Program Design and Technique for Speed and Agility Training
Chapter Objectives

• Describe the underlying biomechanical constructs of sprint, change-of-direction, and agility performance
• Apply sound movement principles to the coaching of locomotion modes and techniques
• Analyze the abilities and skills needed to perform specific movement tasks
• Effectively monitor the development of sprint, change-of-direction, and agility abilities
• Apply sounds means and methods for developing speed, change of direction, and agility
• 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 directions, velocities or modes in response to a stimulus.
- **speed-endurance**: The ability to maintain maximal movement velocities or repeatedly achieve maximal accelerations and velocities.
Key Point

- Speed requires the ability to accelerate and reach maximal velocity, whereas agility performance requires the use of perceptual–cognitive ability in combination with the ability to decelerate and then reaccelerate in an intended direction.
Speed and Agility Mechanics

- In order to execute movement techniques, athletes must skillfully apply force. Due to limited time to produce force during athletic activities, there are two variables that describe force relative to the time available to produce force: rate of force development (RFD) and impulse.
Speed and Agility Mechanics (continued)

• 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 over which force is applied.

• Rate of force development
  – The development of maximal force in minimal time, typically used as an index of explosive strength.

(continued)
Speed and Agility Mechanics (continued)

• Physics of sprinting, change of direction, and agility
  – Force represents the interaction of two physical objects.
  – Acceleration is the change in an object’s velocity due to movement of mass.
  – Velocity describes both how fast an object is traveling and in what direction.
Sprint ground reaction force & impulse

The Acceleration Phase

![Graph showing force and time with phases labeled Braking impulse and Propulsive impulse. The graph indicates the vertical and horizontal forces over time.](image-url)
Sprint ground reaction force & impulse

The Maximum Velocity Phase
Speed and Agility Mechanics

• Practical implications for change of direction and agility
  – In addition to the requirement for acceleration, the production of braking forces over certain periods of time, termed braking impulse, should be considered during change-of-direction and agility maneuvers.
Neurophysiological Basis for Speed

• **Nervous system**
  – Increases in neural drive, which are indicative of an increase in the rate at which action potentials occur, are related to increases in both muscular force production and the rate of force production.
  – Taken together, increases in neural drive may contribute to increases in the athlete’s RFD and impulse generation.

(continued)
Key Term

- **Stretch–shortening cycle (SSC):** An 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.
Neurophysiological Basis for Speed

- **Stretch–shortening cycle**
  - SSC actions exploit two phenomena:
    - Intrinsic muscle–tendon behavior
    - Force and length reflex feedback to the nervous system.
  - Acutely, SSC actions tend to increase mechanical efficiency and impulse via elastic energy recovery.
  - Chronically, they upregulate muscle stiffness and enhance neuromuscular activation.
Neurophysiological Basis for Speed (continued)

• Spring–mass model
  – A mathematical model that depicts sprinting as a type of human locomotion in which the displacement of a body mass is the aftereffect from energy produced and is delivered through the collective coiling and extension of spring-like actions within muscle architecture
Neurophysiological Basis for Speed (continued)

• Figure 19.3 (next slides)
  – A simple spring–mass model relative to the ground reaction force during the stance phase of a sprint
  – During the stance phase, the model demonstrates how the leg (represented as a spring) is uncompressed at initial contact and then is compressed (represented by the change in length of the spring) during midstance or as vertical ground reaction force increases
Figure 19.3(a)
Figure 19.3(b)

![Graph showing vertical force (W_b) over contact time (%). The graph includes a model and two examples. Example 1 has an R^2 of 0.78, and Example 2 has an R^2 of 0.92.](image)

Reprinted by permission from Clark and Weynand 2014.
Key Point

- As sprinting requires an athlete to move at high speeds, strength and conditioning professionals should emphasize the prescription of exercises that have been shown to increase neural drive while overloading musculature of the hip and knee regions involved in the SSC.
Plant phase of a change-of-direction movement

- Point in a change-of-direction movement that represents the transition between the deceleration step and the acceleration step.
- Body positioning and the ability to maintain strong trunk positions during the deceleration of momentum and reorientation of the body to run in a new direction are critical for performance.
Running Speed

• Sprinting is a series of coupled flight and support phases, known as strides, orchestrated in an attempt to displace the athlete’s body down the track at maximal acceleration or velocity, usually for brief distances.
Key Point

• Sprint speed is determined by an athlete’s stride length and stride frequency (rate); more successful sprinters tend to have longer stride lengths as a result of properly directed forces into the ground while also demonstrating a higher stride frequency. These findings suggest that RFD and proper biomechanics are two of the primary limiting factors influencing sprint performance.
Stride Length-Frequency Interaction as a Function of Running Velocity
Running Speed

- **Figure 19.6 (next slides)**
  - (a) Stride length, (b) stride frequency, and (c) running velocity in 100 m sprinters of varying qualifications
  - Elite male sprinters achieve a stride length of 2.70 m, whereas novice sprinters display a stride length of 2.56 m at maximum velocity (figure 19.6a).
  - Elite male sprinters demonstrate stride rates near 4.63 steps per second compared to novice sprinters, who produce a lesser stride rate of 4.43 steps per second (figure 19.6b).
Stride length in 100 m sprinters of varying qualifications

Stride Frequency in 100 m sprinters of varying qualifications

Running Speed

• Sprinting technique guidelines
  – Linear sprinting involves a series of subtasks—the start, acceleration, and top speed.
  – While these phases are technically distinct, they all require the athlete to volitionally move the lower limbs at maximal speeds through a series of stance and flight phases.
Running Speed *(continued)*

- Figure 19.7 (next slide)
  - Sprinting technique during the initial acceleration (start) and acceleration
Sprinting technique during the initial acceleration (start)
Sprinting Technique

- Figure 19.8 (next slide)
  - Sprinting technique at maximum velocity
    - (a) Late flight to early support
    - (b) Early support
    - (c) Midsupport
    - (d) Late support, toe-off
Sprinting Technique at Max Velocity

(a) Late flight to early support
(b) Early support
(c) Midsupport
(d) Late support, toe-off
Running Speed

- **Training goals**
  - Emphasize brief ground support times as a means of achieving rapid stride rate.
  - Requires high levels of explosive strength
  - Developed systematically through consistent exposure to speed training as well as properly designed strength training programs
Running Speed (continued)

• **Training goals**
  – Emphasize further development of the stretch–shortening cycle as a means to increase the amplitude of impulse for each step of the sprint.
  • High achievers at top-speed sprinting produce high forces in a shorter stance phase using the stretch–shortening cycle.
  • Sport specific sagittal plane weightlifting movements and their derivatives are key exercises in overloading the stretch–shortening cycle with forces greater than those produced during an open sprint.
Agility Performance and Change-of-Direction Speed

• Factors affecting change-of-direction and perceptual–cognitive ability
  – Change-of-direction ability
    • May change depending on the demand of the COD test
    • It is a combination of the ability to decelerate, reorient the body to face or partially face the direction of intended travel, and then explosively reaccelerate that truly determines change-of-direction ability

(continued)
Factors affecting change-of-direction and perceptual–cognitive ability

- Perceptual–cognitive ability
  - There are several factors that are components of perceptual–cognitive ability: visual scanning, anticipation, pattern recognition, knowledge of the situation, decision-making time and accuracy, and reaction time.
  - Many of these aspects of development are sport specific.
Key Point

• Athletes improve change-of-direction ability through development of a number of physical factors and technical skills during a variety of speeds and modes of movement. The development of agility also requires improving perceptual–cognitive abilities in relation to the demands of the sport.
Agility Performance and Change-of-Direction Speed

• Technical guidelines and coaching
  – Some technical guidelines and coaching suggestions:
    • Visual focus
    • Body position during braking and reacceleration
    • Leg action
    • Arm action

(continued)
Agility Performance and Change-of-Direction Speed (continued)

• Training goals
  – The primary goal of agility performance is threefold:
    • Enhanced perceptual–cognitive ability in various situations and tactical scenarios
    • Effective and rapid braking of one’s momentum
    • Rapid reacceleration toward the new direction of travel
Methods of Developing Speed

• Sprinting requires near-maximum to maximum muscle activation, which depends on high central nervous system activity. This activity is often referred to as rate coding (firing frequency).
Methods of Developing Speed

• **Strength**
  - The transfer of strength improvements to sprinting may require an emphasis on the specificity of training. This transfer-of-training effect deals with the degree of performance adaptation and may result from the similarities between the movement patterns, peak force, RFD, acceleration, and velocity patterns of an exercise and the sporting environment.

(continued)
Methods of Developing Speed (continued)

- **Mobility**
  - Mobility is the freedom of an athlete’s limb to move through a desired range of motion, whereas flexibility is a joint’s total range of motion.
  - With an understanding that positional characteristics are among several limiting factors in performance, coaches should ensure that proper postural integrity is in place before practice or competition.
<table>
<thead>
<tr>
<th>Agility component</th>
<th>Beginner</th>
<th>Intermediate</th>
<th>Advanced</th>
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| Change of direction| Deceleration drills (forward) progressing to higher entry velocity or shorter distance to stop  
Basic movement patterns for forward, backward, and lateral shuffling  
Change-of-direction drills that involve low velocities (less than 5 yards of acceleration into change of direction)—Z-drill, for example | Deceleration drills (lateral) with same progressions as forward  
Expand to include a broad range of cutting angles less than 75°  
May increase entry velocity during drills (up to 10 yards of acceleration leading into change of direction) | Deceleration to reacceleration in both forward and lateral directions  
Expand further to a comprehensive range of cutting angles including those greater than 75° |
| "Maneuverability" | Basic drills or tests such as the Illinois agility that require nearly straight-line running with slight bends | Drills that increase the difficulty of the "bend" involved such as the L-run  
Drills that require transition between modes of movement (shuffling, sprinting, and backpedalling) such as the T-test | |
| Agility | Physical and technical competence should occur before agility drills are incorporated. | Change-of-direction drills in beginner and intermediate categories with the addition of simple stimuli (arrow, pointing in a certain direction)  
These drills present a limited number of options for the athlete to have to react to (e.g., right or left, forward or back) on the signal | Expand into large degrees of spatial and temporal uncertainty (and therefore greater perceptual–cognitive stress)  
Small-sided games  
Evasion games and drills |

Adapted, by permission, from Nimphius, 2014 (58).
Methods of Developing Agility

• Perceptual–cognitive ability
  – Agility activities should begin by adding a perceptual–cognitive component to common closed skill change-of-direction drills.
  – For example, decelerations or the Z-drill can evolve into agility drills through inclusion of a generic stimulus such as a whistle, a coach command, or a flashing arrow or light.
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 (continued)

- **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.
- **work-to-rest ratio**: The relative density of exercise and relief intervals in a set, expressed as a ratio.
Program Design

• **Speed development strategies**
  
  – Planning tactics should be periodized in a manner that addresses the physical and psychological components of sprinting through emphasis and de-emphasis on particular qualities in a phasic manner.
  
  – An athlete’s capability to sprint can be improved through the incorporation of training periods that are designed to fully maximize and saturate a fitness quality, which may bolster the effects of future training agendas.
Agility Development Strategies

• Step 1: Perform a needs analysis of the sport and match tests appropriately to assess these qualities.

• Step 2: Determine strengths and weaknesses by comparing results as a standardized score to performance standards or team mean.
Agility Development Strategies *(continued)*

• Step 3: Plan the development of a primary area of need and a secondary area of need for the athlete.

• Step 4: Distribute the time available for this development based on need identification.

• Step 5: Provide a preliminary plan for transition of percent distribution through the training blocks.
Exercise Drills
Exercise 19.1: A-Skip

• **Starting position**
  – Begin the exercise in a tall stance with torso directly above the hips, knees, and ankles (stacked joints).

• **Movement phase**
  – Initiate movement by lifting one leg to a bent-knee position with the top of thigh near parallel. The foot of the lifted leg (swing leg) should be approximately at knee height of the stance leg, with the heel pulled up under the buttocks. This will result in the appearance of a “figure 4” at the legs.
“Figure 4” at the Legs
Exercise 19.1: A-Skip

• Movement phase
  – Begin the first skip by aggressively driving the swing leg down to the ground through an active foot, established through slight dorsiflexion. “Lift the big toe up” to establish appropriate dorsiflexion.
  – Complete the aggressive drive down of the swing leg through the forefoot until near-triple extension of the newly acquired stance leg occurs.
  – The fore- to midfoot of the new stance leg should land under the hips, maintaining the “stacked joints” appearance.
  – At the initiation of contact, the opposing leg should quickly “pop up” to create a swing leg.
  – The force generated from the active push down should coincide with a skipping motion that will result in a horizontal displacement of the body down the track.
Exercise 19.2: Fast Feet

• Designed to enhance the stride frequency of a sprinter

• Starting position
  – Athlete begins exercise in a tall stance with torso directly above the hips, knees, and ankles (stacked joints).
Exercise 19.2: Fast Feet

• Movement phase
  – Athlete initiates movement by lifting one leg to a bent-knee position, with the foot of the lifted leg approximately at the halfway point of the shank, in order to replicate a swing leg. All swing legs will follow this description.
  – Once this position has been achieved, instruct the athlete to alternate stance and swing legs as quickly as possible while maintaining the “stacked joints.”
Exercise 19.2: Fast Feet

• Movement phase
  – The quick and aggressive drive down of the swing leg should be completed through the forefoot, ensuring that the feet do not rise above the halfway point of the shank. The shortened rise of the swing leg is to ensure quicker stepping frequency.
  – The fore- to midfoot of the new stance leg should land under the athlete’s hips, maintaining the “stacked joints” appearance.
  – The athlete’s arm should move at the same rate as the legs, with minimal to no pausing of arm action between cycles.
Exercise 19.2: Fast Feet
Quick Drive Down of the Swing Leg
Exercise 19.2: Fast Feet

• Movement phase
  – The athlete’s arm should move at the same rate as the legs, with minimal to no pausing of arm action between cycles.
Exercise 19.3
Sprint Resistance: Incline for Acceleration

• Inclined sprinting is a type of resisted sprinting that is prescribed to promote improvements within the acceleration phase of a sprint.
Exercise 19.3
Sprint Resistance: Incline for Acceleration

- **Starting position**
  - Begin the exercise by placing the athlete in the correct starting position (commonly called a crouched start).
  - Instruct the sprinter to split the stance position by placing the dominant leg forward and to drop the back/swing leg by one to two foot lengths.

Crouched Start
Starting position

- The length of split between the drive and swing leg is largely determined by the compromise between
  - The athlete’s ability to generate sufficient forces needed to overcome gravity and a lower center of gravity
  - The athlete’s comfort
- The feet should be split in such a manner that the front and back legs are “in line” with the pelvis, so that no unnecessary twisting of the hips occurs.
- Once the split stance has been established, instruct the athlete to drop the back knee “straight down” so that the shank (shin) is nearer (“more parallel”) to the ground. This aids in promoting the proper driving positions needed to begin acceleration.

Exercise 19.3

Sprint Resistance: Incline for Acceleration
Exercise 19.3
Sprint Resistance: Incline for Acceleration

• **Starting position**
  - With a tall and rigid torso, the athlete should then raise the arm that is opposite the front/drive leg to a position near or slightly above the forehead. The hand should be spaced approximately 6 to 8 inches away from the forehead.
  - The rear arm should be pulled back to the point that the hand is near the lateral aspect of the buttocks with an elbow angle that may range from $100^\circ$ to $120^\circ$.
  - Upon completion of setup, instruct the athlete to lean the entire body forward so that 60% of the body weight is on the front leg. Ensure that the athlete does not “break at the waist” during this shift.
  - The athlete should continue to feel balanced and stable.
Exercise 19.3
Sprint Resistance: Incline for Acceleration

• Movement phase
  – After body weight has been transferred, the athlete can initiate the sprint through an aggressive push “down and through” the ground via the front/drive leg. The back leg should also assist in force production but will leave the ground earlier due to starting stance position.
  – Arm action should be synchronous with leg action.
Exercise 19.4: Deceleration Drill

• **Movement phase**
  - Depending on the physical and technical competence of the athlete, have the athlete run forward at half speed and then decelerate and stop within three steps.
  - If he or she is successful in effectively absorbing the load by the third step, increase the drill to involve running at three-quarters speed (more than 10 yards of acceleration) and then decelerating within five steps.
  - The most advanced version of this drill requires braking from top speed and decelerating within seven steps.
  - The most demanding braking step or the step resulting in the greatest deceleration will occur one or more steps before stopping and doesn’t typically occur solely on the final deceleration or change-of-direction step.
Figure 19.4: Forward Deceleration Drill
Figure 19.4: Forward Deceleration Drill (continued)
Figure 19.4: Forward Deceleration Drill
Lateral Deceleration Drill
Exercise 19.5: Z-Drill

• **Starting position**
  - Begin the exercise by starting at the first cone with a lowered center of mass and a stance wider than shoulder-width.
Exercise 19.5: Z-Drill

- **Movement phase**
  - Side shuffle to the next cone while keeping the center of mass at a constant height (as low as the original center of mass height during the start position). Emphasize pushing the ground away; as a coach, one may look at the angle of the shank, ensuring that it is directed toward the direction of intended travel.
  - The athlete should plant at or near the cone and rapidly transition into a sprint toward the cone located on the diagonal.
  - Entering the cone, the athlete should effectively decelerate and transition into another shuffle (as with step 2).
Z-Drill Setup

(continued)
Z-Drill Setup (continued)
Exercise 19.6
Agility Drill (Y-Shaped Agility)

• Starting position
  – Start at a cone 10 yards away from a person who will serve as the “stimulus” or “director.”

• Movement phase
  – Run toward the “stimulus” and change direction based on the direction in which the director points or the audible signal the director provides (two options considered generic stimuli).
Exercise 19.6
Agility Drill (Y-Shaped Agility) (continued)

• **Movement phase**
  
  – The director should point left or right when the athlete reaches the 5-yard mark (mark this by another cone for reference of the director).

  – The athlete should plant and change direction as soon as possible, accelerating to the cone that is 3 yards to the left or right of the stimulus.