Practical considerations for utilizing plyometrics

Part 1

1. What are the expected training effects of plyometrics.

Costello: If used properly and cycled correctly into the over-all program, plyometrics can have a major effect on improving power. Plyometric drills are designed to work fast-twitch muscle fibers, so consequently they can have a positive effect on quickness, speed and jumping ability. It must be remembered an athlete will not get the improvement if he or she is not utilizing a resistance program of some kind. You will get the best effects from plyometrics when they are cycled in with a good weight training program.

Rogers: Plyometrics bridge the gap between pure strength training and the applicable skills used by athletes in competition. Bigger and stronger do not necessarily mean better. But, bigger, stronger, and more powerful (excluding technique) means better. One theory proposes plyometrics allow an athlete to produce greater reactive force at the neuromuscular junction due to greater fiber recruitment and neuromuscular efficiency following a pre-stretch of that muscle. This, in turn, allows an athlete to be more powerful.

Different drills stress different regions of the body. The shoulders, lower abdomen, lower back, hip flexors, knee extensors and flexors, and calf muscles are all stressed to varying degrees by the different drills. As individual athletes’ weaknesses are discovered in these areas, different drills can be prescribed in order to strengthen and quicken these muscles. As the athlete continues to train and improve, an increase in reactive power can be expected which can be translated into greater leaping ability and faster sprinting times.

Chu: The training effects experienced through plyometrics are improved speed and strength qualities of the athlete. Plyometrics provide an overload to the musculature in a way which is different from weight training. Body weight accelerated by gravity provides a force and velocity which exceeds that of machine or free weights and also simulates actions present in many jumping, sprinting and throwing activities. This specificity in training is a necessary component for teaching the neuromuscular apparatus to respond more quickly and forcefully. Too often we look for means of accelerating the body or an implement horizontally, vertically or laterally, but we ignore the importance of decelerating the body more quickly. Converting work done on the body by gravity (or some other external force) to work done by the muscular system of the body in the recoil of elastic energy is dependent on the body’s ability to act quickly during the stretch-shortening cycle. Slow and/or long prestretch of the muscle will result in potential energy in the form of elastic recoil being lost as heat.

Thus, plyometrics becomes a means of training the neuromuscular system to react quickly and forcefully during a stretch-shortening type of action. Plyometrics also act to increase the neuromuscular system’s ability to perform concentric contraction more effectively because the forces encountered in plyometric exercises may lead to greater synchronous activity of motor units and earlier recruitment of larger motor units via the myotatic reflex. This behavior of motor units differs from voluntary actions where motor units normally fire asynchronously and motor units are recruited sequentially from small-slow-twitch to large-fast-twitch types.

The end results of plyometric training, then, are increased force production, greater speed and speed-strength capabilities demonstrated by the “reactivity” of the muscles.

Gambetta: Plyometric training is specific work for the enhancement of explosive power. Plyometrics improves the relationship between maximum strength and explosive power. Properly applied it will optimize this relationship. In sport there is seldom enough time to develop either maximum strength or maximum speed. According to Russian expert Veroschanski, it takes .5-7 seconds to develop maximum strength. There are few explosive/ballistic movements in sport that take this long. For example, ground contact time in sprinting is 1.15 seconds. Therefore, in most activities, a tremendous amount of force must be developed in an extremely short period of time. This is the ultimate function of plyometric training.

How does plyometric training achieve this function? It enhances the tolerance of the muscle for
increased stretch loads. This increased tolerance develops efficiency in the stretch-shortening cycle of muscle contraction. During the stretching (eccentric lengthening phase) of muscle contraction a greater amount of elastic energy is stored in the muscle. In ballistic types of exercise this elastic energy is re-used as mechanical work during the following positive work phase.

Wilt: Plyometrics are expected to improve the eccentric aspect of muscle action. It may have some effect upon evoking the stretch-reflex if done correctly. Some claim plyometric exercises seek to bridge the gap between sheer strength and power, but I know of no evidence indicating this is true. There may be other training effects of plyometrics with which I am unfamiliar.

Santos: For the track and field athlete, the most unique aspect of plyometrics is the ability of the athlete to be able to react quicker off the leg in the throws, sprints, and jumps, with positive effect on performance levels. For throwers, plyometrics has been a terrific aid in training as it prepares the athlete to respond quickly, without a loss of force during the pushing phase of the throws by the legs. For jumpers, and especially triple jumpers, it has been most beneficial in preventing the jumper from collapsing the takeoff leg on the takeoff phase of the jump. By using plyometrics and strengthening the jumping leg, often the athlete can save a jump and get off a successful attempt without bailing out.

Upper-body plyometrics is now coming into prominence, and we can see some very positive results in increased arm speed in the shot, discus, javelin, and other throwing events such as the baseball pitch and basketball release.

In track and field, the upper body has been neglected for years in the area of plyometric training, but through the use of medicine balls, upper-body training is making big strides for many athletic events. It has very positive results for the gymnast using the arms and hands to push-off the horse, pommel horse, or gymnastic mat. I think the field is wide open at this stage of development of exercises using upper-body plyometrics and strength exercises using medicine balls or other training devices to increase the reactive speed of the upper body in sports movements.

Bielik: When looking at what occurs during a plyometric response we see the breaking of inertia by the eccentric contraction and a myotatic stretch reflex followed instantaneously by a concentric contraction. For the entire series to occur properly a very brief time span is allowed for reaction time response.

During the descent of a bounding exercise, particularly a box drill, the body has developed much kinetic energy in the form of momentum. Upon ground contact the eccentric forces generated to break the inertial effects of ground contact tend to be of great magnitude. The increased muscular effort in the form of eccentric contractions are of higher values than normally experienced by the involved musculature. The athlete in turn will adapt, gaining an increase in eccentric strength.

At ground contact during the eccentric muscular contraction, the myotatic stretch reflex is initiated. Automatically following the reflex influence upon the concentric contraction, greater contractile force is expected allowing a corresponding jump response of greater magnitude. With the aid of the myotatic stretch reflex, the muscles involved are subjected to a training stimulus allowing the development of not only greater typical strength but also greater ballistic strength. We feel the latter is of primary importance. Plyometric training provides the training stimulus allowing the development
of greater muscular force characteristics at higher contractile velocities.

The final training effect of plyometric training involves the whole plyometric movement. Throughout each individual part a very brief time span is allowed for response. The short response time is due to both the timing required for technique execution and, of primary importance here, to allow the most effective utilization of the myotatic stretch reflex. Plyometric exercises provide the stimulus to develop the athlete’s reaction time.

We find our younger athletes have not yet learned how to use what speed potential they have recently acquired or have had for a relatively long period of time. Simple jumping activities usually associated with plyometrics allow our athletes not only to develop ballistic strength characteristics but also to nurture already acquired ballistic strength behavior.

Lundin: Plyometrics training appears to enhance the stretch-shortening cycle of muscle so frequently seen in ballistic movements as jumping, throwing and running. Experiments have shown that when a muscle resists being stretched, when it is performing eccentrically, it can resist with a force that is considerably greater than in concentric contractions (Atha, 1981). This eccentric force will increase with the increasing speed of lengthening, up to a certain limit. The high tension developed in such contractions, however, disappears very rapidly because the “stiffness” and elasticity of the muscle is related to the engagement and disengagement of molecular bridges between the myosin and actin filaments of the muscle fiber. When a muscle fiber is stimulated, a number of actinmyosin bridges are formed creating the stiffness in the muscle fiber which will either shorten or strongly resist being stretched.

Unlike a rubber band, however, the muscle fiber very rapidly loses its tension due to the breakdown of the actinmyosin bridges. The stored elastic energy is then dissipated as heat. If a shortening contraction takes place in the muscle in the short time before the tension has disappeared completely the high tension in the previously stretched muscle will act as an elastic recoil whose force can be added to the force developed in the following shortening contraction (Bosco & Komi, 1979; Cavagna, 1968; Komi & Bosco, 1978). Thus, an appreciable fraction of the external positive work performed by the muscle fiber in the stretch-shortening cycle is achieved free of cost (Asmussen & Bond-Peterson, 1974; Cavagna & Kaneko, 1977; Cavagna et al., 1971).

Plyometric training has been demonstrated to improve jumping ability (Bosco et al., 1979; Blattner & Noble, 1979; Polhemus & Burkhardt, 1980). Such “bounce” training is widely utilized in strength programs designed to develop power or speed-strength. Although the training effects of plyometrics are not completely understood, the increase in muscle strength and power may be attributed to an increase in muscle elasticity and adaptation in neuromuscular functions. Improved elastic potential in muscle may also be due to an enhancement of the stretch reflex which is stimulated during stretch-shortening muscle activity. As Bosco and Komi (1979) have noted, we must assume that increased performances be attributed to utilization of elastic energy and to the stretch reflex potentiation of muscle until such time as the two can be separated.

Plyometric training also appears to create certain adaptations in neuromuscular function (Bosco, 1982). The very high tension developed in the leg extensor muscles during eccentric work in depth jump (DJ) conditions can lead to a strong inhibition of the following shortening contraction by the goll tendon organ (GTO). DJ exercises may be used to raise the firing threshold of the GTO, thereby improving the tolerance for increased stretch loads in the muscle. Simply put, if the athlete practices sustaining high levels of tension during the amortization phase, the negative influence on the shortening contraction due to the GTO may weaken.

Plyometric exercise appears to increase the possibility of storing a greater amount of elastic energy with muscles during eccentric work. This is possibly accomplished by neuromuscular adaptations which include a weakening of the inhibitory effects of the GTO. This allows a greater loading of the muscle in the eccentric or stretch phase which increases the stored elastic energy to be re-used in the ensuing shortening contraction. Also, greater tolerance to stretch loads may create a stronger stretch reflex which could result in facilitating a more powerful shortening muscle contraction.

2. What are the maturation and basic strength requirements to begin plyometric training?

Lundin: The maturation and strength requirements for beginning plyometric training have not been investigated to any great extent. Preparatory strength training of leg extensor muscles with barbells and other resistance forms has been recommended as a foundation for plyometric work such as depth jumps (DJ). A maximum squat of 1.5-2 times body weight (BW) has been recommended by some Eastern Bloc authorities as a prerequisite for plyometric training (Radcliff, J. & Farentinos, R., 1985; Verkhoshanski, Y. & Chornosov, G., 1974). This goes along with traditional training patterns which normally follow the metric training in the yearly cycle. This pattern, however, has been shown to be less effective than training both components simultaneously throughout the year (Bosco, 1985; Verkhoshanski, Y. & Tatyev, V., 1983). Eastern Bloc literature concerning prepubescent and pubescent strength training utilizes various forms of “bouncing” activities starting as young as 7 to 8 years of age (Fritzsche, 1977; Löffler, 1979; Mekhonoshin, 1983; Ushkevich, 1985). Experience seems to indicate a natural inclination...
and adaptation by children to various forms of hops, steps, skips and jumps if properly administered. A squat of 1.5-2 times a child’s BW as a prerequisite for such training is highly questionable and was probably never intended for such a population. Even among mature athletes, a minimum strength level necessary to begin a plyometric program has been questioned (Radcliffe, J., & Farentinos, R., 1985). This is not to say that maximum strength training is not necessary, for it occupies a very important part of power development. The role it plays in the training scheme is going to be altered depending upon the biological age of the athletes. Maximum strength activities are not recommended for prepubescent or pubescent athletes (NSCA position paper, 1985; Dvorkin, L.; 1983), yet plyometric activities can be utilized throughout childhood. Increases in strength prior to the age of 12 may be due more to improvements in neuromuscular coordination than increased force production of muscle. Various plyometric drills for prepubescent and pubescent athletes can be viewed as improving leg power though an increasingly improved take-off mechanism (Jurisma, 1980). The key to all of this is proper training loads, dependent upon training age and stage of biological development.

**Bielik:** We follow two rules when initially prescribing plyometric type exercises. For the lower body plyometrics all of our athletes participate in a progressive plyometric program. The progressive nature of our drills allow technique to be rehearsed at the early off-season and allow for the athlete to slowly adapt to the increased intensity of the more advanced plyometric drills.

Secondly, we do not allow our younger athletes to participate in the moderate to advanced exercises until they have acquired the relative lower body strength requirements of 1.75 times body weight on the back squat exercise.

In our depth jump program we have a special requirement in addition to the above stated criteria. Our athletes participate in depth jumps with boxes of increasing heights. When they cannot jump back up after jumping off the box as high as they normally can in a sergeant (vertical) jump test, the box height is too great. Until the athlete in question passes the requirements, they are not involved in the high boxes. Experience in plyometric activities and increasing lower body strength will enable the athletes’ involvement with higher box jumps.

**Wilt:** I am not aware of any maturation or strength requirements for plyometrics. Common sense must serve as a guide to their use. Children at play often engage in jumping activities that resemble plyometrics. Many normal athletes might improve sprinting and jumping ability through common-sense utilization of plyometrics. There may be some individuals such as athletes with injuries and extremely weak non-athletes who should not use them.

**Santos:** As a practicing coach in track and field, I would certainly not recommend plyometric exercises for athletes who have not gone through a sound program of strength and conditioning exercises. Strength development is a must prior to the use of plyometric exercises if positive gains in speed and strength are to be acquired and expected. Without a basic strength program, the legs or arms of the athlete simply will not be able to withstand the extreme forces generated by plyometrics. The athlete who starts off with plyometrics will find that it is extremely difficult, not only from the standpoint of his/her arms and legs in being able to perform the various exercises, but more importantly, the cardiovascular system will not be able to keep up with the demands placed on the system. The athlete will tire easily and not be able to do a quality workout. That in turn reduces the effects of plyometrics.

<table>
<thead>
<tr>
<th>1st Year Plyometric Program</th>
<th>BEGINNING PHASE (Pre-season)</th>
<th>INTERMEDIATE PHASE (Pre-season Preparatory)</th>
<th>IN-SEASON</th>
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<tbody>
<tr>
<td>AGE</td>
<td>BASE OF* STRENGTH</td>
<td>NUMBER OF FOOT CONTACTS</td>
<td>AGE</td>
</tr>
<tr>
<td>12-15</td>
<td>50%</td>
<td>40 (per session)</td>
<td>12-15</td>
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<tr>
<td>15-18</td>
<td>100%</td>
<td>50</td>
<td>15-18</td>
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<td>18+</td>
<td>150%</td>
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<tr>
<th>2nd Year on, Plyometric Program</th>
<th>INTERMEDIATE PHASE (Pre-season)</th>
<th>ADVANCED PHASE (Pre-season Preparatory)</th>
<th>IN-SEASON</th>
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<td>AGE</td>
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<td>NUMBER OF FOOT CONTACTS</td>
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<td>12-15</td>
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<td>150%</td>
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*Base of strength is the percent of the athletes body weight that he/she is able to do in a one repetition maximum squat.
**One jump counts as one foot contact, i.e. an in-depth jump is one foot contact, a double leg hop is one, 2 double leg hops are 2 foot contacts and a triple jump is two foot contacts.
***Plyometrics are to be done once a week in-season

**Figure 1. Chu. Two-year plyometrics program**
Some people will say that we should wait until the athlete is in post-puberty prior to starting a program. However, I think based upon previous experiences, that kids starting at 10 to 11 years of age could do some forms of plyometrics. After all, most of us grew up jumping rope, playing hopscotch, or seeing how far we could hop on one leg, and those exercises were rarely causes of injury. I like plyometrics for young athletes as it gives the child some terrific variability in training and can make the training phase fun.

We are using plyometrics in many of our training programs for Special Olympic athletes who are mentally retarded. The coaches of these athletes have reported some very positive results and an increase in cardiovascular development that could not have been possible in some cases. For the wheelchair athletes, using the medicine ball has been a real breakthrough, and is an excellent strength and cardiovascular developer.

Chu: There has been some concern about the use of plyometrics with prepubescent populations because of the stress placed on developing joints involved in various exercises. Although some of this concern is warranted, appropriate planning and special attention to training principles should eliminate potential problems.

The key to prescribing plyometric exercises to children and young adults is lower intensity (amplitude of the jump or decreased load) and fewer repetitions (Figure 1). Emphasis during these developing years should be on learning to do the exercises properly, not absolute speed or strength development. Coordination and motor control are being developed along with physical maturity, and younger athletes should be presented with a wide variety of low intensity exercises to help develop motor skills.

Plyometrics for the mature athlete becomes serious business. Post-pubescent athletes should be able to squat 150 percent of their body as a standard, and should be placed on a limited program of plyometrics in their first year of training. After this point plyometric training becomes progressive in nature and should parallel the developing athlete’s strength training.

Gambetta: Basic strength is the fundamental prerequisite in order to get optimum return from plyometric training. Even more specific is the need for a high degree of eccentric strength, a prerequisite for high volume and high intensity jumping. The high level is necessary since the stretch-shortening cycle is based on the rapid switching from eccentric to concentric strength. Without adequate eccentric strength levels this would be impossible.

Research has shown that children are unable to express large amounts of eccentric force. This can be explained by the immaturity of the central nervous system (CNS) and the fact that threshold for activation of the golgi tendon organ (GTO) is low. The effect is that the proprioceptive feedback mechanism operates to protect the body against high stretch loads to prevent injury. This is especially true at an age when muscle and bones have not yet reached maturity. The ossification and overall maturation process continue during puberty.

According to Bosco (1985), children are unable to tolerate “even moderate stretch loads.” In Bosco’s experiments this was the case in spite of the children being able to develop high levels of mechanical power from a squat jump without a counter movement. The squat jump requires good concentric strength.

With these facts in mind, plyometric training for athletes of pre-pubertal age should be of a low volume and low intensity variety. Low intensity jumps consist of jumps off both feet with no added stimulus such as a weight vest or boxes. They are performed in place—not moving repetitively forward.

At this beginning level the emphasis should be proper execution of the exercise. In my opinion, the best way to utilize plyometric training with young athletes is to make it a game-type situation. The focus should be on developing proper nerve patterns on which to base more complex training once the athlete begins to mature.

Russian research has shown that the period from 8 to 12 years of age is the time when running speed will increase due to an increase in the frequency of movement and general increase in speed. Between the ages of 12 and 15 running speed will continue to increase, but mainly due to an increase in muscular strength and speed-strength qualities. It is at this latter period that the volume and intensity of plyometric type training can be increased as the body will be more ready to accept and profit from it.

In order to perform high intensity jumps (for example, in-depth jumps, box jumps, single leg hop) the athlete must be able to full squat two times body weight. This is an absolute measure. Without this fundamental strength base the athlete will be able to perform the movement but will not get optimum results. Without this base the risk of injury is very high.

There are several other strength
guidelines, although not as absolute as the two times body weight figure. One is the single leg squat. I would not recommend doing a high volume of single leg hops unless the athlete can perform five repetitions of single leg squats using body weights resistance. This single leg squat should be performed standing on a box with support from one arm. Another indicator for single leg jumping is a single leg press (inverted) with one and a half times body weight for five reps, or seated leg press—one leg, one and a half times body weight for five reps.

Rogers: In general terms, I feel an athlete would be ready to begin a basic plyometric program during his sophomore year of high school, providing he had undergone at least one year of supervised weight training program. A basic rule-of-thumb strength base would be an athlete who can demonstrate a 1RM in the squat of one and a half times his body weight. Here at the University of Missouri we also test for muscle imbalances in the hamstrings and quadriceps, and use this as a second criteria to determine if an athlete is ready to participate in a basic plyometric program.

Costello: One of the best things about plyometrics is it can be a fun and enjoyable type of training. The beginner who has a relative low level of strength should start with very elementary plyometric drills. As their strength improves, the difficulty of the plyometrics increases. The scale of difficulty would run from your basic rope jumping up to depth jumps from over two meters. It is the job of the coach to decide when the athlete is ready to move to more advanced drills.

3. In working with beginners, what are typical problems or mistakes? What are the appropriate load, volume and intensity for beginner? How does this progress with experience and/or adaptation?

Costello: In most cases I use plyometrics as a quality type of training. With a novice athlete or beginner, you use very simple plyometrics for general conditioning. Aerobic exercises are a perfect example of this. Many of the aerobic programs I have seen have several very basic jumping and bouncing exercises. These exercises are not explosive and are used for muscular endurance.

I think this is a great way to prepare the athlete for more advanced drills down the road. As I stated earlier, when the athlete is ready to move to more advanced drills, it should be in relation to his or her level of strength.

Rogers: Many times a beginner will try too hard or “think” too much in starting a plyometric drill. Therefore, we will have an athlete “walk into” the drill rather than start from a stance. See Figure 2.

As the athletes progress in training, other drills can be added—jumping onto boxes of various heights, single leg hopping and bouncing, and finally, stepping off of boxes of various heights. Each succeeding level of drills can be added after three to six weeks of training at the previous level.

Gambetta: It is important to understand the concept of chronological age versus training age. Chronological age refers to the actual age of the athlete in years and months. Along with this it is important to evaluate maturation level. Is the athlete physically well developed? Has he or she passed puberty? Has there been a recent period of unusual growth in height or weight, or weight loss? Training age, on the other hand, refers to the number of years the athlete has been training. What is the athlete’s background in training? All of these factors must be carefully weighed before the beginner undertakes a plyometric training program.

For the beginner, start with low intensity, lower complexity type of jumps. The volume of jumps can reach 100 jumps in a session—300 jumps in a week, distributed over three workouts, spaced to occur every other day. These jumps include simple jump rope exercises, light double leg jumps, and easy jumps off two legs over a low obstacle six to twelve inches in height. For the pre-pubescent athlete this training should take the form of games such as hop scotch, jump rope and relays involving different types of jumps. For athletes who have achieved a degree of maturity, the volume can be increased significantly to 600 jumps a week with the intensity of the jumps governed by the athletes’ progress in accompanying strength training. Some single leg support jumps-hops can be included at this level.

A very important consideration in the more mature performer is body weight. High body weight as found in certain position in football and basketball greatly limits the volume of jumps. The added weight puts more stress on the joints and tendons, thus predisposing the athlete to injury. Therefore the intensity and volume of jumps should be carefully monitored for anyone over 200 pounds.

The most important aspect of plyometrics that must be stressed with the beginner is proper technique in execution of jumping movement. The key element in proper technique is foot placement with emphasis on a full foot landing using the foot to absorb the shock of landing and rolling forward and pushing off the ball of the foot. It is incorrect to land either completely on the heel or the ball of the foot. This type of landing will transfer the high impact forces through the bone and ankle and knee joints rather than allowing the elasticity of the muscle to absorb the shock of landing. Stressing proper mechanics at the foot and ankle will significantly reduce the stress-related injuries associated with jumping. A good coaching cue is to tell the athlete that the ground is like a hot stove–emphasizing optimum quickness off the ground.

In proper technique it is important to stress other areas as well. An upright carriage of the torso is necessary to avoid undue stress on one joint. Upright posture is directly related to strength in the torso, lower back and abdominal regions.
The importance of the free leg in single support jumping should not be neglected. The free leg should be cycled through in coordination with the jumping leg. And do not ignore the contribution of the arms. They contribute up to 10 percent to the jump. That makes coordination of the arms with the action of the legs essential.

Proper footwear is also a necessity. A shoe that fully supports the foot and provides some shock absorption without being spongy is important.

Jumping surface is another factor. A good, firm--but forgiving--surface is necessary. Too soft a surface will absorb too much of the impact force and not allow the muscle to stretch at the magnitude and rate normally would. This in turn will reduce the elastic recoil, thus reducing the training effect.

The overall progression in jump training from the simple to the complex, general to specific is as follows:

**Bouncing Movements**--In place, primarily off two feet, i.e., jump rope, ankle bounces, tuck jumps.

**Standing Jumps**--Jumps starting from a standing position. Some single support jumps in the form of hopping and bounding, i.e., standing long jump, standing triple jump, five hops left, five hops right, five double leg bounds.

**Short Jumps**--Jumps to 30m or less, more single support type jumps.

**In-Depth Jumps** and **Box Jumps**--Should be used only when a good strength level has been achieved and jump technique is sound. Not for the beginner!

Other problem often encountered by coaches and athletes is trying to do too much in one training session. A little work early in the training stage is much more beneficial than an overload and taking a chance on a break-down.

Allowing athletes to compete against each other is another problem seen in the early stages of plyometric training. Each athlete should compete against himself and not try to keep up or go ahead of others in the training group.

In setting up a training program for the beginner using plyometrics, I would recommend a general basic program as follows:

I. Train only 2 times per week.
II. For the first 3 weeks, use only 4 to 5 specific exercises
   A. Develop a good understanding of each exercise.
   B. Develop a good technique in each athlete as he/she does the exercise (plyometric).
III. Allow at least 3 to 4 minutes rest between each set of plyometrics.
    A. Do not go from one exercise directly to another without proper recovery.
    B. If the athlete appears to be breaking down during a plyometric exercise, stop the exercise at once and do not continue. Speed and good technique are important, and they are lost if the athlete is fatigued. No development takes place after the breakdown.

As the athlete develops in strength and technique, add more plyometrics to the training regime. Work from the base of short time periods, short distance or low heights, to longer training periods, longer distances or higher heights. In other words, if an athlete is bounding, he/she should start off with 5 sets of 30 meter bounds. As the season progresses, this can be upted to 50 to 70 meters of bounding, with as many as 5 to 8 sets.

As the athlete adapts to the stress placed on the body during training in plyometrics, he/she will be able to work at a higher rate of speed, longer training periods and increased muscle response. This allows the coach and athlete to devise new exercises that are beneficial, challenging and fun.

**Wilt**--This depends upon what plyometric activities are used. As in the case of most athletic training, the application of plyometrics should begin with "easy" and progress to "difficult," progress from "few" to "many," and gradually adapt the organism to the stress of the activity. As an example I recommend female athletes 18 to 22 years of age do depth-jumps twice per week. They start with one-foot height downward jump, and gradually increase to 2.5 feet or a bit higher. They start with 5 repetitions and gradually increase to 4 sets of 10 repetitions for that particular exercise. This progression takes place over a period of about 3 months. I am unaware of any particular law specifying this is correct. I base this procedure on trial and error experience. It would be a mistake to not gradually adapt the athlete to this particular stress, engage in the activity too frequently, and/or use too many repetitions or too intense activity without becoming first adapted to a small dose of the exercise.

**Bielic**--With all the different lower body plyometric activities available, most of the technique problems are associated with the ground contact.

At ground contact it's important that the athlete maintains an upright body position. Bending over at the waist can cause back injuries, and from a technique standpoint, being bent over at the waist causes difficulty in the mechanical execution of the exercises.

Upon ground contact it is imperative that a bent knee and mid-foot landing is executed. For obvious reasons, knee and lower back injury would occur. With the mid-foot landing instead of a heel landing a shorter time between ground contact and the forceful plantar flexion of the ankle joint is allowed. The athlete should spend as little time as possible on the ground.
Lundin: Typical problems or mistakes in planning a plyometrics program for any level concerns appropriate training loads. This is difficult at best because of the limited research concerning the practical aspects of implementing a plyometrics program. What research has been done has primarily focused on mature athletes in a depth jump (DJ) format. Little, if any, research has been attempted concerning the myriad of multiple jumps of a vertical or horizontal nature which comprise the bulk of many plyometric programs. With so little to go by in reference to proper training loads, the coach must proceed with a conservative bias in developing a plyometrics program for beginners, children and/or youth. Such a program should consider the following points (Fritzsche, 1977; McFarlane, 1983):

1. Proceed from general to more specific jumping exercises. General drills would include double-leg (DL) multiple jumps and hops of a vertical or horizontal nature. Also included in such a category would be vertical multi-jumps over medicine balls, hurdles, boxes, etc. and horizontal multi-jumps of hopping, skipping and/or stepping nature with single-leg (SL) take-offs. Specific jumps closely resemble or correspond exactly in speed and movement to competitive jumps. Triple, long or high jumps from a half to full approach or repeated stepping or hop-step activity from a 5 to 6 stride approach appear to correspond highly with competitive take-off action. Drop or depth jumps (DJ) are not specific so much in reference to the motor action of take-offs in the competitive jumps, but allows the possibility for increasing the load on the leg extensor muscles over and above what various forms of multi-jumps may offer. It seems reasonable that the use of DJ with beginners should be individualized and preceded by the various forms of multi-jumps.

A suggested progression of exercises from a general to more specific nature might proceed accordingly:

1. DL, straight-leg ankle hops in place.
2. DL, straight-leg ankle hops over objects (20 to 40 cm).
3. DL, in place, vertical hops and jumps.
4. DL, horizontal hops and jumps.
5. Various forms of horizontal hops, skips, steps and jumps with loading (contact) of single-leg (SL) nature.
6. Competitive forms of high, long, triple jumps from partial approach.
7. Depth jumps (DJ)
8. Competitive forms of high, long, and triple jumps from full approach.

The progression is from general to specific in respect to intensities encountered and complexity of motor task.

The choice of exercises must correspond to the age and biological development of athletes without endangering due to overload. The majority of jumping exercises used with children and youth from 8 to 13 should be of a general nature. To determine the training load, not only the type of jumping exercise must be considered (general or specific), but also the number of jumps, take-offs, or contacts employed. Loffler (1979) suggests that general jumping ability should initiate a jump program with the number of contacts per session ranging from 150 to 220 in series from 7 to 20. Recoveries between series should be 45 seconds with 1 to 2 minutes between exercises. Total workout time should be 15 to 20 minutes between exercises. Total workout time should be 15 to 20 minutes. Specific jumping drills should follow the development of general jumping ability entailing 2 to 6 contacts in 3 to 4 series per exercise with total work equal to 80 to 100 contacts and 20 to 25 minutes. Rest intervals should be lengthened to allow recovery from specific jumping exercises. Loffler stresses the importance of technically correct performance with body weight (BW) the only resistance encountered. Such training loads represent maximum levels, so initially with beginners it may be more prudent to start with 30 to 50 contacts. As adaptation occurs, greater workloads may be attempted.

Ushkevich (1985) reported on training loads of 14 to 15-year old youths in the second year of long and triple jump training. Load in a single session consisted of any where from 25 to 120 contacts and/or 120 to 200m (broken into series not to exceed 50m) of multi-jumps. Some form of jump training was included 4 times per week with gradual increases in volume and specificity to the competitive take-off mechanism.

Mekhonoshin (1983) reported that the training of the take-off (amortization phase) may start in third grade (9 to 11 years). The training consisted of DJ immediately followed by 3 to 5 hops over medicine balls. The DJ height for third graders ranged from 25 to 35 cm and for fourth graders 35 to 45 cm with DL contact. Contact DJ consisted of dropping from 15 to 25 cm and 20 to 30 cm for third and fourth graders respectively. No more than 1 to 3 repetitions of this drill

"Plyometric training for prepubescent athletes should be of low volume and low intensity." -- Gambetta
were repeated in any session along with other drills of a general and specific nature. Also, the DJ drills were employed only after 5 to 6 weeks of other jumping exercises.

Investigations by Bosco (1985) of muscle elasticity have indicated that the "breaking point" or maximum tolerance of stretch loads to extensor muscles of the leg increased at ages 20 to 25 and then decreased. In eccentric work (amortization phase), children were unable to achieve similar values as related to maximum isometric force as adults. Bosco reports in some cases eccentric force being less than maximal isometric force among 4 to 6 year old children.

Such findings suggest that the central nervous system (CNS) at that age is not mature and the firing threshold of the GTO is relatively low in contrast with adults to protect the body against high stretch loads. This seems reasonable at this age when muscle and, particularly, bones have not yet reached maturity. As to when the CNS and GTO reach adult maturity and firing thresholds is difficult to assess. From a practical view, the best depth jump (BDJ), or maximum rise of the center of gravity after a drop from height, was achieved from a DJ of approximately 20 cm for 6 to 7 year olds and 40 cm for ages 10 to 15. The ranges appear to fall within those recommended by Meckonoshin (1983).

It appears, then, that determining BDJ is a means of individualizing DJ training regardless of age. BDJ represents a stretch load which allows the neuromuscular system to maximize available forces. DJ from heights which lead to a decrement in vertical jump performance are overloading the system and, among beginners, children and youth, may lead to possible overload. Presently, this method of determining training loads via BDJ appears to clear up much of the controversy concerning appropriate DJ height. Also, such an activity allows the coach to monitor adaptation. Increasing vertical jumps from a BDJ height indicates increased tolerance to stretch loads and a necessary increase in training load. Methods of determining BDJ are nicely explained by Radeliffe and Farentinos (1985) and Costello (1984).

The number of contacts recommended for mature athletes in DJ training ranges from 40 to 100, generally in a series of 8 to 10 contacts with rest periods of 1 to 3 minutes which include light running and stretching. Training loads for beginners should be 30 contacts per session twice weekly according to Verkhoshanski (1973). For children and youth, training loads are not completely understood. It appears, however, that conservative jumping programs which follow accepted training principles may enhance leg extensor power among children (Mekkonoshin, 1983).

The choice of exercises should allow for a gradual increase in load during the year. This can be accomplished by:

1. Gradual transition from general to specific jumping exercises.
2. Gradual increase in the number of contacts per session, per week, etc.
3. Increase in number of sessions employing jumping exercises per week.
4. Testing for BDJ on a regular basis allowing intensity (height of DJ) to increase as adaptation occurs.

It must be remembered that DJ are intense and should be used sparingly among beginners, children and youth. Multi-jumps appear to develop leg strength and improve motor efficiency in jumping movements. It seems reasonable that such activities should constitute the bulk of exercises for such a population.

**Chu:** The emphasis in teaching a beginner should be in developing a short amortization phase. Beginners tend to spend too much time absorbing the impact of landing. This results in too much time on the ground surface and a reduction of the stimulus to the nervous system.

Another problem encountered with beginners (and experienced athletes for that matter) is improper foot placement. The tendency to place the foot in front of the center of gravity during bounding and hopping necessitates a "pulling" action by the athlete putting undue stress on the heel, knee joint and the lower back. This action results in a "jarring" transfer of energy to the skeletal system rather than the muscular system where the energy can be converted to positive work. Emphasis on proper leg cycling can help alleviate this problem.

The third activity that is often difficult to translate is proper use of the arms. Arm action can make a significant contribution to the activity of lifting the body from the ground.

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**Table 1: Problems encountered in beginning plyometrics.**

<table>
<thead>
<tr>
<th>Problem</th>
<th>Cause</th>
<th>Correction</th>
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<tbody>
<tr>
<td>(1) Athlete stays on the ground too long.</td>
<td>a) Landing flat-footed or w/weight too far back. b) Not keeping concept of &quot;light feet&quot; in mind.</td>
<td>Get center of gravity forward - land on balls of feet. Promote mental set of &quot;light, quick, fast.&quot; &quot;Yell &quot;up&quot; as athlete makes contact with the ground.</td>
</tr>
<tr>
<td>(2) Excessive trunk movement/poor distance of height.</td>
<td>a) Improper arm swing. b) Arms not swinging from shoulder in natural arc from &quot;cheek to cheek.&quot;</td>
<td>Have athlete stand in place and just swing arms with the elbows locked at 90° from buttocks cheek to face cheek. Begin slow and increase velocity to maximum.</td>
</tr>
<tr>
<td>(3) Sore back or &quot;settling into ground&quot; upon contact.</td>
<td>Athlete not landing in good athletic position. Usually by excessive hip flexion.</td>
<td>Stress &quot;chest over knees over toes with the head up.&quot; Good basic athletic position. Verbally instruct the athlete to drive his knees to his chest or heels to buttocks. Stress keeping chin and chest up.</td>
</tr>
<tr>
<td>(4) Excessive balance loss in mid-air.</td>
<td>Excessive trunk/hip flexion - not driving knees to chest or heels to buttocks.</td>
<td></td>
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</tbody>
</table>

**BEGINNER**

**Load:** Body Weight. **Volumes:** Warm-up - 20-25 repetitions. **Drills:** About 5 exercises. 1 set each: 8-12 repetitions 24-32 total reps **Intensity:** After warm-up 85-90% of maximum. Stress technique at all times - quality...not quantity.

**ADVANCED**

**Load:** Body Weight. **Volumes:** 25-30 repetitions. **Drills:** About 4-5 exercises. 2-3 sets each: 8-12 repetitions 60-75 total reps **Intensity:** After warm-up stress 90-100% intensity.

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