chapter

18

Plyometric Training
Chapter Objectives

• Explain the physiology of plyometric exercise.
• Identify the phases of the stretch-shortening cycle.
• Identify components of a plyometric training program.
• Design a safe and effective plyometric training program.
• Recommend proper equipment for plyometric exercise.
• Teach correct technique for plyometric exercises.
Plyometrics

• Practical Definition of Plyometric Exercise
  – Quick powerful movement using a pre-stretch, or countermovement, that involves the stretch-shortening cycle in which peak force is produced as quickly as possible.
  – Plyometric exercises or drills link strength with movement speed to produce muscular POWER
Plyometric Mechanics and Physiology

• **Mechanical Model of Plyometric Exercise**
  – Elastic energy in tendons and muscles is increased with a rapid stretch (as in an eccentric muscle action) and then briefly stored.
  – If a concentric muscle action follows immediately, the stored energy is released, contributing to the total force production.
• The series elastic component (SEC) (e.g., tendons), when stretched, stores elastic energy that increases the force produced.

• The contractile component (CC) (i.e., actin, myosin, and cross-bridges) is the primary source of muscle force during concentric muscle action.

• The parallel elastic component (PEC) (i.e., epimysium, perimysium, endomysium, and sarcolemma) exerts a passive force with unstimulated muscle stretch.
When muscle spindles are stimulated, the stretch reflex is stimulated, sending input to the spinal cord via Type Ia nerve fibers. After synapsing with the alpha motor neurons in the spinal cord, impulses travel to the agonist extrafusal fibers, causing a reflexive muscle action.

Adapted, by permission, from Wilk et al., 1993.
Plyometric Mechanics and Physiology

- **Stretch-Shortening Cycle**
  - The stretch-shortening cycle (SSC) employs both the energy storage of the SEC and stimulation of the stretch reflex to facilitate maximal increase in muscle recruitment over a minimal amount of time.
  - A fast rate of musculotendinous stretch is vital to muscle recruitment and activity resulting from the SSC.
  - There are three phases: eccentric, amortization, and concentric.
### Table 16.1

**Stretch-Shortening Cycle**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Action</th>
<th>Physiological event</th>
</tr>
</thead>
<tbody>
<tr>
<td>I—Eccentric</td>
<td>Stretch of the agonist muscle</td>
<td>- Elastic energy is stored in the series elastic component.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Muscle spindles are stimulated.</td>
</tr>
<tr>
<td>II—Amortization</td>
<td>Pause between phases I and III</td>
<td>- Type Ia afferent nerves synapse with alpha motor neurons.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Alpha motor neurons transmit signals to agonist muscle group.</td>
</tr>
<tr>
<td>III—Concentric</td>
<td>Shortening of agonist muscle fibers</td>
<td>- Elastic energy is released from the series elastic component.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Alpha motor neurons stimulate the agonist muscle group.</td>
</tr>
</tbody>
</table>

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• The long jump and stretch-shortening cycle
  – (a) The eccentric phase begins at touchdown and continues until the movement ends.
  – (b) The amortization phase is the transition from eccentric to concentric phases; it is quick and without movement.
  – (c) The concentric phase follows the amortization phase and comprises the entire push-off time, until the athlete’s foot leaves the surface.
Amortization Phase

• If the amortization phase is too long, the potentiating ability of stretch reflex is negated, and stored elastic energy is dissipated as heat.

• The average duration of the amortization phase has been reported to be 23 ms in countermovement jumps, and a 15 ms amortization phase has been suggested as ideal. A primary goal of plyometric training is decreasing the amortization phase.

• Because the amortization phase increases as training intensity increases, there is a point of diminishing returns related to increasing the intensity of plyometric exercise.
Key Points

• The stretch-shortening cycle combines mechanical (elastic energy stored in SEC and PEC) and neurophysiological (reflexive component due to stretch reflex, increased threshold of the GTO, and enhanced neuromuscular coordination) mechanisms and is the basis of plyometric exercise.

• A rapid eccentric muscle action (i.e., a quick stretch) stimulates the stretch reflex and results in a storage of elastic energy. This reflexive response increases agonist activity from motor cortex stimulation, which increases the force produced during the subsequent concentric action.
Plyometric Program Design

• Needs analysis
  – Athletes must be evaluated for their
    • Sport (eg, more sagittal plane power for jumping and sprinting sports; more transverse plane power for hitting and throwing sports)
    • Sport position
    • Training status
  – By understanding each sport’s individual requirements, the positions within the sport, and the needs of each athlete, the strength and conditioning professional can design a safe, effective plyometric training program.

(continued)
Plyometric Program Design

• Mode
  – Lower Body Plyometrics
    • These are appropriate for virtually any athlete and any sport.
    • Direction of movement varies by sport, but many sports require athletes to produce maximal vertical or lateral movement in a short amount of time.
    • There are a wide variety of lower body drills with various intensity levels and directional movements.
Plyometric Program Design

• **Mode**
  – Upper Body Plyometrics
    • Drills include medicine ball throws, catches, and several types of push-ups.
  – Trunk Plyometrics
    • Exercises for the trunk may be performed “plyometrically” provided that movement modifications are made.
    • Specifically, the exercise movements must be shorter and quicker to allow stimulation and use of the stretch reflex.
Plyometric Program Design

• **Intensity**
  – Plyometric intensity refers to the amount of stress placed on muscles, connective tissues, and joints.
  – It is controlled primarily by the type of plyometric drill.
  – Generally, as intensity increases, volume should decrease.
  – Progression normally occurs from low to high intensity
### TABLE 16.3
Factors Affecting the Intensity of Lower Body Plyometric Drills

<table>
<thead>
<tr>
<th>Factor</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points of contact</td>
<td>The ground reaction force during single-leg lower body plyometric drills places more stress on an extremity’s muscles, connective tissues, and joints than during double-leg plyometric drills.</td>
</tr>
<tr>
<td>Speed</td>
<td>Greater speed increases the intensity of the drill.</td>
</tr>
<tr>
<td>Height of the drill</td>
<td>The higher the body’s center of gravity, the greater the force on landing.</td>
</tr>
<tr>
<td>Body weight</td>
<td>The greater the athlete’s body weight, the more stress is placed on muscles, connective tissues, and joints. External weight (in the form of weight vests, ankle weights, and wrist weights) can be added to the body to increase a drill’s intensity.</td>
</tr>
</tbody>
</table>

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Remember $\Sigma F = ma$
Plyometric Program Design

• Frequency
  – Forty-eight to 72 hours between plyometric sessions is a typical recovery time guideline for prescribing plyometrics.
  – Using these typical recovery times, athletes commonly perform two to four plyometric sessions per week.
  – Inadequate recovery may result in excessive muscle soreness and damage, diminishing function of GTO, muscle spindles, and SSC, decreased muscle stiffness, decreased performance, and increased injury risk.
• Recovery
  – Recovery for depth jumps (step off box and upon landing jump as high in the air as possible) may consist of 5 to 10 seconds of rest between repetitions and 2 to 3 minutes between sets.
  – The time between sets is determined by a proper work-to-rest ratio (i.e., 1:5 to 1:10) and is specific to the volume and type of drill being performed.
  – Drills should not be thought of as cardiorespiratory conditioning exercises but as power training.
  – Furthermore, drills for a given body area should not be performed two days in succession.
Plyometric Program Design

• Volume
  – For lower body drills, plyometric volume is expressed as contacts per workout (or in distance for bounding drills).
  – For upper body drills, plyometric volume is expressed as the number of throws or catches per workout.
  – Recommended lower body volumes vary for athletes with different levels of experience.
<table>
<thead>
<tr>
<th>Plyometric experience</th>
<th>Beginning volume*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginner (no experience)</td>
<td>80 to 100</td>
</tr>
<tr>
<td>Intermediate (some experience)</td>
<td>100 to 120</td>
</tr>
<tr>
<td>Advanced (considerable experience)</td>
<td>120 to 140</td>
</tr>
</tbody>
</table>

*Volume is given in contacts per session.

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Plyometric Program Design

• Program Length
  – Currently, most programs range from 6 to 10 weeks; however, vertical jump height improves as quickly as four weeks after the start of a plyometric training program.

• Progression
  – Plyometrics is a form of resistance training and thus must follow the principles of progressive overload (the systematic increase in training frequency, volume, and intensity in various combinations).
**Warm-Up**

- Plyometric exercise sessions must begin with a general warm-up, stretching, and a specific warm-up.
- The specific warm-up should consist of low-intensity, dynamic movements.

### Table 16.5

<table>
<thead>
<tr>
<th>Drill</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marching</td>
<td>Mimics running movements</td>
</tr>
<tr>
<td></td>
<td>Emphasizes posture and movement technique</td>
</tr>
<tr>
<td></td>
<td>Enhances proper lower body movements for running</td>
</tr>
<tr>
<td>Jogging</td>
<td>Prepares for impact and high-intensity plyometric drills</td>
</tr>
<tr>
<td></td>
<td>- Toe jogging—not allowing heel to touch the ground (emphasizes quick reaction)</td>
</tr>
<tr>
<td></td>
<td>- Straight-leg jogging—not allowing or minimizing leg flexion in preparation for impact of plyometric drills</td>
</tr>
<tr>
<td></td>
<td>- “Butt-kickers”—flexing knee to allow heel to touch the buttocks</td>
</tr>
<tr>
<td>Skipping</td>
<td>Exaggerated form of reciprocal upper and lower extremity movements</td>
</tr>
<tr>
<td></td>
<td>Emphasis on quick takeoff and landing, mimics plyometric activities</td>
</tr>
<tr>
<td>Footwork</td>
<td>Drills that target changes of direction</td>
</tr>
<tr>
<td></td>
<td>Preparation for changes of direction during plyometric drills</td>
</tr>
<tr>
<td></td>
<td>Examples: shuttle, shuffle, pattern, and stride drills</td>
</tr>
<tr>
<td>Lunging</td>
<td>Based on the forward step lunge exercise (see pp. 354-355)</td>
</tr>
<tr>
<td></td>
<td>May be multidirectional (e.g., forward, side, backward)</td>
</tr>
</tbody>
</table>
Key Point

- Effective plyometric programs include the same variables that are essential to any training program design: mode, intensity, frequency, recovery, volume, program length, progression, and warm-up.
Age Considerations

• Adolescents
  – Consider both physical and emotional maturity.
  – The primary goal is to develop neuromuscular control and anaerobic skills that will carry over into adult athletic participation.
  – Gradually progress from simple to complex.
  – The recovery time between workouts should be a minimum of two to three days.
Age Considerations

• **Masters**
  – The plyometric program should include no more than five low- to moderate-intensity exercises.
  – The volume should be lower, that is, should include fewer total foot contacts than a standard plyometric training program.
  – The recovery time between plyometric workouts should be three to four days.
Key Points

• Under proper supervision and with an appropriate program, prepubescent and adolescent children may perform plyometric exercises. Depth jumps and high-intensity lower body plyometrics are contraindicated for this population.

• Masters athletes can do plyometrics, as long as modifications are made for orthopedic conditions and joint degeneration.
Plyometrics and Other Forms of Exercise

• **Plyometric Exercise and Resistance Training**
  – Combine lower body resistance training with upper body plyometrics, and upper body resistance training with lower body plyometrics.
  – Performing heavy resistance training and plyometric exercises on the same day is generally not recommended.
  – Some advanced athletes may benefit from complex training, which combines intense resistance training with plyometric exercises.
**TABLE 16.6**

Sample Schedule for Integrating Resistance Training and Plyometrics

<table>
<thead>
<tr>
<th>Day</th>
<th>Resistance training</th>
<th>Plyometrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>High-intensity upper body</td>
<td>Low-intensity lower body</td>
</tr>
<tr>
<td>Tuesday</td>
<td>Low-intensity lower body</td>
<td>High-intensity upper body</td>
</tr>
<tr>
<td>Thursday</td>
<td>Low-intensity upper body</td>
<td>High-intensity lower body</td>
</tr>
<tr>
<td>Friday</td>
<td>High-intensity lower body</td>
<td>Low-intensity upper body</td>
</tr>
</tbody>
</table>

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Plyometrics and Other Forms of Exercise

• **Plyometric and Aerobic Exercise**
  – Because aerobic exercise may have a negative effect on power production, it is advisable to perform plyometric exercise before aerobic endurance training.
  – When attempting to maximize anaerobic power and performance from plyometric training, aerobic training should be limited as it may hinder performance and may lead to over training and increase injury risk.
Safety Considerations

• Pretraining Evaluation of the Athlete
  – Technique
    • Before adding any drill, the strength and conditioning professional must demonstrate proper technique to the athlete.
    • Proper landing technique is essential to prevent injury and improve performance in lower body plyometrics.
Proper Plyometric Landing Position

- The shoulders are in line with the knees, which helps to place the center of gravity over the body’s base of support.
Safety Considerations

• Pretraining Evaluation of the Athlete
  – Strength for High Intensity Plyometrics
    • For lower body plyometrics, the athlete’s 1RM squat should be at least 1.5 times his or her body weight.
    • For upper body plyometrics, the bench press 1RM should be at least between 1-1.5 times body weight.
    • An alternative measure of prerequisite upper body strength is the ability to perform five clap push-ups in a row.
Safety Considerations

• Pretraining Evaluation of the Athlete
  – Speed
    • The athlete should be able to perform five repetitions of the squat or bench press with 60% body weight in 5 seconds or less.
Safety Considerations

• Pretraining Evaluation of the Athlete
  – Balance
    • Three balance tests are provided in table 18.7, listed in order of difficulty.
    • Each test position must be held for 30 seconds. Tests should be performed on the same surface used for drills.
    • An athlete beginning plyometric training for the first time must stand on one leg for 30 seconds without falling.
    • An athlete beginning an advanced plyometric program must maintain a single-leg half squat for 30 seconds without falling.
<table>
<thead>
<tr>
<th>Test</th>
<th>Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>Double leg</td>
</tr>
<tr>
<td></td>
<td>Single leg</td>
</tr>
<tr>
<td>Quarter squat</td>
<td>Double leg</td>
</tr>
<tr>
<td></td>
<td>Single leg</td>
</tr>
<tr>
<td>Half squat</td>
<td>Double leg</td>
</tr>
<tr>
<td></td>
<td>Single leg</td>
</tr>
</tbody>
</table>
Safety Considerations

• Pretraining Evaluation of the Athlete
  – Physical Characteristics
    • Athletes who weigh more than 220 pounds (100 kg) may be at an increased risk for injury when performing plyometric exercises.
    • Further, athletes weighing over 220 pounds should not perform depth jumps from heights greater than 18 inches (46 cm).
  – Landing Surface
    • To prevent injuries, the landing surface used for lower body plyometrics must possess adequate shock-absorbing properties.
    • A grass field, suspended floor, or rubber mat is a good surface choice.
Safety Considerations (continued)

• Equipment and facilities
  – Training area
    • The amount of space needed depends on the drill.
    • Most bounding and running drills require at least 30 m (33 yards) of straightaway, though some drills may require a straightaway of 100 m (109 yards).
    • For most standing, box, and depth jumps, only a minimal surface area is needed, but the ceiling height must be 3 to 4 m (9.8-13.1 feet) in order to be adequate.

(continued)
Safety Considerations

• **Equipment and Facilities**
  – Boxes used for jumps must be sturdy & have nonslip top.
    • Box height should be from 6 to 42 in (15 to 107 cm), with 30-32 in (76 to 81 cm) the norm for depth jumps.
    • Box height for athletes over 220 lbs (100 kg) should be 18 in (46 cm) or less for depth jumping.
    • Box Landing surfaces should be at least 18 by 24 in (46 by 61 cm).
  – Proper Footwear
    • Participants must use footwear with ankle and arch support; lateral stability; and a wide, nonslip sole.
  – Supervision
    • Closely monitor athletes to ensure proper technique.
Safety Considerations

- **What Are the Steps for Implementing a Plyometric Program?**
  - Evaluate the athlete.
  - Ensure that facilities and equipment are safe.
  - Establish sport-specific goals.
  - Determine program design variables.
  - Teach the athlete proper technique.
  - Properly progress the program.
Use of Plyometrics in Training & Rehab

• Plyometrics training studies (primarily LE) have demonstrated an increase in athletic performance, such as an increase in max jumping height, enhanced agility, a decrease in sprint times, an increase in club head speed & driving distance in golf, and enhanced running economy & distance running performance.

• Lower extremity muscle strength and neuromuscular control has also been shown to increase, as well as a faster rate of force development. Plyometric training enhances neuromuscular control and decreases LE injury risk (e.g., ACL) in females (e.g., reduces LE valgus during jumping and landing).
Use of Plyometrics in Training & Rehab

- **Jump Training**
  - Jumps in Place
  - Bounding in Place
  - Bounding for Distance
  - Broad Jumps (stick landing)
  - Cone Jumps
  - Hop, Hop, Stick
  - Squat Jumps

- After neuromuscular jump training, peak landing forces from a jump ↓ 22%, knee valgus moments ↓ 50%, ham:quad peak torque ratio ↑ 15-25%, hamstring muscle power ↑ 20-45%, vertical jump Ht ↑ 10%, max hip adduction & ankle eversion angles ↓, & max knee flexion angle ↑
Use of Plyometrics in Training & Rehab

• **Flexed landing**
  – “Stay flexed”

• **Land soft (pretend ground is hot)**

• **Dissipate ground reaction forces**
  – With soft landing LE muscles absorb 19% more KE, with hip ext eccentric contraction absorbing 22% KE
Use of Plyometrics in Training & Rehab

- After neuromuscular jump training, females had significant increases in knee separation distances during jump take-up, pre-landing, and landing.
Select Photos of Plyometric Drills
<table>
<thead>
<tr>
<th>Type of jump</th>
<th>Lower Intensity Drills</th>
<th>Moderate Intensity Drills</th>
<th>Higher Intensity Drills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumps in place</td>
<td>These drills involve jumping and landing in the same spot. Jumps in place emphasize the vertical component of jumping and are performed repeatedly, without rest between jumps; the time between jumps is the SSC’s amortization phase. Examples of jumps in place include the squat jump and tuck jump.</td>
<td>These jumps emphasize either horizontal or vertical components. Standing jumps are maximal efforts with recovery between repetitions. The vertical jump and jumps over barriers are examples of standing jumps.</td>
<td>Multiple hops and jumps involve repeated movements and may be viewed as a combination of jumps in place and standing jumps. One example of a multiple jump is the zigzag hop.</td>
</tr>
<tr>
<td>Standing jumps</td>
<td>Bounding drills involve exaggerated movements with greater horizontal speed than other drills. Volume for bounding is typically measured by distance but may be measured by the number of repetitions performed. Bounding drills are normally greater than 98 ft (30 m) and may include single- and double-leg bounds in addition to the alternate-leg bounds illustrated in this chapter.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple hops and jumps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bounds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Box drills</td>
<td>These drills increase the intensity of multiple hops and jumps by using a box. The box may be used to jump on or off. The height of the box depends on the size of the athlete, the landing surface, and the goals of the program. Box drills may involve one, both, or alternating legs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth jumps</td>
<td>Depth jumps use gravity and the athlete’s weight to increase exercise intensity. The athlete assumes a position on a box, steps off, lands, and immediately jumps vertically, horizontally, or to another box. The height of the the box depends on the size of the athlete, the landing surface, and the goals of the program. Depth jumps may involve one or both legs.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Jumps in Place
Two-Foot Ankle Hop
Squat Jump
Cycled Split Squat Jump
Standing Jumps
Double-Leg Vertical Jump
Single-Leg Vertical Jump
Double-Leg Tuck Jump

(Can also be performed as “Jumps in Place”)
Single-Leg Tuck Jump

(Can also be performed as “Jumps in Place”)
Pike Jump
(Can also be performed as “Jumps in Place”)
Jump Over Barrier ( & Standing Long Jump)
Multiple Hops and Jumps
Double-Leg Hop
Single-Leg Hop
Front Barrier Hop
Lateral Barrier Hop
Bounds
Skip
Power Skip
Backward Skip
Single-Arm Alternate-Leg Bound
Double-Arm Alternate-Leg Bound
Box Drills
Jump to Box
Squat Box Jump
Lateral Box Jump
Single-Leg Push-Off
Alternate-Leg Push-Off
Lateral Push-Off
Side-to-Side Push-Off
Depth Jumps
Jump From Box

Step from box
The recommended box height for safely and effectively performing depth jumps ranges between 16-42 inches, with 30-32 inches being the norm (20-30 inches for heavier athletes who weight >100 kg.)
Single-Leg Depth Jump
Depth Jump to Second Box
Depth Jump with Lateral Movement
Depth Jump With Standing Long Jump
Upper Extremity Plyometric Drills
Chest Pass
Two-Hand Overhead Throw
Two-Hand Side-to-Side Throw
Single-Arm Throw
Power Drop
Depth Push-Up
45° Sit-Up