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736 Cambridge Street, Brighton, MA 02136
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Muscle Function and Exercise

The muscle cell is the basic unit that makes up a muscle. When looking at a whole muscle, we are actually seeing a collection of muscle cells grouped together. If we were to draw out one cell from the whole muscle, it would appear as a long " spaghetti " like strand.

Each strand is made up of sub-units called "sarcomeres". These sarcomeres contain the "contraction proteins" called actin and myosin. The chemical interactions of these two proteins are responsible for the abilities of the muscle to contract (shorten), relax and produce force (necessary to move the body or objects).

Each muscle fiber or cell possesses what is called a " myoneural junction ". This is the point where the nerve fiber, which originates in the brain and spinal cord, reaches the muscle, and passes -on the signal for the muscle to contract or relax. This is an area of the muscle that can be trained, as well as the muscle itself. The muscle fibers are grouped together and surrounded by a tissue sheath, much like the wrapper around a cable or wire. Groups of many muscle fibers in their sheaths are collected together to form the whole muscle.

Muscle fiber recruitment

When the demand of lifting a weight or moving an object (the object can be your body itself) is placed upon a muscle, the nervous system will "recruit " or gather together as many muscle fibers as necessary to move the weight or object through the required distance. Muscle fibers not needed will not contract or contract very weakly. However, as a heavier and heavier weight is lifted, then more and more muscle fibers will be recruited until all of the muscle fibers within a muscle participate in the contraction necessary to move the weight. If the weight is increased above the maximally recruited state of all the muscle fibers contacting at their highest tensions, the muscle will be unable to overcome the weight imposed upon it.

The repetition-maximum (RM) principal applies muscle fiber recruitment principals to establish safe limits to how much weight is lifted in a particular set and when it is safe to raise weights being utilized. . For example, a 10 RM for the bench press exercise is the amount of weight that can be lifted "just 10 times", and No More, before fatigue or failure sets in. That is, the particular weight being lifted is so heavy that an 11th repetition is not possible.

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When a 10 RM weight of 100 lb is used in the bench press, if you can lift 9 repetitions but not complete a 10th repetition, then you can be sure maximal muscle fiber recruitment was reached. The overload principal applies when you are able to lift for 10 repetitions. To continue to stimulate maximal muscle fiber recruitment the weight must be increased for the next exercise set or workout session, that is, a new 10 RM weight has been established.

Forced Repetitions

When strength training, as you reach the RM of a particular set, that is when you reach the 10^{th} repetition of a 10 RM set, the muscle and nerve-muscle units are experiencing momentary fatigue. If, with the aid of an assistant's help, you continue more repetitions, you are practicing forced repetitions. These repetitions are impossible for you to do without the help of the assistant. Usually, you are able to perform the eccentric or negative lowering part of the exercise alone, but then require the assistants help in the concentric or lifting phase.

In general, I do not recommend practicing forced repetitions in any strength building programs. There is a much higher potential for injury when doing forced repetitions since the artificial aide of the assistant helping complete the repetitions is overriding the muscle's natural fatigue mechanism. The same fatiguing effect on the muscle desired by doing forced repetitions can be gained by lowering the weight and performing another set without resting between sets.

Muscular Energy Systems

For a muscle to contract and produce force, energy must be supplied to the muscle by the metabolic systems of the body. There are two basic forms of muscle energy metabolism:

1. Aerobic metabolism

2. Anaerobic metabolism

Aerobic Metabolism

This type of metabolism refers to the utilization of oxygen for the muscle energy or "fuel" to produce muscle contraction and subsequent force production. The presence of oxygen allows the muscle energy systems to produce the chemical ATP from the breakdown of glucose, providing the energy to carry out the muscle contraction. Glucose is obtained in the muscle cell from the breakdown of the chemical called glycogen.
The aerobic energy system is usually involved in activities which are longer than 2 minutes in duration. Endurance activities such as walking, jogging, cycling, rowing,

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swimming and stair master all utilize the aerobic energy system as the prime source of muscle energy metabolism.

Anaerobic Metabolism

This type of metabolism refers to the utilization of glucose and ATP for the energy for muscle contraction. Glucose is stored in the muscle fibers in the form of glycogen. The presence of oxygen is not necessary for muscle contraction, as is the case with aerobic metabolism. When forceful or fast utilization of muscle energy is needed, ATP, creatinine phosphate and glucose are chemically metabolized or "broken down" by the internal chemical systems of the muscle. Glucose and ATP are a ready source of fast energy for muscle contraction. However, these anaerobic systems are limited in how long they will last by how much chemical stores of them are present in the muscle cell. Generally, activities that last from 1 to 30 seconds utilize the ATP/creatinine phosphate (CP) anaerobic system for energy production. Examples of ATP/CP system activities would be weight training at low to medium repetitions (5 to 10), football, 100 meter dash, shot put throw in track or any rapid, forceful burst of activity. Activities that last from 15 seconds to 2 minutes utilize the glucose system for energy production. Energy produced via the glucose system comes about when glucose is converted to lactic acid in the muscle cell.

Examples of glucose system activities would be higher repetition weight training sets or any high intensity running or sprinting which lasts up to 2 minutes.

After prolonged periods of anaerobic energy expenditure, greater than normal amounts of oxygen are used by the muscle cells to convert lactic acid back to glucose and restore the cell's supply of creatinine phosphate and ATP. This process of recovery and increased oxygen utilization by the muscle cell is termed the "oxygen debt".
Muscle fatigue occurs when the energy producing mechanisms of the muscle are no longer able to meet the demands that are imposed by the exercise activity.

Some causes of muscle fatigue are:

1. Depletion of muscle energy stores

ATP/CP- temporary fatigue after high intensity exercise burst of up to 30 seconds' duration.

Glucose/Lactic acid- temporary fatigue after high intensity exercise activities of up to 2 minutes duration.

Glycogen/Glucose for aerobic energy- A longer lasting fatigue as a result of moderate intensity exercises which would last for a period of hours.

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2. Depletion of chemicals at the nerve muscle junction.

3. Dehydration

Muscle Fiber Types

The energy systems that are called into action during exercise carry out their processes in the muscle cell or fiber. Muscle fibers are divided into "types" which determine their "specialty" in carrying out the function of energy production in the muscle cell. In general muscle cells are classified as follows:

Type I Slow Twitch

These fibers are referred to as "endurance" or aerobic muscle cells. They specialize in the production of energy using oxygen. These muscle cells are not capable of producing large forces, but they are capable of producing low forces for long periods of time, i.e. greater than 2 minutes.

Type IIa Fast Twitch

These fibers are referred to as "strength" or anaerobic muscle cells. They specialize in the production of energy without oxygen present in the cell. These cells are capable of producing large forces of limited duration of 30 seconds to 2 minutes utilizing the ATP/CP and glucose/lactic acid systems.

Type IIb Mixed

These fibers are referred to as "mixed" in terms are their ability to produce energy both aerobically and anaerobically. These cells are "trainable" in that they can adapt to the energy demands imposed by becoming more like a Type I fiber if training is predominately aerobic, or more like a Type IIa fiber if training is anaerobic.

Types of Muscle Contractions

1. Isometric

When tension or force is produced in the muscle cell, but the fibers do not shorten or lengthen, this is an "isometric contraction". If you were on the floor, on your arms in the "push-up" starting position, your upper body muscles would be holding you in that position without shortening or lengthening. This is an isometric contraction.

2. Concentric

When performing a biceps-curl exercise, the biceps muscle shortens as it raises the weight. This contraction of the biceps where the muscle shortens, usually against the effect of gravity, is called a “concentric” muscle contraction. This type of contraction is also referred to as a “positive” contraction.

3. Eccentric

When performing the same biceps-curl exercise, the phase where the weight is being slowly lowered by the biceps muscle produces an “eccentric” muscle contraction. Eccentric contractions take place usually when the muscle is lengthening while allowing the weight to slowly move toward the floor.

When comparing the amount of force or tension that can be produced by these 3 types of contractions, the most force can be produced eccentrically, the second most force can be produced isometrically, and the least force produced, comparatively, is concentric. In functional terms, you will be able to lower more weight down than you will be able to raise up against gravity. You will be able to hold more weight in a fixed, unmoving position than you will raise upward, against gravity.

In all exercises and activities, you are using a synchronous combination of all three contraction types. The feeling of sore muscles after exercise, especially after not exercising for a long time or taking up a new exercise activity, is due to muscle overload eccentrically. “Delayed-onset muscle soreness” occurs 24 to 48 hours after exercise. The soreness is caused by mild inflammation of the muscle cells due to breakdown of contractile proteins and the membrane surrounding the muscle cell. Delayed onset muscle soreness usually resolves after an additional 24 to 48 hours. At that time, the exercise activity can be repeated, but not at a greater intensity than the initial activity that caused the soreness. Repeated and regular training of the particular exercise activity will prevent the return of delayed onset muscle soreness in the future.

The muscle soreness that is felt during exercise is probably due to the build-up of lactic acid in the muscle cells. This type of soreness usually resolves after a few minutes.

In general, strength training will causes small increases in endurance or aerobic capacity. However, endurance training will cause no increases in muscle strength. In fact, training endurance activities consistently without doing strength training, at least at a maintenance level, will cause a loss of muscle strength and size.

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Interval Training

The term "interval training" refers to a form of training where the aerobic and anaerobic energy systems are trained simultaneously. Periods of steady-state, low intensity aerobic exercise are interspersed with high-intensity, short duration anaerobic bursts of exercise, followed by a return to the previous aerobic steady-state. These cycles of high intensity, low intensity alternations are repeated based on the desired sport specific or training effect desired.

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Effects of Strength Training on Muscles and Other Tissues

1. Increase in size of the contraction proteins actin and myosin.

2. Increase in thickness and strength of the connective tissue envelope that surrounds the muscle cell.

3. Increase in size and efficiency of the nerve-muscle junction.

4. Increase in muscle cell contents, especially glycogen/glucose and the chemical machinery for producing energy.

5. Increase in size and density of bone.

6. Decrease in body fat.

7. Reduce resting heart rate and blood pressure.

8. Increase strength and size of tendons and ligaments.

9. Increase strength and density of joint articular cartilage.

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Effects of Endurance (Aerobic) Training on Muscle and Other Tissues

1. Increase in pumping ability and size of the heart.

2. Increase in the efficiency and capacity of the body to utilize oxygen.

3. Improved ability of the circulatory system to move blood and oxygen to the working muscles.

4. Increased bone size and density.

5. Decreased body fat.

6. Reduced resting blood pressure and heart rate.

Effects of Training Strength and Endurance Simultaneously

1. Strength training can cause modest improvement in endurance.

2. Endurance training causes no improvement in muscle strength.

3. Strength gains obtained in a program combining simultaneous strength and endurance training are less than strength gains obtained in a strength training only program.

4. These effects are important to consider in training programs where maximal strength gains are desired.

5. It is not recommended that you avoid endurance training for the sake of maximal strength gains. A moderate endurance program or an interval training program will allow the positive benefits of endurance training while minimizing the depreciating effect of endurance training on strength.