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Conditioning Fundamentals

Features

**A Practical Comparison
of Different Lower Body
Resistance Training Modes**
*Jonathan Anning, PhD,
CSCS,*D*

**Landing Mechanics:
What, Why and When**
*Mitch Hauschildt, MA,
ATC, CSCS*

**Central and Peripheral
Adaptations to Training**
Todd Miller, PhD, CSCS



about this
PUBLICATION

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table of CONTENTS

conditioning fundamentals



10 **A Practical Comparison of Different Lower Body Resistance Training Modes**

Jonathan Anning PhD, CSCS,*D
Learn the difference between some common lower body exercises.

18 **Central and Peripheral Adaptations to Training**

Todd Miller, PhD, CSCS
This article presents the basic adaptations that occur with both aerobic and resistance training.

13 **Landing Mechanics: What, Why, and When**

Mitch Hauschildt, MA, ATC, CSCS
Learn the reasons for proper landing mechanics and how to incorporate drills into your program to help develop proper landing mechanics.

departments

4 ***InTheGym* Elevation:Vertical Jump Training Exposed**

Kyle Brown, CSCS
Learn about common myths surrounding the vertical jump, and how you can improve your vertical jump.

8 ***FitnessFrontlines***

G. Gregory Haff, PhD, CSCS, FNCSA
The latest news from the field training on stable versus unstable surfaces and periodized training and sprint performance.

6 ***Ounce of Prevention* Hydration and Water Consumption: What You Should Know**

Jason Brumitt, MSPT, SCS, ATC, CSCS,*D
This article discusses risks associated with improper rehydration and an evidence supported rehydration strategy.

16 ***Training Table* Nutrients for Recovery From Muscle Injury**

Debra Wein, MS, RD, LDN, CSSD, NSCA-CPT,*D and Stacie Sieloff
Key nutrients can aid in recovery. Learn which ones in this article.

about the
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Elevation: Vertical Jump Training Exposed

Ever since Michael Jordan's "hang time" appeared to defy gravity, most youth have had more clarity on their goal of being able to dunk a basketball than on knowing what they want to be when they grow up. As we get older, however, most people come to grips that this dream of dunking a basketball is out of reach. Eventually, they become happy if they are able to jump out of bed in the morning. Yet there are those rare individuals who seem to be able to leap with ease—and you know us athletes strive to be the exception not the rule. Whether it's the ability to dunk a ball, block a shot, catch a football, spike volleyball, or complete a double axel—performance in nearly every land sport is enhanced if you can jump higher than your competition. To increase your vertical jump, you must first dispel the myths about vertical jumping and then develop a holistic strategy to improve.

Myths About One's Vertical Jump

One of the most common myths is that your vertical jump is 100% genetic. Most people think you're born with your vertical jumping ability and there isn't anything you can do to improve it. Not necessarily true. While many people are natural gifted, that doesn't mean you've reached your own genetic potential.

The second most common myth is that lifting weights will "bulk you up" too much and hurt your vertical jump. The exact opposite is true. Both resistance training and plyometrics can dramatically increase both your strength and explosive power, which in turn have a direct correlation with a potential increase in your vertical jump. Ask nearly any elite athlete at the top of their game if they incorporate resistance training and plyometric training into their workouts and you'll get a resounding, yes.

Biomechanics of Vertical Jump

Understanding and applying the proper mechanics of a vertical jump is an important factor to making improvements. There are two different types of vertical jumps: the countermovement jump and the squat jump. A countermovement jump is where the jumper starts

from an upright standing position, makes a preliminary downward movement by flexing at the hips, knees, and ankles, then immediately extends the hips, knees, and ankles to jump vertically up off the ground. Such a movement makes use of the 'stretch-shorten cycle,' where the muscles are 'pre-stretched' before shortening in the desired direction (1).

A less common type of jump is the squat jump, where the jumper starts from a stationary semi-squatted position. The jumper does not employ a preliminary downward phase (i.e., a countermovement) and the jump does not involve pre-stretching of muscles. Most athletes can jump 3 – 6 cm higher in a countermovement jump than in a squat jump (2). Therefore, by implementing the proper mechanics of a countermovement jump you may instantly see improvements in your vertical jump capability.

Exercises for Improving Your Vertical Jump

Strength training and plyometrics are the two main exercise protocols that you should incorporate into your routine. Strength training will allow you exert more force when you jump. Plyometric exercises will increase your explosive muscular power. The combination of strength and plyometric training are the two foundational ingredients to increasing your vertical jump.

Supersets sets are an effective technique for incorporating strength training and plyometric training. You can also complete your plyometric exercises after your strength training exercises or on separate days. Table 1 (page 5) shows a sample lower body exercise program super-setting resistance and plyometric exercises for improving your vertical jump. ■

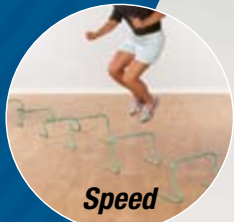
¹ Aragon, Luis. Evaluation of four vertical jump tests: Methodology, reliability, validity, and accuracy. *Measurement in Physical Education & Physical Science* Vol. 4, No. 4, Pages 215 – 228. 2000.

² Linthorne N.P. Optimum take-off range in vertical jumping in Book of Abstracts, 3rd Australasian Biomechanics Conference, Griffith University, 31 January – 1 February, pp. 49 – 50. 2000.

Resistance / Plyometric Exercise Superset		
Exercise	Sets	Reps
Squats / Squat Jumps	3 / 3	10 – 12/15
Walking Lunges / Single Leg Jumps	3 / 3	10 – 12/15 (each leg)
Step Ups / Plyo Lunges	3 / 3	10 – 12/15 (each leg)
Calf Raises / Side to Side Lateral Jumps	3 / 3	10 – 12/15

Table 1

Sample superset lower body exercise program for improving vertical jump.



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Hydration and Water Consumption: What You Should Know

An article recently published in the British Medical Journal titled “Medical Myths” has generated a lot of attention as of late in both the traditional print media and on the internet (4). The authors of “Medical Myths” searched the medical literature for studies that either supported or disproved widely held medical beliefs and assumptions (4). For example, that we only use 10% of our brain’s capacity. As it turns out there is no basis to this belief. This “myth” was created in the early 1900s by turn of the century self help gurus (4). The reality is that we utilize the majority of our brain at all times (4).

Do We Need to Drink Eight Glasses of Water a Day?

Another well known assumption that the authors explored is the belief that one should drink a minimum of eight glasses of water each day (1). Maintaining proper hydration is necessary for optimal physiologic function and for athletes it is crucial for optimal athletic performance (2). The authors determined that this “medical myth” probably originated around 1945 and later gained acceptance after receiving an endorsement by a well known nutritionist (4). Despite the universal acceptance of this assumption, the authors reported that there is no evidence in the medical literature to support this claim (4). As to what one should drink and how much one should consume each day to maintain hydration, Vreeman et al (4) wrote the following: “existing studies suggest that adequate fluid intake is usually met through typical daily consumption of juice, milk, and even caffeinated drinks. But drinking excess amounts of water can be dangerous, resulting in water intoxication, hyponatremia, and even death” (4).

The manner in how the media reported this article (and especially the two previously quoted sentences) requires further review. Based solely upon those two sentences (and the subsequent media reports) an athlete may avoid properly rehydrating after an event fearing that drinking water might seriously affect one’s health (4).

Unfortunately, Vreeman et al’s (4) article provides limited practical information for individuals, let alone athletes. The purpose of this article is to present the risks associated with improper rehydration and an evidence supported rehydration strategy.

Hyponatremia: Incidence and Risks

Hyponatremia is a potentially serious condition that if left untreated can have deadly implications for an athlete. Hyponatremia is the result of significant electrolyte loss (through sweating) and consuming too much water during or after exercise (2). Symptoms associated with hyponatremia include nausea, malaise, headache, and vomiting (2). If the condition progresses, the athlete may experience confusion, seizures, become unconscious, stop breathing, or experience a heart attack (2). Fortunately, the risk of developing hyponatremia is low. One study found that only 0.6% of all marathoners developed a severe form of hyponatremia (4).

Tips to Prevent Hyponatremia

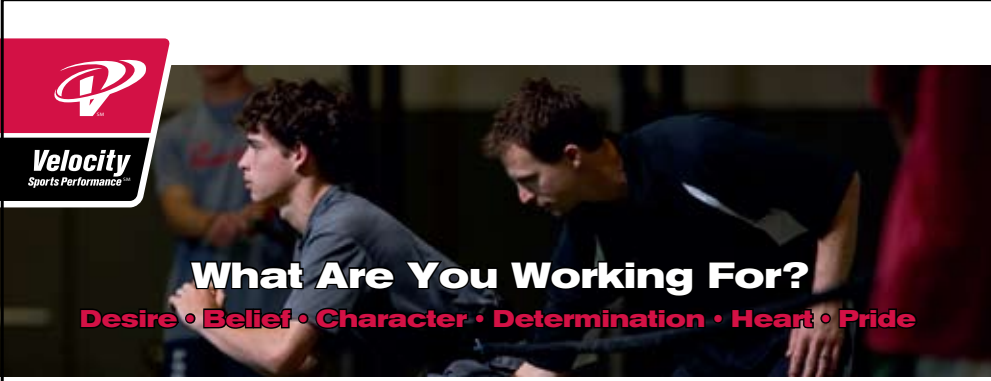
Landry et al (3) recommends that one should drink 16 oz of fluid for every one pound of weight that is lost while exercising. Landry et al (3) also suggest that it is acceptable for athletes to drink water in order to rehydrate. Sports drinks that contain electrolytes are also considered acceptable for rehydrating after sports (and in some cases may be preferable over water) (3).

Conclusion


Drinking water during and after exercise is safe to consume when rehydrating. Athletes, working with their coaches, may consider other drinks to consume in order to maintain hydration. If an athlete experiences any symptoms after exercising that are indicative of hyponatremia, that individual should receive medical attention immediately. ■

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Should Unstable Surfaces Be Used for the Development of Strength and Power?

Recently Researchers from Australia investigated the effects of performing squats on increasingly unstable environments. Fourteen active men performed three repetitions of back squats with three different resistances: 1) 10-repetition maximum (10-RM), 2) 40% of 10-RM, and 3) 20.45 kg. All squats were performed on a stable floor, a foam pad, and a half dome stability ball. When transitioning from a stable environment to a very unstable environment (ball) it was determined that a clinically significant decrease in squat depth and concentric force occurred when comparing the most unstable condition (ball) to the most stable condition regardless of resistance used. Additionally, the stable condition exhibited the highest movement velocities, while both of the unstable conditions resulted in significantly slower movement velocities. Based upon these results the authors concluded that the performance of squats on unstable surfaces most likely does not provide an optimal stimulus for strength and power training. Additionally, it was suggested that the use of instability devices in conjunction with resistance training is "misguided" for individuals attempting to optimize strength power gains. Thus the authors suggested that balance training should be separated from strength and power training.

Drinkwater, E.J., E.J. Prichett, and D.G. Behm. Effect of instability and resistance on unintentional squat-lifting kinetics. *Int. J. Sports Physiol. Perf.* 2:400 – 413. 2007.

Performing Push-ups on Unstable Surfaces Does Not Increase Muscle Activation.

The electromyographic (EMG) effects of performing various push-up exercises on an unstable (stability Ball) and stable surfaces (Bench) were recently compared by researchers from Canada. Ten male subjects performed pushups with feet or hands placed upon a stable bench or on a ball in order to determine if EMG activity of the scapulothoracic muscles (upper trapezius, lower trapezius, serratus anterior, and biceps) are affected by the type of surface. Additionally, various hand positions

were evaluated. Interestingly there were no differences in EMG activity of the scapulothoracic muscles between the stable and unstable environments. Additionally, while no difference was noted between the conditions, placing the feet on either the ball or flat bench resulted in significantly greater EMG activity when compared to when the hands were placed on the ball or flat bench. The authors suggested that this study demonstrates that the use of a stability ball with this type of exercise does not result in a greater recruitment of "stabilizing muscles". Thus suggesting that the type of unstable environment does not result in a greater muscle activation when compared to stable environments.

Lehman, G.J., D. Gilas, and U. Patel. An unstable support surface does not increase scapulothoracic stabilizing muscle activity during push up and push up plus exercises. *Man Ther* 2007 (in press).

How does muscle activation compare between stable and relatively unstable environments?

Recently researchers from Brazil compared the electromyographic (EMG) activity during axial load exercises on stable and relatively unstable environments. EMG activity was recorded from the biceps brachii, anterior deltoid, clavicular portion of the pectoralis major, upper trapezius, and the serratus anterior using surface electrodes during the performance of a wall-push up, a traditional push up, and a bench press exercise performed on either a stable or relatively unstable environment. The deltoid exhibited significantly greater EMG activation when performed on a relatively unstable environment regardless of exercise used. When looking at the pectoralis major and the serratus anterior, it was noted that there was no difference in EMG activation between the stable and unstable environments for both the wall push up and the bench press. However, the push-up when performed on a stable environment resulted in significantly greater EMG activation than the push performed on the unstable environment. Additionally, there was no significant difference between the EMG activation patterns during the push up or bench press for the trapezius or biceps brachii when performed on a stable or unstable environment. However, the trape-

zius appeared to exhibit a greater EMG activation pattern when performing the wall push up in the unstable environment. As a whole the data collected in this investigation demonstrate that performing exercises on unstable environments does not always result in greater muscle activation when compared to the same exercise performed on a stable surface.

De Oliveira, A.S., M. De Moraes Carvalho, and D.P. De Brum. Activation of the shoulder and arm muscles during axial load exercises on a stable base of support and on a medicine ball. *J Electromyogr Kinesiol* 2007 (in press).

How does a periodized resistance training regime affect accelerative sprint performance?

The development of strength appears to play a crucial role in sprinting ability. However, different types of resistance training regimes appear to result in alterations to different phases of a straight-line sprint. Prior to the beginning of this investigation all subjects (n = 16) partici-

pated in a four week familiarization period. After the familiarization period the subject were randomly divided into an experimental (n = 10) and a control (n = 6) group. The experimental group performed eight weeks of resistance training three times per week on non-consecutive days. The first mesocycle was a strength-endurance phase in which higher volumes of training were encountered with 12 repetition maximum (RM) loads. The second mesocycle was representative of a maximum strength and power phase of training and utilized sets of five performed at 5-RM loads. Sprint performance was measured before and after the eight weeks of training with the use of a 20 meter sprint test. Sprint time was recorded at 10 and 20 meters. Additionally, sprint performance was videotaped over the first and second 10 meters. The video was then analyzed for kinematic variables (flight time, stance time, stride length, and stride frequency). Finally, changes in lower body strength were assessed with the use of a 1-RM back squat test, while explosive strength was determined by measuring peak power output while performing loaded (30% 1-RM) and un-

loaded jumps on a force plate. The eight week resistance training program resulted in significant increases in maximal strength (+19%) and explosive strength (+6 – 10%). Conversely, both groups improved their sprint times (experimental = +7%; control = +4%). No significant differences were noted between the groups for stance time or stride length. Both groups exhibited a decrease in stride frequency after the eight weeks of training. While there were no significant differences between the groups, the authors suggested that the data may suggest that a delayed effect of resistance training on performance might occur. The sprint time improved by almost 3% more in the experimental group, and if the testing was conducted after a taper significance may have occurred. Therefore this data suggests that there is a time delay before muscular strength and power adaptations translate to sprinting performance.

Moir, G., R. Sanders, C. Button, and M. Glaister. The effect of periodized resistance training on accelerative sprint performance. *Sports Biomech* 6:285 – 300. 2007.



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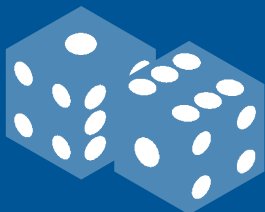
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A Practical Comparison of Different Lower Body Resistance Training Modes

Jonathan Anning, PhD, CSCS,*D

Exercise selection for a resistance training program begins with the specificity principle, which means the chosen exercise should imitate the activity as closely as possible. Also known as the transfer of training effect, Stone and associates (4) stressed the selected resistance exercise determines the extent of adaptation that will occur following a training program.

An obvious part of applying the specificity principle is to match an exercise with the movement patterns of an activity, but comprehending the forces placed on the body along with the musculoskeletal functions associated with resisting those forces may not be as obvious. In other words, this “line of resistance” consists of muscular efforts that are required to oppose the forces or loads applied to the body. By measuring the moment arm or perpendicular distance between the line of resistance and any major joint involved with the exercise, it can be concluded how much stress will be placed on a joint. For instance, the further a weight is held away from the body while standing, the harder it is to resist the forces. The same thing applies to the moment arm distance when comparing different joints in relation to the line of resistance. Obviously this means the muscle effort associated with the joint furthest away from the line of resistance will require greater effort than those with a shorter moment arm. Altogether, appreciation for the musculoskeletal efforts occurring during an exercise is dependent upon recognition of the line of resistance and moment arms, which enables the fitness professional to differentiate between resistance exercises that appear to have identical movements.

The rest of this article will explore numerous lower extremity multiple-joint exercises known to train the large muscle groups associated with the triple extensors (Table 1). Although the exercises have similar movements and coincide with daily lifting activities or performing jumping activities, Abelbeck (1) reported muscle recruitment is influenced by the depth achieved and



FIGURE 1: Line of resistance (- -) and joint moment arm (↔) demonstrate knee extensor emphasis during the (A) wall sit and (B) stability ball wall sit.

the actual foot placement. Since the deepest position of lower extremity triple extensor exercises places the most stress on the muscles, all the exercises examined within this article will be portrayed at the depth traditionally achieved. Foot placement will also be discussed along with the effects of machines and free weights relative to muscle recruitment. All this will be accomplished while differentiating between common lower extremity triple extensor resistance exercises.

Lower Extremity Triple Extensor Exercise Comparisons

Wall Sit

A common strengthening exercise is the fundamental wall sit. The wall sit involves holding the squat position while leaning against the wall as portrayed in Figure 1A. The line of resistance in this position will be based on gravity, but it will be directed through the hips as the feet push forward with limited movement due to friction. The stress on knee stability then results in higher forces produced by the knee extensors. A modification

Table 1

Lower Extremity Triple Extensors	
Movement	Primary Movers
Hip Extension	Gluteus Maximus and Hamstrings
Knee Extensors	Quadriceps
Ankle Plantar Flexors	Gastrocnemius and Soleus

that can minimize the stresses placed on the knee extensors might be to place the stability ball between the low back region and the wall. This permits the hips to move backward while minimizing the stress placed on the knees as observed during the stability wall squat (Figure 1B).

Leg Press and Hack Squat

Some dynamic exercise like the leg press can be used to strengthen the hip, knee, and ankle musculature through a greater range of motion. Note that the range of motion can vary depending on the angle of the platform in comparison to the torso, as evidenced by both versions of the leg press or hack squat machine (Figure 2). Interestingly, the deepest position for the lying leg press (Figure 2A) and hack squat (Figure 2C) are very similar, resulting in a major emphasis placed on the knee extensors. When referring to the line of resistance produced at the deepest position for an incline leg press (Figure 2B), a lack of friction at the feet causes the forces to travel perpendicular from the platform, resulting in greater forces directed through the hip extensors. In other words, if the goal is to solely strengthen the knee extensors, selecting the lying leg press or hack squat are optimal modes, whereas the incline leg press is a great hip extensor exercise.

Smith Machine

Another dynamic option is the Smith machine, where foot placement is important. Alalbeck (1) found that when the torso remains erect underneath the barbell, placing the feet directly underneath the hips emphasizes the knee extensors, whereas the hip extensor emphasis occurs when

the foot placement results in a right angle at the knee when the thigh is parallel to the floor. As represented by the line of resistance in Figure 3, equal hip and knee extensor recruitment occurs when the feet are in-between the previously described positions, as long as the torso remains vertical (1). Smith machine hip and knee extensor recruitment can also be modified to match the traditional squat or lunge, and the next section discusses those muscle demands.

Back Squat and Lunge

Once body control appears to be mastered, the traditional squat and lunge are logical selections because they require balance. Note that a partial squat (Figure 4A) and lunge (Figure 4B) place equivalent stresses on the hips and knees, whereas the full squat (Figure 4C) emphasizes the hip extensors at the greatest depth. The interesting observation is that partial and full squats produce different demands on the joints when the deepest position is achieved. It should not be a surprise though, because Abelbeck (1) recognized that targeting specific muscle groups can be accomplished by varying the depth of the squat.

Dumbbells and barbells may be added once body control can be achieved, but be careful to watch for inward (varus) or outward (valgus) rotation at the knees because of instability due to a lack of hip stabilization. In addition, valgus forces at the knees put additional stress on the ligaments like the ACL (3), which can be attributed to weak hamstring activity compared to the quadriceps (5). Even though this observation is

more common among women (5), recognition is crucial since hamstring activity is expected to be greater during squats when compared to the leg press (2). If these instability concerns arise, Youdas and associates (5) suggest avoiding single leg squat activities (i.e., lunge), meaning wall squats and body weight squats might be a beneficial neuromuscular training technique to facilitate stability development.

Conclusion

Only the line of resistance and moment arms of common lower extremity triple extensor resistance exercises were identified in this article. In addition, lower extremity single-joint exercises combined with all the trunk and upper extremity options provide even more opportunities to add variety to workouts, but that will require self motivation to discover applicable line of resistance and moment arms.

Keep in mind that the line of resistance changes with exercise depth, foot placement, and body dimensions. While it is easy to manipulate the exercise depth and foot placement, body dimensions such as tall individuals with longer extremities or trunks are permanent characteristics. When the length of extremities and trunks are longer, moment arms are extended making it more challenging for the muscles to generate force. It is these physical characteristics that require individualized exercise selections to accommodate specific goals and capabilities. ■

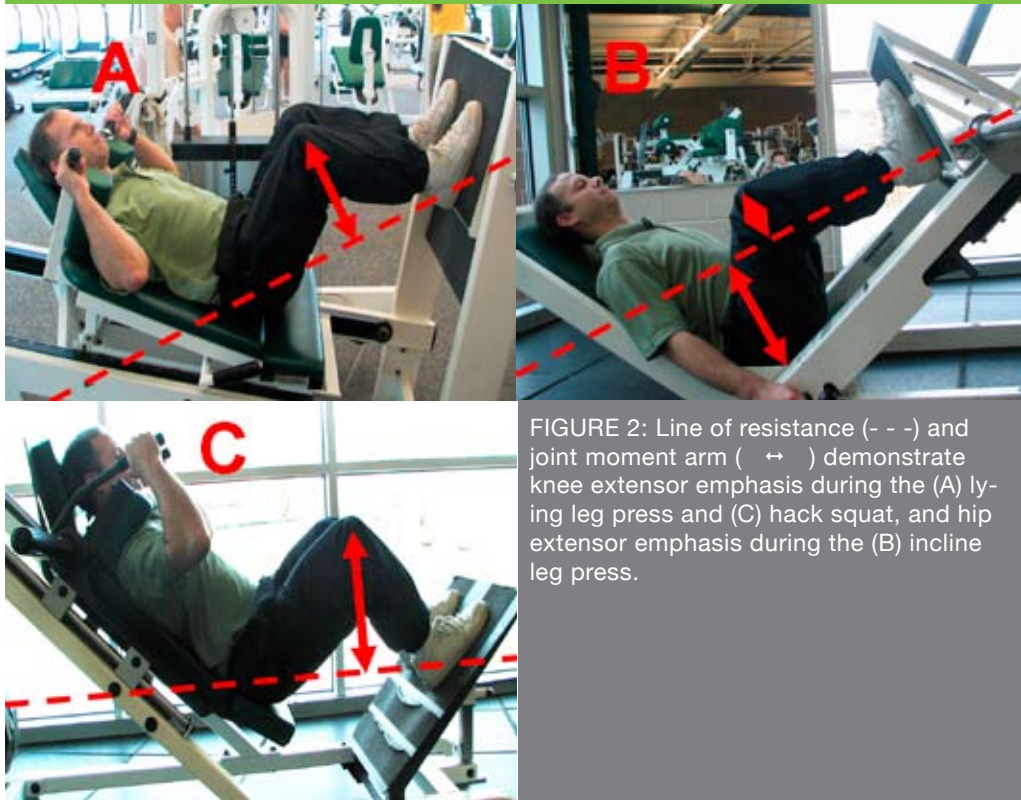


FIGURE 2: Line of resistance (- -) and joint moment arm (↔) demonstrate knee extensor emphasis during the (A) lying leg press and (C) hack squat, and hip extensor emphasis during the (B) incline leg press.



FIGURE 3: Line of resistance (- -) and joint moment arm (↔) demonstrates equal distribution between hip and knee extensors during the stability ball wall squat.



FIGURE 4: Line of resistance (- -) and joint moment arm (↔) demonstrates equal distribution between hip and knee extensors during the Smith machine squat.

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Landing Mechanics: What, Why, and When

Mitch Hauschildt, MA, ATC, CSCS

Over the years, athletes have learned to jump higher with the help of plyometrics and strength training for the lower body. However, we have fallen behind in teaching the landing portion of the jumping movement. Of course, working on landing technique is not as fun as seeing how high we can jump, but it is just as, if not more, important than the concentric (upward) motion of jumping.

What Exactly Does This Mean?

Basically, we are looking at how effectively an athlete loads and absorbs force as they descend from a jumping movement, while putting themselves in a prime position to re-initiate running and jumping movements. The vast majority of athletes will naturally land stiff legged in a very rigid manner. As a result, all of the impact is absorbed between the hip, knee, and ankle joints. It is much more advantageous for athletes to land softly and transfer their force to the glutes, hamstrings, quads, and calf musculature.

One of the recent points of discussion in strength and conditioning communities is athletes who are quad dominant v. glute dominate. Quad dominant athletes tend to use their quads to shift their weight forward with squatting and jumping movements. This not only transfers a lot of pressure to the front of the knee, but puts a large load on the anterior cruciate ligament (ACL) (4). It is important to realize that the quads are at a mechanical disadvantage when compared to the glutes, making quad dominant athletes less explosive and less likely to succeed in speed and power sports. In figure 1, you will see an athlete who is squatting in a quad dominant pattern. Conversely, figure 2 shows an athlete who is much more glute dominant. Notice the shift posteriorly with the athlete's weight on their heels.

When landing and jumping, we want to utilize this glute dominant position. We know that to maximize jumping, we need the "triple extension" of hip exten-

sion, knee extension, and ankle plantar flexion. That is, with the legs completely straightened and toes pointed. When an athlete uses their quadriceps muscles as a primary source of movement (quad dominant), they have difficulty getting a full hip extension and appear as though they are always sticking their rear out (figure 3). This position robs them of valuable power production as the glutes are the most powerful muscle group of the lower extremity.

Why Are Landing Mechanics Important?

There are two main reasons for focusing on how athletes land: injury prevention and power production. Both are equally important for athletes of all ages, levels, and positions.

All athletes expose themselves to lower body injuries ranging from ankle sprains to low back pain; osteoarthritis to fractures; and probably the most feared, the ACL tear. Recurrent hard landings will lead to premature wear and degeneration of the ankle, knee, and hip joints. These frequent jolts of the lower extremity transfer force up the kinetic chain at a rate much higher than that which the body normally experiences during activity. Learning to land softly, without noise and slowly decelerating the weight of the body will significantly lower the impact forces, decrease the risk of injury, and extend the life of joints.

The other major concern related to poor landing techniques is the ACL tear. The most common position for an athlete tearing the ACL is foot pronation, tibial internal rotation, and a valgus position of the knee (1). In other words, the foot flattens out, and the lower leg rotates inward, while the knee collapses towards the body's midline. For our athletes (especially female) who have weak muscles of the outer hips and poor muscular control of their lower body, this position may be common while attempting to decelerate the body (Figure 4)(2).



FIGURE 1: A quad dominant squatting position



FIGURE 2: A glute dominant squatting position

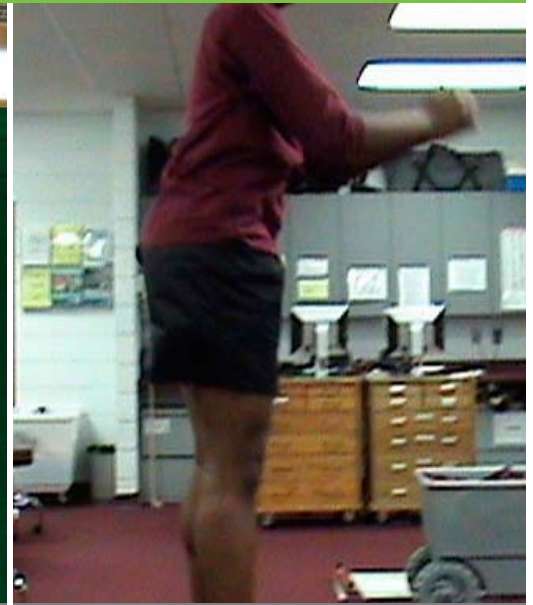


FIGURE 3: Quad dominant jump without hip extension

This is why most non-contact ACL tears happen while slowing the body down to change direction.

The ACL is unloaded with proper landing mechanics when the athlete loads the glutes upon landing. When you look at the role of the ACL in the knee, its primary role is to prevent the tibia (shin bone) of the lower leg from sliding forward during movement. When we look deeper into the biomechanics of the human body, we see that the hamstrings originate at the lower pelvis, and end on the back of the bones of the lower leg. When they fire (shorten) in conjunction with the glutes upon deceleration of the body, they pull the lower leg back into the knee joint and unload the ACL.

As touched on earlier, landing mechanics are extremely important for power production during sports. If an athlete does not land and decelerate themselves with their weight distributed over their entire foot and their glutes firing, they will be in a poor position to reinitiate explosive jumping or sprinting movements. Many times in sports, athletes are expected to jump multiple times in a row and/or combine jumping with sprinting movements. Athletes must learn to not only initiate the first jumping movement in an advantageous position but also land in the correct position to initiate the next movement.

When Should You Work On Landing Mechanics?

The answer is simple, everyday. Everyday that athletes train in our facilities, we are addressing this issue. Many times we teach it with a simple box jump (Figure 5). Sometimes we work on it specifically with single leg lateral bounds, teaching them to land softly and hold for three seconds before initiating the next movement. We may also choose to combine it with traditional plyometric jumping drills by performing multiple hops for quickness (enhancing the stretch reflex) finished by a soft, glute dominated landing. But, even when we are not specifically teaching the landing mechanics, it should always be in an athlete's mind with every ballistic movement they perform.

The last concern that most people have is whether or not athletes can take this concept into their sport and perform it at game speed. Keep in mind that the neuromuscular system is very active during sporting activities. Research tells us that it takes three to six weeks for athletes to fully learn new movement patterns. During this stage of motor learning, the nervous system is working very hard to perform the activity. Once the movement is successfully mastered, the body creates specific motor programs that become rather permanent fixtures within our

neuromuscular system (3). So, once an athlete has learned the basics of landing, their body will be very likely to apply at least portions of the motor programs whenever possible. Even when an athlete comes down in an awkward position, they will be much more likely to initiate their glutes and land more softly than before.

The key points in teaching landing technique are:

- Land as softly as possible, making no noise when the feet come in contact with the surface (“absorb force with your muscles, not your joints”).
- Land flat footed, keeping weight evenly distributed over the entire foot.
- Shift the glutes back and keep the knees behind the toes (“butt out”).

An athlete should start their basic landing technique training with one to two exercises, two to three times per week. Keep the sets and repetitions fairly basic (two to three sets of six to ten repetitions) as this should be considered an accessory exercise. It should be performed early in the workout, after a quality dynamic warmup and prior to the strength portion of your training.

Jumping and landing training are highly demanding on the nervous system. Thus, the body must be warm enough to perform the ex-



FIGURE 4: Single leg landing in poor positioning



FIGURE 5: Finish position of the Box Jump—Emphasize Landing

ercises efficiently, but not too fatigued to allow for proper motor learning to take place. Once an athlete has mastered the basics of landing, only general daily maintenance (one exercise, two times per week, two sets of six to ten repetitions) is required to keep them injury free and very explosive. ■

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Table 1

Exercise progression of jumping movements (easiest to hardest) to work on proper landing mechanics.

Lower Extremity Triple Extensors	
Exercise	Primary Movers
Box Jumps-Emphasize Landing	Start with feet flat facing a box. Perform a concentric box jump, landing as softly as possible with full foot flat upon landing on the box. Step down off of the box. Start with 12" box and progress to higher boxes to challenge an athlete's explosiveness.
Jump, Jump, Squat	Perform two jumps consecutively in place. The second jump should finish with a soft landing in a glute dominant squatting position (thus jump, jump, squat) holding for 3 seconds.
Single Leg Lateral Jumps	Start on one leg and bound laterally, landing on the opposing foot. Athlete should land with hip, knee, and ankle in neutral position. Athlete should look for good hang time (not necessarily jumping for distance or height, but hang time.
Broad Jumps-Emphasize	Jump concentrically off of two feet, landing as softly as possible in a good position with feet flat. Walk back to the starting position before repeating.
Single Leg Box Step Offs	Start standing on a box on both feet. Step off of the box with one foot, landing on the ground in a good position, absorbing force. Start with 6" box and progress to a box as the athlete develops eccentric strength and ability to absorb forces.
Stair Step Jumps	Utilize two different sized boxes (i.e. 12" and 36" box). Start on the ground facing the short box with the taller box behind it. Jump concentrically onto the small box. Quickly and explosively jump off of small box spending as little time as possible before landing softly in a good position on the tall box. Applies the concept of the depth jump, but in a safer and less demanding exercise.
Single Leg Box Jumps-Emphasize Landing	Same as the box jumps above, but with a single leg landing. Jump off of two feet, but land on one.
Single Leg Jump, Jump, Squat	Same as the broad Jump-Emphasize landing above, but on a single leg.
Depth Jumps	The classic plyometrics exercise of stepping off of a small box, jumping quickly and explosively off of the floor before landing softly in a good position on a larger box. Should only be performed with athletes who possess a good strength base.
Jumping Course	Combine a variety of jumping over obstacles, with rotation, onto boxes, etc. with landing softly to challenge the athlete and replicate the demands of the sport.

about the
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Nutrients For Recovery From Muscle Injury

Muscle strain and injury are common among athletes especially due to the high commitment and intensity required by sports. The incidence of muscle injury ranges from 10 – 55% of all sports related injuries (3) and depending on the extent to which the muscle is damaged, return to regular training and sport participation can take up to three months. To minimize recovery time and scarring of the muscle tissue, athletes must consider key nutrients in their diet.

A study focusing on recreational athletes with chronic tendon disorders found that the treatment group given the following supplements (table 1) had 99% pain reduction as compared to 31% reduction in the control group. Additionally, activity in the sport increased with the treatment group 42% over the placebo group (5).

Let's Take a Closer Look at Each of the Ingredients

Eicosapentaenoic Acid, Docosa-Hexaenoic Acid and Gamma-Linolenic Acid

There is significant evidence to suggest that eicosapentaenoic acid (EPA), docosa-hexaenoic acid (DHA) and gamma-linolenic acids play a role in the reduction of inflammation as well as acting as anti-inflammatories. Our diets are often high in arachidonic acid (n-6 polyunsaturated acid) and low in EPA, DHA, and GLA. As consumption of omega-3's are increased, cytokines, pro-inflammatory compounds produced by the body, decrease (2). To confer the benefits of these anti-inflammatory effects, high levels of DHA have demonstrated a decrease in inflammation as well (6). Try to eat three ounces of fatty fish twice a week and focus on plant oils as opposed to saturated fats. If you prefer not to eat fish, try walnuts, flaxseed, canol, and soybean oils.

Selenium

Selenium is important in the function of many enzymes, but in the case of muscle injury, plays a vital role in the glutathione peroxidase and thioredoxin reductase pathways. These pathways are essential for pro-

tection against oxidative injury and operate at optimal efficiency with adequate amounts of selenium (7). Food sources of selenium include tuna, cod, turkey, eggs, garlic and fortified grains such as, oatmeal and breads. The RDA for selenium is 55ug/day for men and women.

Zinc

Zinc is essential for wound healing and inflammation as well as proper immune response. Foods that are high in zinc include yogurt, lentils, beans, peas, milk, spinach, and seafood. The RDA for zinc is 11mg/day for men and 8mg/day for women.

Vitamin A

In order for muscle injuries to heal properly, it is essential that the diet includes vitamin A. Functions of vitamin A include cellular growth, development, bone repair, and immune function. Food sources plentiful in vitamin A include sweet potatoes, carrots, mangos, spinach, and red bell peppers. The RDA for vitamin A is 900 retinal activity equivalents (RAE)/day for men and 700 RAE/day for women.

B6

Vitamin B6 is imperative for proper protein and red blood cell metabolism – both important for muscle recovery. Vitamin B6 is commonly found in fortified foods, garbanzo beans, potatoes (with the skin), seafood, and avocados. The RDA for vitamin B6 is 1.3mg per day for both men and women.

Vitamin C

Vitamin C plays an important role in the formation of collagen which is needed for strength and flexibility and it also helps repair tendons, ligaments, and strengthens bones. Vitamin C can be found in foods such as citrus fruits, cabbage, tomatoes, broccoli, and strawberries. The RDA for vitamin C is 90mg/day for men and 75mg/day for women.

Vitamin E

Animal studies have shown the potential for Vitamin E (or alpha-tocopherol) to decrease the amount of oxidative stress and inflammatory damage that occurs with exercise. After a diet high in vitamin E for three weeks,

Key Recovery Nutrients	
Ingredient	Amount
Elcosapentaenoic Acid (EPA)	376 mg
Docosa-Hexaenoic Acid (DHA)	264 mg
Gamma-Linolenic Acid (GLA)	672 mg
Selenium	100 ug
Zinc	15 mg
Vitamin A	1 mg
Vitamin B6	2.2 mg
Vitamin C	90 mg
Vitamin E	15 mg

Table 1

rats ran on a treadmill for 60 minutes. Markers of oxidative and inflammatory stress were measured and results showed that the treatment group that was high in vitamin E had significantly lower levels of these markers than the non-treated exercise group (1). Food sources of vitamin E include wheat germ, sunflower oil, peanuts, almonds, spinach and broccoli. The RDA for vitamin E is 15mg/day of RRR-alpha-tocopherol.

Protein

During muscle recovery, energy and protein needs are increased and metabolism is altered. For muscle soreness, the least severe injury, protein and energy needs are increased for up to 48 hours post-injury. Additionally, fat oxidation is increased and insulin sensitivity is decreased (4). For more intense injuries such as those in the soft tissue and skeletal muscle, basal metabolic rate (BMR) may be increased by 32% for up to three weeks. Furthermore, highly trained athletes often continue an alternative workout program which could create a negative nitrogen balance and increase protein needs in the diet (4). Recommendations for protein are 1.2 – 1.8g/kg body weight for athletes and those in recovery.

Proper nutrition is an important component for recovery of muscle injury. In the long-term, foods with anti-inflammatory properties not only enhance recovery, but help to prevent reoccurrence of injury. Eat well for recovery. ■

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Central and Peripheral Adaptations to Training

Todd Miller, PhD, CSCS

The coming of the New Year inevitably brings with it countless resolutions, most of which typically involve some type of positive behavior change. Two of the most popular New Year's resolutions are to lose weight and exercise more, not necessarily in that order. The fact that these resolutions are the most popular year after year is a testament to the fact that these resolutions are rarely kept; for if they were, the number of people in need of this positive lifestyle modification would be decreasing, not increasing.

Exercise adherence is a well studied issue, and conservative estimates show that 50% of people who self monitor their exercise programs will drop out in the first six months (1). While a host of factors contribute to this poor level of adherence, a major factor that deters people from maintaining an exercise program is a perceived lack of results. It's not surprising that an individual who logs hours on a treadmill over several weeks and shows no loss in weight would lose interest and drop out. Despite good intentions, these people often feel as though their exercise programs "didn't work", since they saw no change on the bathroom scale. The reality is that exercise training, despite whether it induces weight gain, causes profound changes in the body, most of which are not visibly evident. This paper will describe what those fundamental changes are, focusing primarily on endurance and resistance training.

Training Adaptations

The body interprets exercise as a stress, and when stressed repeatedly, attempts to adapt in ways that make that stress less fatiguing. These adaptations can generally be divided into two categories; central and peripheral. Central adaptations can be classified as ones that affect the heart, lungs, and central nervous system, while peripheral adaptations are ones that affect the working muscles themselves. A good analogy to explain these adaptations would be to examine a simpler mechanical system- the automobile. A car's engine receives fuel

from the gas tank via a fuel pump. The pump delivers a metered volume of fuel at any given time; an amount that is determined by how much fuel the engine can burn during that same given time. Increasing the volume of fuel that the pump delivers (a central adaptation) will not result in an increased power output of the engine, unless the engine's capability to burn the fuel is also increased. Similarly, increasing the size of the engine (a peripheral adaptation) will not result in increased power output unless we also increase the volume of fuel the pump can deliver. If we translate this analogy to the human body, and we think of the heart as the fuel pump and the muscles as the engine, we can see that both central and peripheral adaptations must occur following chronic exercise in order to increase the body's overall performance. The degree to which central and/or peripheral adaptations occur is fundamentally dependent on the type of exercise that is performed; aerobic or anaerobic.

Aerobic Training

Aerobic training involves relatively low intensity rhythmic movements which elevate heart rate to a steady state, and is most commonly employed when one's goal is to increase cardiovascular fitness and/or lose weight. By definition, "aerobic" means requiring oxygen. Therefore, we can think of any aerobic exercise as one that depends on oxygen for energy production. Again, the automobile provides a good example. A car's basic function is to mix gasoline and air, and burn it to release energy. That energy is then transferred to the wheels to make the car move. We can think of this fuel burning process as an "aerobic" one, since oxygen is a necessary requirement for it to occur. Without oxygen, the fuel can't burn and the car can't move. A very similar process occurs in humans during aerobic exercise. Oxygen is delivered via the blood to the muscles, where it is used to help metabolize or "burn" the food that we eat, releasing energy that is used to power the muscles to do mechanical work. In order to increase the maximal amount of

mechanical work we can perform aerobically, we must maximize both the heart's ability to pump blood to the muscles, and the muscles' ability to extract oxygen from the blood.

Central Adaptations to Aerobic Training

Aerobic exercise incorporates rhythmic movements, and typically involves the large muscles of the legs. Each time these muscles contract, a large amount of blood is forced out of them, and back toward the heart. This pumping action is responsible for creating a venous return to the heart. In turn, this increased volume of blood returning to the heart fills the heart to a greater degree than at resting levels, and literally stretches the heart. As a result of this stretching, the heart contracts with a higher degree of force, ejecting more blood into the circulation. The volume of blood ejected by the heart is called stroke volume, and the ability to alter maximal stroke volume is the single most important adaptation to aerobic exercise. Performing aerobic exercise over a long period of time causes large increases in venous return. This chronic stretching of the heart causes the internal volume of the heart to increase. As a result, stroke volume undergoes dramatic increases following aerobic training. For example, well trained athletes can have maximal stroke volume values that are twice that of normally active people (2). This increase in stroke volume is what is responsible for the significantly reduced heart rate that is seen in well trained endurance athletes at rest. Put simply, the heart does not need to pump as often, since it is ejecting such a high volume of blood per beat.

Peripheral Adaptations to Aerobic Training

As was alluded to earlier, increasing the heart's ability to deliver blood would have a relatively small effect on exercise performance, if it were not for the large training induced changes that occur in the exercising muscles. Because the

heart's ability to increase its output is so dramatically increased with training, the muscles' ability to accommodate this large increase in blood flow must increase accordingly. The ability to accept large increases in blood flow is accomplished by generating new capillary networks within the muscle, effectively increasing the volume of blood the muscle can hold at any given time. Additionally, muscles are rich with mitochondria, the cellular structures where oxygen is metabolized to produce energy. The size, density and number of these structures increase profoundly with aerobic training. This increased ability to metabolize oxygen, coupled with the muscles' ability to accept greater volumes of blood, are the primary peripheral adaptations to aerobic exercise training and can lead to tremendous increases in aerobic exercise performance with long term training.

Resistance Training

One of the primary features of resistance exercise is that unlike an automobile, it relies primarily on energy that is produced in the absence of oxygen (anaerobic). Because this type of exercise does not rely heavily on oxygen, the ability to maximize blood flow to muscle is less important than it is with aerobic exercise. Therefore, the increases in stroke volume and muscle capillarization that are seen with aerobic exercise do not occur to the same extent with resistance training. As you might expect, there are pros and cons to not requiring oxygen for energy production. On one hand, because energy production is not reliant on oxygen delivery to muscle, we can produce energy very rapidly anaerobically. However, anaerobic energy production generates high levels of lactic acid, which limits our ability to exercise. Therefore, although energy can be produced rapidly anaerobically, we cannot maintain anaerobic activities for nearly as long as we can aerobic ones. Despite this, significant adaptations to resistance training do occur, and they are well matched to the demands of this type of activity.

Central Adaptations to Resistance Training

Unlike aerobic exercise, which involves repeated contraction and relaxation cycles of a muscle, resistance training causes muscles to be under constant tension during the course of a given set. As a result, pressure within the muscles is very high and causes a temporary occlusion of blood flow into the muscle while the exercise is being performed. Because there is little blood flowing into the muscle during the exercise, there is little blood leaving the muscle, and unlike the case of aerobic exercise, venous return to the heart is low. Without the increase in venous return, increased stretching of the heart does not occur with resistance training and stroke volume typically does not increase. This is one of the main reasons why resistance training does not bring about significant changes in maximal aerobic exercise performance. While the central adaptations to aerobic training focus mainly on the heart, the most important central adaptation to resistance training involves the brain. With most sport activities, repetition brings about improved performance, in large part due to the brain's ability to coordinate the musculature. These same principles apply to resistance training, as is evidenced by the rapid increase in strength that is enjoyed when an untrained person begins resistance training. Typically, at the onset of a resistance training program, increases in strength occur long before any measurable increase in muscle size. These profound increases in strength are due primarily to the brain's improved ability to increase the number of muscle fibers it can simultaneously recruit. Additionally with training, the brain becomes more adept at synchronizing the fibers within a given muscle, resulting in a higher muscle contraction force.

Peripheral Adaptations to Resistance Training

While resistance training brings about profound, important changes in muscle, these changes are very different from the peripheral changes seen

with aerobic training. Resistance training is typically employed for the purpose of increasing muscle strength. While these increases in strength are initially accomplished by increasing neural activity of the muscle, further gains in strength occur from changes in the muscle itself. Chronic resistance training causes increases in muscle protein production, and this protein gets incorporated into existing muscle fibers, causing an increase in muscle fiber size. This increase in fiber size contributes to the increase in muscle strength that occurs following long term resistance training. This increase in muscle fiber size can actually decrease the capillary density within a muscle, hampering performance during aerobic activities.

Programmatic Concerns

The fact that resistance and aerobic training can result in completely opposite adaptations raises important questions regarding program design. These questions are often posed far too generally to be answered with any accuracy. Some common examples are “Can I do aerobic training and resistance training on the same day?” and “Will doing aerobic exercise after lifting cancel out my strength training benefits?” The short answer to these and virtually every other question on this issue is “it depends”. The most important factor to determine when designing any exercise program is the desired outcome. If one’s goal is to maximize aerobic exercise performance, then it makes little practical or physi-

ological sense to spend a great deal of time, if any, strength training. Similarly, if one’s goal is to maximize muscular strength, aerobic training will not help to achieve this goal. Indeed, we do not often find an elite powerlifter running on a treadmill, nor do we see marathoners trying to maximize their deadlifts. However, if one’s goal is to improve general fitness, or participate in a sport that has a mix of physical demands, a program that combines both aerobic and resistance training is likely the most sensible approach. ■

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