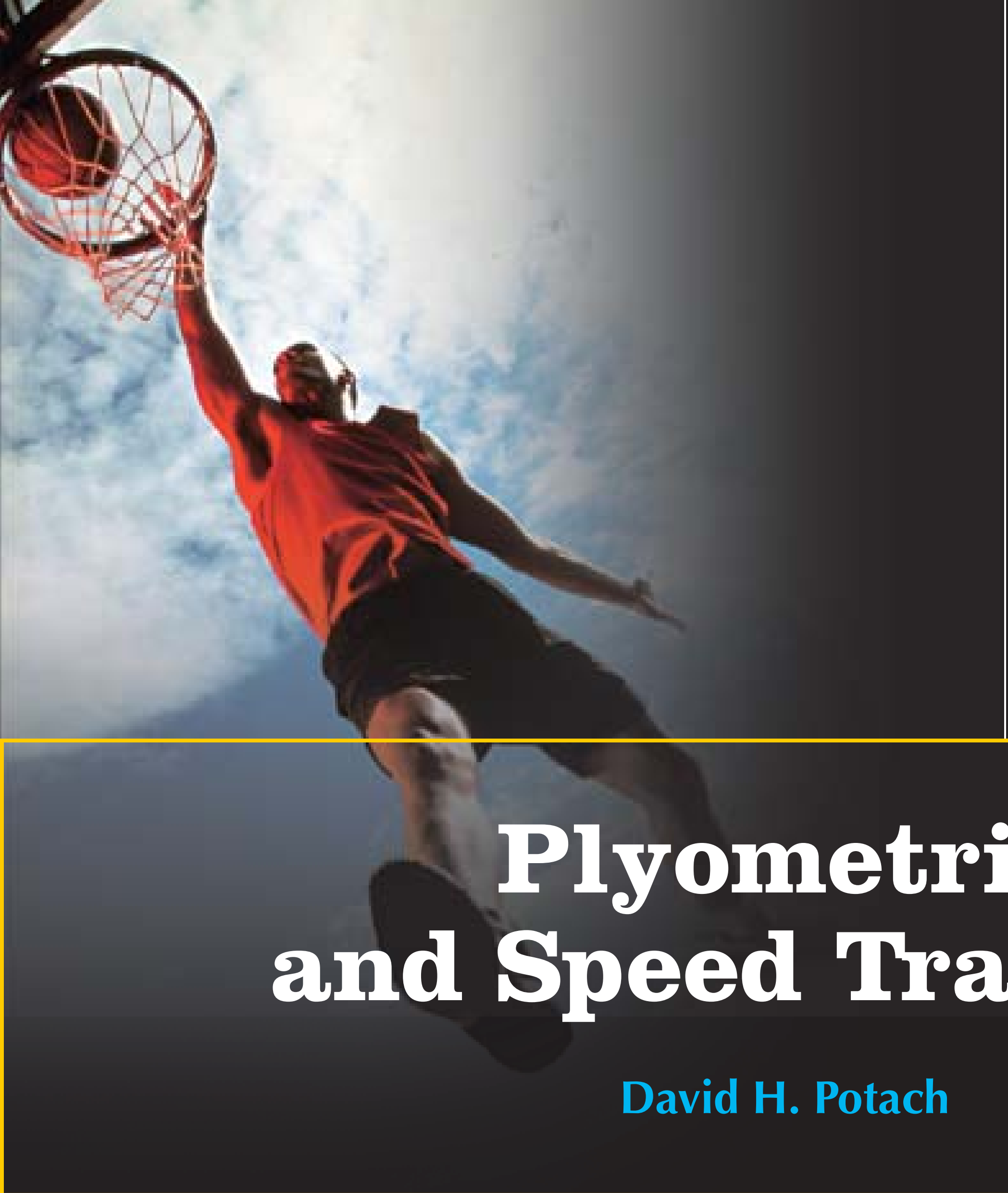
CHAPTER 17



Plyometric and Speed Training

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After completing this chapter, you will be able to

- explain the mechanics and physiology of plyometric and speed-enhancing exercises,
- identify the phases of the stretch-shortening cycle;
- understand the different roles of plyometric and speed training;
- recommend proper equipment for use during plyometric exercise performance;
- design safe and effective plyometric and speed training programs; and
- provide instruction in correct plyometric and speed training technique and recognize common errors.

In an effort to improve sport performance, athletes at all levels want an advantage that allows them to outplay their opponent. Obtaining this edge through the use of plyometric and speed training has commonly been available to only high-level athletes, with the training provided by a team of strength and conditioning professionals [3]. Although not typically emphasized in the design of programs for personal training clients, plyometric and speed training are fast becoming important components of a well-balanced plan to improve not only sport performance, but function during job and activities of daily living. Exercises designed to train clients to jump higher and run faster are becoming popular, and arguably essential, program components. Further, because so many injuries occur as the result of an inability to control decelerative forces, the use of both plyometric and speed training, with their emphasis on the efficient production and use of ground reaction forces, should be considered an integral part of any program whose goal is injury prevention.

A practical definition of plyometric exercise is a quick, powerful movement preceded by a prestretch, or countermovement, and involving the **stretch-shortening cycle (SSC)** [84], while speed is simply the ability to achieve high velocity. Though its definition may be simpler, speed training also relies heavily on the SSC to elicit its desired outcome, that is, the achievement of higher velocity. The purpose of plyometric exercise is to use the stretch reflex and natural elastic components of both muscle and tendon to increase the power of subsequent movements; speed training exercises are designed to use these same mechanical and neurophysiological components, in concert with technique and muscular strength, to produce larger ground forces, thereby allowing clients to run faster. This chapter describes how to use plyometric and speed training exercise effectively as part of an overall training program.

Plyometric Mechanics and Physiology

To be successful, goal-directed movements—athletic, job-related, and functional—depend on all active musculotendinous structures working in concert at appropriate velocities. The term used to define this force-speed relationship is **power** (see chapter 4 for a definition of power). When used correctly, plyometric training has consistently demonstrated the ability to improve the production of muscle force and power [6, 44, 69, 78]. This increased production of muscular power is best explained by two proposed models as discussed in this section—mechanical and neurophysiological [84]. Each model's function is then summarized by a description of the SSC.

Mechanical Model of Plyometric Exercise

In the *mechanical model*, elastic energy is stored following a rapid stretch and then released during a subsequent concentric muscle action, thereby increasing the total force production [2, 16, 45]. A common model presents the function of the musculotendinous unit as a relationship between three mechanical components, the series and parallel elastic components and the contractile component (CC) (figure 17.1, second row). While the **series elastic component (SEC)**—a primary contributor to force production during plyometric exercise—includes some muscular components, it is composed mainly of tendons. When the musculotendinous unit is stretched, as during an eccentric muscle action, the SEC acts as a spring and is lengthened, storing elastic energy. If the muscle then *immediately* begins a concentric muscle action, the stored energy is released, contributing to the total force production by naturally returning the muscles and tendons to their resting configuration. If a concentric muscle action does not occur immediately following the eccentric action, or if the eccentric phase is too long or requires too great a motion about the given joint, the stored energy dissipates and is lost as heat.

Neurophysiological Model of Plyometric Exercise

The *neurophysiological element* involves a change in the force-velocity characteristics of the muscle's contractile components caused by stretch [30]; concentric muscle force is increased with the use of the stretch reflex (figure 17.1, third row) [9, 10, 11, 12]. The **stretch reflex** is the body's involuntary response to an external stimulus [40, 60]. This reflexive component of plyometric exercise is composed primarily of muscle spindle activity. **Muscle spindles** are intramuscular organs that are sensitive to the rate and magnitude of a stretch; when a quick stretch is detected, muscular activity reflexively increases [40, 60]. This reflexive response **potentiates,** or increases, the activity in the agonist muscle, thereby increasing the force the muscle produces [9, 10, 11, 12, 49]. As with the mechanical model, if a concentric muscle action does not immediately follow a

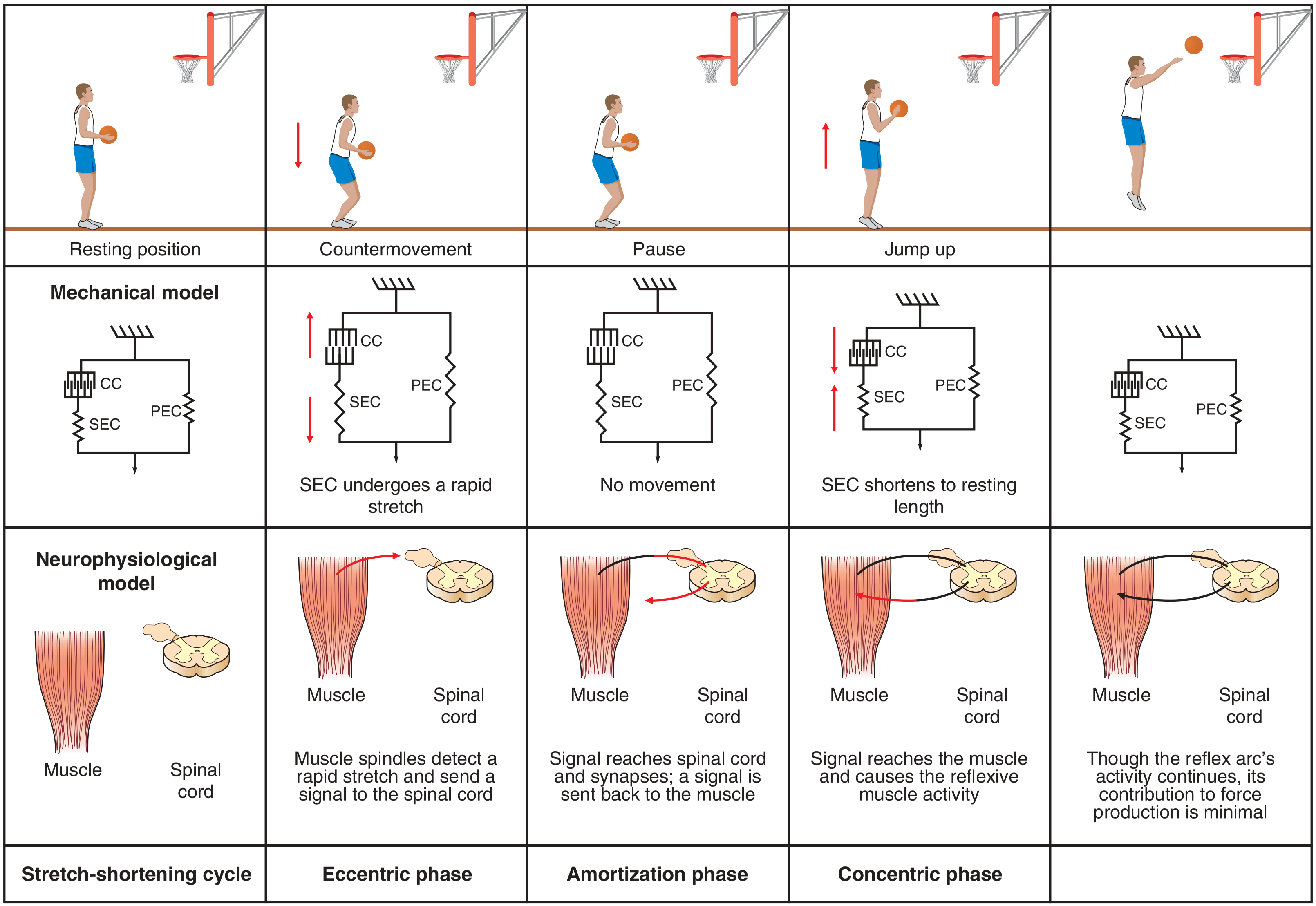


Figure 17.1 Illustration of the stretch-shortening cycle (SSC) with the events of the mechanical model (row two) and neurophysiological model (row three) that occur during each of its three phases (row four). For example, during the eccentric phase of the SSC (column two)—ie., the client's countermovement shown above—the series elastic component (SEC) undergoes a rapid stretch that the muscle spindles detect and send a signal to the spinal cord.

Mechanical model (middle row of figure) adapted from Albert 1995.

stretch (e.g., due to an excessive delay between the stretch and concentric action or with a movement occurring over too large a range), the potentiating ability of the stretch reflex is negated.

Stretch-Shortening Cycle

The SSC is a model explaining the energy-storing capabilities of the SEC and stimulation of the stretch reflex that facilitate a maximal increase in muscle recruitment over a minimal amount of time. The SSC involves three distinct phases (table 17.1). While these phases outline the SSC's individual mechanical and neurophysiological events, it is important to remember that all of the events listed do not necessarily occur within the given phase, as some events may last longer or require less time than the given phase allows. The **eccentric phase**—the first phase—involves preloading the agonist muscle group(s). During this phase, the SEC stores elastic energy and the muscle spindles are stimulated [7, 41]. To visualize the eccentric phase, think about a basketball jump shot. The person quickly performs a half-squat and immediately jumps up to shoot the ball. The time from the beginning of the squat—or countermovement—to the bottom of the movement is the eccentric phase (figure 17.1, second column).

The **amortization,** or transition, **phase** is the time between the eccentric and concentric phases—the time from the end of the eccentric phase to the initiation of the concentric muscle action. There is a delay between the eccentric and concentric muscle actions during which the spinal cord begins to transmit signals to the agonist—stretched—muscle group. This phase must be kept short in duration. If the amortization phase lasts too long, the energy stored during the eccentric phase will be dissipated as heat, and the stretch reflex will not increase muscle activity during the concentric phase [14]. Consider again the basketball jump shot. Once the person's downward half-squat has stopped, the amortization phase has begun. As soon as upward movement begins, the amortization phase has ended (figure 17.1, third column).

The **concentric phase** is the body's response to the events occurring during the eccentric and amortization phases. During this final phase of the SSC, the energy stored in the SEC during the eccentric phase is either used to increase the force of the subsequent movement or is dissipated as heat. Use of the stored elastic energy increases the force produced during the concentric phase movement to a level above that of an isolated concentric muscle action [15, 78, 82]. In addition, the agonist muscle group performs a reflexive concentric muscle action as a result of the stretch reflex. Again visualize the jump shot. Following the half-squat movement, as soon as movement begins in an upward direction, the concentric phase of the SSC has begun and the amortization phase has ended (figure 17.1, fourth column). In this example, one of the agonist muscles is the quadriceps femoris. During the countermovement, quadriceps femoris undergoes a rapid stretch (eccentric phase); there is a delay in movement (amortization phase); then the muscle acts concentrically to extend the knee, allowing the person to push off the ground (concentric phase) (figure 17.1 second, third, and fourth columns, respectively).

The stretch-shortening cycle describes the stretch reflex and stored elastic energy-induced increases in concentric force production that follow a rapid eccentric muscle action.

TABLE 17.1

Stretch-Shortening Cycle

Phase	Action	Physiological event
I—Eccentric	Stretch of the agonist muscle	• Elastic energy is stored. • Muscle spindles are stimulated. • Signal is sent to spinal cord.
II—Amortization	Pause between phases I and III	• Nerves synapse (meet) in spinal cord. • Signal is sent to stretched muscle.
III—Concentric	Shortening of agonist muscle fibers	• Elastic energy is released from the SEC. • The stretched muscle is stimulated by nerve.

When to Use Plyometric Exercise

It should seem obvious that plyometric training offers significant benefits to athletic clients in that most sporting movements rely on quick, powerful movements to be successful [3]. What other populations may benefit from use of these types of movements is less clear. This bias has allowed plyometric exercise to become an ignored training modality for the general population. Many nonathletic clients, however, may benefit from the increases in muscular power production that plyometric training provides. The ability of the personal trainer to identify nonathletic clients who may benefit from plyometrics, as well as those for whom plyometrics are not needed or are contraindicated, is an essential skill for designing individualized exercise programs.

Plyometric Training and Sport Performance

Increased production of muscular power is an established outcome of participation in a plyometric training program [2, 16, 43, 44, 45, 59, 64, 78, 85]. The ability to produce more muscular power has been associated with improved sport performance [4, 5, 54, 77]. Plyometric training, then, is an ideal exercise mode when the goal is to improve muscular power production. In addition to bringing about this increase in muscular power, plyometric training prepares athletes for the deceleration-acceleration and change-of-direction requirements in most sports by improving their ability to perform these types of tasks.

Plyometric Training and Work Performance

In addition to sport performance, participation in a plyometric training program has the potential to improve performance at work [52]. Though this has not been sufficiently examined in the literature, an analysis of some job requirements indicates that the production of muscular power is a key to movement efficiency and may improve job output. For example, police officers must be able to run quickly, change directions effectively, and jump onto or over objects (e.g., fences) in preparation for their occupational demands.

Plyometric Exercise and Injury Prevention

Decreasing the incidence of injury, especially in populations who are at a greater risk of injury than others, is an important consideration when one is designing an exercise training program. Specifically, there is great interest in the utility of plyometric training in decreasing risk of injury. Studies have shown that athletic injury rates decrease following participation in a plyometric training program [8, 43, 44]. It is difficult, however, to extrapolate the results of these studies to different populations. Further, researchers have yet to examine the effect of plyometric training on nonathletic populations. A component of plyometric training is eccentric control of movement, which research has shown may decrease the risk of injury [74]. Eccentric training may therefore be a compromise for clients who wish to engage in injury prevention activities but for whom plyometric training is not appropriate. For example, although plyometric training may not be appropriate for a 75-year-old female client, this client would benefit from eccentric training to lessen her chance of falling.

Contraindicated Populations

There has been no research to delineate populations for whom plyometric training is contraindicated, though analysis of a client's age, experience, and current training level may help identify those clients who are and are not ready for plyometric training.

Age

Plyometric training alters bone structure; spine height has been shown to decrease by up to two millimeters following a depth jumping program [36, 37]. Plyometric training also reportedly increased bone mineral content by up to 7%, though the changes were similar in the non-plyometrically trained control group [88]. Given these limited findings, research has yet to determine the age at which one is physically able to participate in a plyometric training program without experiencing deleterious effects on growing (or aging) muscles, bones, and joints. However, the body's development provides insight into the issue. Clients at both extremes of age should avoid plyometric training for primarily the same reason. Because the epiphyseal plates of the bones of prepubescent children have yet to close [48, 56], and because bones weaken with osteoporosis, depth jumps and other high-intensity lower body plyometric drills are contraindicated for these clients [1, 46, 53]. The personal trainer needs to take care regarding the level of plyometric training appropriate for these client types. For clients younger than 14 years and those older than 60 years, the personal trainer should use caution when prescribing plyometric exercise as a training modality.

Experience and Current Training Level

Clients who have never participated in a resistance training program should be precluded from taking part in a plyometric training program. Plyometric training requires significant strength and muscle control, especially during the eccentric phase. For this reason, clients should be encouraged to take part in a resistance training program that includes core exercises (e.g., squat, bench press, deadlift) before beginning a plyometric training program.

Plyometric Program Design

Plyometric exercise prescription is similar to resistance and aerobic exercise prescriptions [34]. After an evaluation of the client's needs, the mode, intensity, frequency, duration, recovery, progression, and a warm-up period must all be included in the design of a sound plyometric training program. Unfortunately, there is little research demarcating optimal program variables for the design of plyometric exercise programs. Therefore, in addition to the available research, personal trainers must rely on the methodology used during the design of resistance and aerobic training programs and on practical experience when prescribing plyometric exercise. The guidelines that follow are based in part on Chu's work [18, 19, 20, 21, 23, 24] and the National Strength and Conditioning Association's position statement [63].

Needs Analysis

As with other training modalities, when incorporating plyometric exercise into a training program the personal trainer must perform a needs analysis to evaluate a client's current abilities. Specifically, the personal trainer determines the client's needs and the requirements of the client's activities and lifestyle. A combination of the following factors helps in the analysis of a client's needs:

- **Age—**Does the client's age predispose the client to injury and therefore preclude plyometric training?
- **Training experience and current training level—**Has the client been resistance training? If so, what types of exercises has the client been performing? Has he or she participated in a plyometric training program? If so, when?
- **Injury history—**Is the client currently injured? Has the client experienced an injury that might affect his or her ability to participate in a plyometric training program?
- **Physical testing results—**What are the client's current abilities as they relate to muscular power production (e.g., vertical and standing long jump results)?
- **Training goals—**What does the client want to improve? A specific movement (e.g., throwing)? A particular skill (e.g., volleyball hitting)? An on-the-job activity (e.g., loading a truck)?
- **Incidence of injury in a client's job or chosen activity—**What is the risk of injury in the client's chosen activity? Is the activity relatively sedentary (e.g., student or office worker)? Does the activity require constant change of direction (e.g., racquetball player or construction worker)? If the activity is dynamic, is the client prepared for it physically?

"Client Examples—Needs Analysis" on the facing page illustrates one form of the plyometric needs analysis. At the end of this discussion of program design are sample programs for each of these six clients, illustrating the "how" of program design.

Mode

The *mode* of plyometric training is determined by the general part(s) of the body that are performing the given exercise. For example, a **depth jump** is a *lower body* plyometric exercise, whereas a medicine ball chest pass is an *upper body* exercise.

Lower Body Plyometrics

Lower body plyometrics are appropriate for clients involved in virtually any sport—including soccer, volleyball, basketball, and baseball—as well as in nonathletic activities or occupations that require muscular power production or quick changes of direction. These types of activities require participants to produce a maximal amount of force in a minimal amount of time. Soccer and basketball require quick, powerful movements and changes of direction from competitors. A client who plays basketball is an example of one who would benefit greatly from a plyometric training program, as basketball players must jump repeatedly for rebounds.

Client Examples— Needs Analysis for Plyometric Exercise

Sport Client A. A healthy, 30-year-old male has been fairly active all of his life and joins a YMCA basketball league. He is currently in a resistance training program and performed plyometrics two years ago. He is six feet (182 centimeters) tall, weighs 200 pounds (91 kilograms), and has a 16-inch (40-centimeter) vertical jump and 180-pound (82-kilogram) 1-repetition maximum (1RM) squat. He wants to

1. increase his vertical jump to improve his ability to rebound the basketball and
2. run up and down the court faster as well as change directions quickly.

Sport Client B. A healthy, 28-year-old female fast pitch softball player has played first base for the past five years but is transitioning to an outfield position. She trains with weights one to two times a week, with a circuit weight training program for both the upper and lower body. She is five feet, three inches (160 centimeters) tall and weighs 125 pounds (57 kilograms). Her testing session reveals a 60-pound (27-kilogram) 1RM bench press and an 11-inch (28-centimeter) vertical jump. She requests help in improving her

1. ability to cover right field and
2. arm strength to help throw the ball to the infield.

Work Client A. A 35-year-old firefighter participates in a resistance training program five days a week with both upper and lower body exercises. He was in a plyometric training program six months ago. He is six feet, two inches (187 centimeters) and weighs 225 pounds (102 kilograms). He has a 5.3-second 40-yard (37-meter) dash time, 225-pound (102-kilogram) squat, and 20-inch (51-centimeter) vertical jump. In addition to the necessary cardiovascular training, he has requested help in improving his

1. lifting ability and
2. speed while carrying the hose.

Work Client B. A 40-year-old female warehouse worker has had difficulty the past two months lifting boxes up and onto shelves at or above shoulder level. She has no complaints of pain and has been cleared by the company physician of any musculoskeletal dysfunction. She is five feet, 10 inches (177 centimeters) and weighs 150 pounds (68 kilograms). Her estimated 1RM bench press is 70 pounds (32 kilograms); estimated 1RM squat is 135 pounds (61 kilograms); and vertical jump is 13 inches (33 centimeters). She has never participated in a resistance training program. She has come to a personal trainer to assist her in improving her

1. arm strength, especially when pushing the boxes onto a shelf and
2. leg strength to assist her in lifting the heavier boxes.

Injury Prevention Client A. A healthy 14-year-old female soccer player is preparing to try out for her high school soccer team. She is five feet, seven inches (170 centimeters) and weighs 110 pounds (50 kilograms). She has not performed 1RM testing, but her vertical jump is 12 inches (30 centimeters). Her parents are concerned that she will get hurt playing with girls who are so much older than she. She has been involved in a general resistance training program for the past six months but has never participated in a plyometric training program. The parents have requested help for their daughter to

1. reduce her risk of injury and
2. "get in shape."

Injury Prevention Client B. A 55-year-old female Master's level tennis player is returning to play following a year-long layoff and is concerned about "losing a step" and injuring herself. She has not had any serious injuries. She is five feet, six inches (168 centimeters) and weighs 150 pounds (68 kilograms). Physical testing reveals an estimated 1RM squat of 140 pounds (64 kilograms), vertical jump of 10 inches (25 centimeters), and 40-yard (37-meter) dash of 7.0 seconds. She has been resistance training for the past four months. She would like to

1. improve her speed when coming to the net and
2. reduce her risk of injury.

Lower body plyometric training allows the client's muscles to produce more force in a shorter amount of time, thereby allowing the person to jump higher. There are a wide variety of lower body plyometric drills with various intensity levels and directional movements. Descriptions of different types of lower body plyometric drills are provided in table 17.2 and in general are listed from lower to higher intensities.

Upper Body Plyometrics

Rapid, powerful upper body movements are requisites of several sports and activities, including golf, baseball, softball, and tennis. As an example, a baseball pitcher routinely throws a baseball at 80 to 100 miles per hour (129-161 kilometers per hour). To reach velocities of this magnitude, the pitcher's shoulder joint must move at over 6,000 degrees per second [27, 32, 35, 68]. Plyometric training of the shoulder joint would not only increase pitching velocity it may also prevent injury to the shoulder and elbow joints, although further research is needed to substantiate the role of plyometrics in injury prevention.

Plyometric drills for the upper body are not used as often as those for the lower body and have been studied less vigorously. Nonetheless, they are essential to athletes requiring upper body power [65] and may help clients who need greater levels of upper body strength. Plyometrics for the upper body include medicine ball **throws,** catches, and push-up variations.

Intensity

Plyometric *intensity* refers to the amount of stress placed on muscles, connective tissues, and joints,

TABLE 17.2

Lower Body Plyometric Drills

Type of jump	Definition	Examples
Jumps-in-place	Jumping and landing in the same spot, performed repeatedly, without rest between jumps	Squat jump, tuck jump
Standing jumps	Maximal effort jumps involving either vertical or horizontal components Recovery between repetitions is required	Vertical jump, jump over barrier
Multiple hops and jumps	Drills involving repeated movements Commonly viewed as a combination of jumps-in-place and standing jumps	Double-leg hop, front barrier hop
Bounds	Drills that involve exaggerated movements with greater horizontal speed than other drills Volume for bounding is typically measured by distance and is normally greater than 30 meters (98 feet)	Skip and alternate-leg bound
Box drills	Multiple hops and jumps using a box to jump on or off The height of the box depends on the size of the client, the landing surface, and goals of the program	Jump to box, jump from box
Depth jumps	Drills in which the client assumes a position on a box, steps off, lands, and immediately jumps vertically, horizontally, or to another box	Depth jump, depth jump to second box

TABLE 17.3

Factors Affecting the Intensity of Lower Body Plyometric Drills

Factor	Methods to increase plyometric drill intensity
Points of contact	Progress from double- to single-leg support.
Speed	Increase the drill's speed of movement.
Height of the drill	Raise the body's center of gravity by increasing the height of a drill (e.g., depth jump).
Participant's weight	Add weight (in the form of weight vests, ankle weights, and wrist weights).

and is controlled both by the type of drill performed and by the distance covered (e.g., height of a jump) (table 17.3). The intensity of plyometric drills ranges from low-level skipping to depth jumps that apply significant stress to the agonist muscles and joints.

Intensity should be kept at a low level for those just beginning a plyometric program. Double-leg **jumps-in-place,** double-leg **standing jumps,** and simple skips are appropriate for such clients. Rather than concentrating on advancing intensity, efforts should focus on ensuring proper technique to prevent injury when the client is ready for more advanced drills.

Frequency

Frequency is the number of plyometric training sessions per week and depends on the client's goals. As with other program variables, research is limited on the optimal frequency for plyometric training sessions, again necessitating reliance on practical experience when one is determining the appropriate plyometric training frequency. Rather than concentrating on the *frequency,* many authors and personal trainers rely more on the *recovery time* between plyometric training sessions [19, 20, 21, 23]. Forty-eight to 72 hours between plyometric sessions (i.e., recovery time) is a typical guideline when one is prescribing plyometrics [19, 20, 21, 23]; using these typical recovery times, most clients should perform one to three plyometric sessions per week.

Recovery

Because plyometric drills involve maximal efforts to improve anaerobic power, a complete, adequate *recovery* (the time between repetitions, sets, and workouts) is required [63, 83]. Recovery for depth jumps may consist of 5 to 10 seconds of rest between repetitions and two to three minutes between sets. The time between sets is determined by a proper work-to-rest ratio (i.e., a range of 1:5 to 1:10) and is specific to the volume and type of drill being performed. That is, the higher the intensity of a drill, the more rest a client requires. For example, rest between sets of a plyometric skip will be shorter than the rest between sets of a depth jump.

Volume

Plyometric *volume* is typically expressed as the number of repetitions and sets performed during a given training session. Lower body plyometric volume is normally expressed as the number of foot contacts (each time a foot, or feet together, contact the surface) per workout [1, 19, 20, 21, 23], but may also be expressed as distance, as with plyometric bounding. For example, a client beginning a plyometric training program may start with a double-arm **bound** for 30 meters (33 yards) per repetition but advance to 100 meters (109 yards) per repetition for the same drill. Lower body plyometric volumes vary for clients of different needs (i.e., client age and goals; resistance training and plyometric experience); suggested volumes are provided in table 17.4. Upper body plyometric volume is typically expressed as the number of throws or catches per workout.

The guidelines of mode, intensity, frequency, and volume can now be applied to the sample clients, first introduced on page . See the chart on page for sample plyometric programs designed for these clients.

Progression

Plyometric exercise is a form of resistance training and thus must follow the principles of progressive overload—a systematic increase in training frequency, volume, and intensity through the use of various combinations. Typically, as intensity in-

TABLE 17.4

General Plyometric Volume Guidelines Based on Age and Experience

Age	No resistance training experience	More than 3 months general resistance training experience	More than 3 months resistance training experience, including power exercises	More than 1 year general resistance training experience	More than 1 year resistance training experience, including power exercises	Resistance training but no plyometric training experience	Resistance training and plyometric training more than 1 year ago	Resistance training and plyometric training within past year
≤13	Nr*	Nr	Nr	Nr	Nr	Nr	Nr	Nr
14-17	Nr	40-60	40-60	60-80	80-100	40-60	60-80	80-100
18-30	Nr	60-80	60-80	80-100	100-120	80-100	100-120	120-140
31-40	Nr	40-60	60-80	60-80	80-100	60-80	80-100	100-120
41-60	Nr	40-60	40-60	60-80	60-80	40-60	60-80	80-100

Note: Volume is expressed as number of foot contacts (lower body plyometrics) or throws and catches (upper body plyometrics). Beginning plyometric training volume may be based on a variety of factors. The volumes included in this table may be modified according to individual client goals and abilities.

Nr = not recommended (i.e., no plyometric training for a client in this situation).

creases, volume decreases, progressing from low to moderate volume of low-intensity plyometrics to low to moderate volumes of moderate to high intensity.

Warm-Up

As with any training program, the plyometric exercise session must begin with general and specific warm-ups (refer to chapter 12 for discussion of warm-up). The general warm-up may consist of light jogging or using a stationary bicycle at low intensity, while a specific warm-up for plyometric training should consist of low-intensity, dynamic movements similar in style to those performed during plyometric exercises. Refer to table 17.5 for a description of dynamic warm-up drills that are generally appropriate for most clients.

Plyometric programs must include the many elements essential to effective training program design. Following a needs analysis, the variables to be included in the program design are mode, intensity, frequency, recovery, volume, program length, progression, and warm-up.

Safety Considerations

Plyometric exercise is not inherently dangerous; however, as with all modes of exercise, injury risk is present. Injuries may occur following an accident, but they more typically occur when training procedures are violated and may result from an improper program design, inadequate instruction and supervision, or inappropriate training environment. Personal trainers must understand and address these and other risk factors to improve the safety of the client performing plyometric exercise.

Pretraining Evaluation

To reduce the risk of injury and to improve the performance of plyometric exercises, the client must understand proper plyometric technique and possess a sufficient base of strength, speed, and balance. In addition, the client must be sufficiently mature both physically and psychologically to participate in a plyometric training program. The following evaluative items will help determine whether these conditions have been met.

Sample Plyometric Programs for Client Examples

	Mode	Intensity*	Frequency (sessions per week)*	Volume*	Activity-specific drills**
Sport Client A	LB***	Medium	2	100 contacts	Double-leg tuck jump Standing long jump Double-leg vertical jump Double-leg hop Jump to box Jump from box
Sports Client B	LB and UB	Low	1	60 contacts 20 throws for UB	Standing long jump Double-leg hop Skip Jump to box Chest pass Two-hand overhead throw
Work Client A	LB and UB	Medium-high	2	100 contacts for LB 20 throws for UB	Split squat jump Standing long jump Double-leg vertical jump Single-leg push-off Jump to box Chest pass Depth push-up
Work Client B	Though this client would benefit from plyometrics eventually, because she has not previously participated in a resistance training program she must begin there and can progress to plyometric training after three months.				
Injury Prevention Client A	LB	Low	1	40 contacts	Split squat jump Double-leg vertical jump Skip Jump from box
Injury Prevention Client B	LB and UB	Low	1	40 contacts	Split squat jump Standing long jump Single-leg push-off Lateral push-off

* The values for these variables represent beginning levels; each will be advanced according to client tolerance and performance. (See page for a description of these clients.)

**The drills provided for each client are examples of exercises that are appropriate, based on the client's background, goals, and experience. The client is not expected to include all of the listed drills in his or her program.

***LB = lower body; UB = upper body.

Landing Position

Before the personal trainer adds any drill to a client's plyometric program, it is necessary to demonstrate proper technique in order to maximize the drill's effectiveness and minimize the risk of injury. For lower body plyometrics, proper landing technique is essential and is of particular importance for depth jumps. If the center of gravity is offset from the base of support, performance will be hindered and injury may occur. During the landing the shoulders should be over the knees, and the knees should be over the toes, with the ankles, knees, and hips flexed (figure 17.2).

Strength

One must consider the client's level of strength before the client performs plyometrics. If the

TABLE 17.5

Plyometric Warm-Up Drills

Dynamic warm-up drill	Description
Lunging	Performed to improve the client's readiness to move into a variety of positions May be performed in a variety of directions (e.g., forward, diagonal, backward)
Toe jogging	Jogging while not allowing the heels to touch the ground
Straight-leg jogging	Jogging while maintaining an extended (or nearly extended) knee
"Butt-kicker"	Jogging and allowing the heel to touch the buttocks through leg flexion
Skipping	Exaggerated mode of reciprocal upper and lower body movements
Footwork	A variety of drills that require changes in direction (e.g., shuffling, sliding, carioca, backward running)

Figure 17.2 Proper plyometric landing position. *(a)* The shoulders are in line with the knees, which helps place the center of gravity over the body's base of support. *(b)* The knees are in line with the feet. There is no valgus (·········) or varus (------) deviation.

client does not possess sufficient muscular strength, plyometrics should be delayed until certain standards—originally intended for athletes—are met. Because research has yet to define a prerequisite level of strength, the following guidelines offer the only published recommendations available for personal trainers to use when determining a client's readiness to participate in a plyometric training program.

For lower body plyometrics, the client's 1RM squat should be at least 1.5 times his or her body weight [17, 29, 46, 63, 83]. For upper body plyometrics, clients weighing more than 220 pounds (100 kilograms) should have a bench press 1RM of at least

1.0 times their body weight, while those under 220 pounds should have a bench press 1RM of at least 1.5 times their body weight [46, 63, 83]. An alternative measure of prerequisite upper body strength is the ability to perform five clap push-ups in a row [63, 83]. These guidelines assure that the client has sufficient strength to engage in plyometric exercises; but if this is not the case, the client may begin a plyometric training program using a low volume of low-intensity exercises provided that he or she has been consistently involved in a resistance training program. Table 17.4 provides suggested volumes according to different training experiences.

Speed

Perhaps a more specific need for plyometric training participants is speed of exercise movement. Because plyometric exercise relies on quick movements, the ability to move rapidly is essential before a client begins a plyometric program. Again, in the absence of research specifying the level of speed necessary to perform plyometric exercise, the following requirements provide an acceptable speed base. For lower body plyometrics, the client should be able to perform five repetitions of the squat with 60% body weight in five seconds or less [63, 83]. To satisfy the speed requirement for upper body plyometrics, the client should be able to perform five repetitions of the bench press with 60% body weight in five seconds or less. Like the strength guidelines mentioned previously, the speed requirements provided here were originally intended for athletic populations. As with the strength requirement, should a client lack the speed of movement described here, he or she may begin a plyometric training program provided that the program starts with lower-intensity drills that do not rely as heavily on speed of movement (e.g., two-foot ankle hop, standing long jump, double-leg vertical jump).

Balance

A less obvious lower body plyometric requirement is **balance—**the ability to maintain a position for a given period of time without moving. Many lower body plyometric drills require the client to move in nontraditional movement patterns (e.g., double-leg zigzag hop and backward skip) or on a single leg (e.g., single-leg tuck jump and single-leg hop). These types of drills necessitate a solid, stable base of support upon which the client can safely and correctly perform the plyometric exercises. Even lower-intensity drills performed by clients just beginning a plyometric program require sufficient balance to prevent injury.

Three balance tests are provided in table 17.6 and are divided into level of difficulty; each test position must be held for 30 seconds [81]. For example, a client beginning plyometric training with double-leg drills for the first time is required to stand on one leg for 30 seconds without falling. An experienced client beginning an advanced plyometric training program involving single-leg drills must maintain a single-leg half-squat for 30 seconds without falling. The surface on which the balance testing is performed must be the same as that for the plyometric drills.

TABLE 17.6

Balance Tests

Level*	Position**	Drill variation***
Beginning	Standing	Double leg Single leg
Intermediate	Quarter-squat	Double leg Single leg
Advanced	Half-squat	Double leg Single leg

*Each of these levels corresponds with a drill's intensity level (e.g., beginning-level balance corresponds with low-intensity plyometric drills).

**The client is required to maintain each position with each variation for 30 seconds before attempting plyometric exercises of the same intensity and the more difficult balance test.

***The type of balance test (i.e., how many legs are used) needs to match the intended type of plyometric drill (e.g., the beginning client has to pass the standing single-leg balance test to qualify to perform single-leg plyometric drills).

Maturity

Though one guideline is to exercise caution with use of plyometric training for clients under 14 years and older than 60 years of age, physical maturity should not be the sole determinant of plyometric preparedness; psychological and mental maturity are necessary before someone begins plyometric training. The client must respond positively to the personal trainer's instructions to proceed with plyometric training. If he or she does not, plyometric training should be postponed. Injury, overtraining, or undertraining may result if the client is inattentive to instructions.

Physical Characteristics

As with other forms of exercise, joint structure, posture, body type, and previous injuries must be examined and reviewed prior to beginning a plyometric training program. Previous injuries or abnormalities of the spine, lower extremities, or upper extremities may increase a client's risk of injury during performance of plyometric exercise. Specifically, clients with a history of muscle strains, pathological joint laxity, or spinal dysfunction, including vertebral disc dysfunction or compression injuries [36, 37], should exercise caution when beginning plyometric training [46, 72].

A specific characteristic requiring a personal trainer's caution is client size. Clients weighing more than 220 pounds (100 kilograms) may be at an increased risk for injury when performing plyometric exercises [63, 83]. Because greater weight increases joint compressive forces, these clients are at increased risk of injuring their lower extremity joints. Therefore, clients weighing over 220 pounds (100 kilograms) should avoid high-volume, high-intensity plyometric exercises. For the same reason, clients weighing over 220 pounds should not perform depth jumps from heights greater than 18 inches (46 centimeters) [63, 83].

Equipment and Facilities

In addition to proper participant fitness and health, the area where the client performs plyometric drills and the equipment used may significantly affect his or her safety.

Landing Surface

To prevent injuries, the landing surface used for lower body plyometrics must possess adequate shock-absorbing properties but must not be so absorbent as to significantly increase the transition between eccentric and concentric phases. A grass field, a suspended floor, and rubber mats are good surface choices [46]. Surfaces such as concrete, tile, and hardwood are not recommended because they lack effective shock-absorbing properties [46]. Excessively thick (greater than or equal to six inches [15 centimeters]) exercise mats and mini-trampolines may extend the amortization phase, thus not allowing efficient use of the stretch reflex.

Minimum Requirements for Participation in a Plyometric Training Program

- Proper technique for each drill
- More than three months of resistance training experience
- Sufficient strength, speed, and balance for the level of drill used
- Over 13 years of age
- No current injuries to involved body segments

Training Area

The amount of space needed depends on the drill. Most bounding and running drills require at least 30 meters (33 yards) of straightaway, though some drills may require a straightaway of 100 meters (109 yards). For most standing, box, and depth jumps, only a minimal surface area is needed; but adequate height—three to four meters (9.8 to 13.2 feet)—is required.

Equipment

Boxes used for box jumps and depth jumps must be sturdy and should have a nonslip top. Box heights should range from 6 to 42 inches (15-107 centimeters) [3, 24, 38, 50, 57] with landing surfaces of at least 18 by 24 inches (46 by 61 centimeters) [20]. The box should be constructed of sturdy wood (e.g., 3/4-inch [1.9-centimeter] plywood) or heavy gauge metal. To further reduce injury risk, ways to make the landing surface nonslip are to (1) add nonslip treads, (2) mix sand into the paint used on the box, or (3) affix rubberized flooring to the top of the box [20].

Proper Footwear

Plyometrics require footwear with good ankle and arch support, good lateral stability, and a wide, nonslip sole [63, 83]. Shoes with a narrow sole and poor upper support (e.g., running shoes) may invite ankle problems, especially with excessive lateral movements.

Supervision

In addition to the safety considerations already mentioned, clients must be closely monitored to ensure proper technique. Plyometric exercise is not intrinsically dangerous when performed correctly; but as with other forms of training, poor technique may unnecessarily predispose a client to injury. It is especially important for personal trainers to monitor client jumping and landing technique for lower extremity drills. In particular, personal trainers must instruct clients to avoid extremes of lateral knee motion (i.e., valgus and varus movements (see figure 17.2)) and to minimize time spent on the ground. While not passing them in the front (anteriorly), knees should line up with the second and third toes, with the amortization phase kept as short as possible. Should the client deviate from these norms, drill intensity should be lowered to allow successful completion of each drill. Common technique errors are provided for each drill at the end of this chapter.

Speed Training Mechanics and Physiology

All sports depend on the speed of execution; that is, whether a client is a sprinter, cross country runner, or swimmer, success depends on the ability to perform a given task in the shortest time possible. Speed training has been classically considered a modality used to improve sport function. Indeed, many of the concepts discussed in the paragraphs that follow are difficult to incorporate into personal training programs for those uninvolved in sport. For example, training to improve speed in soccer and baserunning in baseball should seem obvious. Training to improve speed in a work setting is more challenging to envision and difficult to defend as an appropriate exercise mode for the personal trainer to choose. The paragraphs that follow, then, use primarily athletic settings and situations as examples. Some nonsporting applications, however, are provided as appropriate.

Speed Training Definitions

The basis of speed training is the application of maximal force in a minimal amount of time. Accomplished in a variety of ways, this simply means that if a client is to move more quickly, he or she must *explode* when his or her feet are on the ground. **Speed-strength** is this application of maximum force at high velocities [79, 80]. People improve speed-strength in essentially the same way they improve muscular power production, by performing rapid movements both with and without resistance. Examples include weightlifting-type movements (e.g., power clean, hang clean, snatch) and plyometric exercise; each of these exercise modes is performed quickly to potentiate muscle force through the release of stored elastic energy and the stretch reflex. Therefore, to improve speed-strength, the exercise prescription should rely on powerful exercises and avoid those requiring slow movement [76].

Speed-endurance is the ability to maintain running speed over an *extended duration* (typically longer than six seconds) [28]. The development of speed-endurance helps prevent a client from slowing down during a maximal-speed effort. Consider a soccer player caught from behind on a breakaway or a police officer on foot who is unable to keep up with a fleeing suspect. Each of these illustrates poor speed-endurance; that is, each person either slowed down or was unable to accelerate due to fatigue.

Sprinting Technique

Technique evaluation is an important tool to use when assessing movement efficiency and, ultimately, when training to improve speed. The basic techniques of running are presented in chapter 14; running for speed, or sprinting, though similar, is a considerably different form of training. Like running, sprinting is a somewhat natural activity, though it may be performed in a variety of ways. Because of this relative normalcy, technique training should initially focus on optimizing form and correcting faults [22]; developing completely new movement patterns is typically unnecessary. The form and faults that characteristically need correction center on posture and action of the legs and arms. Maximizing sprinting speed, therefore, depends on a combination of optimal body posture, leg action, and arm action (figure 17.3, a-b) [26, 39, 47, 58, 70, 75].

Posture

While maintaining a relaxed, upright position, the head, torso, and legs should be aligned at all times. Although commonly viewed as a controlled fall [13], sprinting may be more accurately described as a series of "ballistic strides where the body is repeatedly launched forward as a projectile" [71]. The body should lean forward approximately 45 degrees during acceleration and should quickly move upright to a less than 5-degree lean during maximal speed (with the lean coming from the ground up, not the waist up). Head should be relaxed with minimal movement, and eyes should be focused straight ahead.

Leg Action

During the **support phase,** the client's weight should be concentrated near the ball of the foot directly under the client; once the foot leaves the ground it remains dorsiflexed and should move directly toward the buttocks. Increasing sprinting speed should increase the height the foot moves toward the buttocks (the heel kick). The knee then extends to an approximately 90-degree position and then becomes nearly straight as the foot moves down and forward during flight. At foot strike, the foot should be placed directly under—or a very short distance in front of—the hips (i.e., center of gravity). Ground contact time should be minimal while allowing explosive leg movement.

Arm Action

Remaining relaxed, each elbow should be flexed to approximately 90 degrees; movement must be an aggressive front-to-back action originating from the shoulder with minimal frontal plane motion. Hands should rise to nose level during anterior arm swing and should pass the buttocks when moving posteriorly. Using aggressive hand and knee hammering or punching motions helps to improve leg action.

During a sprint, support time should be kept brief while braking forces at ground contact are minimized and the backward velocity of the lower leg and foot at touchdown is maximized. Maximizing sprinting speed depends on a combination of optimal body posture, leg action, and arm action.

Speed Training Program Design

As with plyometric exercise prescription, research on program design for speed training is sparse and therefore practical experience must be the guide. Speed training exercise prescription uses typical program design variables to provide a safe and effective plan to improve a client's speed.

Mode

The *mode* of speed training is determined by the speed characteristics that the given drill is designed

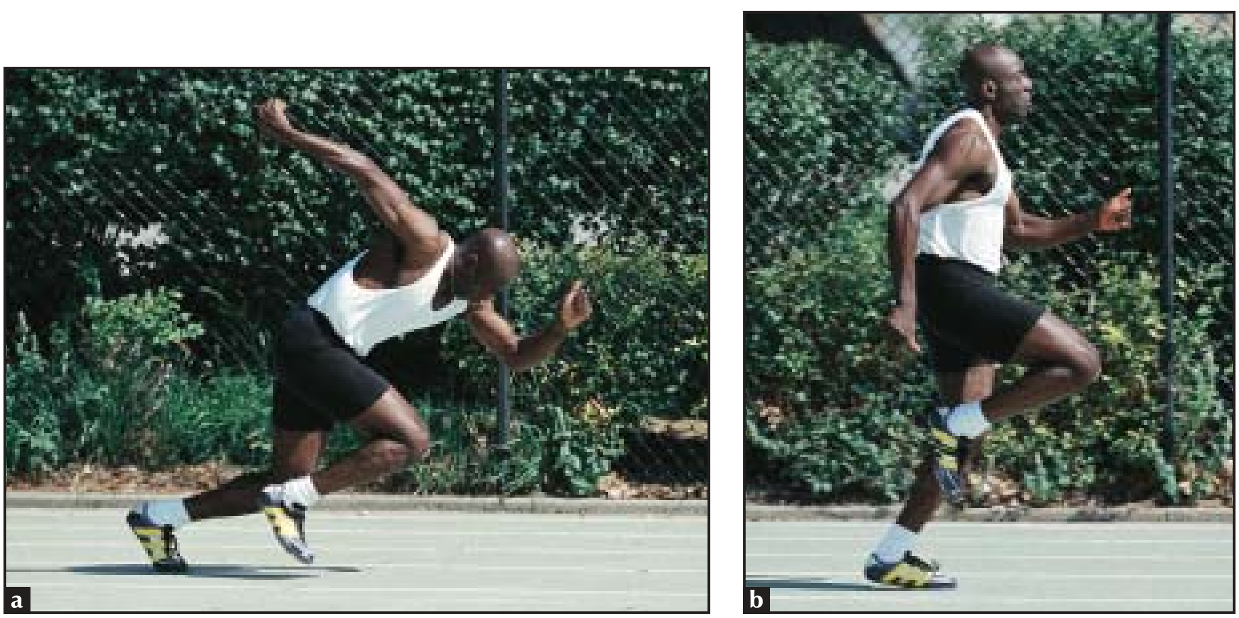


Figure 17.3 Proper sprinting technique. *(a)* At initial acceleration, the body should be leaning forward approximately 45 degrees, and *(b)* should then quickly move upright to a less than 5-degree lean.

to improve. Speed training focuses on three areas: form, stride frequency, and stride length. Improving sprinting technique may be accomplished in a number of ways, including sprint performance, stride analysis, and specific **form drills.** Drills designed to improve form are provided at the end of this chapter.

Within an analysis of running speed, stride frequency and stride length have an intimate relationship. In general, as both the **stride frequency** (the number of strides performed in a given amount of time) and **stride length** (the distance covered in one stride) increase, running speed improves. During the start, speed is highly dependent on stride length; as sprinting speed increases, frequency becomes the more important variable [61, 66, 67, 75, 87]. Of the two components, stride frequency is likely the more trainable, as stride length is highly dependent on body height and leg length [61, 62].

Stride frequency is typically increased through the use of **sprint-assisted training,** or running at speeds greater than a client is able to independently achieve [25]. The supramaximal speed forces the client to take more steps than he or she is accustomed to taking during a typical sprint. Assuming that stride length remains the same as during normal sprinting, increasing the frequency of strides will help the client run faster. There are a variety of methods by which to accomplish sprint-assisted training, including downgrade sprinting (3-7 degrees), high-speed towing, and use of a high-speed treadmill. Regardless of the method used, sprint-assisted training should not increase speed by more than 10% of the client's maximal speed.

Sprint-assisted training is an advanced technique that requires careful instruction and demonstration on the part of the personal trainer and clear understanding on the part of the client. Sprint-assisted training may cause a client to alter his or her technique, which will affect running without assistance. Further, a proper warm-up to each session should be considered mandatory.

Resisted sprinting is used to help a client increase stride length, as well as speed-strength, by increasing the client's ground force production during the support phase [26, 31, 39, 42, 47, 51, 55, 73], which is arguably the most important determinant of speed [76]. Again, while maintaining proper form, clients may use upgrade sprinting or sprinting while being resisted by a sled, elastic tubing, or a parachute [25]. Resisted sprinting should not increase external resistance by more than 10% [71].

As with most other speed training techniques, resisted sprinting targets clients wanting to improve speed strength. Adding resistance to a nonathletic client's gait, however, may also improve function. For example, attaching elastic tubing to provide resistance to a 70-year-old client during walking may improve his or her ability to walk up hills or may increase confidence during walking, thereby reducing the risk of injury from a possible fall. Providing resistance to a construction worker by having the individual push a weighted implement or sled may improve his or her ability to push a wheelbarrow filled with cement.

Although nearly all clients may perform form drills, sprint-assisted and -resisted training may be too advanced for some. A more general mode of speed training that most clients can easily perform is **interval sprinting.** Specifically, a client sprints (or runs or walks, depending on abilities) as fast as possible over a given distance or for a predetermined amount of time, then rests. Following the rest period, the client repeats the bout. In performing interval training, clients are able to maintain higher-intensity work periods (i.e., sprint/run/walk) by interspersing them with times of rest [33].

Intensity

Speed training *intensity* refers to the physical effort required during execution of a given drill, and is controlled both by the type of drill performed and by the distance covered. The intensity of speed training ranges from the low-level form drills to sprint-assisted and -resisted sprinting drills that apply significant stress to the body.

Frequency

Frequency, the number of speed training sessions per week, depends on the client's goals. As with other program variables, research is limited on the optimal frequency for speed training sessions; again, personal trainers must rely on practical experience when determining the appropriate frequency. For clients who are athletes participating in a sport, two to four speed sessions per week is common; nonathletic clients may benefit from one to two speed sessions per week.

Recovery

Because speed training drills involve maximal efforts to improve speed and anaerobic power, complete, adequate *recovery* (the time between repetitions and sets) is required to ensure maximal effort with each repetition [63, 83]. The time between repetitions is determined by a proper work-to-rest ratio (i.e., a range of 1:5 to 1:10) and is specific to the volume and type of drill being performed. That is, the higher the intensity of a drill, the more rest a client requires. Recovery for form training may be minimal, whereas rest between repetitions of downgrade running may last two to three minutes.

Volume

Speed training *volume* typically refers to the number of repetitions and sets performed during a given training session and is normally expressed as the distance covered. For example, a client beginning a speed training program may start with a 30-meter (33-yard) sprint but advance to 100 meters (109 yards) per repetition for the same drill. As with intensity, speed training volume should vary according to the client's goals.

Progression

Speed training must follow the principles of progressive overload—a systematic increase in training frequency, volume, and intensity through various combinations. Typically, as intensity increases, volume decreases. The program's intensity should progress from

1. low to moderate volume of low-intensity speed drills (e.g., stationary arm swing) to
2. low to moderate volumes of moderate intensity (e.g., butt kicker) to
3. low to moderate volumes of moderate to high intensity (e.g., downhill sprinting).

Warm-Up

As with any training program, the speed training session must begin with both general and specific warm-ups (refer to chapter 12 for a discussion of warm-up). The specific warm-up for speed training should consist of low-intensity, dynamic movements. Once mastered, many of the form drills provided at the end of this chapter may be incorporated into warm-up drills.

Speed Training Safety Considerations

While not inherently dangerous, speed training—like all modes of exercise—places the client at risk of injury. Injuries during speed training commonly occur because of insufficient strength or flexibility, inadequate instruction and supervision, or inappropriate training environment.

Pretraining Evaluation

To reduce the risk of injury during participation in a speed training program, the client must understand proper technique and possess a sufficient base of strength and flexibility. In addition, the client must be sufficiently prepared to participate in a speed training program. The following evaluative elements will help determine whether a client meets these conditions.

Physical Characteristics

As in the case of other forms of exercise, it is necessary to examine and review joint structure, posture, body type, and previous injuries before a client begins a speed training program. Previous injuries or abnormalities of the spine, lower extremities, and upper extremities may increase a client's risk of injury during participation in a speed training program. An area of concern is hamstring flexibility and strength; as the swing leg—the leg not on the training surface—transitions from an eccentric muscle action to concentric, the hamstring must be prepared to undergo extreme amounts of stretch (during the eccentric phase of the movement) followed by nearly instantaneous concentric muscle action. If this muscle is not prepared (through both strength and flexibility training), injury becomes likely.

Technique and Supervision

When a client will be performing speed training drills, the personal trainer must demonstrate proper technique—as previously described—to maximize the drill's effectiveness and to minimize the risk of injury. Posture and proper arm and leg actions are especially important characteristics for the personal trainer to watch. It is essential to monitor clients closely to ensure proper movement patterns and sprinting technique. Should the client not demonstrate correct technique, drill intensity must be lowered to allow successful completion of each drill. Common technique errors are listed for each drill at the end of this chapter.

Exercise Surface and Footwear

In addition to proper participant fitness, health, and technique, the area where the client performs speed training drills may significantly affect his or her safety. To prevent injuries, the landing surface used for speed training drills must possess adequate shock-absorbing properties, but must not be so absorbent as to significantly increase the transition between the eccentric and concentric phases of the SSC. Grass fields, suspended floors, and rubber mats are good surface choices [46]. Avoid excessively thick exercise mats (greater than or equal to six inches [15 centimeters]) because they may lengthen the amortization phase, thus not allowing efficient use of the stretch reflex. In addition, footwear with good ankle and arch support and a wide, nonslip sole is required [63, 83].

Combining Plyometrics and Speed Training With Other Forms of Exercise

Plyometrics and speed training are just parts of a client's overall training program. Many sports and activities use multiple energy systems or require other forms of exercise to properly prepare athletes for their competitions or to help clients reach their goals. A well-designed training program must address each energy system and training need.

Resistance, Plyometric, and Speed Training

Combining plyometric and speed training with resistance training requires careful consideration to optimize recovery while maximizing performance. The following list and table 17.7 provide appropriate guidelines for developing a program that combines these different, but complementary, modes of training:

- In general, clients should perform *either* lower body plyometric training, speed training, *or* lower body resistance training on a given day, but not more than one of these types of training on the same day.
- It is appropriate to combine lower body resistance training with upper body plyometrics, and upper body resistance training with lower body plyometrics.
- Performing heavy resistance training and plyometrics on the same day is not usually recommended [17, 42]. However, some athletes may benefit from **complex training**—a combination of resistance and plyometric training—by performing high-intensity resistance training followed by plyometrics. If an individual is engaging in this type of training, adequate recovery between the plyometrics and other high-intensity lower body training—including speed training—is essential.
- Traditional resistance training exercises may be combined with plyometric movements to further enhance gains in muscular power [85, 86]. For example, performing a squat jump with approximately 30% of one's 1RM squat as an external resistance further increases performance [85, 86]. This is an advanced form of complex training that should be performed only by clients with previous participation in high-intensity plyometric training programs.

Plyometric and Aerobic Exercise

Many sports and activities require both a power and an aerobic component. It is necessary to combine multiple types of training to best prepare clients for these types of sports. Because aerobic exercise may have a negative effect on power production during a given training session [17], it is advisable to perform plyometric exercise prior to the longer, aerobic endurance-type training. The design variables do not change and should complement each other

TABLE 17.7

Sample Schedule for Resistance, Plyometric, and Speed Training

Day	Resistance training	Plyometric training	Speed training
Monday	Upper body	Lower body	Rest
Tuesday	Lower body	Upper body	Rest
Wednesday	Rest	Rest	Technique and sprint-assisted drills
Thursday	Upper body	Lower body	Rest
Friday	Lower body	Upper body	Rest
Saturday	Rest	Rest	Technique and sprint-resisted drills

to most effectively train the athlete for competition or help a client meet his or her goals. Recent studies actually indicate that plyometrics may improve long-distance running [77]; therefore adding low-intensity bounding-type drills to non-running days may improve long-distance running performance.

> Plyometric exercise should be incorporated into an overall training program, including both strength and aerobic exercise. Speed training may be combined with plyometric and resistance training, but this requires careful planning to optimize recovery while maximizing performance.

CONCLUSION

The ability to apply force quickly and provide an overload to the agonist muscles is the major goal of plyometric training, a benefit to most sporting activities and many occupations. Further, because the ability to move rapidly is needed in sport, speed training may be another important component to include for clients active in competitive and recreational sports. Necessary during performance of each of these forms of exercise is the proper application of force to the ground in a minimal amount of time. If the force used is insufficient or if it requires too long a time to generate, the ability to effectively accelerate, change direction, or overtake an opponent is lost.

In addition to improving the potential to succeed in sport, speed and especially plyometric training may improve function on the job or may reduce the risk of injury. Many occupations require employees to lift or move large objects, move quickly, or otherwise perform explosive movements. Using the plyometric and speed training principles outlined is an ideal method of improving the important speed-strength quality important to so many activities. In addition, the ability to decelerate efficiently and under control is indispensable to any attempt to reduce a client's risk of injury. Proper performance of plyometric drills helps clients learn how to decelerate when landing from a jump or when changing directions.

Plyometric training and speed training should not be considered ends in themselves, but as parts of an overall program (in addition to resistance, flexibility, and aerobic training and proper nutrition). Clients possessing adequate levels of strength perform plyometric and speed training drills more successfully. Further, combining these modes of exercise with others allows clients to optimize performance, regardless of sport or activity requirements.

Plyometric and Speed Drills

Lower-Body Plyometric Drills

- Double-Leg Tuck Jump
- Split Squat Jump
- Standing Long Jump
- Double-Leg Vertical Jump
- Double-Leg Hop
- Front Barrier Hop
- Skip
- Alternate Leg Bound—Double Arm
- Jump to Box
- Jump From Box
- Depth Jump

Upper-Body Plyometric Drills

- Chest Pass
- Depth Push-Up
- 45-Degree Sit-Up

Speed Drills

- Butt Kicker
- Stationary Arm Swing
- Downhill Sprint
- Partner-Assisted Towing
- Uphill Sprint
- Partner-Resisted Sprinting

Lower Body Plyometric Drills

Double-Leg Tuck Jump

Intensity level: Medium

Direction of jump: Vertical

Beginning position: Assume a comfortable upright stance with feet shoulder-width apart.

Arm action: Double arm

Preparatory movement: Begin with a countermovement.

Upward movement: Explosively jump up. Pull the knees to the chest and quickly grasp the knees with both hands and release before landing.

Downward movement: Land in the starting position and **immediately** repeat the jump.

Advanced variation: A way to increase the intensity of the double-leg tuck jump is to perform the jump with one leg only. This changes the drill's intensity from medium to high.

Common Errors

- Amortization phase (i.e., time on the floor/ground) is too long.
- Clients do not jump and land in the same place; there is excessive lateral and anterior/posterior movement.

Split Squat Jump

Intensity level: Medium

Direction of jump: Vertical

Beginning position: Assume a lunge position with one leg forward (hip and knee joints in approximately 90 degrees of flexion) and the other behind the midline of the body.

Arm action: Double or none

Preparatory movement: Begin with a countermovement.

Upward movement: Explosively jump up, using the arms to assist as needed. Maximum height and power should be emphasized.

Downward movement: When landing, maintain the lunge position (same leg forward) and **immediately** repeat the jump.

Note: After completing a set, rest and switch front legs.

Advanced variation: While off the ground, switch the position of the legs so the front is in the back and the back is in the front. When landing, maintain the lunge position (opposite leg forward) and immediately repeat the jump.

Common Errors

- The lunge position is too shallow.
- Amortization phase (i.e., time on the floor/ground) is too long.
- Clients do not jump and land in the same place; there is excessive lateral and anterior/posterior movement.

Standing Long Jump

Intensity level: Low

Direction of jump: Horizontal

Beginning position: Half-squat position with feet shoulder-width apart

Arm action: Double arm

Preparatory movement: Begin with a countermovement.

Upward movement: Explosively jump forward as far as possible with both feet. Use the arms to assist with the jump.

Downward movement: Land in the starting position and repeat jump. Allow complete rest between repetitions.

Common Errors

- Clients jump and land asynchronously; that is, feet neither leave nor contact the floor/ground at the same time.

Double-Leg Vertical Jump

Intensity level: Low

Direction of jump: Vertical

Beginning position: Assume a comfortable upright stance with feet shoulder-width apart.

Arm action: Double arm

Preparatory movement: Begin with a countermovement.

Upward movement: Explosively jump up with both legs, using both arms to assist and reach for a target.

Downward movement: Land in the starting position and repeat the jump. Allow complete recovery between jumps.

Advanced variation: One can increase the intensity of the double-leg vertical jump by performing the jump with one leg only. This changes the drill's intensity from low to high.

Common Errors

- Countermovement is too deep.
- Clients do not jump and land in the same place; there is excessive lateral and anterior/posterior movement.

Double-Leg Hop

Intensity level: Medium

Direction of jump: Horizontal and vertical

Beginning position: Assume a comfortable upright stance with feet shoulder-width apart.

Arm action: Double arm

Preparatory movement: Begin with a countermovement.

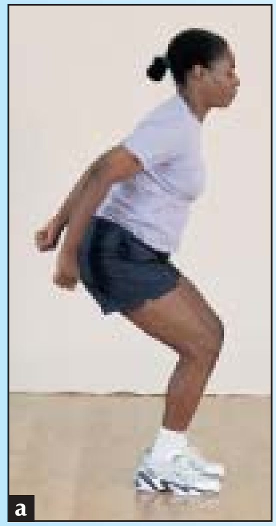
Upward movement: Jump as far forward as possible.

Downward movement: Land in the beginning position and **immediately** repeat the hop.

Advanced variation: A way to increase the intensity of the double-leg hop is to perform the hop with one leg only. This changes the drill's intensity from medium to high.

Common Errors

- Amortization phase (i.e., time on the floor/ground) between hops is too long.


a


b

Front Barrier Hop

Intensity level: Medium

Direction of jump: Horizontal and vertical

Beginning position: Assume a comfortable upright stance facing a barrier, with feet shoulder-width apart.

Arm action: Double arm

Preparatory movement: Begin with a countermovement.

Upward movement: Jump over a barrier with both legs, using primarily hip and knee flexion to clear the barrier. Keep the knees and feet together without lateral deviation.

Downward movement: Land in the starting position and **immediately** repeat the jump over the next barrier.

Alternate variation: This drill may also be performed laterally. Stand to either side of the barrier; jump over the barrier with both legs. Land in the starting position and immediately repeat the jump to the starting side.

Advanced variations: A way to increase the intensity of barrier hops is to progressively increase the height of the barrier (e.g., from a cone to a hurdle) or to perform the hops with one leg only. This changes the drill's intensity from medium to high.

Common Errors

- Amortization phase (i.e., time on the floor/ground) between hops is too long.
- Knees and feet separate in an effort to clear the barrier.


a


b

Skip

Intensity level: Low

Direction of jump: Horizontal and vertical

Beginning position: One leg is lifted to 90 degrees of hip and knee flexion.

Arm action: Reciprocal (as one leg is lifted, the opposite arm is lifted)

Preparatory movement: Begin with a countermovement.

Upward movement: Jump up and forward on one leg. The opposite leg should remain in the starting position until landing.

Downward movement: Land in the starting position with the same leg. Repeat the motion with the opposite leg.

Advanced variation: This drill may also be performed backward. Jump up and backward on one leg. Land in the starting position with the same leg. Repeat the motion with the opposite leg.

Common Errors

- Incoordination, that is, difficulty coordinating the transition from one leg to the other

Alternate-Leg Bound—Double-Arm

Intensity level: Medium

Direction of jump: Horizontal and vertical

Beginning position: Assume a comfortable upright stance with feet shoulder-width apart.

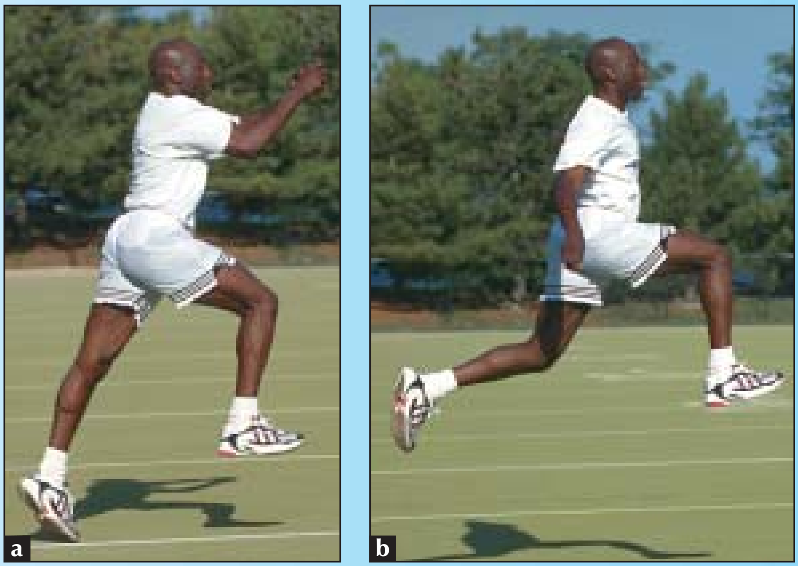
Arm action: Single arm

Preparatory movement: Jog at a comfortable pace; begin the drill with the left foot forward.

Upward movement: Push off with the left foot as it contacts the ground. During push-off, bring the right leg forward by flexing the thigh to a position parallel with the ground and the knee at 90 degrees. During this flight phase of the drill, reach forward with both arms.

Downward movement: Land on the right leg and **immediately** repeat the sequence with the opposite leg upon landing.

Note: A bound is an exaggeration of the running gait; the goal is to cover as great a distance as possible during each stride.



Alternate variation: Instead of reaching forward with both arms during the flight phase, the client may reach with a single arm while the opposite leg is in the flight phase.

Common Error:

- Clients do not have an appropriate balance between the horizontal and vertical components of the bound.

Jump to Box

Intensity level: Low

Equipment: Plyometric box, 6 to 42 inches (15 to 107 centimeters) high

Direction of jump: Vertical and slightly horizontal

Beginning position: Facing the plyometric box, assume a comfortable upright stance with feet shoulder-width apart.

Arm action: Double arm

Preparatory movement: Begin with a countermovement.

Upward movement: Jump onto the top of the box using both feet.

Downward movement: Land on both feet in a semisquat position; step down from the box and repeat.

Advanced variation: A way to increase the intensity of this jump is for the client to clasp the hands behind the head.

Common Errors

- Knees and feet separate in an effort to clear the barrier.
- Countermovement is too deep.
- Box is too tall for client's height or abilities.

Jump From Box

Intensity level: Medium

Equipment: Plyometric box, 12 to 42 inches (30 to 107 centimeters) high

Direction of jump: Vertical

Beginning position: Assume a comfortable upright stance with feet shoulder-width apart on the plyometric box.

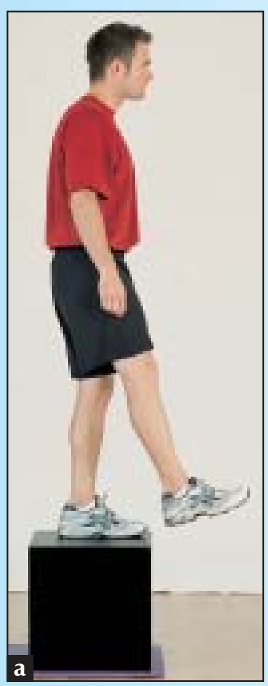
Arm action: None

Preparatory movement: Step from box.

Downward movement: Land on the floor with both feet quickly absorbing the impact upon touchdown. Step back onto box and repeat.

Common Errors

- Clients land asynchronously; that is, feet do not contact the floor/ground at the same time.
- Box is too tall for client's height or abilities.



Depth Jump

Intensity level: High

Equipment: Plyometric box, 12 to 42 inches (30 to 107 centimeters) high

Direction of jump: Vertical

Beginning position: Assume a comfortable upright stance with feet shoulder-width apart on the plyometric box; toes should be near the edge of the box.

Arm action: Double arm

Preparatory movement: Step from box.

Downward movement: Land on the floor with both feet.

Upward movement: Upon landing, **immediately** jump up as high as possible.

Note: Time on the ground should be kept to a minimum.

Note: A way to vary the intensity is to increase the height of the box. Begin with height of 12 inches (30 centimeters).

Common Errors

- Amortization phase (i.e., time on the floor/ground) is too long.
- Clients do not jump and land in the same place; there is excessive lateral and anterior/posterior movement after landing.
- Box is too tall for client's height or abilities.

Upper Body Plyometric Drills

Chest Pass

Intensity level: Low

Equipment: Medicine or plyometric ball (weight 2-8 pounds [1-3.6 kilograms]); personal trainer or partner

Direction of throw: Forward

Beginning position: Assume a comfortable upright stance with feet shoulder-width apart; face the personal trainer or partner approximately 10 feet (three meters) away. Raise the ball to chest level with elbows flexed.

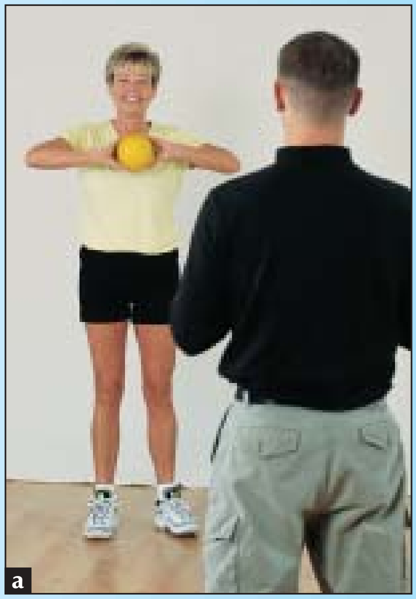
Preparatory movement: Begin with a countermovement. (With plyometric throws, a countermovement requires the performer to "cock" the arm(s), that is, move the arms slightly backward before the actual throw.)

Arm action: Using both arms, throw the ball to the personal trainer or partner by extending the elbows. When the personal trainer or partner returns the ball, catch it, return to the beginning position, and **immediately** repeat the movement.

Note: One can increase intensity by increasing the weight of the medicine ball. Begin with a 2-pound (1-kilogram) ball.

Common Errors

- Amortization phase (i.e., time ball is in hands) is too long.
- Ball is too heavy.


a


b

Depth Push-Up

Intensity level: Medium

Equipment: Medicine ball

Direction of movement: Vertical

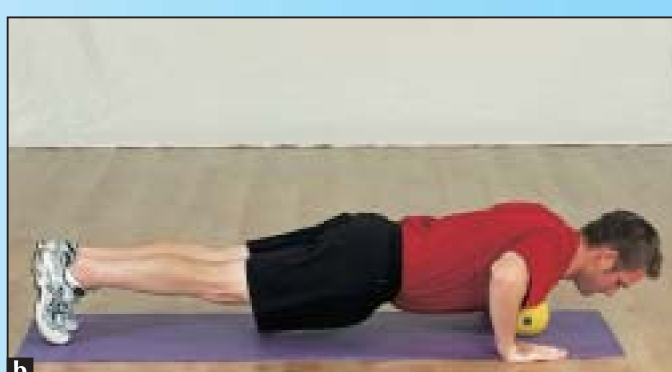
Beginning position: Lie in a push-up position, with the hands on the medicine ball and elbows extended.

Preparatory movement: None

Downward movement: Quickly remove the hands from the medicine ball and drop down. Contact the ground with hands slightly more than shoulder-width apart and elbows slightly flexed. Allow the chest to almost touch the medicine ball.

Upward movement: **Immediately** and explosively push up by extending the elbows to full extension. Quickly place the palms on the medicine ball and repeat the exercise.


a


b

Note: When the upper body is at maximal height during the upward movement, the hands should be higher than the medicine ball.

Note: One can increase intensity by increasing the size of the medicine ball. Begin with a 5-pound (2.3-kilogram) ball.

Advanced variation: A way to increase the intensity of this drill is for the client to perform it as described with the feet placed on an elevated surface (e.g., a plyometric box).

Common Errors

- Amortization phase (i.e., time hands are on the ground) is too long.
- Ball is too big, increasing the distance from the beginning position to the bottom of the downward movement.

45-Degree Sit-Up

Intensity level: Medium

Equipment: Medicine or plyometric ball; personal trainer or partner

Beginning position: Sit on the ground with the trunk approximately at a 45-degree angle to the ground. The personal trainer or partner should be in front with the medicine ball.

Preparatory movement: The personal trainer or partner throws the ball to outstretched hands.

Downward action: Once the partner throws the ball, catch it using both arms, allow some trunk extension, and **immediately** return the ball to the partner.

Note: One can increase the intensity by increasing the weight of the medicine ball. Begin with a 2-pound (1-kilogram) ball.

Note: The force used to return the ball to the personal trainer or partner should be predominantly derived from the abdominal muscles.

Common Errors

- Eccentric phase (i.e., amount of trunk extension) is too long.
- Ball is too heavy.


a


b


c

Speed Drills

Butt Kicker

Intensity level: Low
Equipment: None
Beginning position: Assume a comfortable, upright stance with feet shoulder-width apart. Begin to jog.
Movement: Pull the heel toward the buttocks by swinging the lower leg back. Allow the heel to "bounce" off the buttocks.
Advanced variation: The wall slide is performed using this same technique, except that the heel of the recovery leg stays anterior to the buttocks. This variation improves knee lift during the flight phase of sprinting.

Common Errors

- Forcing the heel toward the buttocks; instead the client should "allow" the heel to elevate toward the buttocks.
- Excessive thigh motion; the thigh should not move too much, and the client should concentrate on moving at the knee versus the hip joint.

Stationary Arm Swing

Intensity level: Low
Equipment: None
Beginning position: Assume a comfortable, upright stance with feet shoulder-width apart. Elbows should be in 90 degrees of flexion.
Movement: Maintaining elbows at 90 degrees and keeping hands relaxed, swing arms forward and back in a sprinting-type motion. The hands' arc of motion should be from nose level anteriorly to just past the hips posteriorly.

Common Errors

- Arms often cross the line of the body; client should maintain arm swing within the sagittal plane.
- Arm swing is often not forceful; be sure to maintain an aggressive hammering or punching motion.

Downhill Sprint

Intensity level: High
Equipment: A 3- to 7-degree downhill sprinting surface
Beginning position: At the top of the downhill area, assume a comfortable, upright stance with feet shoulder-width apart.
Movement: Maintaining correct posture and technique, sprint 30 to 50 meters (33 to 55 yards) downhill.

Common Errors

- Excessive braking or deceleration; do not exceed a 7-degree slope, and decrease the slope if braking continues.
- Proper form is not maintained; decrease the slope until proper technique returns.

Partner-Assisted Towing

Intensity level: High

Equipment: 10 to 20 meters (11 to 22 yards) of rubber tubing; personal trainer or partner

Beginning position: Attach the tubing to both the client and the personal trainer or partner, with the personal trainer or partner in front. The personal trainer or partner moves approximately 5 meters (5.5 yards) ahead while the client maintains the beginning position.

Movement: Maintaining the beginning distance between them, the personal trainer or partner and client beginning sprinting simultaneously.

Common Errors

- Insufficient assistance; be sure the personal trainer or partner is at least as fast as the client.
- Proper form is not maintained with increased speed; the personal trainer or partner should decrease the sprinting speed until proper technique returns.

Uphill Sprint

Intensity level: High

Equipment: A 3- to 7-degree uphill sprinting surface

Beginning position: At the bottom of the downhill area, assume a comfortable, upright stance with feet shoulder-width apart.

Movement: Maintaining correct posture and technique, sprint 30 to 50 meters (33 to 55 yards) uphill.

Common Errors

- Sprinting speed slows more than 10%; do not exceed a 7-degree slope, and decrease the slope if slowdown continues.
- Proper form is not maintained; decrease the slope until proper technique returns.

Partner-Resisted Sprinting

Intensity level: High

Equipment: 10 to 20 meters (11 to 22 yards) of rubber tubing; personal trainer or partner

Beginning position: With the client in front, attach one end of the tubing to the client while the personal trainer or partner holds the other end. The client moves approximately five meters (5.5 yards) ahead while the personal trainer or partner maintains the beginning position.

Movement: Maintaining the beginning distance between them, the client begins sprinting while the personal trainer or partner resists.

Common Errors

- Sprinting speed slows more than 10%; decrease the resistance until proper technique returns.
- Proper form is not maintained; the personal trainer or partner decreases the resistance until proper technique returns.

STUDY QUESTIONS

1. Which of the following exercises is best able to benefit from the advantages offered by the SSC?
   A. push press
   B. deadlift
   C. back squat
   D. front squat
2. Which of the following should be considered a requirement to participate in a plyometric training program?
   A. at least 18 years of age
   B. more than one year performing power exercises
   C. at least three months of general resistance training exercises
   D. less than 50 years of age
3. If a client is having difficulty performing a depth jump correctly—the amortization phase is too long—which of the following adjustments would be appropriate?
   A. discontinue the depth jump
   B. have the client try the jump using just one leg
   C. focus on "giving" with the landing
   D. decrease the height of the box
4. The personal trainer notices that a client takes short, choppy steps when sprinting. Which of the following types of training will help this client improve stride length?
   I. resisted sprinting
   II. assisted sprinting
   III. technique training
   IV. plyometric training
   A. I and III only
   B. II and IV only
   C. I, III, and IV only
   D. I, II, and III only

APPLIED KNOWLEDGE QUESTION

Fill in the chart to describe a sample plyometric training program based on the description and goals of the client.

A healthy, 35-year-old female who is a parttime aerobics instructor wants to begin a training program to compete in an aerobic fitness (sport aerobics) event. She has been resistance training since college and is familiar with how to perform plyometric drills. She is five feet, five inches (165 centimeters) tall, weighs 130 pounds (59 kilograms), and has a 195-pound (87-kilogram) 1RM back squat. During one of the weekly classes she teaches, she performs depth jumps and pushups off an aerobic step.

Mode	Intensity	Frequency	Volume	Activity-specific drills

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