

FITNESSTM

MANAGEMENT

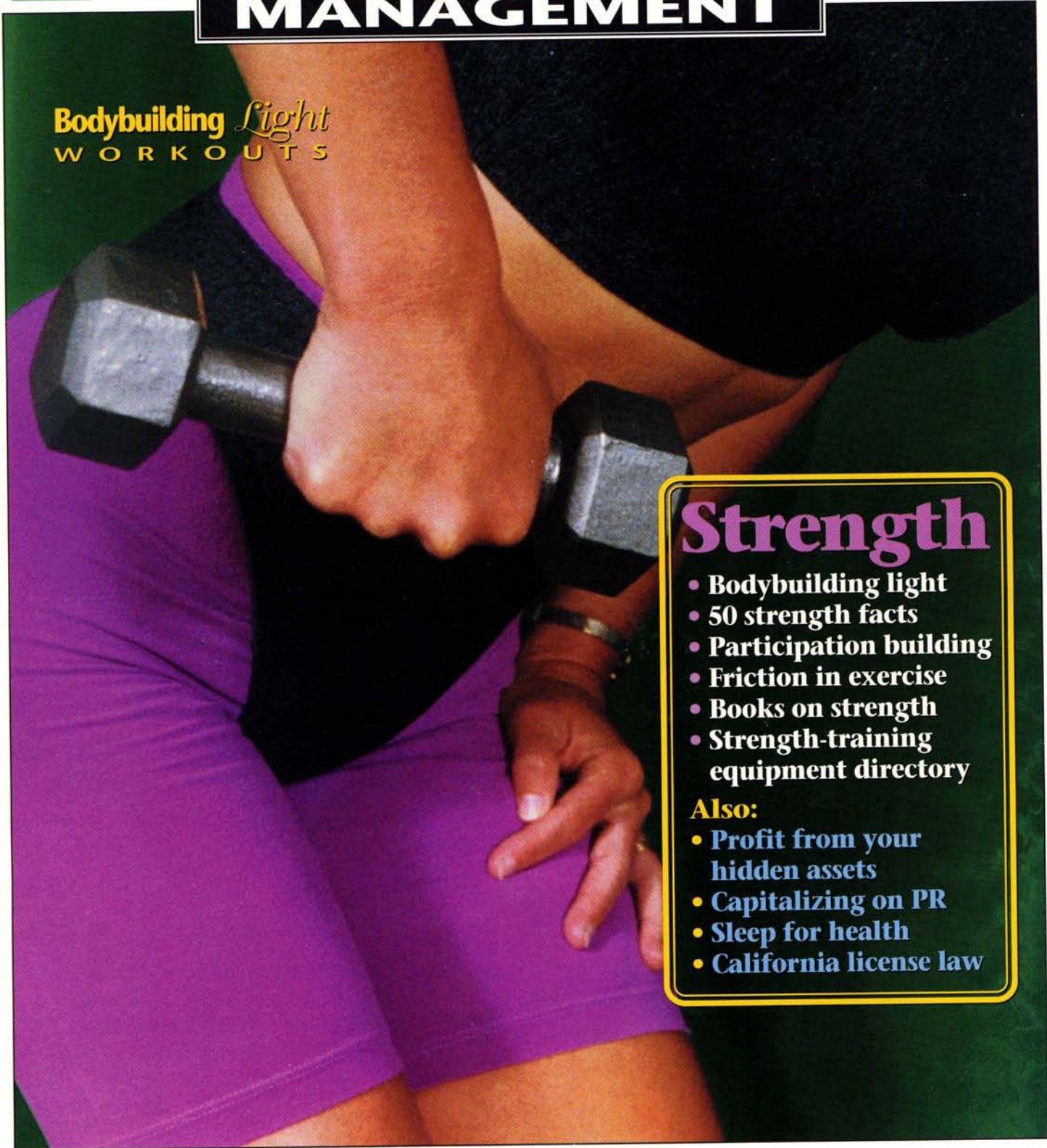
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FACTS of FRICTION

IN EXERCISE

When your trainers understand friction in muscles and machines, they can help clients better understand positive, negative and isometric strength training.

By Matt Brzycki

FRICTION IS A FORCE that opposes movement. Such resistance is created whenever an object moves through a medium such as air or water, or 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: your muscles and 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 to 1.2 to 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's necessary to describe the basic anatomical elements of muscle tissue. Your mus-

cles 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's 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, pulling 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 (on repetition). Remember, too, that this occurs along the entire myofibril and among all the myofibrils of a muscular 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 and 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 in the opposite direction.

How muscular friction influences 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 from horizontal. These ramps are the same except that one has a relatively smooth surface

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and the other has a rough surface. Your job is to stand at the top of a ramp and pull a 600-pound block up the incline using a rope. (Assume that, with zero friction, moving the block up the ramp would take 100 pounds of force.) Which ramp would you rather use to raise the block? 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 20 pounds of friction and the rough ramp created 30 pounds, you'd be pulling 120 pounds up the smooth ramp (100-pound force plus 20 pounds of friction) and 130 pounds up the rough ramp (100-pound force plus 30 pounds of friction). As you can see, for ease of movement you'd want the ramp with the least amount of friction.

Okay, now let's use those same two ramps but this time stand at the top of the ramp and lower the 600-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. Because friction opposes movement, when you lower the block, the friction works with you — you're actually lowering the block minus the friction that is involved. Staying with the previous example, you'd be lowering 80 pounds down the smooth ramp and 70 pounds down the rough ramp.

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. Suppose there's five pounds of friction produced within a particular muscle when it contracts and you're lifting a 50-pound barbell. You're actually raising 55 pounds and lowering 45 pounds. In other words, your muscles don't have to work as hard when you lower a weight. 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.

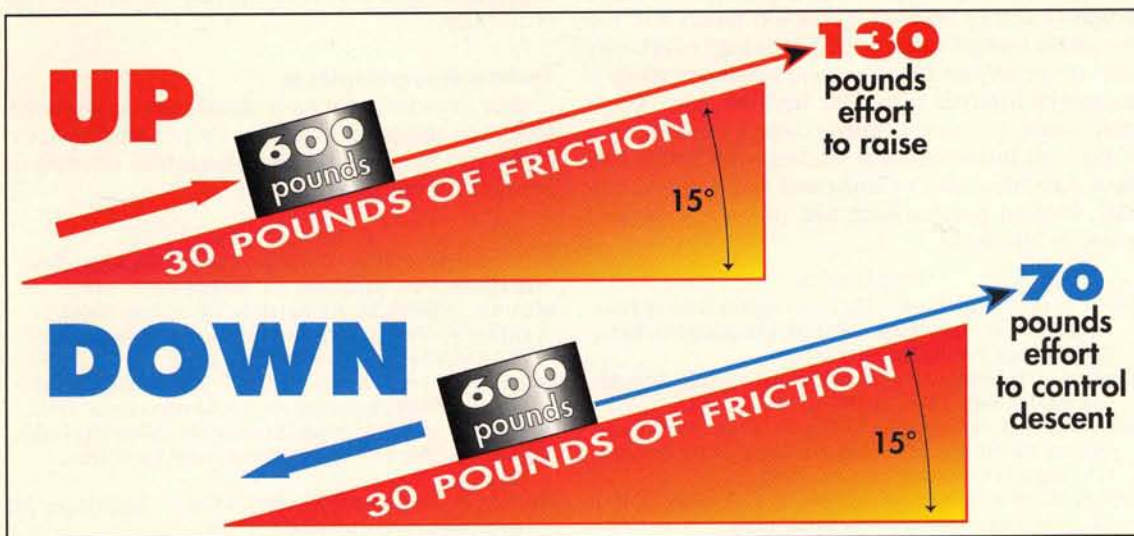
(It should be noted that our inclined ramp illustration is greatly simplified. An in-depth analysis would include the effects of static and kinetic friction, and involve trigonometric calculations, because the 600-pound block is on an inclined surface. But, this simplified version does demonstrate the intended points in a factual manner.)

Mechanical friction

If a machine has an articulation between two or more surfaces and movement occurs around these surfaces, 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 redirection sprocket or a bolt that pivots with 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 practices 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 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 10 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

**Rule of thumb:
If you can lift 100 pounds, you can hold 120 pounds and lower 140 pounds.**



Friction plays a large role in exercise, and maybe in muscle soreness afterward.

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. 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 quadriceps concentrically, you receive extra resistance from your hamstrings.)

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). As a result, metabolic waste products (e.g., lactic acid) cannot be removed and accumulate to the point of stimulating pain receptors in the muscles.

Delayed-onset muscular soreness (DOMS) refers to the pain and soreness that occurs 24 to 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 short periods of time, you'd begin to develop callouses on your palm. Basically, these callouses are a protective adaptation to frictional heat. However, if you were to use the hammer for a long enough period, you'd 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.

Perhaps future research studies will explore this as a possible cause of muscular soreness. At any rate, friction plays a large role in exercise — and possibly afterward. □

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efits from participating in a sound, supervised strength-training program. Research has shown that the positive consequences of such training far outweigh the potential risks.

45. A breath of common sense. Breathing properly is a basic safety consideration while strength training. A fundamental precept to which you should always adhere is to never hold your breath while strength training. Holding your breath results in a potentially dangerous buildup of intra-thoracic pressure. This pressure (inside your rib cage) compresses the right side of your heart, which in turn restricts the flow of blood and oxygen to your entire body.

46. Balancing act. Your strength-training program should emphasize muscle balance. In your body, you have muscles that oppose each other (e.g., your quadriceps muscles are opposed by your hamstring muscles). These muscles have a proportional strength relationship between them. If one is much stronger than the other, you run the risk of injuring the weaker muscle.

47. It makes sense to be intense. In order for improvement to occur in your strength level, you must place a demand on your muscular system. No demand, no improvement.

48. It's insane to overtrain. Part of the "art" of prescribing strength fitness exercise is the ability to design your program in such a manner that it provides a sufficient training stimulus to induce positive physiological changes without exceeding your body's capacity to safely adapt to that stimulus. In other words, you need to achieve an appropriate balance between training and recovery.

49. With a little help from your friends. Individuals who strength train with a partner tend to achieve better results. A training partner can help ensure that you perform each exercise correctly and that you exert a more intense effort.

50. A tune-up for life. Because muscular fitness is a critical component of functional fitness, strength training must be an essential part of your workout regimen. The better you keep your muscles tuned up, the better they will function and the longer they will operate effectively and efficiently.

Technical masterpieces

Your muscles are merely tissue, but no less valuable than the rarest of jewels. Proper resistance exercise can help sustain their bountiful offering of benefits for your lifetime. □

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