

## Friction As a Factor in Exercise

by Matt Brzycki

Friction is a force that opposes movement. This extra resistance is created whenever an object moves through a medium such as air or water. Additionally, friction is produced when an object slides over or rolls along other surfaces. Friction also plays a role in every weight training exercise that you perform. Essentially, this friction comes from two sources: (1) your muscles and (2) the equipment.

### Internal Muscular Friction

There are three types of muscular contractions -- concentric, static, and eccentric. A concentric (or positive) contraction is one in which a muscle shortens against a resistance such as when you raise a weight. A static (or isometric) contraction occurs when a muscle exerts tension but there is no significant change in its length. This happens when you push or pull against an immovable object. Lastly, an eccentric (or negative) contraction is one in which a muscle lengthens against a resistance such as when you lower a weight.

Some research indicates that a fairly constant relationship exists between these three types of muscular contractions in terms of their strength levels. For a fresh, unfatigued muscle, the ratio seems to be about 1: 1.2: 1.4. This means that if you can raise 100 pounds concentrically, you can hold 120 pounds statically and you can lower 140 pounds eccentrically. This ratio changes as a muscle fatigues... but it appears as if your static strength is always midway between your concentric and eccentric strength. As early as 1975, it was proposed that these differences in strength were due to the effects of internal muscular friction... friction that is produced when a muscle contracts.

Before beginning a discussion of muscular contraction, it is necessary to describe the basic anatomical elements of muscle tissue. Your muscles are made up of numerous muscle fibers which, in turn, are made up of many myofibrils. (To get an idea of this arrangement, picture a telephone cable containing hundreds of wires.) Your myofibrils contain two contractile filaments,

actin and myosin, which lie parallel to one another. Muscular contraction occurs at this level.

The most widely-accepted theory of explaining muscular contraction is the Sliding Filament Theory. As the name implies, one set of filaments is thought to slide over the other and overlap (like pistons in a sleeve) thereby shortening the muscle. Here is how: the myosin filaments have tiny protein projections in the shape of globular heads which extend toward the actin filaments. During a concentric muscular contraction, it is believed that these projections, or cross-bridges, bind to the actin filament and then swivel in a ratchet-like fashion in such a way that it pulls the actin over the myosin filament. The cross-bridges then uncouple from the actin, pivot, reattach and repeat the cycle. Thus, this process can be summed up as "attach-rotate-detach-rotate." A single myosin cross-bridge may attach and detach with an actin filament hundreds of times in the course of a single muscular contraction (one repetition)! Remember, too, that this occurs along the entire myofibril and among all the myofibrils of a muscle fiber. However, the cross-bridges do not attach-rotate-detach-rotate at the same time since this would result in a series of jerks rather than a smooth movement.

The contact between the myosin cross-bridges with the surfaces of the actin filaments creates friction. Friction is also produced when a muscle lengthens eccentrically. Again the filaments slide past one another but this time it is in the opposite direction. Okay, the presence of internal muscular friction has been established but how and why does it influence your levels of strength?

In order to illustrate the effects of muscular friction, let's suppose that there are two nearly-identical inclined ramps that are angled about 15 degrees with respect to the horizontal. These ramps are the same except that one has a relatively smooth surface and the other has a rough surface. Your job is to stand at the top of a ramp and pull a large 100 pound block up the incline using a rope. (Assume that the block has no wheels and is laying flat on the ramp.) Which ramp would you rather use to raise the block --

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the smooth ramp or the rough ramp? You would make your lumbar a lot happier if you chose the smooth ramp. Why is the smooth ramp easier? Recall that friction is a force that opposes movement. When you raise the block the friction works against you. In effect, you are actually raising the block plus the friction that is involved. So, if the smooth ramp created ten pounds of friction and the rough ramp created fifteen pounds of friction, you would be pulling 110 pounds up the smooth ramp (100 pound block plus 10 pounds of friction) and 115 pounds up the rough ramp (100 pound block plus 15 pounds of friction). As you can see, you would want the smooth ramp -- the ramp with the least amount of friction.

So, now let's use

those same two ramps but this time your job is to stand at the top of the ramp and lower the 100 pound block. Which ramp would you use for this? In this case, it would be easier on your muscles to use the ramp with the greater friction. Once again, remember that friction opposes movement. This time, however, when you lower the block the friction works with you -- you are actually lowering the block minus the friction that is involved. Staying with the previous example, you would be lowering 90 pounds down the smooth ramp (100 pound block minus the 10 pounds of friction) and 85 pounds down the rough ramp (100 pound block minus the 15 pounds of friction).

(It should be noted that the aforementioned illustration is greatly simplified. An in-depth analysis would include the effects of static and kinetic friction and involve trigonometric calculations because the 100 pound block is on an inclined surface. However, it is not within the scope of this article for such a detailed explanation. Nevertheless, this simplified version has been enough to prove the intended points in a factual manner.)

Essentially, this is also what happens within your muscles when they contract. When you raise a weight, the friction within your muscles works against you - you are lifting the weight plus internal muscular friction; when you lower a weight, the friction works for you - you are lowering the weight minus internal muscular friction. For example, suppose there is five pounds of friction produced within a particular muscle when it contracts and you are lifting a 50 pound barbell. You are actually raising 55 pounds (50 pound barbell plus 5 pounds of muscular friction)

and lowering 45 pounds (50 pound barbell minus 5 pounds of muscular friction). In other words, your muscles do not have to work as hard when you lower a weight ... because of internal muscular friction. So, the friction within your muscles decreases your concentric strength and increases your negative strength. In fact, for any given exercise a muscle can always lower more weight than it can raise.

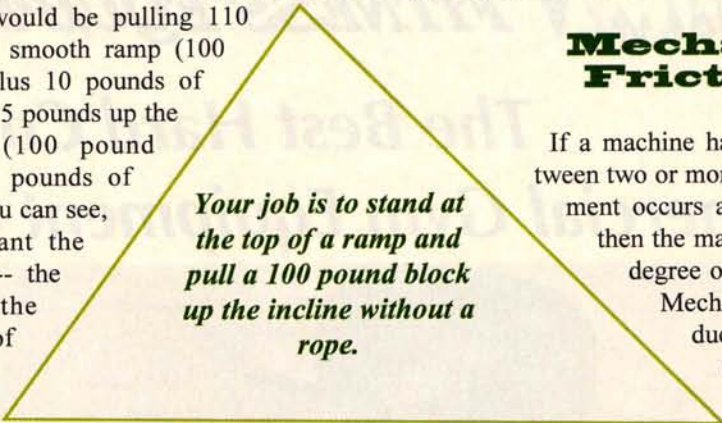
## Mechanical Friction

If a machine has an articulation between two or more surfaces and movement occurs around these surfaces then the machine will have some degree of mechanical friction.

Mechanical friction is produced by a weight stack traveling over guide rods, a cable winding around a pulley,

a chain moving around a redirectional sprocket and a bolt that pivots within a bushing. In an effort to design machines that feel smooth, many companies have reduced the amount of mechanical friction within their equipment. This has given rise to such things as using belts or cables instead of linked chains, installing bushings in every plate (not just the top plate) and incorporating sealed bearings at pivot points. (It should be noted that free weight exercises do not have any mechanical friction, since there are essentially no moving parts.)

The ramp analogy that was used earlier to explain the effects of internal muscular friction also applies to mechanical friction. In other words, when you raise a weight you are actually lifting the weight plus internal muscular friction plus mechanical friction (from the machine); when you lower a weight you are actually lowering the weight minus internal muscular friction minus mechanical friction. As an example, let's suppose you are doing leg extensions and the following is true: (1) the resistance is 100 pounds; (2) the mechanical friction inherent in the machine is ten pounds; and (3) the friction within your quadriceps muscles is five pounds. In this case, the 100 pounds of resistance that you selected actually feels like 115 pounds when you raise it ( $100 + 10 + 5$ ) and 85 pounds when you lower it ( $100 - 10 - 5$ ). As the amount of friction increases - whether it be muscular or mechanical - the harder it is to raise a weight and the easier it is to lower it. (When a muscle contracts, additional force is also necessary to stretch its antagonist. For example, when you contract your



*Your job is to stand at the top of a ramp and pull a 100 pound block up the incline without a rope.*

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quadriceps concentrically, you receive extra resistance from your hamstrings. This has been omitted from the discussion for the sake of simplicity).

### Muscular Soreness

At one time or another, most of us have experienced some degree of muscular soreness. The two types of muscle soreness are acute and delayed-onset.

Acute soreness occurs during and immediately following exercise. It is believed that this soreness is associated with an occlusion of blood flow to the muscles (ischemia). Because of this, metabolic waste products (e.g. lactic acid) cannot be removed and accumulate to the point of stimulating the pain receptors in the muscles.

Delayed-onset muscular soreness (DOMS) refers to the pain and soreness that occurs 24 - 48 hours after exercise. It has been found that eccentric muscle contractions produce greater DOMS than either concentric or static contractions. The exact cause of DOMS is unknown. The most popular theory is that cellular damage occurs to the muscle fibers and/or connective tissue (e.g. tendons).

Perhaps muscular friction is at least partly responsible for muscular soreness. Any friction that involves movement of biological tissue across another surface will cause irritation. Too much irritation will injure the tissue. For example, if you were to use a hammer on a regular basis for a short period of time you would begin to develop calluses on your palm. Basically, these calluses are a protective adaptation to frictional heat. However, if you were to use the hammer for a long enough period of time you would develop blisters instead. In this instance, the excessive friction surpassed the tissue's adaptive ability because it was too much and too frequent. I suspect that this "blistering" effect may also occur within muscle tissue whenever there is excessive internal muscular friction from either concentric, static or eccentric contractions.

Maybe future research studies will explore this as a possible cause of muscular soreness. At any rate, friction is a factor during exercise ... and possibly even after exercise.

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