physical fitness areas, the FITT Principle is applied as follows:

**Cardiorespiratory Endurance:**
F: 3-5 Days per week (most days)
I: 65-90% of the maximum heart rate
T: 20-60 Minutes
T: Any activity relying on the oxidative energy system (120 seconds or longer)

**Muscular Strength/Endurance:**
F: 2-3 Non Consecutive days per week
I: 100-80% (strength); 80-60% (endurance)
T: 1-8 Repetitions (strength); 12-20 Repetitions (endurance)
T: As many exercises it must be to at least use every muscle of the body once.

**Flexibility:**
F: 3-7 days per week
I: To a place of slight discomfort
T: 20-30 Seconds; at least 2 times
T: Dynamic Stretches (Warm-up), Static Stretches (Cool-down)

**Web Links**
What makes muscles grow?
Type of Exercise

| Web Links
<table>
<thead>
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<th></th>
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<tbody>
<tr>
<td>Difference between Endurance and Strength</td>
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</table>

In cardiorespiratory fitness, the objective of the exercise is to stimulate the cardiorespiratory system. Other activities that accomplish the same objective include swimming, biking, dancing, cross country skiing, aerobic classes, and much more. As such, these activities can be used to build lung capacity and improve cellular and heart function.

However, the more specific the exercise, the better. While vigorous ballroom dancing will certainly help develop the cardiorespiratory system, it will unlikely improve a person’s 10k time. To improve performance in a 10k, athletes spend the majority of their time training by running, as they will have to do in the actual 10k. Cyclists training for the Tour de France, spend up to six hours a day in the saddle, peddling feverishly. These athletes know the importance of training the way they want their body to adapt. This concept, called the principle of specificity, should be taken into consideration when creating a training plan.

In this discussion of type and the principle of specificity, a few additional items should be considered. Stress, as it relates to exercise, is very specific. There are multiple types of stress. The three main stressors are metabolic stress, force stress, and environmental stress. Keep in mind, the body will adapt based on the type of stress being placed on it.

Metabolic stress results from exercise sessions when the energy systems of the body are taxed. For example, sprinting short distances requires near maximum intensity and requires energy (ATP) to be produced primarily through anaerobic pathways, that is, pathways not requiring oxygen to produce ATP. Anaerobic energy production can only be supported for a very limited time (10 seconds to 2 minutes). However, distance running at steady paces requires aerobic energy production, which can last for hours. As a result, the training strategy for the distance runner must be different than the training plan of a sprinter, so the energy systems will adequately adapt.

Likewise, force stress accounts for the amount of force required during an activity. In weightlifting, significant force production is required to lift heavy loads. The type of muscles being developed, fast-twitch muscle fibers, must be recruited to support the activity. In walking and jogging, the forces being absorbed come from the body weight combined with forward momentum. Slow twitch fibers, which are unable to generate as much force as the fast twitch fibers, are the type of muscle fibers primarily recruited in this activity. Because the force...
requirements differ, the training strategies must also vary to develop the right kind of musculature.

Environmental stress, such as exercising in the heat, places a tremendous amount of stress on the thermoregulatory systems. As an adaptation to the heat, the amount of sweating increases as does plasma volume, making it much easier to keep the body at a normal temperature during exercise. The only way to adapt is through heat exposure, which can take days to weeks to properly adapt.

In summary, to improve performance, being specific in your training, or training the way you want to adapt, is paramount.

References & Links
1. ACSM guidelines (ACSM.org)

Links
https://www.pledgesports.org/2017/04/the-key-difference-between-fitness-and-endurance/

Video
Muscles TED talk: https://www.youtube.com/watch?v=2tM1LFxeKg

19.2 Nutrition for Fitness/Athletes

Energy Systems and Fuels to Support Activity

The three energy systems used during an exercise bout will be as follows:

Explosive (Immediate) System:
0-7 Seconds
Typical Energy Source: Stored ATP and Phosphogen
Typical Activities in this system: Sprinting, Jumping, Throwing (shotput, javelin, discus), volleyball, softball, football

Anaerobic (Non-Oxidative) System:
7-120 Seconds
Typical Energy Source: Glucose and Glycogen
Typical Activities in this system: Long sprints (200m-600m, Basketball, soccer

Aerobic (Oxidative) System:
From 120 Seconds on
Typical Energy Source: Oxygen
Typical Activities in this system: Long distance running, cycling, rowing

When looking at the energy systems it is a simplistic view to look at the energy systems as a binomial energy source utilizing only one thing or the other. The activity intensity can dictate what type of substrate utilization your body uses. Use the Weblink to better understand the substrate utilization during different exercises.

Web Links
Fat Burning or Sugar Burning Exercise?

Fuels for Exercise

Fat for Energy
Fats (or triglycerides) within the body are ingested as food or synthesized by adipocytes or hepatocytes from carbohydrate precursors (Figure). Lipid metabolism entails the oxidation of fatty acids to either generate energy or synthesize new lipids from smaller constituent molecules. Lipid metabolism is associated with carbohydrate metabolism, as products of glucose (such as acetyl CoA) can be converted into lipids.

Triglyceride Broken Down into a Monoglyceride
A triglyceride molecule (a) breaks down into a monoglyceride (b).

Lipid metabolism begins in the intestine where ingested triglycerides are broken down into smaller chain fatty acids and subsequently into monoglyceride molecules (see Figure b) by pancreatic lipases, enzymes that break down fats after they are emulsified by bile salts. When food reaches the small intestine in the form of chyme, a digestive hormone called cholecystokinin (CCK) is released by intestinal cells in the intestinal mucosa. CCK stimulates the release of pancreatic lipase from the pancreas and stimulates the contraction of the gallbladder to release stored bile salts into the intestine. CCK also travels to the brain, where it can act as a hunger suppressant.

Together, the pancreatic lipases and bile salts break down triglycerides into free fatty acids. These fatty acids can be transported across the intestinal membrane. However, once they cross the membrane, they are recombined to again form triglyceride molecules. Within the intestinal cells, these triglycerides are packaged along with cholesterol molecules in phospholipid vesicles called chylomicrons (Figure). The chylomicrons enable fats and cholesterol to move within the aqueous environment of your lymphatic and circulatory systems. Chylomicrons leave the
enterocytes by exocytosis and enter the lymphatic system via lacteals in the villi of the intestine. From the lymphatic system, the chylomicrons are transported to the circulatory system. Once in the circulation, they can either go to the liver or be stored in fat cells (adipocytes) that comprise adipose (fat) tissue found throughout the body.

Chylomicrons contain triglycerides, cholesterol molecules, and other apolipoproteins (protein molecules). They function to carry these water-insoluble molecules from the intestine, through the lymphatic system, and into the bloodstream, which carries the lipids to adipose tissue for storage.

**Lipolysis**

To obtain energy from fat, triglycerides must first be broken down by hydrolysis into their two principal components, fatty acids and glycerol. This process, called **lipolysis**, takes place in the cytoplasm. The resulting fatty acids are oxidized by β-oxidation into acetyl CoA, which is used by the Krebs cycle. The glycerol that is released from triglycerides after lipolysis directly enters the glycolysis pathway as DHAP. Because one triglyceride molecule yields three fatty acid molecules with as much as 16 or more carbons in each one, fat molecules yield more energy than carbohydrates and are an important source of energy for the human body. Triglycerides yield more than twice the energy per unit mass when compared to carbohydrates and proteins. Therefore, when glucose levels are low, triglycerides can be converted into acetyl CoA molecules and used to generate ATP through aerobic respiration.

The breakdown of fatty acids, called **fatty acid oxidation** or **beta (β)-oxidation**, begins in the cytoplasm, where fatty acids are converted into fatty acyl CoA molecules. This fatty acyl CoA combines with carnitine to create a fatty acyl carnitine molecule, which helps to transport the fatty acid across the mitochondrial membrane. Once inside the mitochondrial matrix, the fatty acyl carnitine molecule is converted back into fatty acyl CoA and then into acetyl CoA (**Figure**). The newly formed acetyl CoA enters the Krebs cycle and is used to produce ATP in the same way as acetyl CoA derived from pyruvate.
1) Converting a fatty acid to fatty acyl carnitine allows transport through the mitochondrial membranes.

2) Fatty acyl carnitine is converted back to fatty acyl CoA within a mitochondrion.

3) Fatty acyl CoA is converted to β-ketoacyl CoA, which is split into an Acyl CoA and Acetyl CoA.
During fatty acid oxidation, triglycerides can be broken down into acetyl CoA molecules and used for energy when glucose levels are low.

**Ketogenesis**
If excessive acetyl CoA is created from the oxidation of fatty acids and the Krebs cycle is overloaded and cannot handle it, the acetyl CoA is diverted to create *ketone bodies*. These ketone bodies can serve as a fuel source if glucose levels are too low in the body. Ketones serve as fuel in times of prolonged starvation or when patients suffer from uncontrolled diabetes and cannot utilize most of the circulating glucose. In both cases, fat stores are liberated to generate energy through the Krebs cycle and will generate ketone bodies when too much acetyl CoA accumulates.

In this ketone synthesis reaction, excess acetyl CoA is converted into *hydroxymethylglutaryl CoA (HMG CoA)*. HMG CoA is a precursor of cholesterol and is an intermediate that is subsequently converted into β-hydroxybutyrate, the primary ketone body in the blood (Figure).

Excess acetyl CoA is diverted from the Krebs cycle to the ketogenesis pathway. This reaction occurs in the mitochondria of liver cells. The result is the production of β-hydroxybutyrate, the primary ketone body found in the blood.

**Ketone Body Oxidation**
Organs that have classically been thought to be dependent solely on glucose, such as the brain, can actually use ketones as an alternative energy source. This keeps the brain functioning when glucose is limited. When ketones are produced faster than they can be used, they can be broken down into CO2 and acetone. The acetone is removed by exhalation. One symptom of ketogenesis is that the patient’s breath smells sweet like alcohol. This effect provides one way of telling if a diabetic is properly controlling the disease. The carbon dioxide produced can acidify the blood, leading to diabetic ketoacidosis, a dangerous condition in diabetics. Ketones oxidize to produce energy for the brain. *beta (β)-hydroxybutyrate* is oxidized to acetoacetate and NADH is released. An HS-CoA molecule is added to acetoacetate, forming acetoacetyl CoA. The carbon within the acetoacetyl CoA that is not bonded to the CoA then detaches, splitting the molecule in two. This carbon then attaches to another free HS-CoA, resulting in two acetyl CoA molecules. These two acetyl CoA molecules are then processed through the Krebs cycle to generate energy (Figure).
Ketone Oxidation

When glucose is limited, ketone bodies can be oxidized to produce acetyl CoA to be used in the Krebs cycle to generate energy.

Lipogenesis
When glucose levels are plentiful, the excess acetyl CoA generated by glycolysis can be converted into fatty acids, triglycerides, cholesterol, steroids, and bile salts. This process, called lipogenesis, creates lipids (fat) from the acetyl CoA and takes place in the cytoplasm of adipocytes (fat cells) and hepatocytes (liver cells). When you eat more glucose or carbohydrates than your body needs, your system uses acetyl CoA to turn the excess into fat. Although there are several metabolic sources of acetyl CoA, it is most commonly derived from glycolysis. Acetyl CoA availability is significant, because it initiates lipogenesis. Lipogenesis begins with acetyl CoA and advances by the subsequent addition of two carbon atoms from another acetyl CoA; this process is repeated until fatty acids are the appropriate length. Because this is a bond-creating anabolic process, ATP is consumed. However, the creation of triglycerides and lipids is an efficient way of storing the energy available in carbohydrates. Triglycerides and lipids, high-energy molecules, are stored in adipose tissue until they are needed.

Although lipogenesis occurs in the cytoplasm, the necessary acetyl CoA is created in the
mitochondria and cannot be transported across the mitochondrial membrane. To solve this problem, pyruvate is converted into both oxaloacetate and acetyl CoA. Two different enzymes are required for these conversions. Oxaloacetate forms via the action of pyruvate carboxylase, whereas the action of pyruvate dehydrogenase creates acetyl CoA. Oxaloacetate and acetyl CoA combine to form citrate, which can cross the mitochondrial membrane and enter the cytoplasm. In the cytoplasm, citrate is converted back into oxaloacetate and acetyl CoA. Oxaloacetate is converted into malate and then into pyruvate. Pyruvate crosses back across the mitochondrial membrane to wait for the next cycle of lipogenesis. The acetyl CoA is converted into malonyl CoA that is used to synthesize fatty acids. Figure summarizes the pathways of lipid metabolism.

**Lipid Metabolism**

Lipids may follow one of several pathways during metabolism. Glycerol and fatty acids follow different pathways.
Carbohydrates for Energy

Carbohydrates are organic molecules composed of carbon, hydrogen, and oxygen atoms. The family of carbohydrates includes both simple and complex sugars. Glucose and fructose are examples of simple sugars, and starch, glycogen, and cellulose are all examples of complex sugars. The complex sugars are also called polysaccharides and are made of multiple monosaccharide molecules. Polysaccharides serve as energy storage (e.g., starch and glycogen) and as structural components (e.g., chitin in insects and cellulose in plants).

During digestion, carbohydrates are broken down into simple, soluble sugars that can be transported across the intestinal wall into the circulatory system to be transported throughout the body. Carbohydrate digestion begins in the mouth with the action of salivary amylase on starches and ends with monosaccharides being absorbed across the epithelium of the small intestine. Once the absorbed monosaccharides are transported to the tissues, the process of cellular respiration begins (Figure). This section will focus first on glycolysis, a process where the monosaccharide glucose is oxidized, releasing the energy stored in its bonds to produce ATP.

Web Links

Macros for an athlete
Cellular respiration oxidizes glucose molecules through glycolysis, the Krebs cycle, and oxidative phosphorylation to produce ATP.
**Glycolysis**

Glucose is the body’s most readily available source of energy. After digestive processes break polysaccharides down into monosaccharides, including glucose, the monosaccharides are transported across the wall of the small intestine and into the circulatory system, which transports them to the liver. In the liver, hepatocytes either pass the glucose on through the circulatory system or store excess glucose as glycogen. Cells in the body take up the circulating glucose in response to insulin and, through a series of reactions called **glycolysis**, transfer some of the energy in glucose to ADP to form ATP (Figure). The last step in glycolysis produces the product **pyruvate**.

Glycolysis begins with the phosphorylation of glucose by hexokinase to form glucose-6-phosphate. This step uses one ATP, which is the donor of the phosphate group. Under the action of phosphofructokinase, glucose-6-phosphate is converted into fructose-6-phosphate. At this point, a second ATP donates its phosphate group, forming fructose-1,6-bisphosphate. This six-carbon sugar is split to form two phosphorylated three-carbon molecules, glyceraldehyde-3-phosphate and dihydroxyacetone phosphate, which are both converted into glyceraldehyde-3-phosphate. The glyceraldehyde-3-phosphate is further phosphorylated with groups donated by dihydrogen phosphate present in the cell to form the three-carbon molecule 1,3-bisphosphoglycerate. The energy of this reaction comes from the oxidation of (removal of electrons from) glyceraldehyde-3-phosphate. In a series of reactions leading to pyruvate, the two phosphate groups are then transferred to two ADPs to form two ATPs. Thus, glycolysis uses two ATPs but generates four ATPs, yielding a net gain of two ATPs and two molecules of pyruvate. In the presence of oxygen, pyruvate continues on to the Krebs cycle (also called the **citric acid cycle** or **tricarboxylic acid cycle (TCA)**), where additional energy is extracted and passed on.
Glycolysis Overview
During the energy-consuming phase of glycolysis, two ATPs are consumed, transferring two phosphates to the glucose molecule. The glucose molecule then splits into two three-carbon compounds, each containing a phosphate. During the second phase, an additional phosphate is
added to each of the three-carbon compounds. The energy for this endergonic reaction is provided by the removal (oxidation) of two electrons from each three-carbon compound. During the energy-releasing phase, the phosphates are removed from both three-carbon compounds and used to produce four ATP molecules.

This equation states that glucose, in combination with ATP (the energy source), NAD+ (a coenzyme that serves as an electron acceptor), and inorganic phosphate, breaks down into two pyruvate molecules, generating four ATP molecules—for a net yield of two ATP—and two energy-containing NADH coenzymes. The NADH that is produced in this process will be used later to produce ATP in the mitochondria. Importantly, by the end of this process, one glucose molecule generates two pyruvate molecules, two high-energy ATP molecules, and two electron-carrying NADH molecules.

The following discussions of glycolysis include the enzymes responsible for the reactions. When glucose enters a cell, the enzyme hexokinase (or glucokinase, in the liver) rapidly adds a phosphate to convert it into glucose-6-phosphate. A kinase is a type of enzyme that adds a phosphate molecule to a substrate (in this case, glucose, but it can be true of other molecules also). This conversion step requires one ATP and essentially traps the glucose in the cell, preventing it from passing back through the plasma membrane, thus allowing glycolysis to proceed. It also functions to maintain a concentration gradient with higher glucose levels in the blood than in the tissues. By establishing this concentration gradient, the glucose in the blood will be able to flow from an area of high concentration (the blood) into an area of low concentration (the tissues) to be either used or stored. Hexokinase is found in nearly every tissue in the body. Glucokinase, on the other hand, is expressed in tissues that are active when blood glucose levels are high, such as the liver. Hexokinase has a higher affinity for glucose than glucokinase and therefore is able to convert glucose at a faster rate than glucokinase. This is important when levels of glucose are very low in the body, as it allows glucose to travel preferentially to those tissues that require it more.

In the next step of the first phase of glycolysis, the enzyme glucose-6-phosphate isomerase converts glucose-6-phosphate into fructose-6-phosphate. Like glucose, fructose is also a six carbon-containing sugar. The enzyme phosphofructokinase-1 then adds one more phosphate to convert fructose-6-phosphate into fructose-1-6-bisphosphate, another six-carbon sugar, using another ATP molecule. Aldolase then breaks down this fructose-1-6-bisphosphate into two three-carbon molecules, glyceraldehyde-3-phosphate and dihydroxyacetone phosphate. The triosephosphate isomerase enzyme then converts dihydroxyacetone phosphate into a second glyceraldehyde-3-phosphate molecule. Therefore, by the end of this chemical-priming or energy-consuming phase, one glucose molecule is broken down into two glyceraldehyde-3-phosphate molecules.

The second phase of glycolysis, the energy-yielding phase, creates the energy that is the product of glycolysis. Glyceraldehyde-3-phosphate dehydrogenase converts each three-carbon glyceraldehyde-3-phosphate produced during the energy-consuming phase into 1,3-bisphosphoglycerate. This reaction releases an electron that is then picked up by NAD+ to
create an NADH molecule. NADH is a high-energy molecule, like ATP, but unlike ATP, it is not used as energy currency by the cell. Because there are two glyceraldehyde-3-phosphate molecules, two NADH molecules are synthesized during this step. Each 1,3-bisphosphoglycerate is subsequently dephosphorylated (i.e., a phosphate is removed) by phosphoglycerate kinase into 3-phosphoglycerate. Each phosphate released in this reaction can convert one molecule of ADP into one high-energy ATP molecule, resulting in a gain of two ATP molecules. The enzyme phosphoglycerate mutase then converts the 3-phosphoglycerate molecules into 2-phosphoglycerate. The enolase enzyme then acts upon the 2-phosphoglycerate molecules to convert them into phosphoenolpyruvate molecules. The last step of glycolysis involves the dephosphorylation of the two phosphoenolpyruvate molecules by pyruvate kinase to create two pyruvate molecules and two ATP molecules.

In summary, one glucose molecule breaks down into two pyruvate molecules, and creates two net ATP molecules and two NADH molecules by glycolysis. Therefore, glycolysis generates energy for the cell and creates pyruvate molecules that can be processed further through the aerobic Krebs cycle (also called the citric acid cycle or tricarboxylic acid cycle); converted into lactic acid or alcohol (in yeast) by fermentation; or used later for the synthesis of glucose through gluconeogenesis.

Anaerobic Respiration
When oxygen is limited or absent, pyruvate enters an anaerobic pathway. In these reactions, pyruvate can be converted into lactic acid. In addition to generating an additional ATP, this pathway serves to keep the pyruvate concentration low so glycolysis continues, and it oxidizes NADH into the NAD+ needed by glycolysis. In this reaction, lactic acid replaces oxygen as the final electron acceptor. Anaerobic respiration occurs in most cells of the body when oxygen is limited or mitochondria are absent or nonfunctional. For example, because erythrocytes (red blood cells) lack mitochondria, they must produce their ATP from anaerobic respiration. This is an effective pathway of ATP production for short periods of time, ranging from seconds to a few minutes. The lactic acid produced diffuses into the plasma and is carried to the liver, where it is converted back into pyruvate or glucose via the Cori cycle. Similarly, when a person exercises, muscles use ATP faster than oxygen can be delivered to them. They depend on glycolysis and lactic acid production for rapid ATP production.

Aerobic Respiration
In the presence of oxygen, pyruvate can enter the Krebs cycle where additional energy is extracted as electrons are transferred from the pyruvate to the receptors NAD+, GDP, and FAD, with carbon dioxide being a “waste product” (Figure). The NADH and FADH2 pass electrons on to the electron transport chain, which uses the transferred energy to produce ATP. As the terminal step in the electron transport chain, oxygen is the terminal electron acceptor and creates water inside the mitochondria.
Aerobic versus Anaerobic Respiration

The process of anaerobic respiration converts glucose into two lactate molecules in the absence of oxygen or within erythrocytes that lack mitochondria. During aerobic respiration, glucose is oxidized into two pyruvate molecules.
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Metabolic stress results from exercise sessions when the energy systems of the body are taxed. For example, sprinting short distances requires near maximum intensity and requires energy (ATP) to be produced primarily through anaerobic pathways, that is, pathways not requiring oxygen to produce ATP. Anaerobic energy production can only be supported for a very limited time (10 seconds to 2 minutes). However, distance running at steady paces requires aerobic energy production, which can last for hours. As a result, the training strategy for the distance runner must be different than the training plan of a sprinter, so the energy systems will adequately adapt.

Likewise, force stress accounts for the amount of force required during an activity. In weightlifting, significant force production is required to lift heavy loads. The type of muscles being developed, fast-twitch muscle fibers, must be recruited to support the activity. In walking and jogging, the forces being absorbed come from the body weight combined with forward momentum. Slow twitch fibers, which are unable to generate as much force as the fast twitch fibers, are the type of muscle fibers primarily recruited in this activity. Because the force requirements differ, the training strategies must also vary to develop the right kind of musculature.

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In summary, to improve performance, being specific in your training, or training the way you want to adapt, is paramount.

References & Links
1. ACSM guidelines (ACSM.org)

Links
http://extension.colostate.edu/topic-areas/nutrition-food-safety-health/nutrition-for-the-athlete-9-362/

Video
Sugar or Fat Video: https://www.youtube.com/watch?v=uWSt-AsqYRU

19.3 Nutrition for Fitness/Athletes

Vitamins, minerals and supplements for Athletes

Vitamins, minerals and supplements for the body are essential for most bodily functions so if an athlete speeds this body process up it becomes essentially more important for athletes to maintain a balance. Most of the vitamin and mineral levels could be met through a balanced diet using a variety of foods.

Vitamins needed for activity:

B Vitamin:

The B vitamin group is known for giving energy by converting protein and sugar into energy. Athletes looking for more energy during high-intensity exercises should look for foods with more B6, B12, thiamin, riboflavin (especially females) and folate. This conversion into energy could include the production red blood cells which would have an obvious benefit in long-endurance activities, using the aerobic system. Given the water soluble nature of the B vitamin group there is not a risk for excess/toxicity.

Vitamin D:

Due to the importance of vitamin D in the diet in the roll of the absorption of calcium, athletes who play sports with weight bearing stress, especially those played indoors should make sure that the amount of vitamin D in the diet is sufficient to overcome the stress placed on the bones.
Vitamin E:
Vitamin E can lessen the stress placed on the body during the oxidative stress. The stress can lower immunity, so taking vitamin E can increase the immune system which can lessen the risk of getting sick.

Vitamin C:
Water soluble vitamin C will help for reducing coughing, wheezing and shortness of breath during or post exercise. Taking large amounts 600-1000 mg of vitamin C can reduce the incidences of athletic-induced asthma.

**Minerals needed for activity:**

Calcium:
Most activities and sports are reliant upon a strong skeletal system. The absorption of calcium is important for bone density. This absorption of calcium is dependent on absorbing vitamin D also. Great sources of vitamin D and calcium together are in milk. According to the American Academy of Physical Medicine and Rehabilitation stress fracture could be reduced by 62 percent through an extra cup of skim milk per day. Significantly improving skeletal bone density has an obvious effect on performance, especially on those using repetitive movements that place a large amount stress on the skeletal system.

Iron:
The mineral iron will help red blood cells bring oxygen to muscles. Exercise can lead to a large drop in iron which can lead to anemia. Having low level of iron can lead to energy levels to drop, especially in endurance activities. Females, due to menstruation can have a higher risk of iron deficiencies which can lead to amenorrhea (loss of period) so that they will conserve iron.

Magnesium:
The component of energy metabolism, magnesium, has a role in energy as well as bone formation. Magnesium, as sodium does, is lost through sweat, therefore the longer the duration or the higher the intensity or higher temperatures can lead to both magnesium and sodium level deficiencies.

Sodium:
As one of the electrolytes, the maintenance of hydration is dependent on the levels of
sodium in the body. A low concentration of sodium in the blood can lead to hyponatremia and if one is to replace all fluids by just water alone can be bad for performance, recovery and can be fatal in some cases. Athletes that produce a lot of sweat or perform long endurance activities will need to replace the sodium, possibly during exercise.

Potassium:
Because potassium is essential as the other electrolyte, it keeps the balance of water in the body as sodium does and intake will help prevent cramps and will help with post workout recovery. It keeps intracellular fluid, helping balance water in the body so it is essential either during exercise or post exercise.

Supplements possibly needed for activity:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Proposed Mechanism of Action</th>
<th>Evidence of Efficacy**</th>
<th>Evidence of Safety**</th>
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</thead>
<tbody>
<tr>
<td>Antioxidants (vitamin C, vitamin E, and coenzyme Q10)</td>
<td>Minimize free-radical damage to skeletal muscle, thereby reducing muscle fatigue, inflammation, and soreness</td>
<td>Several small clinical trials</td>
<td>Safe at recommended intakes; some safety concerns reported with high doses</td>
</tr>
<tr>
<td>Research findings: Do not directly improve performance; appear to hinder some physiological and physical exercise-induced adaptations</td>
<td></td>
<td>Reported adverse effects: Potential for diarrhea, nausea, abdominal cramps, and other gastrointestinal disturbances with vitamin C intakes of more than 2,000 mg/day in adults; increased risk of hemorrhagic effects with vitamin E intakes of more than 1,500 IU/day (natural form) or 1,100 IU/day (synthetic form) in adults; nausea, heartburn, and other side effects with coenzyme Q10</td>
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<td>Arginine</td>
<td>Increases blood flow and delivery of oxygen and nutrients to skeletal muscle; serves as a substrate for creatine production; increases secretion of human growth hormone to stimulate muscle growth</td>
<td>Limited clinical trials with conflicting results</td>
<td>No safety concerns reported for use of up to 9 g/day for weeks; adverse effects possible with larger doses</td>
</tr>
<tr>
<td>Research findings: Little to no effect on vasodilation, blood flow, or exercise metabolites; little evidence of increases in muscle creatine content</td>
<td></td>
<td>Reported adverse effects: Gastrointestinal effects, such as diarrhea and nausea</td>
<td></td>
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<tr>
<td>Beetroot or beet juice</td>
<td>Dilates blood vessels in exercising muscle, reduces oxygen use, and improves energy production</td>
<td>Limited clinical trials with conflicting results</td>
<td>No safety concerns reported for short-term use at commonly recommended amounts (approximately 2 cups)</td>
</tr>
<tr>
<td>Research findings: Might improve performance and endurance to some degree in time trials and time-to-exhaustion tests among runners, swimmers, rowers, and cyclists; appears to be most effective in recreationally active non-athletes</td>
<td></td>
<td>Reported adverse effects: None known</td>
<td></td>
</tr>
<tr>
<td>Supplement</td>
<td>Effects</td>
<td>Research findings</td>
<td>Reported adverse effects</td>
</tr>
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<td>------------------------------------</td>
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<tr>
<td>Branched-chain amino acids (leucine, isoleucine, and valine)</td>
<td>Can be metabolized by mitochondria in skeletal muscle to provide energy during exercise</td>
<td>Limited number of short-term clinical trials</td>
<td>No safety concerns reported for 20 g/day or less for up to 6 weeks</td>
</tr>
<tr>
<td>Caffeine</td>
<td>Blocks activity of the neuromodulator adenosine; reduces perceived pain and exertion</td>
<td>Numerous clinical trials with mostly consistent results</td>
<td>Reassonably safe at up to 400–500 mg/day for adults</td>
</tr>
<tr>
<td>Citrulline</td>
<td>Dilates blood vessels to increase delivery of oxygen and nutrients to skeletal muscle</td>
<td>Few clinical trials with conflicting results</td>
<td>Few safety concerns reported for up to 9 g for 1 day or 6 g/day for up to 16 days</td>
</tr>
<tr>
<td>Creatine</td>
<td>Helps supply muscles with energy for short-term, predominantly anaerobic activity</td>
<td>Numerous clinical trials generally showing a benefit for high-intensity, intermittent activity; potential variation in individual responses</td>
<td>Few safety concerns reported at typical dose (e.g., loading dose of 20 g/day for up to 7 days and 3–5 g/day for up to 12 weeks)</td>
</tr>
<tr>
<td>Deer antler velvet</td>
<td>Contains growth factors (such as insulin-like growth factor-1 [IGF-1]) that could promote muscle tissue growth</td>
<td>Few short-term clinical trials that show no benefit for physical performance</td>
<td>Safety not well studied</td>
</tr>
<tr>
<td>Dehydroepiandrosterone (DHEA)</td>
<td>Steroid hormone that can be converted into testosterone and estradiol</td>
<td>Small number of clinical trials that show no benefit for physical performance</td>
<td>Safety not well studied; no safety concerns reported for up to 150 mg/day for 6–12 weeks</td>
</tr>
</tbody>
</table>

Research findings: Little evidence of improved performance in endurance-related aerobic events; possibility of greater gains in muscle mass and strength during training.

Reported adverse effects: None known.

Research findings: Might enhance performance in endurance-type activities (e.g., running) and intermittent, long-duration activities (e.g., soccer) when taken before activity.

Reported adverse effects: Insomnia, restlessness, nausea, vomiting, tachycardia, and arrhythmia; risk of death with acute oral dose of approximately 10–14 g pure caffeine (150–200 mg/kg).

Research findings: Little research support for use to enhance performance.

Reported adverse effects: Gastrointestinal discomfort.
<table>
<thead>
<tr>
<th>Supplement</th>
<th>Function and Effects</th>
<th>Research findings</th>
<th>Reported adverse effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ginseng</td>
<td>Unknown mechanism of action; Panax ginseng used in traditional Chinese medicine as a tonic for stamina and vitality; Siberian ginseng used to reduce fatigue</td>
<td>Numerous small clinical trials, most showing no benefit for physical performance</td>
<td>Few safety concerns reported with short-term use</td>
</tr>
<tr>
<td></td>
<td><strong>Research findings:</strong> In various doses and types of preparations, no effects on peak power output, time to exhaustion, perceived exertion, recovery from intense activity, oxygen consumption, or heart rate</td>
<td></td>
<td><strong>Reported adverse effects:</strong> For Panax ginseng: headache, sleep disturbances, and gastrointestinal disorders; for Siberian ginseng: none known</td>
</tr>
<tr>
<td>Glutamine</td>
<td>Involved in metabolism and energy production; contributes nitrogen for many critical biochemical reactions</td>
<td>Few studies of use to enhance performance directly</td>
<td>No safety concerns reported with about 45 g/day for 6 weeks; safe use of up to 0.42 g/kg body weight (e.g., 30 g/day in a person weighing 154 lb) by many patients with serious conditions (e.g., infections, intestinal diseases, and burns)</td>
</tr>
<tr>
<td></td>
<td><strong>Research findings:</strong> In adult weight lifters, no effect on muscle performance, body composition, or muscle-protein degradation; may help with recovery of muscle strength and reduce muscle soreness after exercise</td>
<td></td>
<td><strong>Reported adverse effects:</strong> None known</td>
</tr>
<tr>
<td>Iron</td>
<td>Increases oxygen uptake, reduces heart rate, and decreases lactate concentrations during exercise</td>
<td>Numerous clinical trials with conflicting results</td>
<td>No safety concerns reported for use at recommended intakes (8 mg/day for healthy men and postmenopausal women and 18 mg/day for healthy premenopausal women)</td>
</tr>
<tr>
<td></td>
<td><strong>Research findings:</strong> Improved work capacity with correction of iron deficiency anemia; conflicting evidence on whether milder iron deficiency without anemia impairs exercise performance</td>
<td></td>
<td><strong>Reported adverse effects:</strong> Gastric upset, constipation, nausea, abdominal pain, vomiting, and fainting at intakes above 45 mg/day</td>
</tr>
<tr>
<td>Protein</td>
<td>Builds, maintains, and repairs muscle</td>
<td>Numerous clinical trials</td>
<td>No safety concerns reported at daily recommended intakes for athletes of up to about 2.0 g/kg body weight (e.g., 136 g for a person weighing 150 lb)</td>
</tr>
<tr>
<td></td>
<td><strong>Research findings:</strong> Optimizes muscle training response during exercise and subsequent recovery period</td>
<td></td>
<td><strong>Reported adverse effects:</strong> None known</td>
</tr>
<tr>
<td>Quercetin</td>
<td>Increases mitochondria in muscle, reduces oxidative stress, decreases inflammation, and improves blood flow</td>
<td>Numerous small, short-term clinical trials</td>
<td>No safety concerns reported for 1,000 mg/day or less for up to 8 weeks</td>
</tr>
<tr>
<td></td>
<td><strong>Research findings:</strong> Little to no effect on endurance performance or maximal oxygen consumption</td>
<td></td>
<td><strong>Reported adverse effects:</strong> None known</td>
</tr>
<tr>
<td>Ribose</td>
<td>Involved in production of adenosine triphosphate (ATP)</td>
<td>A few small, short-term, clinical trials</td>
<td>Safety as a dietary supplement not well studied; no safety concerns reported for up to 10 g/day for 8 weeks</td>
</tr>
<tr>
<td></td>
<td><strong>Research findings:</strong> Little to no effect on exercise capacity in both trained and untrained adults</td>
<td></td>
<td><strong>Reported adverse effects:</strong> None known</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>Enhances disposal of hydrogen ions generated from intense muscle activity, thereby reducing metabolic acidosis and resulting fatigue</td>
<td>Many small, short-term clinical trials</td>
<td>No safety concerns reported for short-term use of up to 300 mg/kg body weight</td>
</tr>
<tr>
<td></td>
<td><strong>Research findings:</strong> Might provide minor to moderate performance benefit for short-term and intermittent high-intensity activity, especially in trained athletes</td>
<td></td>
<td><strong>Reported adverse effects:</strong> Nausea, stomach pain, diarrhea, and vomiting</td>
</tr>
<tr>
<td>Supplement</td>
<td>Benefits</td>
<td>研究发现:</td>
<td>不良反应</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>----------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Tart or cherry</td>
<td>Phytochemicals in tart cherries may facilitate exercise recovery by reducing pain and inflammation</td>
<td>A few clinical trials with conflicting results</td>
<td>No safety concerns reported for about 1/2 quart of juice or 480 mg freeze-dried Montmorency tart-cherry-skin powder per day for up to 2 weeks</td>
</tr>
<tr>
<td>Tribulus terrestris</td>
<td>Increases serum testosterone and luteinizing hormone concentrations, thereby promoting skeletal muscle hypertrophy</td>
<td>A few small, short-term clinical trials</td>
<td>Safety not well studied; no safety concerns reported at up to 3.21 mg/kg/day for 8 weeks</td>
</tr>
</tbody>
</table>

**Web Links**

5 great supplements for athletes

**References & Links**


**Links**

http://extension.colostate.edu/topic-areas/nutrition-food-safety-health/nutrition-for-the-athlete-9-362/

https://ods.od.nih.gov/factsheets/ExerciseAndAthleticPerformance-HealthProfessional/

**Video**

Sugar or Fat Video: [https://www.youtube.com/watch?v=uWSt-AsqYRU](https://www.youtube.com/watch?v=uWSt-AsqYRU)

### 19.4 Nutrition for Fitness/Athletes

**Fluids and Electrolytes to Support Activity**

Water is a very important micronutrient for athletes. Activity will lead to fluid loss and will lead to dehydration very quickly after exercise. A very good practice for athletes is to weigh themselves pre/post exercise. This practice will help monitor the amount of sweat that is lost during exercise. This practice can also be used to monitor the amount of sodium and potassium that is being lost during exercise.

**Water needed for activity:**
Avoiding dehydration could be done by drinking 5 to 7 mL per kilogram of body mass about four hours prior to the athletic event. Drinking water intermittently during exercise will help match the sweat that is being lost during exercise.

Weighing pre and post exercise can be a beneficial for replenishing the amount of water that is lost. An athlete should be replenishing 16-24oz per pound that is lost during exercise. If an athlete gains weight during activity this can be a sign of excess hydration which can show electrolyte imbalance and hyponatremia (Clifford and Maloney, 2015)

Electrolyte drinks help replenish the minerals lost during exercise. Shirreffs and Sawka had a study where:

Fluids and electrolytes (sodium) are consumed by athletes, or recommended to athletes, for a number of reasons, before, during, and after exercise. These reasons are generally to sustain total body water, as deficits (hypohydration) will increase cardiovascular and thermal strain and degrade aerobic performance. Vigorous exercise and warm/hot weather induce sweat production, which contains both water and electrolytes. Daily water (4-10 L) and sodium (3500-7000 mg) losses in active athletes during hot weather exposure can induce water and electrolyte deficits. Both water and sodium need to be replaced to re-establish "normal" total body water (euhydration). This replacement can be by normal eating and drinking practices if there is no urgency for recovery. But if rapid recovery (<24 h) is desired or severe hypohydration (>5% body mass) is encountered, aggressive drinking of fluids and consuming electrolytes should be encouraged to facilitate recovery for subsequent competition.

Vitamin D:

Web Links
Trade Sports Drink for Water
Potassium: Important Electrolyte

References & Links
1. Exercise and Athletic Performance: https://ods.od.nih.gov/factsheets/ExerciseAndAthleticPerformance-HealthProfessional/

Links
19.5 Nutrition for Fitness/Athletes

Diets for Physically Active People

Timing, amount of food and quality of food is very important for an athlete’s performance and recovery post exercise. In order for athletes to properly fuel themselves for exercise and not see long periods of

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encouraged to facilitate recovery for subsequent competition.

Web Links
Trade Sports Drink for Water

References & Links
1. Exercise and Athletic Performance: https://ods.od.nih.gov/factsheets/ExerciseAndAthleticPerformance-HealthProfessional/

Links
https://www.health.harvard.edu/blog/trade-sports-drinks-for-water-201207305079

https://ods.od.nih.gov/factsheets/ExerciseAndAthleticPerformance-HealthProfessional/