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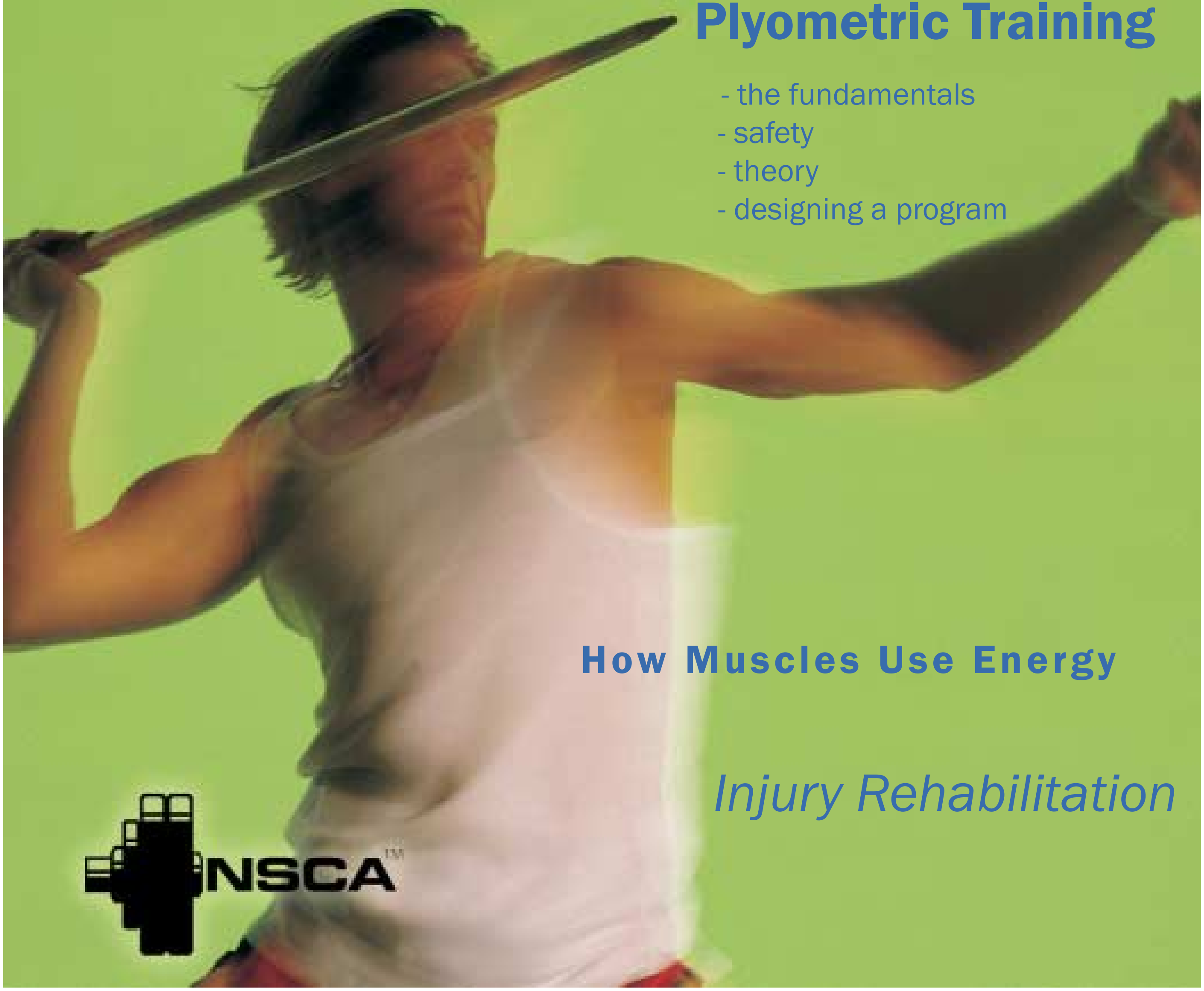
NSCA's Performance Training Journal

Plyometric Training

- the fundamentals
- safety
- theory
- designing a program

How Muscles Use Energy

Injury Rehabilitation



NSCA™

Volume 2, Number 2

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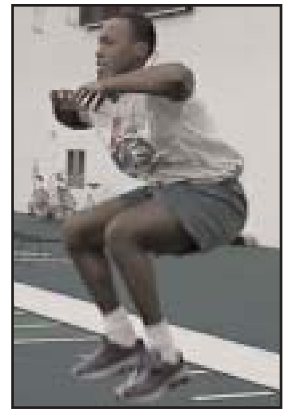

Feature: Plyometrics

Departments

NSCA's Performance Training Journal

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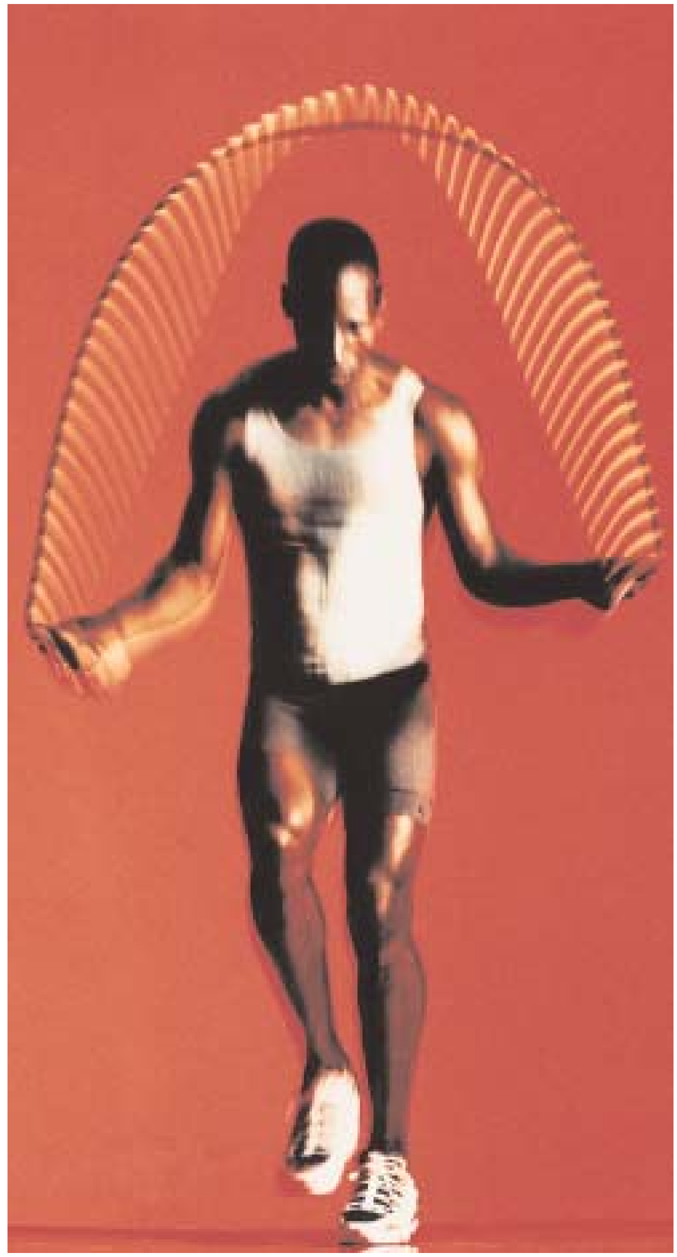
As the worldwide authority on strength and conditioning, we support and disseminate research-based knowledge and its practical application, to improve athletic performance and fitness.



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FitnessFrontlines

G. Gregory Haff, PhD, CSCS

Is Creatine Use Safe?

Recent research performed at Truman State University in Kirksville, MO suggests that long-term creatine supplementation has no detrimental effects on liver and kidney function. Researchers at Truman State examined the effect of long-term creatine supplementation on the liver and kidney function of collegiate football players. Creatine supplementation was undertaken for an average of 2.9 +/- 1.8 years with supplementation dosages that ranged from 5 – 20 grams per day. When venous blood samples were compared between the creatine treatment and control groups there were no differences found in any of the clinical markers typically used to determine impairments in liver and kidney function. Additionally, all measures determined for the creatine group fell within clinically normal ranges.

Mayhew DL, Mayhew JL, Ware JS. (2002). Effects of long-term creatine supplementation on liver and kidney function in American college football players. *International Journal of Sport Nutrition and Exercise Metabolism, 12(4)*:453 – 460.

Does Post-Exercise Nutritional Supplementation Alter the Hormonal Response to Resistance Training?

In a recent study conducted by Alun Williams and colleagues, the acute hormonal responses to different resistance exercise protocols with and without a post-exercise carbohydrate-protein beverage were examined. According to this study, published in the European Journal of Applied Physiology, post-exercise carbohydrate-protein supplementation had no effect on lactate, growth hormone, or cortisol responses to resistance exercise. Conversely, the supplementation protocol resulted in elevations in insulin and blood glucose levels. The authors suggested that these elevations in insulin combined with the increased availability of amino acids post exercise may promote increases in post resistance exercise protein synthesis. Based upon the current study and the current scientific body of knowledge the authors of the present study suggest that post exercise carbohydrate and protein supplementation may result in stimulating muscle growth as a result of enhanced intracellular amino acid availability and the anabolic actions of insulin.

Williams AG, Ismail AN, Sharma A, Jone DA. (2002). Effects of resistance exercise volume and nutritional supplementation on anabolic and catabolic hormones. *European Journal of Applied Physiology, 86*:315 – 321.

Does a Moderate Fat Diet Impair Strength Performance?

Researchers at the University of Findlay in Findlay, OH recently examined the effects of varied levels of dietary carbohydrate and fat intake on exercising training and high intensity exercise performance in moderately trained athletes. Subjects participated in a randomly assigned crossover designed study. Subjects participated in two 3 week treatment conditions: a high carbohydrate, low fat condition (62% carbohydrate, 20% fat, and 18% protein or a moderate carbohydrate and fat condition (42% carbohydrate, 40% fat, and 18% protein). Results of the study revealed no significant differences in isokinetic peak torque, total work production, maximal bench press strength, or muscular endurance between the two dietary conditions. Additionally, exercise logs revealed that over each 3-week treatment period, training volume and intensity were maintained. Based upon the finding of the present study the researchers concluded that a moderate carbohydrate/fat diet does not impair training and muscular strength performance of moderately trained male athletes.

Van Zant RS, Conway JM, Seale JL. (2002). A moderate carbohydrate and fat diet does not impair strength performance in moderately trained males. *Journal of Sports Medicine and Physical Fitness, 42(1)*:31 – 37.

About the Author

G. Gregory Haff, PhD, CSCS is an assistant professor and the Human Performance Laboratory Director at Midwestern State University in Wichita Falls, TX. He serves as the program director for the USA Weightlifting Regional Development Center at Midwestern State University and is a member of the National Strength and Conditioning Association's Research Committee and the USA Weightlifting Sports Science and Sports Medicine Committees. Dr. Haff received the National Strength and Conditioning Association's Young Investigator Award in 2001.

MindGames

Suzie Tuffey Riewald, PhD, NSCA–CPT

Broaden Your Approach to Injury Rehabilitation

Injuries are no fun. Injuries cause discomfort (severe pain in many instances), disrupt training routines, negatively impact fitness level, and can take you away from an activity you enjoy. Given all this, who in their right mind wouldn't find injuries to be "a drag?" Unfortunately, injuries are a relatively common occurrence in athletics. Whether you are a recreational or competitive athlete, chances are you have experienced some sort of injury—a sprained ankle, pulled hamstring, stress fracture, broken bone, torn rotator cuff, or some other injury.

CEDRIC TAYLOR

Many times rehabilitation is an important step in getting back out on the playing field. But besides taking time off, is there anything that can be done to facilitate the injury rehabilitation process? After all, the quicker you can get past the injury, the quicker you can get back to your training routine and back to pursuing your performance goals.

Wait a minute. Why are we discussing injuries in the Mind Games column? These articles are supposed to address the mental aspect of training and performance. A discussion on injuries would be more relevant in a Sports Medicine article, right? Not necessarily, as you'll learn below.

Psychological Aspects of Injury Rehabilitation

Years ago, injuries were strictly viewed as a physical issue; rehabilitation focused entirely on doing what was necessary to facilitate the physical recovery process, including rest, ice, muscle stimulation, physical therapy, and even surgery. The psychological aspect of injury rehabilitation was very rarely considered. Over the years, however, things have changed. We now know, from research on athletes, from talking with athletes, and from talking with athletic trainers, that psychological factors—such as motivation, attitude, goals, optimism, and imagery—play a role in the rehabilitation process. Actually, it makes intuitive sense that mental factors can influence recovery from injury. If psychological factors can influence performance in sport, exercise and other achievement endeavors, it seems reasonable to suggest that the same holds true for rehabilitation. To illustrate this point, compare the following two scenarios and identify which athlete you would guess is going to rehabilitate more

successfully.

- Darren landed wrong on his ankle after grabbing a rebound and hobbled off the court. The doctor told him it was an ankle sprain. A physical therapist provided him with at-home strengthening and mobility exercises for his ankle and he begrudgingly completed most of the exercises, although he couldn't see how many of the exercises would help his recovery. It was just going to take time. And, he was probably going to have to pull out of the upcoming 3-on-3 tournament, so he lacked the motivation to really get after it.
- Kyle wasn't paying attention when he was out for his run. He stepped in a pothole and also sprained his ankle. It occurred at a bad time as he had been training for months for a local 10k road race that was now only three weeks away. His doctor told him if he worked on maintaining his fitness level through cross training and committed to his rehabilitation, he might be able to run the race. Kyle did just that—he switched to swimming and biking and dedicated himself physically and mentally to the rehabilitation process. All along he recognized that the rehabilitation was a necessary, and critically important, step in getting back out onto the road so he kept a positive attitude towards the whole thing.

These examples clearly illustrate how mental factors can influence rehabilitation. A betting person would predict that Kyle is going to recover faster. He maintained a positive attitude, stayed motivated, and was confident in the rehabilitation process. Let's now direct our attention to three strategies you can implement to address and take advantage of the mental aspect of injury rehabilitation.

Strategies To Get You Back to Your Training Routine

Education

As the injured athlete, a critical step to help you successfully navigate through the rehabilitation process is to educate yourself. Too often, athletes take a passive role and allow rehabilitation to happen to them rather than being actively involved in the process. By educating yourself, you can have more of a direct influence on the process.

Get answers to questions such as:

- How severe is the injury?
- What muscle, tendon, ligament, or bone is damaged?
- How will the injury impact my training and other activities?
- What is the rehabilitation program and timeline?
- What can be expected in terms of symptoms and potential setbacks?
- What are my limits?

Having answers to these and other questions, can enhance your understanding of the rehabilitation process, spark your motivation, and help you maintain a positive attitude. In the scenario above, Darren lacked motivation, in part, because he didn't understand what he was doing in rehabilitation and why. Education can facilitate a positive attitude, as you'll have a sense of what to expect and won't be derailed by setbacks.

Rehabilitation and return to training goals

You already know how beneficial goals are in your pursuit of performance accomplishments. Goals provide you with direction (where do you want to go?) a plan (how will you get there?) and feedback (how are you doing/progressing?). These same benefits can, and should, be applied to injury rehabilitation. You are simply shifting your focus from athletic performance to rehabilitation performance. Based on your understanding of the injury and rehabilitation, identify daily and weekly goals regarding rehabilitation (i.e., increase strengthening exercises by five repetitions, increase to two sets of mobility exercises). Keep track of your goals and goal accomplishment. This will force you to recognize incremental improvements that may otherwise go unnoticed and help keep your attitude positive and your motivation high.

As rehabilitation progresses, shift your goals from a focus on rehabilitation to a focus on your return to training. A common mistake made by many athletes is jumping back into training at the level they were at prior to the injury—trying to lift the same weight, run the same distance or cycle at the same intensity. Re-injury or incurring another injury due to over-exerting one's self is a frequent result. It is important to set goals that focus on slowly getting yourself back to normal training loads. Not only does this keep you "reined in" and prevent you from overdoing it, but such goals also provide you with more realistic expectations regarding your performance. Setting progressive post-injury goals helps you recognize improvements made since being injured and avoids the comparison with pre-injury performance.

Use mental skills applied to rehabilitation

The mental skills that you use to enhance your athletic per-

formance—ones we've discussed in this column previously—should be applied to your rehabilitation. Mental skills and strategies such as concentration, confidence, self-talk, imagery and anxiety management have been found to be beneficial in enhancing athletic performance and can be applied to rehabilitation "performance" with similar success. For example, as an athlete, you have undoubtedly worked on managing your self-talk (that internal chatter in your head) so it helps rather than hurts your performance. You've probably used cue words or positive affirmations to direct your self-talk and keep it productive and positive. Take the same approach with your self-talk related to rehabilitation by trying to manage your internal dialogue. Be kind to yourself as opposed to critical; tell yourself what you can do, not what you can't do.

The use of anxiety management strategies presents another good example. Prior to a competition, test set, or maximum training effort, you have probably needed to use various strategies to help manage your nervousness—strategies such as deep breathing, progressive muscle relaxation, imagery and self-talk can help you manage cognitive and somatic anxiety. Do the same regarding the anxiety experienced in rehabilitation. Purposefully apply anxiety management strategies if you find yourself anxious about rehabilitation or your return to training (which is a common reaction).

Summary

While it is my hope that you are injury-free in your pursuit of sport and exercise goals, this article has attempted to "arm" you with information to facilitate the rehabilitation process should you become injured—whether you strain a calf muscle, have plantar fasciitis, or break your leg. As a starting point, it is imperative for you to recognize that psychological factors can influence the rehabilitation process. Next, take advantage of psychological skills and strategies by implementing them in rehabilitation—optimize your rehabilitation performance by taking control of the mental aspect.

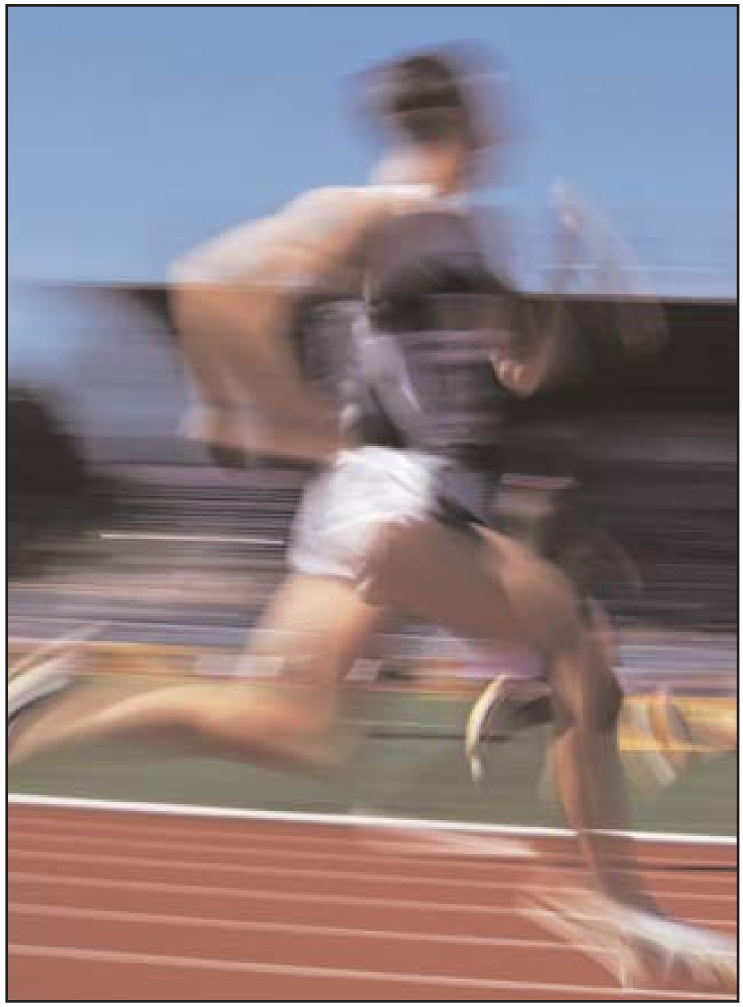
About the Author

Suzie Tuffey Riewald received her Master's and PhD in Sport Psychology/Exercise Science from the University of North Carolina-Greensboro. She has worked for USA Swimming as the Sport Psychology and Sport Science Director, and now is Associate Director of Coaching with the USOC where she works with various sport national governing bodies (NGBs) to develop and enhance coaching education and training. Additionally, Suzie is an NSCA-Certified

YourBody

Scott Riewald, PhD, CSCS, NSCA-CPT

Energy Storage in Muscle



Muscle is an amazing structure, as it is the only tissue in the body that can actually generate forces and drive movement. However the interaction between muscle and its tendon(s) is potentially even more interesting. Believe it or not, muscles and tendons can act much like a spring does—storing energy that can be later used to help propel a movement. Think about what happens to a spring, or even a rubber band, as it is stretched. Some of the energy that you produce to stretch the spring is actually stored as potential energy in the spring. The type of energy that is stored in the spring when it is stretched (and in a muscle-tendon unit when it is stretched) is called elastic energy. When you release one end of the spring it snaps back to its pre-stretch condition. Under the right conditions, muscle and tendon can behave in much the same way as the spring. This feature of muscle-tendon units is beneficial in understanding the theory behind plyometric exercises.

The body uses the energy storage and release properties of muscle and tendon all the time. The best, and most common, example is running. When you run, every time the foot hits the ground, some energy is stored in the Achilles tendon as it is stretched and then returned to provide propulsion as the foot pushes off the ground.

In discussing elastic energy storage, it is important to realize that just because you stretch a muscle it does not mean that you will store energy that can be used later. Stretch any muscle in the body and it will not automatically snap back to its pre-stretch state. Several important events must take place for this storage to occur.

The tendon must be actively stretched in order to store energy. In other words the muscle must undergo an isometric or eccentric contraction in which the fibers of the tendon are stretched. (For more information on the types of contractions see the February 2003 *NSCA's Performance Training Journal*). In both of these scenarios the tendon is actually being stretched. Think about the isometric, or constant length, contraction. Even though the overall length of the muscle and tendon does not change, the muscle fibers are in fact shortening some, which means that the tendon is being stretched—and storing energy. A relaxed muscle will not store energy, unless it is stretched a great amount. Remember, the tendon must be stretched to store elastic energy, not just the muscle. In plyometrics this lengthening of the tendon is called the eccentric phase.

Research has shown that a muscle can generate more work if it is actively stretched (an eccentric contraction) before it contracts concentrically[1].

As a practical example, try performing two different styles of vertical jumps[2].

- The squat jump—Start the jump in a position that resembles the down position in a squat. Your arms should be held straight over your head to minimize their contribution to the jump. Once you get in this position, jump as high as you can, using both legs.
- The countermovement jump—Start the jump standing upright, with the arms held straight over the head. Quickly flex your knees and hips as you move into the down squat position. Then without stopping in the down position, jump as high as you can.

Which jump was higher? If you are like most people, you jumped higher in the second scenario. Why? In the squat jump, you are only using a concentric contraction of the knee, hip and ankle extensors to provide the force used to jump. In the countermovement jump, you are eccentrically stretching the tendons of the knee and hip extensors at the end of the downward movement and then using this stored elastic energy to add to the energy provided by the muscles contacting concentrically. You get an extra boost by eccentrically stretching the muscle-tendon units.

The muscle must actively contract shortly after the stretching phase. If there is little time between the stretch and shortening phases, much of the energy that is stored can be re-used to produce movement. However, the longer it takes to begin the concentric contraction the more energy will be lost. The time it takes to shift from the eccentric to the concentric contraction is called the amortization phase in plyometrics.

As an example, perform the countermovement jump described above, but this time use a slight variation in the technique. Instead of making the jump one continuous movement, stop in the down position for a couple of seconds and then jump. Most likely your jump height will be lower than what it was in the "normal" countermovement jump and close to the height you jumped in the squat jump. The quicker the transition form the eccentric to the concentric contraction the more energy there will be that can be used to augment the normal muscle contraction. If you wait too long, the energy stored in the stretched tendon will be lost. In essence the muscle fibers relax slightly and allow the tendon to shorten and release some of the energy it was holding.

Conclusion

The net result of this energy storage is that the muscle-tendon complex produces a greater amount of force than the muscle could produce on its own when contracting concentrically. Combine this with the activation of the stretch reflex (which is described in other articles in this issue) and the muscles can generate large amounts of force, rapidly.

As you can see, the way forces are generated and used to produce movement can be complex. There are a number of routes through which force can be produced. Plyometric training goes beyond the basic concentric contraction that most people associate with strength training to include the energy storage properties of muscle and tendon. Incorporating this aspect of training into your program will help to build strength and power and make you a better athlete.

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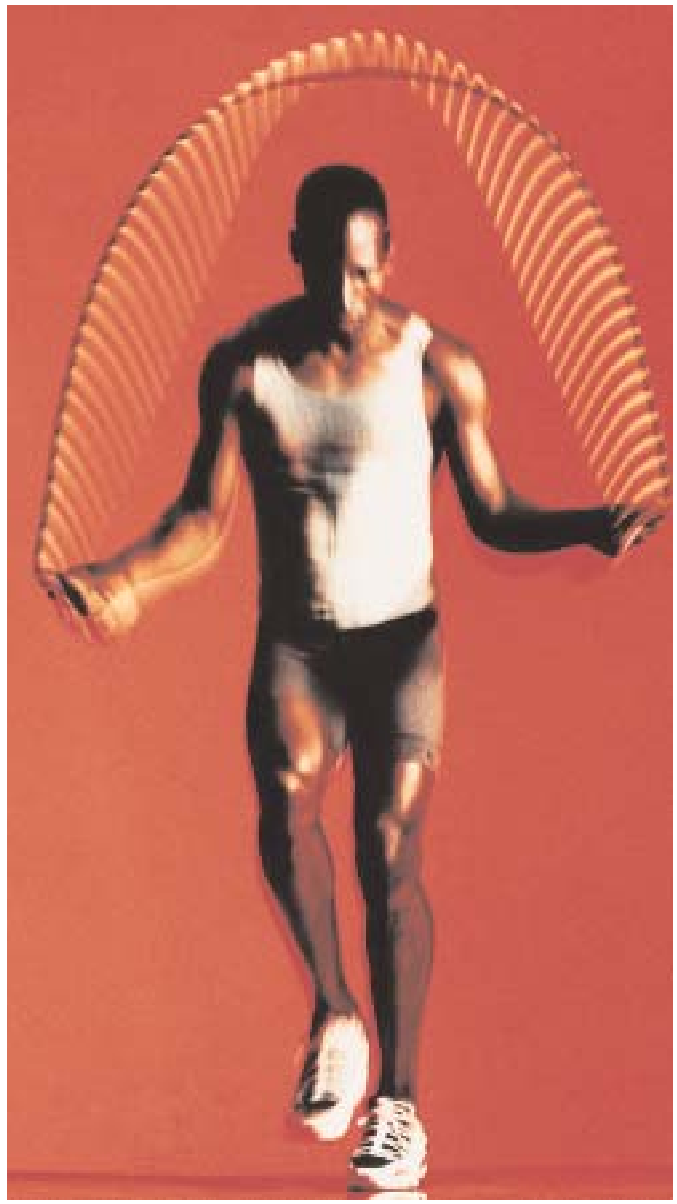
About the Author

Scott Riewald, PhD, CSCS, NSCA-CPT, is currently the Educational Programs Coordinator for the National Strength and Conditioning Association (NSCA). Prior to joining the staff at NSCA, he was the Biomechanics Director for USA Swimming from 1999—2002, where he developed biomechanical testing, research and educational material for the National Team. He obtained his PhD from Northwestern University in Biomedical Engineering/Biomechanics and is a Certified Strength and Conditioning Specialist (CSCS). Scott also worked for the US Olympic Committee as a research assistant and has developed testing protocols for a number of sports. Scott has worked with individuals who range from Olympic caliber athletes to persons who have suffered a stroke.

Theoretical and Practical Issues for Plyometric Training

Matthew R. Kutz, MS, MEd, CSCS



Plyometric exercise is becoming a staple in the training regimens of all levels of athletes and coaches. Twenty years ago plyometric exercise was something mysterious that only a few daring athletes and unconventional coaches did. Today plyometric training has evolved into a widely accepted and greatly effective tool to improve power and agility. Athletes of all ages and skill levels can safely perform plyometric exercises. Once thought as only box jumping this training tool now encompasses so much more than "only" jumping around. Because of the success associated with plyometric training, strength and conditioning programs that incorporate this aspect of training are becoming more and more creative and complex.

History

It was not until the 1970's that plyometric exercises or "jump training" began to gain popularity in the United States. Up until then, jump training was used primarily in eastern European bloc countries by the top athletes in sports like track and field, weightlifting, and gymnastics. A coach by the name of Veroshanski was among one of the first to publish a series of jumping drills. Originally the word "plyometric" comes from two Greek words, plio, meaning "more" and metric, meaning "to measure", or more accurately "measurable increase." The term plyometric was coined in 1975 by one of America's great track coaches, Fred Wilt.

Muscle Physiology

Plyometrics trains the muscle to reach maximum force in as short amount of time as possible. The ability to combine speed and strength is what we refer to as power.

The body has many supportive and connective structures including bones, muscles, and tendons. Muscle fibers are constructed of myofibrils. Each myofibril is made up of a series of contractile units called sarcomeres; sarcomeres are the fundamental contractile unit of the muscle cell.

Muscular contractions that produce movement are called isotonic. Isotonic contractions can come in two forms, concentric and eccentric contractions. A concentric muscle contraction occurs when the muscle shortens against resistance and an eccentric contraction is the lengthening of the muscle against resistance. An example of an eccentric contraction would be when the quadriceps muscles lengthen while contracting in order to decelerate the body after a run or on a landing.

Neurophysiological Aspects of Plyometric Training

The body also has proprioceptors, or receptors that are sensitive to tension and stretch. The muscle spindle is one of these proprioceptors and plays an active role in the stretch reflex. The stretch reflex is an involuntary response (contraction) to external stimuli that stretch the muscle (i.e. knee jerk reaction). In essence, when the spindle is stretched it sends out a signal to the spinal cord, which in turn sends a signal back to the muscle causing it to contract. The strength of the response of the muscle spindle is determined by the rate of stretch. Practically speaking this means the greater and more quickly a load is applied to the muscle, the more forceful the muscular contraction will be.

The Golgi Tendon Organ (GTO) is another proprioceptor located near the muscle-tendon junction and actually inhibits muscle contraction. The GTO protects against overloading and when it is stimulated it signals the muscle to relax. It may be that plyometric exercise can manipulate the threshold of GTO activation to maximize the elastic property of the muscle.

Each muscle fiber is innervated by a nerve, called a motor neuron, and the point where the nerve innervates the muscle fiber is called the neuromuscular junction (motor end plate). A motor neuron can innervate multiple muscle fibers, and the motor neuron and all the fibers it innervates are collectively called a motor unit. There are basically two ways to increase a muscle's force production:

1) increase the rate at which a motor unit is stimulated, and/or

2) increase the number of motor units that are activated.

Plyometric training influences these two factors affecting force production and speed of that force production. Basically it is plyometric exercise that trains the neuromuscular system to respond more efficiently.

Stretch-Shortening Cycle

The stretch-shortening cycle (SSC) involves storing potential energy in a stretched muscle. Phase 1 of the SSC is known as the eccentric phase where preloading and stretching of the muscle occurs. During this phase the stretching of the muscle stimulates the muscle spindle. The muscle spindle sends out a signal that ultimately causes the muscle to contract. The second phase of the SSC is the amortization phase. Amortization (or transition) refers to the time period between the eccentric contraction and the resultant concentric contraction. Simply stated it is the time that elapses between landing and jumping again. The amortization phase is the most important phase and must be kept short. The longer the amortization phase the greater the loss of stored elastic energy. The third and final phase of the SSC is the concentric phase, where stored elastic energy is combined with the voluntary, concentric muscle contraction to contribute to provide the force necessary for the subsequent movement, or jump.

Program Design and Basics

Plyometric training is not merely doing a movement fast, but also at max effort. An increase in power can come one of three ways;

1) increase movement speed while maintaining strength,

2) increase strength while maintaining movement speed, or

3) increase speed and strength simultaneously.

Plyometric training takes a functional approach by incorporating speed and strength into common sports related movements. Repetitions and sets become secondary, because each plyometric movement is its own set and repetition, each one consisting of a maximal bout. Coaches may have athletes perform repetitive or back-to-back jumps, but it is important for the athlete to consider each jump its own set and repetition.

Intensity is paramount to successful plyometric training. Each exercise is performed at a maximal effort and intensity is determined by number of foot strikes or touches. For the elite athlete a high intensity plyometric workout may consist of about 200 – 400 touches or foot strikes. The beginning or intermediate athlete is in the range of 60 – 150 touches.

During short duration, high intensity exercises, such as plyometrics, the body uses the phosphagen system to provide the energy (ATP) needed for muscle contraction. Once ATP stores are depleted it takes time to resynthesize them. Approximately 70% of ATP is resynthesized after about 30 seconds and 100% after three minutes. Therefore, the rest periods used when performing plyometrics should be from 30 seconds to 3 minutes depending on the individual. If a maximal effort is demanded of each touch or foot strike, then it is important to allow for adequate rest between bouts is allowed.

Progression is vitally important. Athletes who have never trained plyometrically should meet certain strength parameters

before beginning. As a general guideline, athletes should not be allowed to perform plyometrics unless they can squat 1.5 – 2.5 times their body weight.

The progression through plyometrics should be intentional, beginning with basic movements like marching and skipping. Progress to activities like footwork and lunging drills, alternate movement drills (forward/backward) then on to jumping drills. Jumping drills should begin with standing jumps progressing toward bounding and then depth jumps.

Safe Progression of Plyometric Exercises

1. Marching and skipping drills
2. Footwork speed drills
3. Lunging drills
4. Alternate movements (forward/backward)
5. Jumping drills

Safe Progression of Jumping Drills

1. Standing in place jumps
2. Standing jumps
3. Multiple hops/jumps
4. Bounding/cone drills
5. Box/depth jumps

Precautions

The National Strength and Conditioning Association (NSCA) has released a position statement on Explosive/Plyometric Exercises that gives the following precautions.

1. As a rule, athletes weighing more than 220 pounds should not depth jump from a platform higher than 18 inches.
2. Surfaces for where plyometric exercises are performed should be resilient and have good shock absorbing qualities.
3. Plyometric training should not be performed on consecutive days or when the athlete is fatigued. Conventional wisdom says to have about 48 hours between plyometric sessions.
4. Depth jumps only be used by a small percentage of athletes engaged in plyometric training.

Obviously progression is also an important key. Too much, too fast, too soon is never a good idea. Take it slow and progress at a reasonable pace, introducing more complex jumps and greater intensities over time maximizing the benefits of plyometric training.

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Introduction to Plyometrics

Michael Barnes, MEd, CSCS,*D, NSCA-CPT

For the healthy athlete, the benefits of a plyometric program have been proven in the scientific literature and anecdotally. Plyometric exercise is one of the most time-efficient training methods available, and has arguably the greatest transfer to sport application. Plyometric techniques can be executed for the entire body and also simulate specific movements observed in competition. They can be done with little to no equipment and the surface of choice is often a level grass field. Plyometrics are often performed in various planes of movement (up/down, left/right, and forward/backward).

There are several considerations that should be observed prior to implementing a plyometric program. Some of those considerations are:

- Age
- Body Weight
- Strength Prerequisite
- Sport Requirements
- Experience
- Previous Injury
- Jumping Surface
- Warm-up
- Progressions
- Recovery
- Frequency

One key aspect of plyometric exercise selection is to use a progression of movements before attempting more complex movements. Generally, try movements with both feet before one. Use a single repetition before moving to multiple repetitions. Emphasis should be placed on quality of movement at all times. There should be complete recovery between sets and exercises before proceeding with the workout. It is advisable to start with only one or two exercises in a training session and then add more to the routine as needed.

The remainder of this article will focus on some basic plyometric movements. These movements should only be implemented with experienced instruction in plyometric training.

Standing Jump Over Cone

The standing jump over a cone is used to progress to multiple jumps over cones. The athlete begins the movement behind the cone (see Figure 1) and makes a single jump (see Figure 2) over the cone and a controlled landing (see Figure 3). There is a combination of vertical and horizontal components that should be emphasized for the drill. In addition to visual observation, good body control can be determined if the athlete does not make any additional steps after the landing to regain balance.

Front Cone Hops

Front cone hops progress from the standing jump over cones. These multiple front cone hops are an excellent double leg plyometric drill for a variety of skill and sized athletes. A series of cones or barriers are placed in a line in front of the athlete. With double arm action the athlete simply hops over the barriers. Contact time on the ground should be as brief as possible, with the athlete maintaining a neutral spine position.

Figure 1 (far left): Standing jump over cone—preload

Figure 2 (left): Standing jump over cone—apex

Figure 3 (below): Standing jump over cone—landing

Lateral Jump Over Cone

A single lateral jump over a cone is used to progress to multiple lateral jumps over a cone. The athlete begins the movement on one side of the cone (see Figure 4) and makes a single jump (see Figure 5) over the cone and a controlled landing (see Figure 6). In addition to visual observation, good body control can be determined if the athlete does not make any additional steps after the landing to regain balance.

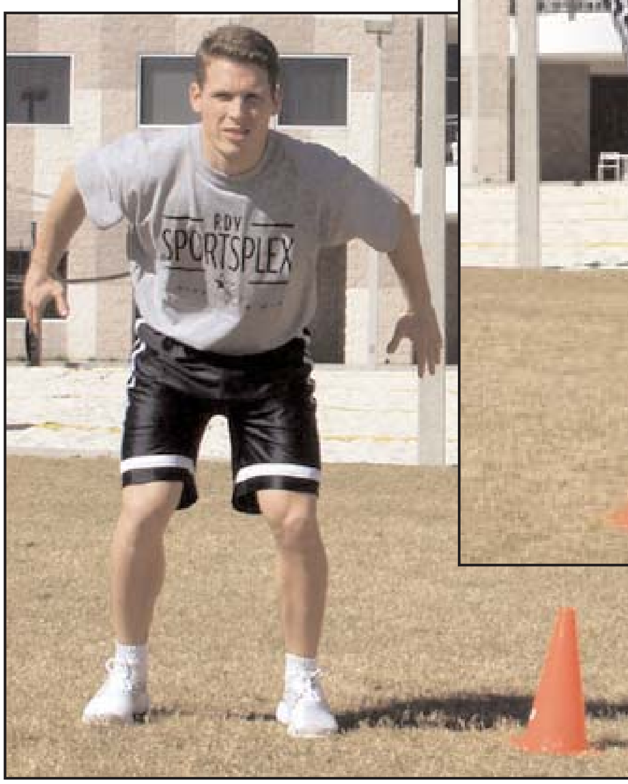

Figure 4 (left): Lateral jump over cone—preload

Figure 5 (center): Lateral jump over cone—apex

Figure 6 (right): Lateral jump over cone—landing

Box Jumps

The athlete is about an arms length away from a box that is of suitable height. The box height should allow the athlete to land with their knee bent to approximately 120 degrees. The athlete takes a forceful countermovement (see Figure 7) with a double arm swing flexing at the knees and hips. The torso is flat with the chest up. The athlete fully extends at the hips and knees, creating maximal force. While preparing for landing the hips and knees flex, the toes are up (see Figure 8). The athlete lands softly on top of the box to complete a single response (see Figures 9 and 10).

(From left to right)

Figure 7: Box jump—preload

Figure 8: Box jump—apex

Figure 9: Box jump—landing (side view)

Figure 10: Box jump—landing (front view)

Double Leg Hops

Double leg hops should emphasis height and distance. Use both arms to help generate power. The athlete takes a quick countermovement (see Figure 11) and explodes with maximum effort, fully extending the body (see Figure 12). The athlete lands softly with bend knees and hips (see Figure 13). No additional steps are taken which depicts good body control. Keep the amortization phase, or foot contact time to a minimum and keep the head up when using multiple repetitions.

Figure 11 (upper left): Double leg hop—preload

Figure 12 (center): Double leg hop—fully extended

Figure 13 (bottom right): Double leg hop—landing

Two Hand Chest Pass

For the two hand chest pass use a medicine or plyometric ball. The athlete stands with feet shoulder width apart (see Figure 14). While taking a step forward they bend and extend their elbows (see Figure 15). When the front foot lands they release the ball from their hands (see Figure 16). Alternate which foot steps forward for the drill. Multiple reponses can be implemented between two athletes when appropriate.

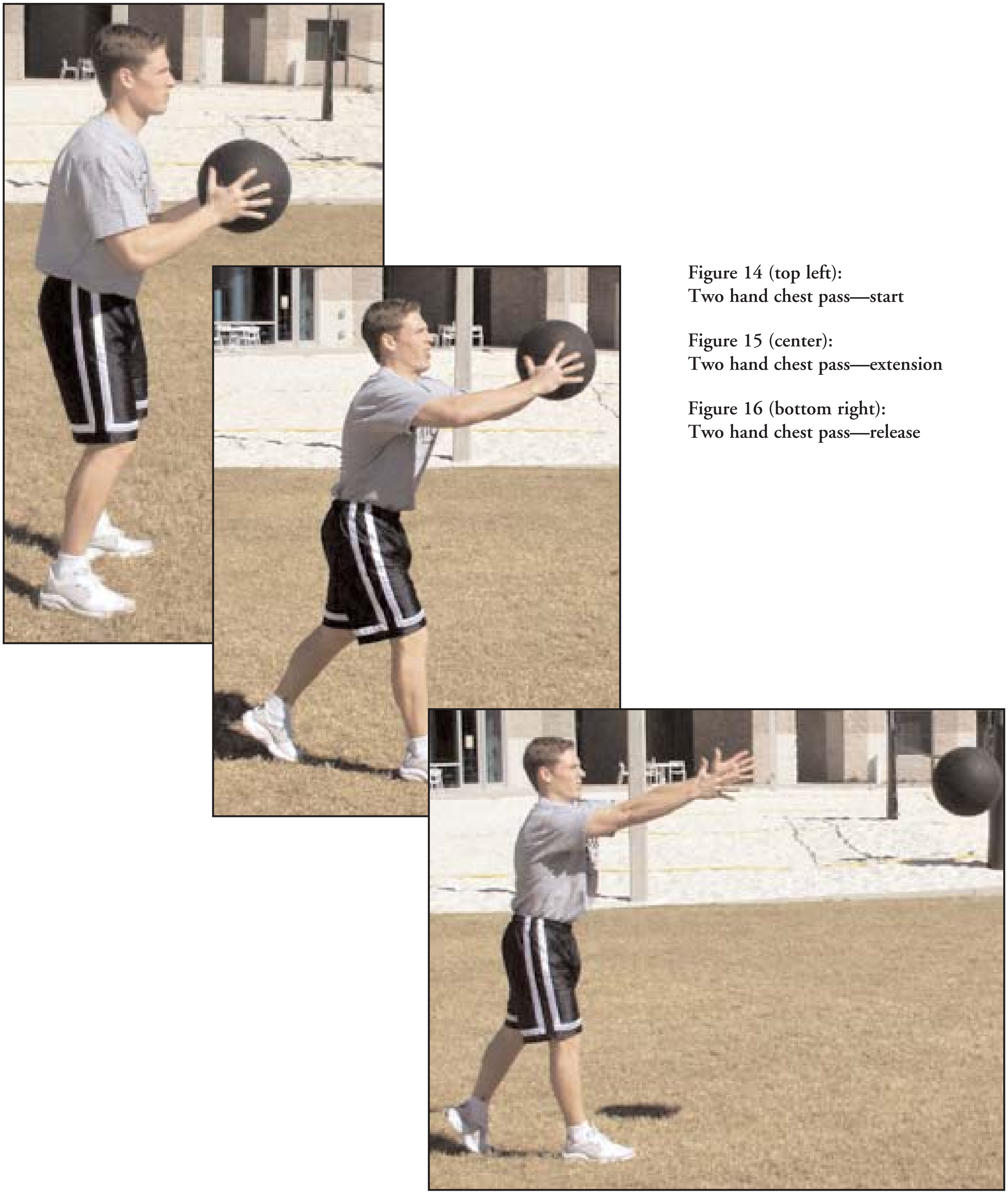

Figure 14 (top left):
Two hand chest pass—start

Figure 15 (center):
Two hand chest pass—extension

Figure 16 (bottom right):
Two hand chest pass—release

Plyometric Push Up

The plyometric push up from the ground is performed in a prone position. For the single response, position the hands wider than shoulder width and place the feet together with the toes on the ground. Maintain a rigid position, with the head, torso, trunk and legs in line. Perform a countermovement by lowering the body (see Figure 17), then exploding back up. Enough force should be generated so that the hands can leave the ground (see Figure 18) and perform a clap. Place the hands back out in front to catch the body, returning to the starting position (see Figure 19). Use a single response before progressing to multiple responses.

For multiple responses the athlete sets up the same way. Perform the counter movement and explode upward, trying to clap the hands. While the upper body is still in the air, return the hands to a position in front of the body. As the hands come in contact with the ground, reverse the motion and repeat the exercise with no rest. Keep the contact time, or amortization phase, as short as possible.

Figure 17 (top): Plyometric push up—start

Figure 18 (right): Plyometric push up—airborne

Figure 19 (bottom right): Plyometric push up—landing

Conclusion

The exercises listed in this article are intended to be a menu from which exercises are selected for a program. These movements should not be used as a plyometric program by itself. For more information on plyometrics, including progression, physiology, and implementing into a periodized program, consult the NSCA's *Essentials of Strength and Conditioning*, *Journal of Strength and Conditioning*, and *Journal of Strength and Conditioning Research*.

About the Author

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Form and Safety in Plyometric Training

James Radcliffe, MS

There is no limit to the variety of plyometric exercises that can be devised. It is possible to analyze each movement pattern of every sport skill and design a plyometric drill for that specific skill. However, for the best results in explosive power training, and safe and efficient utilization, progressions are the key.

For safety it is important to begin with the simpler, more fundamental drills and progress to the more complex and difficult. As you improve in strength and performance, then you can advance to the more difficult drills.

The drills and exercises presented in this article will proceed in a learning progression. The methods employed are exactly the manner in which they should be taught and mastered.

Jumps

Attaining maximum height (projection of the hips upward) is sought in jumping. While lead-up footwork can vary, jumps are usually performed involving both legs in the take-off and landing.

Figure 1 (above) and Figure 2 (right): Box jump

Pogo

This is the first exercise in the teaching and learning of jumping. The posture, landing, and take-off positions for vertical hip projection begin with these simple lower leg executions.

This exercise begins from an upright stance with the knees slightly bent, chest out, and shoulders back. Begin by emphasizing a vertical take-off, projecting the hips upward for height, using only the lower portion of the legs. The arms and shoulders of the upper body are used in an upward "blocking" fashion. Emphasize slight flexion and extension of the knee, and more flexion of the ankle and foot. Upon take-off, the ankle must lock the foot into a "toe-up" position (dorsi-flexion) maintaining this locked position throughout to ensure sturdy contacts and quick, elastic take-offs.

Squat Jump

This is a basic drill for developing power in the legs and hips, and is applicable to many sports.

Assume a relaxed upright stance with feet placed about shoulder width apart. Begin by flexing downward to a half-squat position; immediately check this downward movement and explode upward as high as possible, extending the hips, knees, and ankles to maximum length as quickly as possible. Initially, the landing is frozen, with no steps taken. Progression for this drill is from single response, to multiple response with a pause between repetitions, and then finally multiple responses (initiating the jumping phase just prior to reaching the semi-squat position again).

Box Jumps

The benefit of using a box for jumps is to lessen the forces of impact upon landing, aid in the execution of good landing mechanics, and provide a target for vertical hip projection (see figures 1 and 2). The box height should be set from mid-thigh to hip height. The following progressions for optimal box jumping rely on starting positions from an approximate arms length distance away from the landing platform.

- Static Squat: a semi-squat stance is taken, with feet positioned hip width and arms back in readiness to thrust forward.
- Counter-move: an upright stance with the same foot positioning and a quick flexion into semi-squat and subsequent explosive take-off.
- Step: one foot remains in the previous position under the hip, while the other foot is placed behind.
- Lateral step-bound: positioned approximately one and one-half steps directly to the side of the normal take-off position, push off with the outside foot and lead with the inside leg into a lateral move to a two foot take-off from the original take-off spot.

Figure 3: Knee tuck jump

Double Leg Butt Kick

This drill is used as the first of many movements that practice the transference of force. This drill also combines the act of flexing the knee joint to allow for upward lift with the lower leg. Using a quick counter-movement, extend the hips for vertical height and upon full extension tuck the toes up and pull the heels upward into the buttocks.

Knee Tuck Jump

This drill is performed in the usual progression of single response, multiple response with pause, and finally the multiple response method.

Begin by rapidly dipping down to about the quarter-squat level, and immediately explode upward. Drive the knees high toward the chest and attempt to touch them to the palms of the hands (see Figure 3).

Figure 4: Depth jump—start

Figure 5: Depth jump—landing

Split Jump

These jumps are good for developing striding power for running and cross-country skiing. Assume a split stance with one leg extended forward with the lead knee over the midpoint of the foot and the other leg back with the knee bent and located underneath the hips and shoulders.

Jump as high and straight up as possible. Block with the arms to gain additional lift. Upon landing, retain the split stance position, bending the knees to absorb the shock. It is important to keep the shoulders back and in line with the hips to maintain proper stability.

Scissor Jump

The initial movement of the scissor jump is identical to that of the split jump. Switching of the legs occurs in midair, and must be done very quickly before landing. Attainment of maximal vertical height and leg speed are stressed in this exercise.

Depth Jump

For this drill, an elevated surface (box or bench) approximately 12 to 28 inches in height is used. The step should not be higher than 18 inches if the athlete weighs more than 220 pounds. The landing surface should be forgiving, yet resilient. The depth jump is "shock methodology" via standing at the edge of the platform (see Figure 4). The objective of this position is to slide or fall off, rather than to jump or step off, and set a landing rhythm. As the drop occurs prepare for landing by flexing at the knees and hips (see Figure 5). Progression into the drill begins with repetitions of landing only. As proper landing position is achieved, efficient and immediate take-offs can be progressed to (see Figure 6). In depth jumping, it is upon landing, not after, that the jumping phase is initiated. Jumping, for as much height as possible, is accomplished by thrusting the arms upward and extending the body.

Bounds

Bounding involves movements that alternate from one leg to the other. This may not be executed in early progressions. The emphasis in bounding is to gain maximum horizontal distance with height being a factor in the success of that distance. Early progressions of horizontal hip projection encourage the need for double leg take-offs and landings (e.g. prancing, galloping and skipping) for the purposes of teaching and learning progressively.

Prance

This is the beginning progression for bounding. The hips are projected horizontally off of a two-foot landing and take-off. It is important that this drill is performed with take-offs and landings on both feet simultaneously.

Upon take-off the hips are pushed outward and upward with the knee of one leg recovering forward. Upon landing the take-off repeats itself with the opposite knee recovering forward. The upper body action is the same as in running. In order for both feet to land simultaneously the ankles must remain locked in a “toes up” position.

Gallop

This is a rhythmic exercise that helps to foster good hip projection and back leg push-off. Lead leg mechanics and proper “pawing” or leg cycle mechanics are also emphasized.

Begin by pushing off with the back leg and foot, keeping the ankle locked to emphasize a spring loaded landing and take-off. Continue to keep the same leg behind the hips and projecting them forward, while maintaining the opposite leg in a forward position for initial landing and balance within each stride.

Figure 6: Depth jump—immediate take-off

Ankle Flips

Ankle flips emphasize forward hip projection through extension at the ankle joint.

Begin by pushing the hips forward and outward from the lead foot and leg. With minimal knee flexion and the ankle locked, land with the opposite foot and quickly extend from that position so that the hips remain in a forward thrusting sequence with the ankle always projecting from slightly behind.

Lateral Bound

This exercise emphasizes lateral distance and horizontal trajectory sideways, allow the lead leg to countermove to shift the weight over to the outside leg for an immediate push-off and extension of the outside leg while the lead shoulder and knee drive for distance. The lead foot will land first with the trail foot following to balance out the landing.

Alternate Leg Bounds

This is the prime exercise in specific development of explosive leg and hip power.

Push off with the back leg, driving the knee forward and upward in an attempt to gain as much height and distance as possible before landing. Repeat the sequence, keeping the ankle locked in dorsi-flexion, the heel up under the hips, while reducing ground contact time with efficient hip projection. Either block with the arms in a contra-lateral motion, as with normal running, or execute a double arm swing.

Alternate Leg Diagonal Bounds

Perform this drill in exactly the same manner as the Alternate Leg Bounds but increase the distance from side to side as well as forward upon landings.

Skips

Skipping is performed in an alternating step-hop of right to right step then left to left step manner that emphasizes both height and/or horizontal distance. This step-hop method can be applied in all directions (forward, lateral, and backward).

Fast Skipping

This drill is performed by maintaining close contact with the ground, and eliminating “air” time. Actions consist of driving the lead leg toe up, propelling the knee forward and upward, and keeping the heel up under the hips. This sequence is performed as fast as possible. Stride distances are not emphasized, maximum thigh extension, recovery, and frequency are.

Power Skipping

Power skipping involves driving off of the back leg, initiate a short skipping step, and then with the opposite leg, thrust the toe and knee up. Obtain as much height and explosive power as possible after each short step. Block with the arms, while concentrating on lift, "hang-time," and minimizing ground contact time.

Hops

Hops are take off and landing movements from one leg onto the same leg. The primary emphasis in hopping is to achieve height and/or distance, with a maximum rate of cyclic leg movement. With the complexity of hops, early progressions require the balance and postural stability of using both legs for acquiring good hip projection, and cyclic leg action regardless of the direction (forward, lateral, or backward).

Double Leg Hop Progression

The use of cones or small hurdles help foster the technique in the beginning stages.

Using a quick counter-move, extend the hips for vertical height and upon full extension tuck the toes, knees, and heels upward in a cycling motion in order to clear the hurdle. Maintain posture and upright position by blocking with the arms. The execution progression is as follows:

- Single Response Hops: Upon completion of clearing the first hurdle, land with full foot contact, bending at the knees and hips to absorb the landing forces. After "sticking" this landing, pause and then reset the body position, stance, relationship to the next hurdle, etc, before executing the next hop. This reset allows for a reeducation of landing and take-off technique.
- Multiple Response Hops with Pause: These hops are executed by pausing for a brief moment, in as proper a landing position as possible, then performing the next take-off without having to reset the lower or upper body in order to be successful. Once the take-offs from pause are successful, progress to multiple responses.

Side Hop

This involves the use of 2 cones approximately 18 to 26 inches in height. Jump sideways over the first cone and then the second one. Without hesitating, change direction by jumping back over the second cone and then the first one; continue this back-and-forth sequence. Block with the arms in an upward thrusting motion to aid in lift and posture.

Single Leg Butt Kick

Using a quick counter-movement, extend the hips for vertical height and upon full extension tuck the toe and heel of the take-off leg upward and slightly backward into the buttocks. Maintain posture and upright position by blocking with the arms. In the same single response, to multiple response with pause, to multiple response progression, perform all of the repetitions with one leg then switch to the other.

Single Leg Hop Progression

The same progression that applied for the double leg hopping applies to the advancement of hopping in its most common terminology, with single leg. Using the counter moving effects of the "swing" leg for lift and drive, execute the hops in the same manner as progressed through with the double leg hopping.

Single Leg Hops of single responses

Single Leg Hops of multiple response with pause

Single Leg Hops of multiple response

About the Author

Jimmy Radcliffe, MS, earned a BA in Physical Education and Health from Pacific University and an MS is Exercise and Movement Science from the University of Oregon. He stayed at the University of Oregon as the Head Strength and Conditioning Coach and also contributes as an instructor in the Physical Activities and Recreation Department. Jimmy is the author of several books on plyometrics and has been a presenter at both NSCA and ACSM conferences.

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