CHAPTER **8**

Plyometric Training Concepts for Performance Enhancement

UPON COMPLETION OF THIS CHAPTER, YOU WILL BE ABLE TO:

- Describe plyometric training and its purpose for performance enhancement and injury prevention.
- Rationalize the importance of plyometric training.
- Design a plyometric training program for athletes in any level of training.

Introduction

The ability of muscles to exert maximal force output in a minimal amount of time (also kno wn as rate of force production) enhances performance during functional activities . All else being equal, success in most functional activities depends on the speed at which muscular force is generated. Power output and reactive neuromuscular control represents a component of function. Power and reactive neuromuscular control are perhaps the best measures of success in activities that require rapid force production. Plyometric training, also called reactive training, makes use of the stretch-shortening cycle to produce maximum force in the shortest amount of time and to enhance neuromuscular control efficienc , rate of force production, and reduce neuromuscular inhibition (1–20).

Plyometric Training Concepts

WHAT IS PLYOMETRIC TRAINING?

Plyometric Training *Defined as a qui k, powerful movement involving an eccentric contraction, followed immediately by an explosive concentric contraction.*

Plyometric training is defined as a quick, p werful movement involving an eccentric contraction, followed immediately by an explosive concentric contraction (21–23). This is accomplished through the stretch-shortening cycle or an eccentric-concentric coupling phase . The eccentric-concentric coupling phase is also referred to as the integrated performance paradigm (Fig. 8.1), which states that in order to move with precision, forces must be loaded (eccentrically), stabilized (isometrically), and then unloaded/accelerated (concentrically). Plyometric exercise stimulates the body's proprioceptive and elastic properties to generate maximum force output in a minimum amount of time (24).

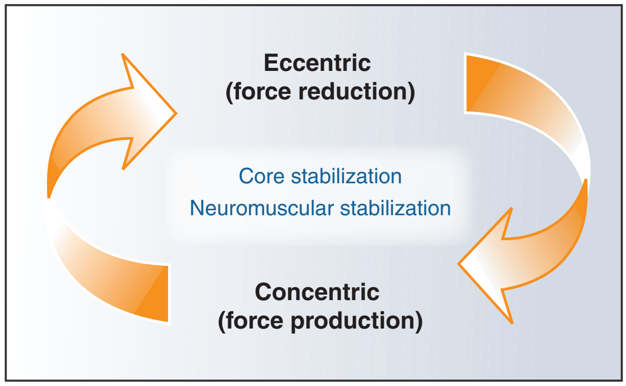

FIGURE 8.1 Integrated Performance Paradigm™.

Plyometric training is an effective mode of training as it enhances motor learning and neuromuscular efficiency y promoting the excitability, sensitivity, and reactivity of the neuromuscular system to increase the rate of force production (po wer), motor-unit recruitment, firin frequency (rate coding), and synchronization.

Muscles produce the necessary force to change the direction of an object' s center of mass (24). All movement patterns that occur during functional activities inv olve a series of repetitiv e stretch-shortening cycles. The neuromuscular system must react quickly and efficiently foll wing an eccentric muscle action to produce a concentric contraction and impart the necessary force (or acceleration) in the appropriate direction. Therefore, specific functional exercises that emphasize a rapid change in di rection must be utilized to prepare each athlete for the functional demands of a specific activit .

Plyometric training provides the opportunity to train specific m vement patterns in a biomechanically correct manner at a more functionally appropriate speed. This provides functional strengthening of the muscle, tendon, and ligaments specific to the demands of e eryday activities and sports. The ultimate goal of plyometric training is to improve the reaction time of the muscle action spectrum (eccentric deceleration, isometric stabilization, and concentric acceleration).

The speed of muscular exertion is limited by neuromuscular coordination. This means that the body will move most effectively and efficiently within a range of speed that the nervous system has been programmed to allow. Plyometric training improves both neuromuscular efficienc and the range of speeds set by the central nervous system. Optimum reactive performance of any activity depends on the speed at which muscular forces can be generated (19).

TIME OUT

Evidence-Based Research to Support the Use of Reactive Training for Injury Prevention and Performance Enhancement

- In 2004, Chimera et al., in a pre-post test control group design with 20 healthy Division I female athletes, found that a 6-week plyometric training program improved hip abductor/adductor coactivation ratios to help control varus/valgus moments at the knee during landing (1).
- In 2004, Wilkerson et al., in a quasi-experimental design with 19 female basketball players, demonstrated that a 6-week plyometric training program improved hamstring-quadricep ratios, which has been shown to enhance dynamic knee stability during the eccentric deceleration phase of landing (2).
- In 2003, Luebbers et al., in a randomized controlled trial with 19 subjects demonstrated that a 4-week and 7-week plyometric training program enhanced anaerobic power and vertical jump height (3).
- In 1996, Hewett et al., in a prospective study, demonstrated decreased peak landing forces, enhanced muscle-balance ratio both with the quadriceps and hamstring complex, and decreased rate of ACL injuries in female soccer, basketball, and volleyball players that incorporated reactive neuromuscular training into their program (4).

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Eccentric Phase of Plyometrics
This phase increases muscle spindle activity by pre-stretching the muscle prior to activation.

Amortization Phase of Plyometrics
The time between the end of the eccentric contraction (the loading or deceleration phase) and the initiation of the concentric contraction (the unloading or force production phase).

Concentric Phase of Plyometrics
Occurs immediately after the amortization phase and involves a concentric contraction.

THREE PHASES OF PLYOMETRIC EXERCISE

There are three distinct phases involved in plyometric training including the eccentric, or loading, phase; the amortization, or transition, phase; and the concentric, or unloading, phase (25).

THE ECCENTRIC PHASE

The first stage of a pl ometric movement can be classified as the eccentric phas , but it has also been called the deceleration, loading, yielding, countermo vement, or cocking phase (26). This phase increases muscle spindle activity by pre-stretching the muscle prior to activation (27). Potential energy is stored in the elastic components of the muscle during this loading phase . A slower eccentric phase prevents taking optimum advantage of the myotatic stretch reflex (22,28).

THE AMORTIZATION PHASE

This phase involves dynamic stabilization and is the time between the end of the eccentric contraction (the loading or deceleration phase) and the initiation of the concentric contraction (the unloading or force production phase) (29). The amortization phase, sometimes referred to as the transition phase, is also referred to as the electromechanical delay between the eccentric and concentric contraction during which the muscle must switch from o vercoming force to imparting force in the intended direction (3 0). A prolonged amortization phase results in less-than-optimum neuromuscular efficiency from a loss of elastic potential energy (1). A rapid switch from an eccentric contraction to a concentric contraction leads to a more powerful response (29,30).

THE CONCENTRIC PHASE

The concentric phase (or unloading phase) occurs immediately after the amortization phase and involves a concentric contraction (29,3 0,32), resulting in enhanced muscular performance following the eccentric phase of muscle contraction. This occurs secondary to enhanced summation and reutilization of elastic potential energy , muscle potentiation, and contribution of the m yotatic stretch reflex (33–35)

PHYSIOLOGICAL PRINCIPLES OF PLYOMETRIC TRAINING

Plyometric training utilizes the elastic and proprioceptive properties of a muscle to generate maximum force production (29,3 0) by stimulating mechanoreceptors to facilitate an increase in muscle recruitment in a minimal amount of time . Muscle spindles and Golgi tendon organs (GTOs) provide the proprioceptive basis for plyometric training. The central nervous system then uses this sensory information to influence muscle ton , motor execution, and kinesthetic awareness (26). Stimulation of these receptors can cause facilitation, inhibition, and modulation of both agonist and antagonist muscle activity . This enhances neuromuscular efficiency and func tional strength (Fig. 8.2) (36–40).

THE ELASTIC PROPERTIES OF MUSCLE

The concept of plyometrics is based on the three-component model of muscle (Fig. 8.3). Muscle is modeled with a contractile element and two elastic elements that are named according to their relationship to the contractile element—one in line with (the series elastic element) and one in parallel (the parallel elastic element). When a muscle contracts, tension is not directly transmitted to the ends of the tendon and the load is not o vercome, leading to movement. This would only happen if the connection between the contractile element and its insertion were rigid and inelastic. In reality, the contractile element develops tension, stretching the series elastic element; the degree of stretch is dependent on the load to be moved. After sufficient tension has been generated the tension at the ends of the muscle is sufficient to overcome the load and the load is moved. When a load is applied to a joint (eccentric phase), the elastic elements stretch and store potential energy (amortization phase) prior to the contractile element contracting (concentric phase).

An eccentric contraction immediately preceding a concentric contraction significantly in creases the force generated concentrically as a result of the storage of elastic potential energy (12). During the loading of the muscle, the load is transferred to the series elastic components and stored as elastic potential energy . The elastic elements then contribute to the o verall force production by converting the stored elastic potential energy to kinetic energy , which enhances the contraction (21,41). The muscle's ability to use the stored elastic potential energy is affected b y the variables of time , magnitude of stretch, and v elocity of stretch. Increased force generation during the concentric contraction is most effective when the preceding eccentric contraction is of short range and is performed without delay (31).

A simple example of the use of the energy stored in the elastic element is the basic v ertical, or countermovement, jump. The initial squat (the countermovement) is the eccentric phase that stretches the elastic elements and stores elastic energy (amortization phase). When the jump is performed (the concentric phase), the stored energy is "added" to the tension produced leading to a higher jump. The amount of stored energy used is inv ersely proportional to the time spent

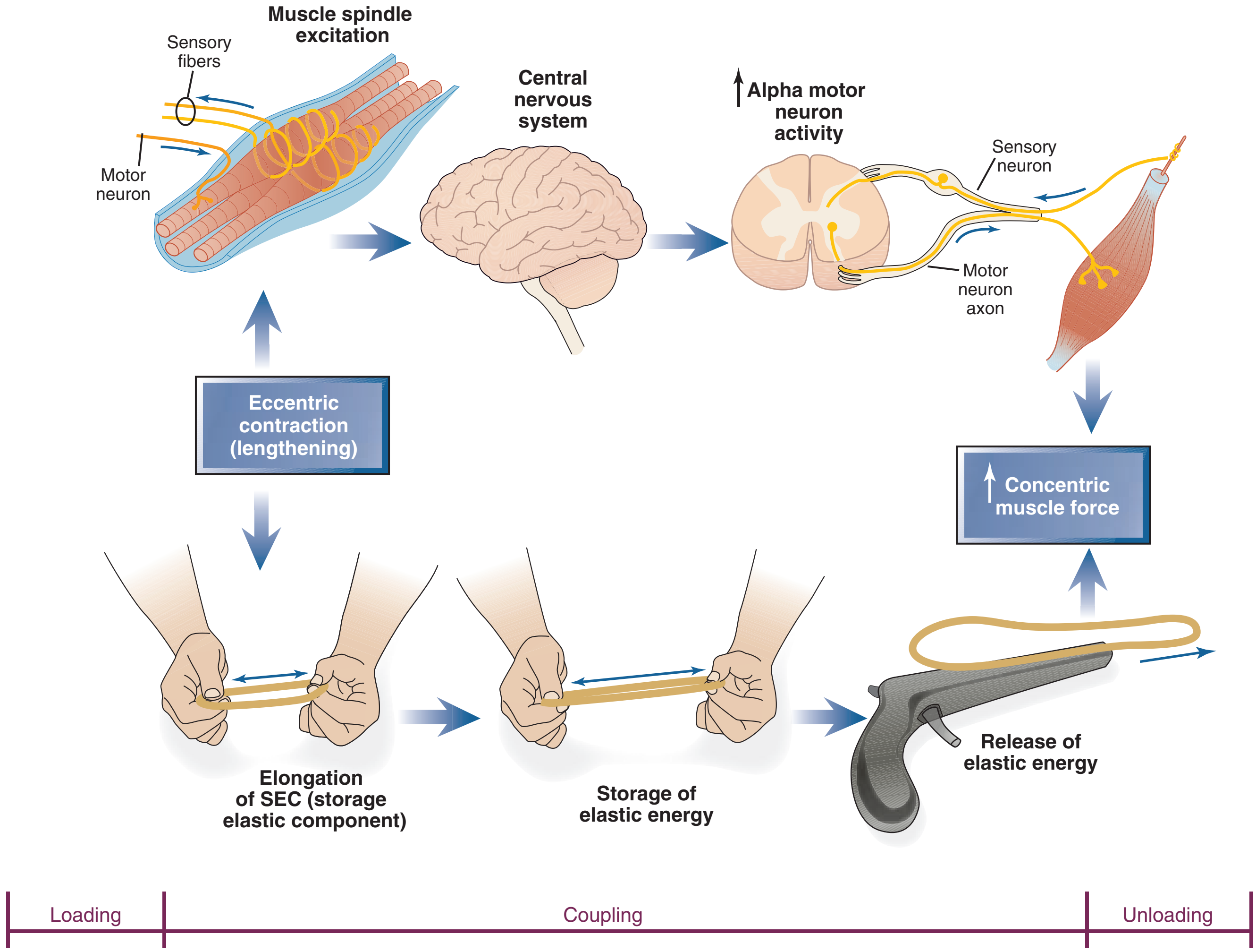

FIGURE 8.2 Physiological principles of plyometric training.

in the amortization phase. When doing a vertical jump, the longer one waits at the end of the countermovement before performing the jump, the lower the eventual jump height due to the inability to recover the stored elastic energy.

The improved muscular performance that occurs with the pre-stretch in a muscle is the result of the combined effects of both the storage of elastic potential energy and the proprioceptive properties of the muscle. The percentage that each component contributes is unknown at this time, but the degree of muscular performance, as stated earlier, is dependent upon the time in transition from the eccentric to the concentric contraction. Training that enhances neuromuscular efficiency decreases the time between the eccentric and concentric contraction, thereby, improving performance. This can be accomplished through integrated training.

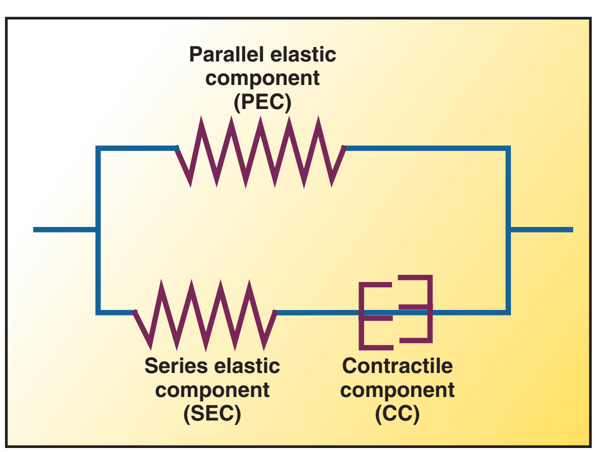

FIGURE 8.3 Elastic properties of muscle.

PROPOSED MECHANISM BY WHICH PLYOMETRIC TRAINING ENHANCES PERFORMANCE

There are three proposed mechanisms by which plyometric training improves performance: enhanced muscle spindle activity, desensitization of the GTO, and enhanced intramuscular and intermuscular neuromuscular efficienc .

ENHANCED MUSCLE SPINDLE ACTIVITY

The speed of a muscular contraction is regulated b y the neuromuscular s ystem. The human movement system will only move within a set speed range regardless of how strong a muscle is. The faster the eccentric loading, the greater the concentric force production (26,31). For example, the quadriceps are loaded more rapidly when dropping from a 1-m box versus a 0.25-m box.

DESENSITIZATION OF THE GOLGI TENDON ORGAN

Desensitizing the G TO increases the stimulation threshold for muscular inhibition. This promotes increased force production with a greater load applied to the musculoskeletal s ystem (29,30).

ENHANCED NEUROMUSCULAR EFFICIENCY

Plyometric training may promote better neuromuscular control of the contracting agonists and synergists, thus enabling the central nervous system to become more reflexi e. These neural adaptations lead to enhanced neuromuscular efficiency e en in the absence of morphological adaptations, such as muscle h ypertrophy. Exploiting the stretch reflex, inhibiting the TO, and enhancing the ability of the nerv ous system to react with maximum speed to the lengthening muscle optimizes the force produced by the concentric contraction.

In the end, plyometric training has wide-ranging effects beyond power output. There is moderate evidence that when ply ometric exercises are incorporated into an integrated training program, there are documented improvements in jumping ability, running economy, power output, and rate of force development, but not strength. When used in an isolated training program, there is moderate evidence that plyometrics have little positive benefits on performanc . There is no evidence that youth athletes, when properly instructed and following directions, cannot use plyometrics in an integrated training program or that ply ometrics should be reserved solely for athletes (8). A common fallacy when considering ply ometric training is that ply ometrics are only useful in training for jumping performance when there are randomized trials showing significan reductions in injury rates (2,42–44).

TIME OUT

Importance of Proper Stability with Plyometric Training

Ground reaction force places tremendous amounts of stress to one's structure. Not only do we have gravity pushing us downward, but we also have ground reaction force pushing from below back up through our body. This is like being placed in a trash compactor with forces coming from above and below. As the speed and amplitude of movement increases, so does the ground reaction force (1). While jumping, ground reaction force can be 4–11 times one's body weight (2–4). Inadequate stability under these types of forces places enormous amounts of stress to the athlete's structure, increasing the risk of injury. Having ample amounts of stability is crucial to the effectiveness and safety of plyometric training.

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PLYOMETRIC TRAINING PROGRAM

A systematic and progressive plyometric training program is a vital component of any integrated training program. As plyometric training is one of the more advanced training tools, the athlete needs proper levels of flexibilit , core strength, and balance before progressing into ply ometric training. Sports Performance Professionals must follow very specific program guideline , proper exercise selection criteria, and detailed program variables for the best outcome and lowest risk of injury (Table 8.1).

TABLE 8.1

Plyometric Training Parameters

Exercise Selection	Variables

• Safe
• Done with supportive shoes
• Performed on a proper training surface
  • Grass fiel
  • Basketball court
  • Tartan track surface
  • Rubber track surface
• Performed with proper supervision
• Progressive
  • Easy to hard
  • Simple to complex
  • Known to unknown
  • Stable to unstable
  • Body weight to loaded
• Activity-specifi
	• Plane of motion
	  • Sagittal
	  • Frontal
	  • Transverse
	• Range of motion
	  • Full
	  • Partial
	• Type of resistance
	  • Medicine ball
	  • Power ball
	• Type of implements
	  • Tape
	  • Cones
	  • Boxes
	• Muscle action
	  • Eccentric
	  • Isometric
	  • Concentric
	• Speed of motion
	• Duration
	• Frequency
	• Amplitude of movement

As with all training programs, overload will need to be considered with plyometrics. Increasing the stretch load increases intensity . This can be accomplished b y using body w eight over a greater jump distance or drop height. Progressing from tw o-legged to one-legged jumps also increases intensity. As the athlete progresses, the duration of the amortization phase should be as brief as possible. The number of foot contacts monitors training volume; the more contacts, the greater the training volume. As always, training volume is inversely related to training intensity Potach and Chu (45) offer the following suggestions for a single training session: lo w-intensity training = 400-foot contacts; moderate-intensity training = 350-foot contacts; high-intensity training = 300-foot contacts; very-high-intensity training = 200-foot contacts. Experience should also be considered when prescribing plyometrics. Athletes with minimal experience using ply ometrics should keep the ground contacts to less than 1 00 maximal efforts per session, whereas those with considerable experience could have as many as 120–140 maximal effort ground contacts per session (45).

The Optimum P erformance Training™ (OPT ™) model pro vides a s ystematic, progressiv e, and integrated plyometric training program to safely and effectively progress an athlete through this portion of their program (see Fig. 8.4).

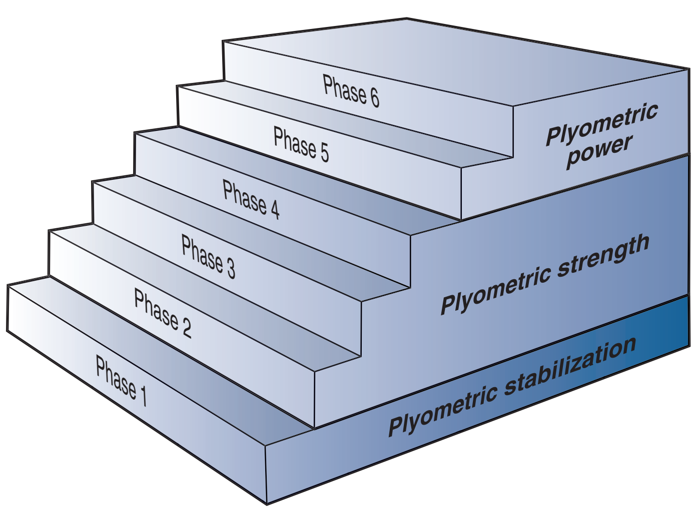


FIGURE 8.4 OPT™ model for plyometric exercises.

Example Plyometric Exercises

PLYOMETRIC STABILIZATION EXERCISES

Plyometric Stabilization Exercises
Plyometric exercises designed to establish optimum landing mechanics, postural alignment, and reactive neuromuscular efficien y.

Exercises in the stabilization level of plyometric training involve little joint motion. They are designed to establish optimum landing mechanics , postural alignment, and reactive neuromuscular efficienc . Upon landing, the athlete should hold the landing position (or stabilize) for 3–5 seconds before repeating (Figs. 8.5–8.7).

FIGURE 8.5 Box jump-up with stabilization progression. (**A**) Sagittal plane. (**B**) Frontal plane. (*continued*)

FIGURE 8.5 (*Continued*) (**C**) Transverse plane.

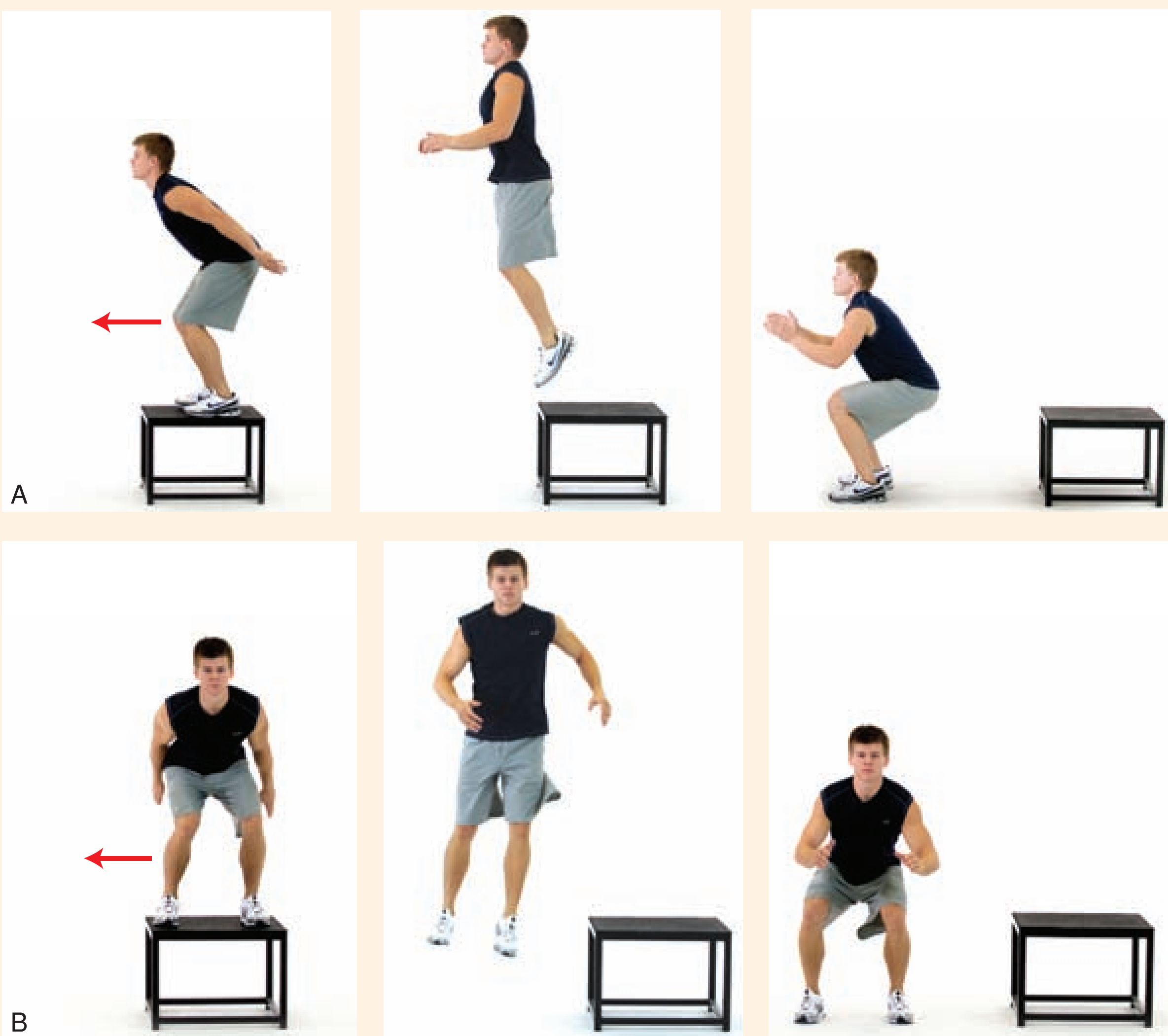


FIGURE 8.6 Box jump-down with stabilization progression. (**A**) Sagittal plane. (**B**) Frontal plane. (*continued*)

FIGURE 8.6 (*Continued*) (**C**) Transverse plane.

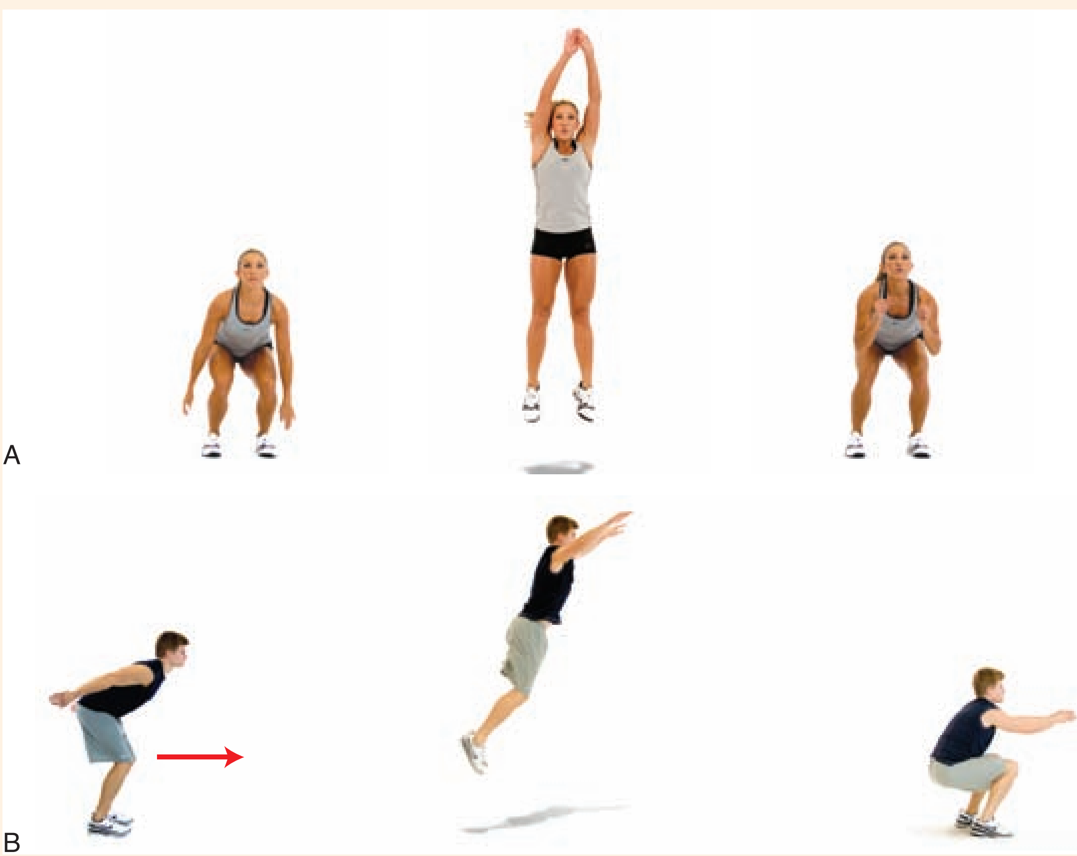
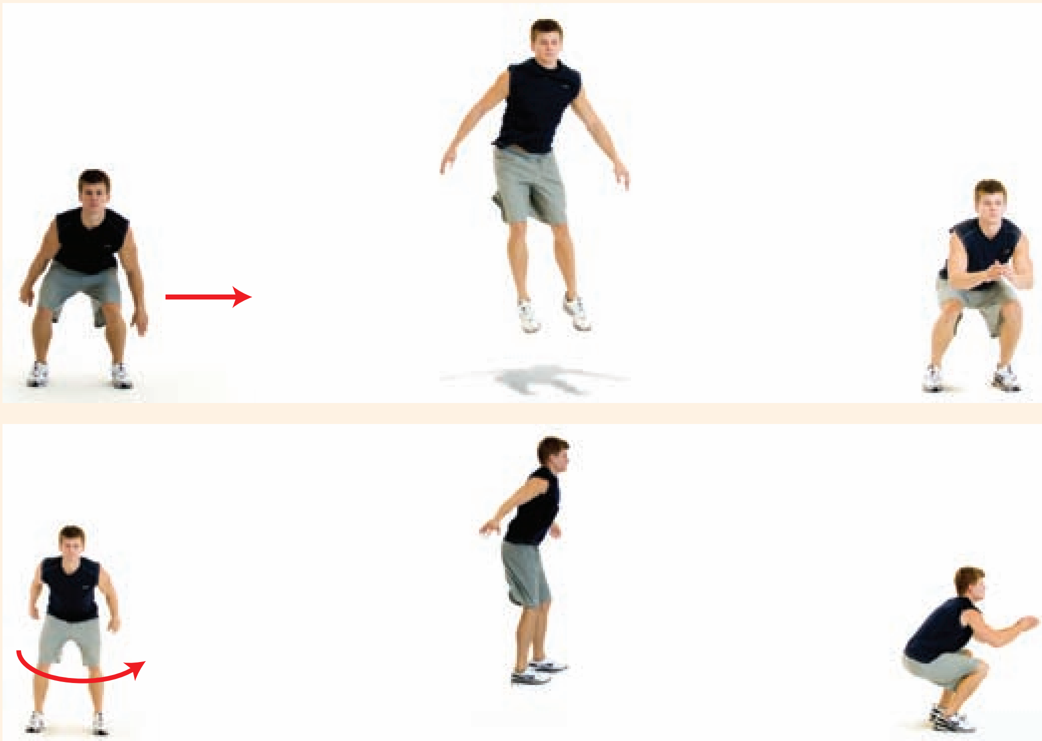


FIGURE 8.7 Squat jump with stabilization progression. (**A**) Squat jump with stabilization. (**B**) Sagittal plane jump with stabilization. (*continued*)

C



D

FIGURE 8.7 (*Continued*) (**C**) Frontal plane jump with stabilization. (**D**) Transverse plan jump with stabilization.

PLYOMETRIC-STRENGTH EXERCISES

Plyometric-Strength Exercises
Plyometric exercises designed to improve dynamic joint stabilization, eccentric strength, rate of force production, and neuromuscular efficien y of the entire human movement system. These exercises are performed in a more repetitive fashion by spending a shorter amount of time on the ground.

In the strength lev el of ply ometric training, exercises are more dynamic, requiring eccentric and concentric mo vement throughout the full range of motion. The specificit , speed, and neural demand are also progressed within this level. Exercises in this level are designed to impro ve dynamic joint stabilization, eccentric strength, rate of force production, and neuromuscular efficiency of the entire human mo vement system. These exercises are performed in a more repetitiv e fashion b y spending a shorter amount of time on the ground. Exercises in this lev el can also be performed in all three planes of motion (Fig. 8.8).

FIGURE 8.8 Plyometric-strength exercises. (**A**) Repeat squat jumps (**B**) Lunge jumps. (*continued*)

FIGURE 8.8 (*Continued*) (**C**) Power step-ups. (**D**) Butt kicks.

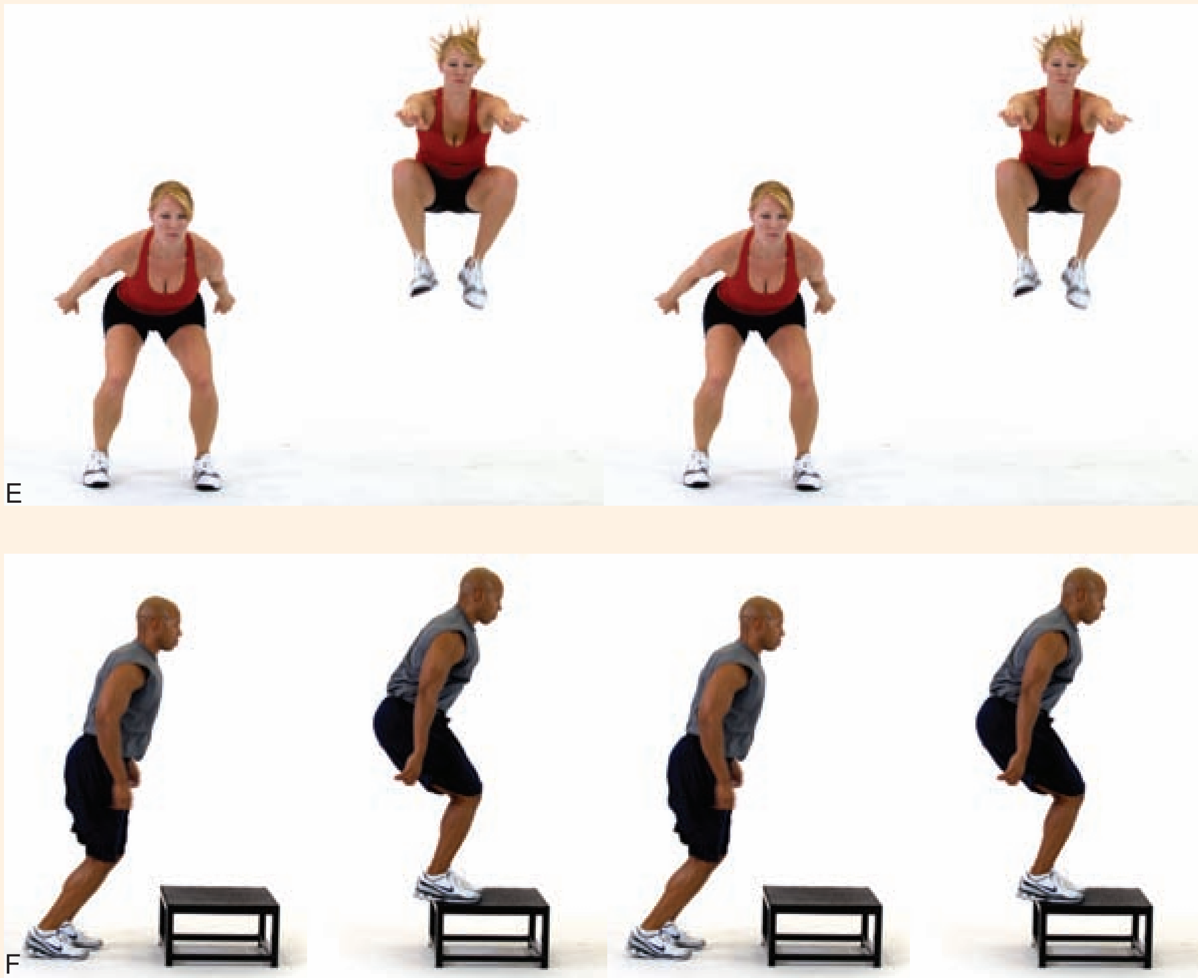


FIGURE 8.8 (*Continued*) (**E**) Tuck jumps. (**F**) Repeat box jumps.

These exercises can be varied and made more intense by adding any one of a variety of tools to increase external resistance such as a weight vest, tubing, medicine ball, or a Bodyblade.

PLYOMETRIC POWER EXERCISES

Plyometric Power Exercises

Plyometric exercises are performed as fast and as explosively as possible.

In the power level of plyometric training, exercises involve the entire spectrum of muscle actions and contraction velocities important for integrated, functional movement. These exercises are designed to improve the rate of force production, eccentric strength, reactive strength, reactive joint stabilization, dynamic neuromuscular efficiency, and optimum force production. These exercises are performed as fast and as explosively as possible. Exercises in this level can also be performed in all three planes of motion (Figs. 8.9 through 8.11).

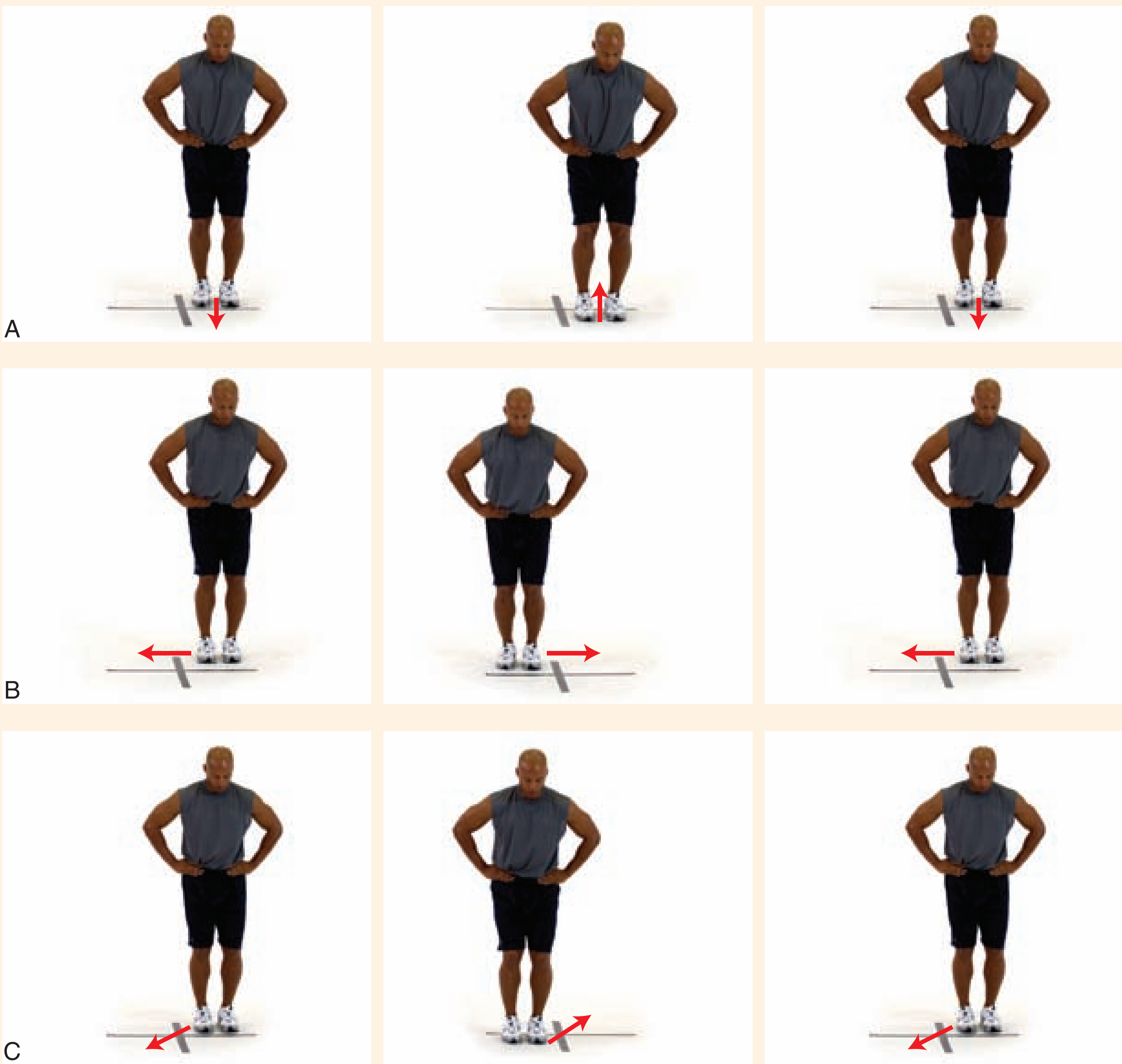
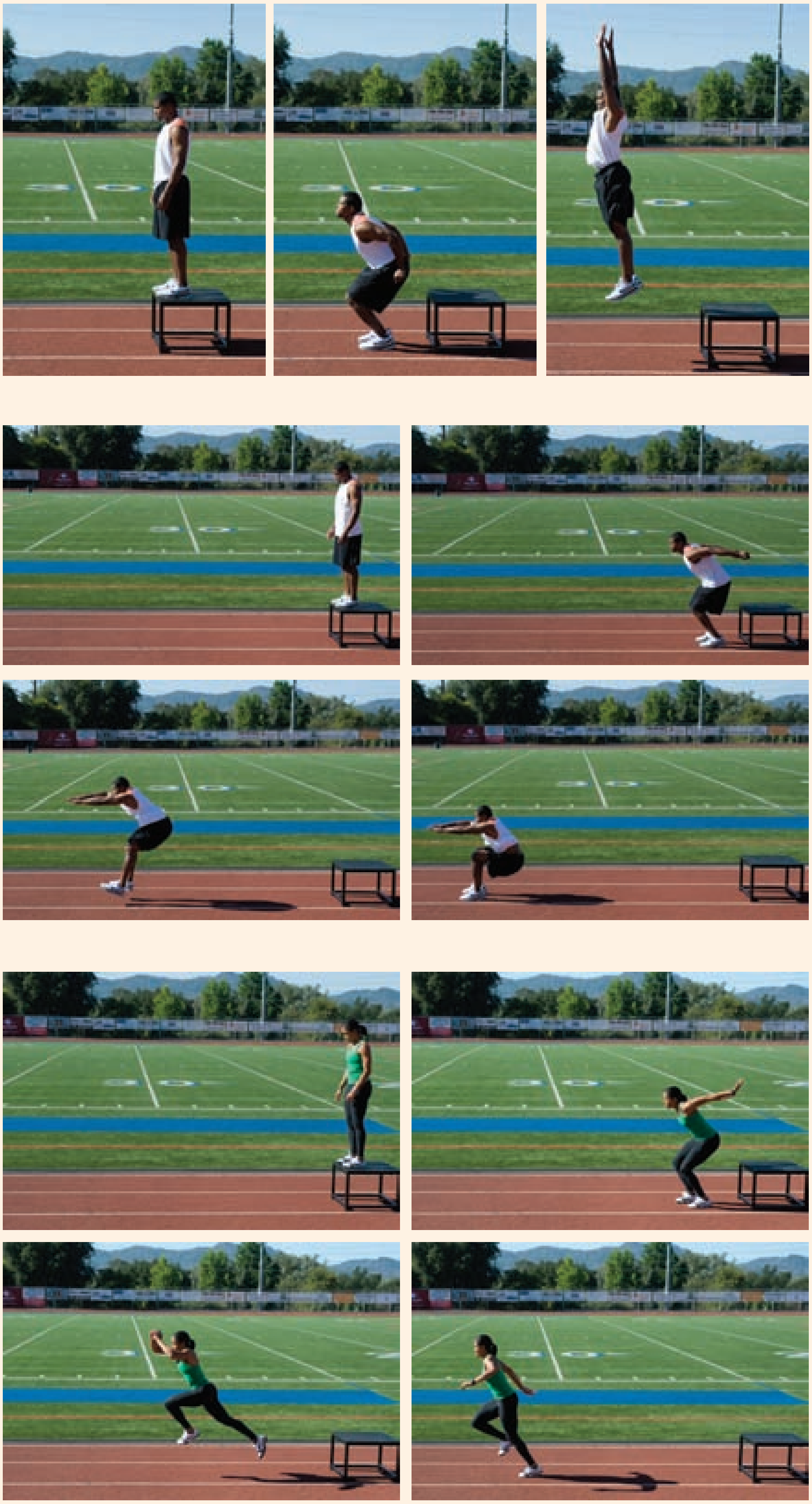


FIGURE 8.9 Two-leg proprioceptive plyometric progression. (**A**) Front to back. (**B**) Side to side. (**C**) Diagonal.



A B C

FIGURE 8.10 Depth jump progression. (**A**) Depth jump to squat jump. (**B**) Depth jump to long jump. (**C**) Depth jump to bounding. (*continued*)

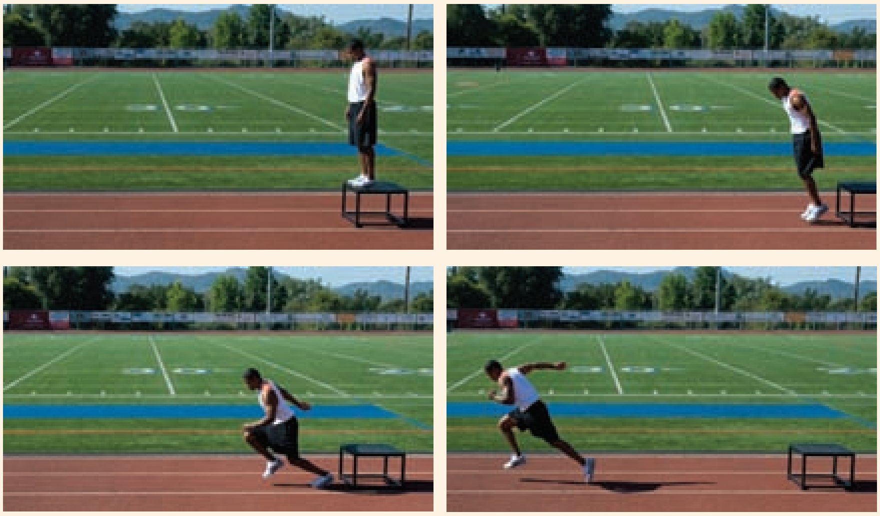


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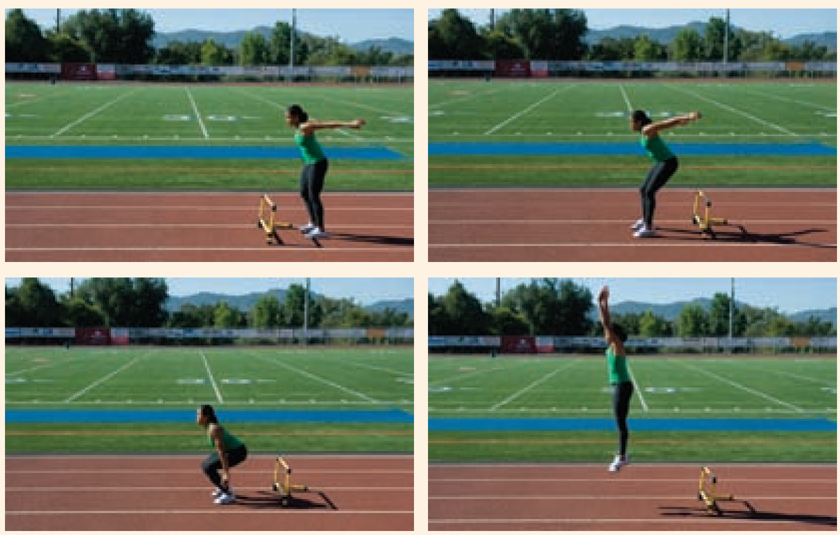
FIGURE 8.10 (*Continued*) (**D**) Depth jump to sprinting.



A

B

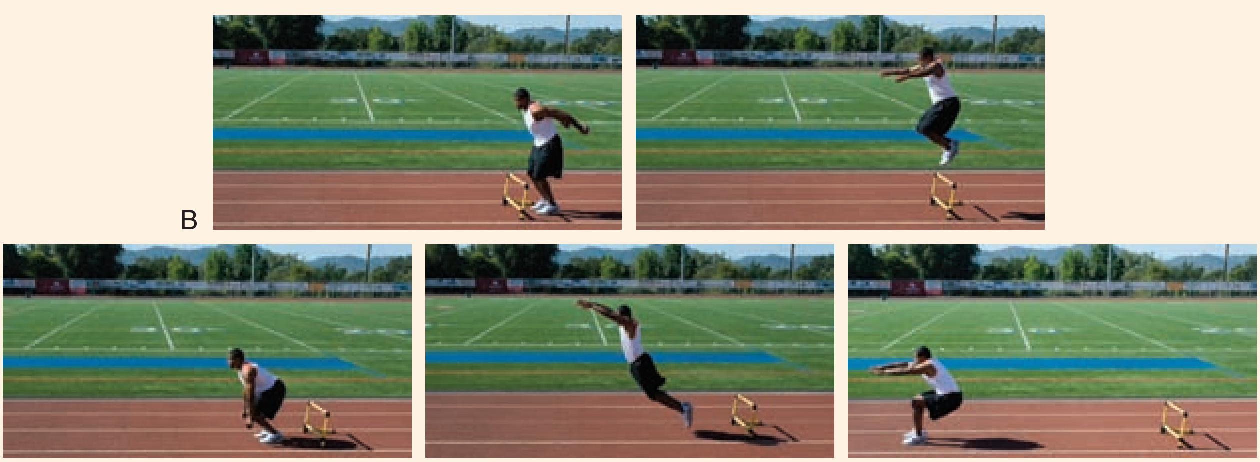
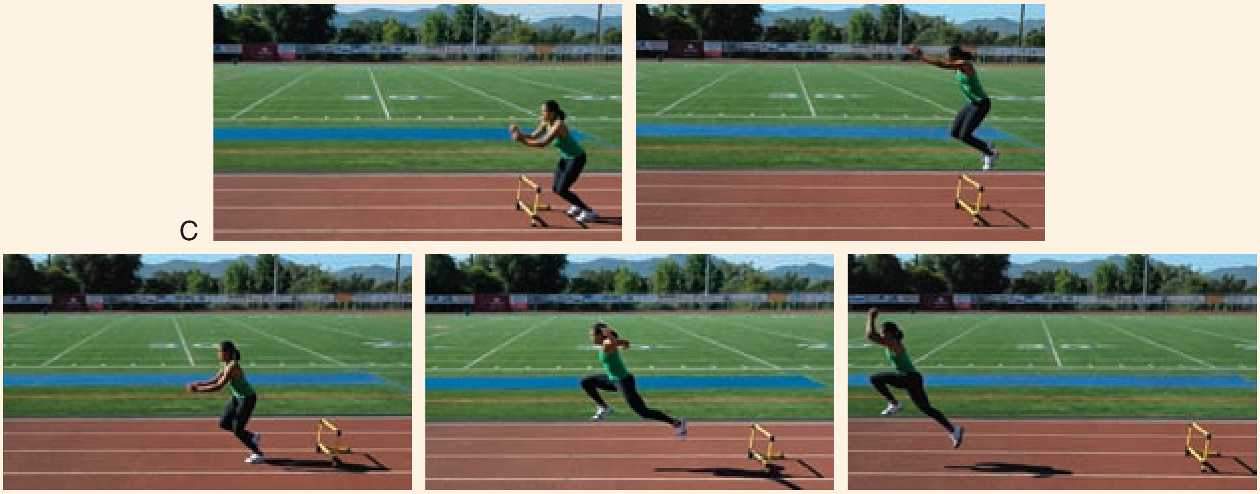


FIGURE 8.11 Obstacle jump progression. (**A**) Hurdle jump to squat jump. (**B**) Hurdle jump to long jump. (*continued*)



C

D

FIGURE 8.11 (*Continued*) (**C**) Hurdle jump to bounding. (**D**) Hurdle jump to sprinting.

Plyometric Training Program Design Parameters

Implementing a plyometric training program requires that Sports Performance Professionals follow a systematic program strategy to ensure safety and effectiveness of the program. For example, if an athlete is in the stabilization level of training (Phase 1), select plyometric-stabilization exercises. For an athlete in the strength level of training (Phase 2, 3, or 4), select plyometric-strength exercises. For an athlete in the power level of training (Phase 5 or 6), select plyometric-power exercises (Table 8.2).

TABLE 8.2

Plyometric Program Design Parameters

OPT Level	Phase	Example Plyometric Exercises	Sets/Reps	Tempo	Rest
Stabilization	1	***0–2 Plyometric Stabilization** Squat jump with stab. Box jump-up with stab.	1–3 sets × 5–8 reps	Controlled (hold the landing position for 3–5 seconds)	0–90 s
Strength	2,3,4	****0–4 Plyometric-Strength** Power step-ups Lunge jumps	2–3 sets × 8–10 reps	Repeating	0–60 s
Power	5,6	*****0–2 Plyometric-Power** Depth jump to bounding Hurdle jump to sprinting	2–3 sets × 8–12 reps	As fast as possible	0–60 s

*Plyometric exercises may not be appropriate for an athlete in this phase of training if they do not possess the appropriate amount of core strength and balance capabilities.
**Due to the goal of certain phases in this level (hypertrophy and maximal strength), plyometric training may not be necessary to do.
***Because one is performing plyometric exercises in the resistance training portion of this phase of training, separate plyometric exercises may not be necessary to perform.

SUMMARY

Plyometric training is an important component of all integrated performance training programs. All sporting activities require efficient use of the integrated performance paradigm Therefore, all performance programs should include plyometric training to enhance neuromuscular efficiency and prevent injury. The human movement system responds to the imposed demands of training. Less than optimum results will occur if the training program does not systematically and progressively challenge the neuromuscular system. Following a progressive plyometric training program as demonstrated through the OPT™ model will ensure the athlete enhances their performance while decreasing their risk of injury.

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