Chapter 17

Speed, Agility, and Speed-Endurance Development

Chapter Objectives

- Apply movement principles to locomotion modes and techniques and teach their correct execution.
- Analyze the abilities and skills needed in specific movement tasks.
- Apply means and methods for developing speed, agility, and speed-endurance.
- Design and implement training programs to maximize athletic performance.

Key Terms

- **speed**: The skills and abilities needed to achieve high movement velocities.
- **agility**: The skills and abilities needed to explosively change movement velocities or modes.
- **speed-endurance**: The ability to maintain maximal movement velocities or repeatedly achieve maximal accelerations and velocities.
Key Point
• Movement techniques involve task-specific application of forces that are manifested in terms of acceleration, time or rate of application, and velocity. Strength and conditioning professionals should identify the target activity’s requisite skills and abilities via task analysis and specifically address them in training.

Section Outline
• Movement Mechanics
  – Impulse
  – Power
  – Practical Implications
    • Functional Versus Simple Movements
    • Aerobic Endurance Versus Power Sports

Movement Mechanics
• In order to execute movement techniques, athletes must skillfully apply force—the product of mass and acceleration.
Force Versus Time

- Figure 17.1 (next slide)
  - The slide shows force as a function of time, indicating maximum strength, rate of force development (RFD), and force at 0.2 seconds for untrained (solid blue line), heavy resistance–trained (dashed purple line), and explosive-ballistic–trained (dotted black line) subjects.
  - Impulse is the change in momentum resulting from a force, measured as the product of force and time (represented by the area under each curve), and is increased by improving RFD.
  - When functional movements are performed, force is typically applied very briefly, that is, often for 0.1 to 0.2 seconds, whereas absolute maximum force development may require 0.6 to 0.8 seconds.

Velocity Versus Force

- Figure 17.2 (next slide)
  - The slide shows velocity as a function of force (dashed purple line) and resulting power production/absorption (solid blue line) in concentric and eccentric muscle actions.
  - The greatest forces occur during explosive eccentric (lengthening) actions.
  - Depending on the movement, maximum power (Pm) is usually produced at 30% to 50% of maximum force (Fm) and velocity (Vm).
Movement Mechanics

- **Impulse**
  - Impulse is the change in momentum resulting from a force, measured as the product of force and time.
  - A basic objective of training is to move the force-time curve up and to the left, generating greater impulse and momentum during the limited time for which force is applied.

- **Power**
  - Power is the rate of doing work, measured as the product of force and velocity.
  - High power outputs are required to rapidly accelerate, decelerate, or achieve high velocities.

**Key Point**

- Athletes skillfully apply forces when executing movement techniques. Because of time and velocity constraints, a technique can be characterized in terms of task-specific impulse and power. The ability to achieve high movement velocities and accelerations involves high RFD as well as force application across a range of power outputs and muscle actions.
Movement Mechanics

• Practical Implications
  – Functional Versus Simple Movements
    • Speed in complex, functional movements involves an interplay of neuromuscular, mechanical, and energetic factors.
    • Speed in complex movements correlates poorly with speed in resisted, elementary actions.
    • Many functional tasks begin with preparatory counter-movements and utilize the stretch-shortening cycle (SSC).

Key Term

• stretch-shortening cycle (SSC): Eccentric-concentric coupling phenomenon in which muscle-tendon complexes are rapidly and forcibly lengthened or stretch loaded and immediately shortened in a reactive or elastic manner; springlike preparatory counter-movement of many functional tasks.

Movement Mechanics

• Practical Implications
  – Functional Versus Simple Movements
    • Training activities aimed at improving SSC performance should fulfill two criteria:
      – They should involve skillful, multijoint movements that transmit forces through the kinetic chain and exploit elastic-reflexive mechanisms.
      – In order to manage fatigue and emphasize work quality and technique, they should be structured around brief work bouts or clusters separated by frequent rest pauses.
Key Terms

- **reactive ability**: A characteristic of explosive strength exhibited in SSC actions that can be improved through reactive-explosive training.
- **reaction time**: Relatively untrainable and correlates poorly with movement action time or performance in many explosive events.

Movement Mechanics

**Practical Implications**
- Aerobic Endurance Versus Power Sports
  - Explosive strength qualities also play an important role in aerobic endurance activities, such as distance running.
  - Ground contact times at intermediate running speeds are longer than those at top speeds but significantly shorter than required for maximal force development.
  - Power, impulse, and reactive ability are important determinants of running performance over any distance.

Key Point

- Stretch-shortening cycle actions are especially prevalent in athletic tasks. The target activity’s movement mechanics have important implications in training and should be addressed in the task analysis.
Section Outline

- Running Speed
  - Sprinting Performance and Stride Analysis
  - Technical Errors and Fatigue Effects
  - Training Goals

Running Speed

- Running speed is the interaction of stride frequency and stride length.

Stride Length, Stride Frequency

- Figure 17.3 (next slide)
  - Stride length–frequency interaction as a function of running velocity
Sprinting Variables

- Figure 17.4 (next slide)
  - (a) Stride length, (b) stride frequency, and (c) running velocity in 100 m sprinters of varying qualification
    - Elite sprinters achieve greater stride length and are capable of increasing it up to ~45 m from a static start, whereas novices achieve their maximum stride length at ~25 m (figure 17.4a).
    - Elite sprinters achieve greater stride frequency (~5 strides per second) and are capable of increasing it up to ~25 m from a static start, whereas novices achieve their maximum stride frequency at ~10 to 15 m (figure 17.4b).
    - Elite sprinters produce greater initial forces and velocities at the start, achieve much greater rates of acceleration, and reach maximal velocities up to 12 m/s after ~5 to 6 seconds (45-55 m); novices reach their top speed at 20 to 30 m (figure 17.4c).
Key Point

• Stride frequency tends to vary among individuals and generally seems to be more trainable than stride length.

Running Speed

• Sprinting Performance and Stride Analysis
  – Linear sprinting involves a series of subtasks—the start and acceleration and maximum velocity.
  – Though the movement mechanics of these subtasks are distinct, both are characterized by two phases:
    • Flight
    • Support

Sprinting Technique

• Figure 17.5 (next slide)
  – Sprinting technique during the start and acceleration
Sprinting Technique

• Figure 17.6 (next slide)
  – Sprinting technique at maximum velocity
    • (i) early flight
    • (ii) midflight
    • (iii) late flight
    • (iv) early support
    • (v) late support
Key Point

- Running is a ballistic mode of locomotion with alternating phases of flight (composed of recovery and ground preparation) and single-leg support (composed of eccentric braking and concentric propulsion).

Running Speed

- **Sprinting Performance and Stride Analysis**
  - Following is a summary of the key muscular requirements in maximum-velocity sprinting:
    - As the recovery leg swings forward, eccentric knee flexor activity controls its forward momentum and helps prepare for efficient touchdown.
    - During ground support, the high moment at the ankle joint indicates the importance of the plantarflexors.
    - According to the available evidence, effort during the late support phase neither is essential to sprinting efficiency nor poses a high risk for injury.

Running Speed

- **Technical Errors and Fatigue Effects**
  - Table 17.1 itemizes common sprinting mistakes and their causes and corrections.
## Table 17.1 Sprouting Technique Errors, Causes, and Corrections

<table>
<thead>
<tr>
<th>Error</th>
<th>Cause</th>
<th>Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start and acceleration</td>
<td>Miscalculating pacing of movement</td>
<td>Placing arms at shoulder width</td>
</tr>
<tr>
<td>60° knee angle at foot plant; marker movement</td>
<td>Hips too high or low</td>
<td>Adjusting hip height</td>
</tr>
<tr>
<td>Excessive weight distribution to arms</td>
<td>Excessive weight distribution to arms</td>
<td>Placing legs spread more than forward, straightening arms and distributing weight evenly</td>
</tr>
<tr>
<td>Unnecessarily tense in hamstrings neck hyperextension</td>
<td>Miscalculating of movement</td>
<td>Increasing forward lean, maintaining proper head alignment, accelerating rear leg action</td>
</tr>
<tr>
<td>Uneven &quot;two steps&quot;</td>
<td>Push-off angle too high, upward thrust too steep</td>
<td>Increasing forward lean, maintaining proper head alignment, accelerating rear leg action</td>
</tr>
<tr>
<td>Primavera upright posture</td>
<td>Inadequate pull-off force, improper carriage of heel</td>
<td>Increasing push-off force, maintaining forward lean, forehead spot focused on ground, allowing fluid head movement</td>
</tr>
</tbody>
</table>

### Running Speed

- **Training Goals**
  - Minimize braking forces at ground contact by maximizing the backward velocity of the leg and foot at touchdown and by planting the foot directly beneath the center of gravity.
  - Emphasize brief ground support times as a means of achieving rapid stride rate.
  - Emphasize functional training of the hamstring muscle group with respect to its biarticular structure and dual role (simultaneous concentric hip extension and eccentric knee flexion) during late recovery.
  - Eccentric knee flexor strength is the most important aspect limiting recovery of the leg as it swings forward.
Key Point

- Running speed is the interaction of stride frequency and stride length. The goal of sprinting is to achieve high stride frequency and optimal stride length, with explosive horizontal push-off and minimal vertical impulse.

Section Outline

- Agility
  - Skill Classification
    - General Versus Special Skills
    - Closed Versus Open Skills
    - Continuous Versus Discrete Versus Serial Skills
  - Change in Velocity
  - Locomotion Mode
  - Technical Considerations
    - Body Position
    - Visual Focus
    - Leg Action
    - Arm Action
    - Braking Mechanics

Agility

- Agility is often broadly defined as an athlete’s collective coordinative abilities:
  - adaptive ability: Modification of action sequence upon observation or anticipation of novel or changing conditions and situations.
  - balance: Static and dynamic equilibrium.
  - combinatory ability: Coordination of body movements into a given action.

(continued)
Agility

- Agility is often broadly defined as an athlete’s collective coordinative abilities (continued):
  - differentiation: Accurate, economical adjustment of body movements and mechanics.
  - orientation: Spatial and temporal control of body movements.
  - reactiveness: Quick, well-directed response to stimuli.
  - rhythm: Observation and implementation of dynamic motion pattern, timing, and variation.

Key Point

- Agility is an expression of an athlete’s coordinative abilities, which are the basis of acceleration, maximum-velocity, and multidirectional skills.

Agility

- Skill Classification
  - General Versus Special Skills
  - Closed Versus Open Skills
  - Continuous Versus Discrete Versus Serial Skills
Agility

- **Change in Velocity**
  - Initial speed and direction
  - Decrease or increase in speed (or both) and redirection of movement
  - Final speed and direction

Agility

- **Locomotion Mode**
  - The specific locomotion mode(s) performed and the movement technique(s) used to execute them discretely
  - The specific sequence(s) in which they are performed and the technique(s) used to transition between them serially

Key Point

- The available evidence suggests that backpedal running is a distinct technique rather than a simple reversal of forward running. Athletes’ maximal backward running velocities tend to be ~60% to 80% of their forward velocities.
Agility

• Technical Considerations
  – Linear sprinting can be described as a closed, serial task:
    • Velocity: the athlete starts with an initial speed of zero, maximally accelerates forward, and achieves maximum speed over a specified distance (e.g., 100 m) with minimal deceleration or redirection.
    • Mode: the athlete runs forward by executing a series of discrete subtasks (start, acceleration, maximum velocity) without transitioning to another mode of locomotion.

• Technical Considerations
  – Certain sprinting mechanics—including body position, visual focus, leg action, arm action, and braking mechanics—can be adapted to various multidirectional tasks.
  – Considering the forces involved in explosive deceleration and the role of SSC actions in redirection, some principles of plyometric training are also applicable.

• Technical Considerations
  – Body Position
  – Visual Focus
  – Leg Action
  – Arm Action
Agility

• Technical Considerations
  – Braking Mechanics
    • Following is an example of how to progressively develop and evaluate eccentric strength and reactive ability:
      – Instruct the athlete to run forward and achieve second gear (1/2 speed), and then decelerate and stop within three steps.
      – Instruct the athlete to run forward and achieve third gear (3/4 speed), and then decelerate and stop within five steps.
      – Instruct the athlete to run forward and achieve fourth gear (full speed), and then decelerate and stop within seven steps.

Key Point

• Strength and conditioning professionals can simplify the agility needs analysis by addressing task specificity on two fronts (change in velocity, mode of locomotion) and classifying motor skills according to basic schemes (general vs. special tasks, closed vs. open tasks, continuous vs. discrete vs. serial tasks).

Section Outline

• Methods of Developing Speed and Agility
  – Primary Method
  – Secondary Methods
    • Sprint Resistance
    • Sprint Assistance
  – Tertiary Methods
    • Mobility
    • Strength
    • Speed-Endurance
Methods of Developing Speed and Agility

• Primary Method
  – The primary method is the execution of sound movement technique in a specific task.
  – Initially, athletes should perform tasks at submaximal learning speeds to establish proper mechanics.
  – As they progress toward mastery, task performance can approach or exceed full competition speed.

Methods of Developing Speed and Agility

• Secondary Methods
  – Sprint Resistance
    • This method includes gravity-resisted running (e.g., upgrade or upstair sprinting) or other means of achieving an overload effect (e.g., harness, parachute, sled, or weighted vest).
    • The objective is to provide resistance without arresting the athlete’s movement mechanics, primarily as a means of improving explosive strength and stride length.

Methods of Developing Speed and Agility

• Secondary Methods
  – Sprint Assistance
    • This method includes gravity-assisted running (e.g., downgrade sprinting on a shallow [3-7°] slope), high-speed towing (e.g., harness and stretch cord), or other means of achieving an overspeed effect.
    • The objective is to provide assistance without significantly altering the athlete’s movement mechanics, primarily as a means of improving stride rate.
Methods of Developing Speed and Agility

• Tertiary Methods
  – Mobility
    • Inadequate ROM for a specific task can result in improper foot placement, longer ground times, and higher braking forces.
    • Identify limitations due to flexibility, and address them in training.
  – Strength
    • Prioritize strength training tasks by their dynamic correspondence with the target activity.
    • SSC actions usually deserve high priority in speed and agility training.
  – Speed-Endurance
    • Figure 17.9 summarizes traditional methods for developing this quality.

Traditional Methods of Endurance Training

• Figure 17.9 (next slide)
  – Repetition methods are appropriate for speed and agility training.
  – Competitive-trial and interval methods are appropriate for speed-endurance training.
Special Endurance Training

- Figure 17.10 (next slide)
  - Procedure to establish special endurance training criteria for various sports

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**Key Point**

- The primary method for speed and agility development is execution of sound movement technique in a specific task. Secondary methods include sprint resistance and sprint assistance training. Tertiary methods include mobility, strength, and speed-endurance training.
Section Outline

- Program Design
  - Short-Term Planning
    - Speed and Agility Sessions
    - Speed-Endurance Sessions
    - Motor Learning Guidelines
  - Medium-Term Planning
  - Long-Term Planning
  - Training Plan

Key Terms

- exercise (or work) interval: The duration or distance over which a repetition is executed.
- exercise order: The sequence in which a set of repetitions is executed.
- exercise relief: The relative density of exercise and relief intervals in a set, expressed as a ratio (also called work:rest ratio).

Key Terms

- frequency: The number of training sessions performed in a given time period (e.g., day or week).
- intensity: The effort with which a repetition is executed.
- relief or recovery (or rest) interval: The time period between repetitions and sets.
- repetition: The execution of a specific workload assignment or movement technique.
Key Terms

- **series**: A group of sets and relief intervals.
- **set**: A group of repetitions and relief intervals.
- **volume**: The amount of work performed in a given training session or time period.

Program Design

- **Short-Term Planning**
  - Speed and Agility Sessions
    - Athletes should conduct speed and agility tasks early in a training session.
    - Structure training sessions around brief work bouts and frequent 2- to 3-minute rest periods in order to maximize the quality of learning and training effects.

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- **Short-Term Planning** (continued)
  - Speed and Agility Sessions
  - Repetition methods are an ideal choice in this case, whereas competitive-trial and interval methods are generally better suited for speed-endurance training.
  - Distribute daily sessions into modules separated by recovery breaks, subdivide workloads into brief clusters separated by frequent rest pauses, or both.
Program Design

• Short-Term Planning
  – Speed-Endurance Sessions
    • Interval training methods often produce the best chronic training effects for intensive sports.
    • A given volume of preparatory speed-endurance work can be divided into segments, with rest pauses as needed.

Program Design

• Short-Term Planning
  – Motor Learning Guidelines
    • Physical versus mental practice
    • Amount of practice
    • Whole versus part practice
    • Augmented feedback and instruction
    • Practice distribution
    • Practice variation

Program Design

• Medium-Term Planning
  – The basic objectives of medium-range planning are to exploit complementary training effects at optimal times and minimize the compatibility problems associated with concurrent training.
  – Sequenced training strategies are based on the premise that the delayed effects of certain training stimuli can alter the responses to others.
Program Design

• Long-Term Planning
  – Years 1-2: Fundamental. Training tasks involve deliberate play rather than performance-oriented activity while emphasizing basic movement competencies and fun.
  – Years 3-4: Novice (learning to train). Training begins to involve basic movement competencies and mechanics while starting to target the development of motor abilities.

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• Long-Term Planning (continued)
  – Years 5-6: Intermediate (training to train). Training begins to involve deliberate practice, with balanced emphasis on competency-based and performance-based tasks.
  – Years 7-8: Advanced (training to compete). Development of specific techniques and abilities gets high priority.
  – Years 9-10: Elite (training to win). Mastery of specific strategies, skills, and abilities gets top priority.

Program Design

• Training Plan
  – The sample 14-week preseason macrocycle for American football is organized into four blocks, each three to four weeks in length:
    • Accumulation (three weeks)
    • Restitution (four weeks)
    • Accumulation (three weeks)
      – Training in this period may simulate ideal or real game conditions.
    • Restitution (four weeks)
Key Point

- Program design involves multiple levels of planning: microcycles (short-term), mesocycles (medium-term), and macrocycles (long-term).