



Acceleration and Speed

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In most sports, athletes start from either a stationary or a partially moving posture and attempt to reach maximum speed as quickly as possible. This is referred to as acceleration, or the rate of change of velocity. Speed refers to the point at which athletes can accelerate no more and have reached their maximum rate of movement. At this point, athletes attempt to hold that pace as long as possible and to minimize “slowing” due to fatigue, friction, and air resistance.

Rates of acceleration vary from one athlete to another. In some 100-meter races, Carl Lewis was still accelerating at the 70-meter mark. Although his acceleration rate was less than that of his competitors in the early part of the race, he continued to increase speed longer, allowing him to pass athletes in the final 20 meters. Other athletes also accelerate more slowly only to reach higher speeds later in the race. Speed (maximum miles per hour) can be mathematically determined from world records in sprint events. The current world record of 19.32 seconds in the 200 meters is equivalent to an average speed of 23.5 miles per hour. Splits of world-class sprinters provide a more accurate indicator of just how fast humans can run. Studies indicate that 20-meter segments (from 60 to 80 meters, and from 70 to 90 meters) in a 100-meter race are covered in as little as 1.6 seconds, equivalent to a speed of 27.9 miles per hour.

Sports are played with multiple starts and stops and many changes in direction. It is no surprise that the average speeds players attain during competition are well below their maximums. On only a few occasions will athletes accelerate for 60 meters, the approximate distance it takes a world-class sprinter to reach maximum speed. A triple in baseball, a 100- or 200-meter sprint in track, and a long run in football, rugby, soccer, or lacrosse would approach or exceed 60 meters. What people generally refer to as speed is more accurately termed acceleration to maximum speed.

For decades, acceleration and speed have been recognized as two of the most important qualities an athlete can possess. Skeptics cling to the belief that speed is a God-given genetic quality that one is born with and that no type or amount of training can bring about change. Since 1912, 100-meter world records have improved from 10.6 (Donald Lippincott, USA) to the current record of 9.79 set in 1999 (Maurice Green, USA)—a change of only 0.81 seconds, or 7.64 percent. The 200-meter world record improved from 20.6 in 1951 (Andy Standfield, USA) to 19.32 in 1996 (Michael Johnson, USA)—a difference of 1.28 seconds, or about 7.16 percent. Women's 100-meter and 200-meter times showed larger improvements of 1.3 seconds (9 percent) in the 100 meters and 2.26 (9 percent) in the 200 meters (Lawson 1997).

It is difficult to determine the contribution of new training programs and new equipment (starting blocks, all-weather synthetic tracks, modern shoes) to these improved times. And the change from manual to electronic timing on January 1, 1977, undoubtedly eliminated previously inflated times that obscured some of the improvement in the previous analysis.

Although coaches still recruit "fast" athletes, they now realize that every athlete can improve speed. Coaches are also aware that dramatic improvement of acceleration and speed in Olympic-caliber sprinters is difficult to attain; as athletes approach their maximum potential, less room is available for improvement. This is not so, however, for most high school and college athletes, who can improve their 40-yard dash times by as much as 0.7 seconds in only eight weeks.

It is now widely accepted that everyone can improve acceleration and speed, but rarely will any athlete approach his or her genetic speed potential unless the correct training techniques are followed.

Decades ago physiologists uncovered changes to muscle fiber types (fast-twitch white and the intermediate fast-twitch red) following the completion of the training programs discussed in this chapter. Since the early 1970s, researchers have also been aware that stride rate (steps per second), stride length, and speed in short distances improve with proper training. This knowledge has broadened training emphasis from programs that focused mainly on form and anaerobic conditioning to a holistic approach that includes programs that also alter stride rate and length.

If reaction time (RT) or response to a stimuli—the starting gun in track; the center snap or movement of an opposing player in football; the crack of the bat in baseball; the impact of the racket in tennis; the faking action of an opponent in ice hockey, lacrosse, rugby, or soccer—is eliminated, only three areas of change can directly cause improvement of acceleration and speed:

1. Taking faster steps (increasing stride rate) without decreasing the length of each stride

2. Increasing the length of each stride without decreasing stride rate
3. Using sound biomechanics (form)

A fourth area, anaerobic endurance (speed endurance), has an indirect effect on acceleration and speed by reducing slowing at the end of a long sprint and permitting repetitive short sprints to occur at the same rate, relatively unaffected by fatigue.

This chapter focuses on the training programs that affect these four areas and that bring about improvements in acceleration and speed that are specific to various sports.

FACTORS AFFECTING ACCELERATION AND SPEED

No body design is perfect for sprinting. Numerous body types and variations in height, weight, and length of levers have proved effective. Present-day Olympic sprinters are slightly heavier and taller than those of 30 to 50 years ago, but geometrically they are no different. Fast sprinters come in all sizes and shapes, with smaller athletes taking shorter strides but faster steps than their taller counterparts.

Several physiological factors, however, affect both acceleration and speed, including genetic factors such as fast-twitch and slow-twitch fiber percentages, body fat, age, gender, and anaerobic or speed endurance.

Muscle Fiber

Three types of muscle fiber are found in various parts of every athlete's body:

- Slow-twitch red (type I)—This fiber type relies on oxygen to produce energy (aerobic). It develops force slowly, is fatigue resistant (high endurance), and has a long twitch time, low power output, high aerobic capacity for energy supply, and limited potential for rapid force development and anaerobic power.
- Fast-twitch red (type IIa)—This intermediate fiber type can contribute to both anaerobic and aerobic activity. It develops force moderately fast and has moderate fatigability, twitch time, power output, aerobic power, and anaerobic power.
- Fast-twitch white (type IIb)—This fiber type does not rely on oxygen to produce energy (anaerobic). It develops force rapidly, and has fatigability (low endurance), a short twitch time, high power output, low aerobic power, and high anaerobic power.

Muscles with a high percentage of fast-twitch fibers exert quicker, more powerful contractions. Individuals born with a high percentage of fast-twitch fiber in the muscles involved in sprinting have a higher speed potential than those born with a preponderance of slow-twitch fiber, which is more suitable for cross country, marathon running, and other sports requiring high aerobic endurance. Inherited percentages of fiber type are similar in both men and women. Although the theory that slow-twitch fibers can be changed into fast-twitch fibers is controversial, new evidence suggests that prolonged high-intensity training may produce that effect and improve the ratio of fast-twitch to slow-twitch fibers.

Table 9.1 Approximate Percentages of Fast-Twitch Fiber in Speed and Endurance Athletes

Type of activity	Men	Women
Speed-based activities		
Sprinters (100 or 200 meters)	48–80%	72–75%
Ice hockey players	44–62%	—
Shot-putters, discus throwers	50–88%	45–52%
Endurance-based activities		
Cross-country skiers	25–45%	25–50%
Cyclists	25–50%	35–65%
800-meter runners	40–64%	25–55%
Untrained individuals	25–62%	25–72%

Source: Dintiman, George B., 1984. *How to Run Faster: Step-by-Step Instructions on How to Increase Foot Speed*. Champaign, IL: Leisure Press.

The right kind of high-intensity training (heavy load) will recruit and train the fast-twitch fibers and aid in the improvement of acceleration and speed. Although “training fast to be fast” is a key principle for improving acceleration and speed, it is the intensity (load), not speed, that activates fast-twitch muscle fibers.

Table 9.1 compares the amount of fast- and slow-twitch muscle fiber found in a study of speed and endurance athletes. Postural muscles such as the soleus are composed mostly of slow-twitch fibers whereas large locomotor muscles such as the quadriceps contain a mixture of both fiber types, which permits both jogging, a low-power output activity, and sprinting, a high-power output activity. Numerous studies have found sprinters to possess high amounts of fast-twitch fiber.

Body Fat

Body fat of 6 to 10 percent of body weight for men and 12 to 17 percent for women is desirable for sprinting short distances. It is important to be aware that the lower range for both men and women may be unhealthy even for athletes, depending on the individual. On the other hand, excess fat provides useless weight that negatively affects both acceleration and speed.

Age

Age eventually affects all aspects of athletic performance. The average age of 41 male world record holders in the 100 meters from 1912 to 1999 was 23; for 21 female record holders it was 24.5. Only three male athletes, Barnes Ewell (age 30) of the USA, E. McDonald Bailey (age 31) of Great Britain, and Carl Lewis (age 30) of the USA, set world records after the age of 30. Two record-setting female athletes, Fanny Blankers-Koen of the Netherlands and Shirley Strickland of Australia, were also 30. The late Florence Griffith Joyner of the USA was 29 when she set the current world records in the 100 and 200 meters in Seoul, South Korea, in 1988.

With the onset of hefty endorsement contracts and the resurgence of interest in track throughout the world, sprinters are now motivated to remain active for longer periods. Consequently, Carl Lewis and others have been able to maintain their speed well into their 30s, something unheard of in the past. No physiological reason exists for speed to diminish significantly from age 25 to age 35 unless the athlete ceases training, loses strength and power, or adds body fat.

Gender

Gender is a factor in sprinting. World records by men in the 100 meters are 0.75 seconds faster than those by women. Studies in the 1980s indicated that Olympic male sprinters had a stride rate of about 5.00 steps per second whereas female sprinters had a stride rate of 4.48 steps per second. The faster stride rates and longer strides of males appear to account for the time differences. Although hormonal and anatomical differences exist that have implications for acceleration and speed, now that female athletes are finally receiving proper training, they are increasing in strength and power, and improving at a faster rate than men in both the 100-meter and 200-meter events.

Speed Endurance

Speed endurance (anaerobic energy) will not change stride rate or stride length, at least on the first short sprint. But it will determine the amount of slowing at the end of a long sprint, the pace at which acceleration to maximum speed occurs, and even speed on repetitive short sprints. In other words, athletes with poor speed endurance are unable to accelerate and sprint at the same high level repeatedly during competition because of fatigue. Ideally, athletes run the fourth or fifth sprint as fast as the first. This often does not occur because of inferior speed endurance.

Anaerobic metabolism occurs at the onset of any type of exercise to provide an immediate source of quick energy until circulatory and respiratory adjustments occur. All sprints under six seconds rely almost exclusively on the phosphagen system; those lasting six to nine seconds begin to rely on lactic acid. In short-term, heavy exercise, the only significant energy available is the breakdown of the phosphagens, adenosine triphosphate (ATP) and creatine phosphate (CP), and glycolysis, the breakdown of glucose to pyruvate and lactic acid. Speed-endurance training develops both systems. Sprinting always takes place in the absence of oxygen, a condition under which the skeletal muscles can function for only a short time. When oxygen requirements exceed the ability of the body to uptake oxygen, pyruvic acid forms from glucose and is reduced to lactic acid. This process (anaerobic glycolysis) occurs only in the absence of oxygen, producing energy-rich phosphate bonds to allow muscle contraction to continue. About eight seconds of maximum-effort sprinting nearly depletes these quick-energy stores.

At this point (much sooner for the poorly conditioned athlete) slowing occurs because of lactic-acid buildup. Improved lactic-acid tolerance, increased quick-energy stores, and improvement in the rate that quick energy is available are related to factors such as anaerobic fitness, age, and nutrition.

Mechanics

Although no two athletes run the same way, proper sprinting mechanics are similar for everyone. Removing errors in arm action, body lean, foot contact, overstriding, understriding, and tension can improve acceleration and speed.

TESTING AND EVALUATION

Before personalized programs can be designed to improve acceleration and speed for any sport, the strengths and weaknesses, or limiting factors, of each athlete must be identified. This approach also helps athletes avoid the common tendency to work on strengths and avoid weaknesses. Although chapter 2 covers the subject in detail, the critical test areas for acceleration and speed are briefly discussed in the following sections.

Sprinting Speed

A stationary 120-yard dash with 40- and 80-yard splits, combined with a stride-length test, reveals an athlete's stride rate and acceleration. Unless a high-speed camera is available, stride rate is determined mathematically using the second 40-yard time and length of stride; acceleration is rated acceptable if the difference between the two 40-yard times is less than 0.7 seconds.

Speed Endurance

The drop-off index compares the time taken to cover the last two 40-yard segments in a 120-yard dash—the 40- to 80-yard segment and the 80- to 120-yard segment. A series of 6 to 10 repeated 40-yard dashes using a rest interval similar to the rest period in a specific sport, such as the length of the huddle in football (25 to 30 seconds), also provides an excellent indication of speed endurance. Standards for these two tests devised by the National Association of Speed and Explosion (NASE) are no more than a 0.2-second difference for the drop-off and no more than a 0.4-second deviation from the best time for any of the repetitive 40-yard sprints. This test can be done manually with stopwatches and flags on each finish tape or by electronically timing splits.

Stride Length

Stride length can be easily measured without high-speed cameras by having athletes run naturally through a 20-yard area. It is a simple matter to measure the distance between two footprints.

Athletes can compare their strides to those of top sprinters using the following formulas (which indicate guidelines for ideal stride length):

Male sprinters:	1.14 × height (+/- 4 inches), or
	1.24 × height (for athletes under age 16), or
	1.265 × height
Female sprinters:	1.15 × height, or
	2.16 × leg length

Coaches should also watch for understriding and overstriding and make a note of either in order to help each athlete find his or her ideal stride length.

Strength

Use the one-repetition maximum (1RM) for a free-weight squat or the leg press on a Nautilus station to determine a ratio of strength to body weight. A ratio of 1:2.5 or 1:3 or more—a free-weight squat or a leg press score of two and a half to three times body weight—suggests a desirable ratio for optimum development of acceleration and speed.

Explosive Power

The standing triple jump, vertical jump, and double and single 20-yard leg hops provide some indication of an athlete's potential for speed improvement and mild insight into the amount of fast-twitch fiber in the muscles involved in sprinting.

Muscle Balance

The prime movers in sprinting are the knee extensors, hip extensors, and the ankle plantar flexors. Comparing the strength and power of left limbs to right limbs, agonists to antagonists, upper body to lower body, and strength to total body weight provides valuable information. Improving the strength of muscle groups that are already near optimum levels and avoiding areas of weakness is unlikely to produce much improvement in acceleration and speed.

An imbalance usually exists between the knee extensors and the flexors. An even greater imbalance is often found between the posterior leg compartment muscles (plantar flexors) and the anterior compartment muscles (dorsiflexors). A strength imbalance between two opposing muscle groups, such as the quadriceps (agonists) and the hamstrings (antagonists), also produces serious limitations. The strength of the hamstring muscle group is a sprinter's weakest link. It should be improved to 70 to 90 percent of the strength of the quadriceps group. A minimum ratio of 70 percent is recommended for the prevention of injury. Ideally, leg extension (quadriceps muscle group) and leg curl (hamstring muscle group) scores should be the same. In almost every athlete at all ages, however, the quadriceps muscles are much stronger than the hamstring muscles. The average leg curl score in 1,625 middle school and high school football players tested in NASE speed camps was less than 50 percent of the leg extension score.

Flexibility

Because flexibility is joint specific, a single test does not provide an accurate assessment of range of motion (ROM), and it is impractical to measure the ROM of every joint. In addition, the flexibility of some joints is not critical to acceleration and speed. Tests are available that involve little equipment and provide a fair assessment of ankle flexion and extension, shoulder flexibility, and hamstring flexibility.

Body Composition

Unless underwater weighing equipment is available, the most accurate and practical method of determining percent of body fat is the skinfold technique. Measure at least four sites to get the most accurate test. Because people carry weight differently, it is best to measure a site on the upper body (triceps, biceps, subscapula, suprailiac, abdomen), lower body (hip, thigh), front of body, and back if possible.

SPEED-IMPROVEMENT TRAINING PROGRAMS

Although speed-improvement training programs are similar for most sports, each should be sport specific in terms of exercises, repetitions, duration, rest interval, and distance or time. Some forms of training may require more emphasis depending on individual test results.

It is also important to apply the principles of periodization by structuring the training into phases for improving acceleration and speed. Phases of each training area should be organized according to the competition schedule to produce peak performance at the most important times. See chapters 12 and 13 for more on periodizing training.

Functional Strength and Power

The purpose of the functional strength and power program presented in table 9.2 is to develop a strong foundation that optimizes the improvement of acceleration and speed and that develops the required force and tissue capacity for the sport. Periodized weight training in this six- to eight-week phase emphasizes strength, speed, and endurance and involves a program of general exercises for the legs, back, shoulders, chest, arms, trunk, abdomen, and neck starting at 60 percent of a 1RM weight. The Olympic lifts (table 9.3) are added in the second four week microcycle and involve heavy weight, near maximum muscular contractions, low repetitions, and full recovery between sets. Key exercises recommended for improving acceleration and speed follow. Chapter 4 describes the techniques for the execution of many of these exercises.

- Olympic lifts: clean (barbell and dumbbell), jerk (barbell, dumbbell, and machine rack), and snatch (barbell and dumbbell). The suggested program using the Olympic lifts (see table 9.3) includes a wide range of intensity, with loads increased to or near 1RM. Maximize rest between sets to reduce fatigue.
- Legs and back: dead lift, calf raises, front squat, leg extension, and leg curl.
- Shoulders and arms: incline press, bench press, dumbbell arm curls, lat raise, lat pull-down, fly, sprinting arm movements holding dumbbells.
- Hamstring muscle group: Olympic lifts and leg curls. Specific hamstring exercises should be included in each workout because this is a neglected area.

Strength training in the weeks just prior to competition should focus on weight-training exercises that mimic the sprinting action such as sprinting arm movements with dumbbells, kick backs on a leg press station (from a sprinter's starting

Table 9.2 Functional Strength and Power Program for Advanced Athletes

Exercise	Mon.	Tue.	Wed.	Thu.	Fri.
Warm-up: Flexibility	•	•	•	•	•
Power					
Clean, power	M		M		
Snatch, power		M		H	
Jerk, rack	H		M		L
Legs and back					
Pull, clean	M		L		H
Dead lift	H		M		
Squat	L		M		H
Squat, front					M
Shoulders, chest, and arms					
Bench press	H		M		
Incline press		M		H	
Rowing	H		M		L
Flys, supine			L		M
Trunk and abdomen					
Trunk hyperextension			3 × 10 (60%)		3 × 10 (70%)
Sit-ups (bent knee)	3 × 25		3 × 25 (60%)		3 × 25 (70%)
Neck					
Partner four-way neck	3 × 8–12		3 × 8–12		3 × 8–12
Light (L) Medium (M) Heavy (H)					
60% 1 × 5	60% 1 × 5		60% 1 × 5		
65% 1 × 5	70% 1 × 5		75% 1 × 5		
70% 1 × 5	68% 1 × 5		85% 1 × 5		
			69% 1 × 5		

position), knee lifts, pull-downs, and other weight machine exercises that simulate exact movements in the start, acceleration, and sprinting phases.

Plyometric Training

Plyometrics revolve around jumping, hopping, and bounding movements for the lower body and swinging, quick-action push-offs, catching and throwing weighted objects (medicine balls, shot puts, sandbags), arm swings, and pulley throws for the upper body. These exercises are critical in developing strength and power in the muscles involved in sprinting. Plyometric training was partially responsible for the unusual progress and success of Russian sprinter Valeri Borzov, a 100-meter gold medalist (10.14) in the 1972 Olympic Games. Borzov progressed from a 100-meter time of 13.0 seconds at age 14 to 10.0 at age 20.

Table 9.3 Olympic Lifts Program for Improving Acceleration and Speed

Monday		Wednesday	
Warm-up		Warm-up	
Cleans		Jerks	
Sets	3 to 6	Sets	3 to 6
Repetitions	3 to 5	Repetitions	3 to 5
% RM	66 to 100%	% RM	66 to 100%
Rest	1 1/2 to 5 minutes between sets	Rest	1 1/2 to 5 minutes between sets
Jerks		Cleans	
Sets	3 to 6	Sets	3 to 6
Repetitions	3 to 5	Repetitions	3 to 5
% RM	66 to 100%	% RM	66 to 100%
Rest	1 1/2 to 5 minutes between sets	Rest	1 1/2 to 5 minutes between sets

The plyometric exercises in table 9.4 are grouped by level of intensity to allow improved progression from one phase of training to another to reach peak performance. Most of the exercises closely resemble specific sprinting movements and can force similar muscle groups to work at high rates of speed. The proper techniques to perform many of these exercises are described in chapter 5, and many can also be found in *Jumping Into Plyometrics*, Second Edition, by Donald Chu (1998, Human Kinetics).

Sprint Loading

Sprint loading is another key part of a holistic approach to improving acceleration and speed. The program is designed to improve explosive concentric movements such as sprinting. Three basic techniques provide the necessary light resistance that helps improve strength and power in the muscles involved in acceleration and speed.

1. Hill sprints. The degree of incline must allow proper starting and sprinting form. A 10- to 30-yard incline of 8 to 10 degrees should be covered in 2.5 to 3.5 seconds, followed by a near full-speed sprint of 20 to 80 yards at the same incline.
2. Stadium stairs. Stadium stairs or other stairs can be used in the same manner as hill sprinting. Stairs should have the same approximate angles.
3. Weighted sleds. Numerous inexpensive sleds are available. A spare tire with a rope and weighted belt can be made for little cost. Metal and plastic models are available that allow quick and easy weight changes. It is important to use a load that permits proper form and high-speed sprinting. Too much weight decreases both stride length and rate and prevents explosive movements. The objective in all high-speed work is to reduce ground contact time and maintain a stride rate as high as or higher than the stride rate of the sprinting action without resistance.

Table 9.4 Plyometrics to Improve Acceleration and Speed

Intensity	Exercise	Sets × reps	Rest (min.)	Progression
Low (two weeks)	<i>Squat jump</i>	3 × 6–10	2	Add one rep each workout until reaching 10
	Double-leg ankle bounce	3 × 6–10		
	Lateral cone jump	2 × 6–10		
	Drop and catch push-up	4 × 6–10		
Low to medium (two weeks)	Lateral cone jump	3 × 8–10	2	Add one rep each workout until reaching 10
	Split squat jump	2 × 8–10		
	<i>Tuck jump</i>	2 × 8–10		
	<i>Standing triple jump</i>	2 × 8–10		
	<i>Backward medicine ball throw</i>	2 × 8–10		
	Underhand forward medicine ball throw	2 × 8–10		
	Clap push-up	2 × 8–10		
Medium (two weeks)	<i>Standing long jump</i>	3 × 8–10	2	Add one rep each workout until reaching 10
	<i>Alternate bound</i>	3 × 8–10		
	Double leg hop	3 × 8–10		
	Pike jump	2 × 8–10		
	<i>Depth jump</i>	2 × 8–10		
	Medicine ball throw with Russian twist	3 × 8–10		
	Double-arm swings	2 × 8–10		
Medium to high (two weeks)	<i>Tuck jump</i>	3 × 10–12	2	Add one rep each workout until reaching 10
	Single-leg zigzag hop	3 × 10–12		
	Double-leg vertical power jump	3 × 10–12		
	Running bound	3 × 10–12		
	<i>Box jump</i>	2 × 8–10		
	Dumbbell arm swing	3 × 12		
	Medicine ball sit-up	3 × 12–15		
High (rest of season)	Single-leg vertical power jump	2 × 8–12	1 to 1.5	Stress form and maximum explosion on each rep. Decrease reps from 12 max to 8 max after 2 weeks.
	Single-leg speed hop	2 × 8–12		
	Double-leg speed hop	2 × 8–12		
	Multiple box jumps	2 × 8–12		
	Side jump and sprint	2 × 8–12		
	Decline hops	2 × 8–12		
	Sprint arm action	2 × 8–12		
	Medicine ball sit-up	2 × 8–12		

Exercises in italics are described in chapter 5 of this book (pages 88-95). For descriptions of other plyometric drills listed here, see Chu 1998.

Power starts and power sprints are essential aspects of sprint loading. Studies show that the length of acceleration-power starts should be about 60 to 80 yards, or 6 to 8 seconds. Athletes attain peak power at about 0.6 to 0.8 seconds (within 10 yards), and training should involve distances of only 10 to 20 yards. The best way to train high-speed power is to perform sprint loading from a flying start using 6 to 10 repetitions for 10 to 80 yards. The athlete is then near maximum speed when the incline sprint begins.

A sprint loading program for hill sprinting, stadium-stair sprinting, and using weighted sleds is shown in table 9.5.

Table 9.5 Sprint Loading Program

Week	Repetitions	Pulling distance*	Rest (heart rate)	Progression
1	3–5	15 yards	Walk back >120 bpm	Use power starts at 75% speed in hill and stadium sprinting or with no weight on the sled. Complete two sets.
2	3–5	20 yards	Walk back >120 bpm	Repeat power starts at maximum speed.
3	6–8	25 yards	Full recovery	Repeat power starts at maximum speed.
	3–5	30 yards	Walk back >120 bpm	Use power sprints at maximum speed in hill and stadium sprinting with no weight on the sled. Complete two sets.
4	7–9	40 yards	Full recovery	Begin power starts at 90%.
	3–5	40 yards	Walk back >120 bpm	Repeat power starts and power sprints; add weight to sled that allows good form. Complete two sets.
5	7–9	50 yards	Full recovery	Repeat previous workout. Add more weight and complete three sets.
6–9	7–9	60 yards	Full recovery	Repeat previous workout. Add more weight each week. Complete three sets. Include one final run to exhaustion by continuing to sprint as long as possible. Record the distance and try to improve distance pulled each week.

*Actual distance sprinting uphill, sprinting up stadium steps, or pulling sled.

Form Training

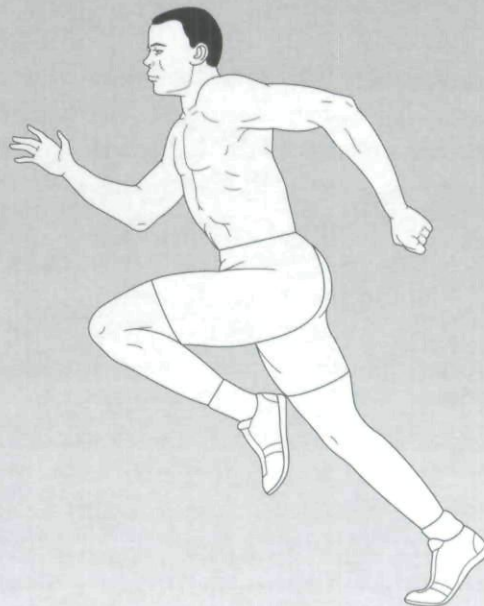
Describing ideal sprinting form in a manner that athletes can understand and apply is difficult. Coach Tom Tellez, who trained 100-meter world record holders Carl Lewis and Leroy Burrell and coached the USA Olympic sprint team, provides an excellent summary of this complicated aspect of acceleration and speed (Dintiman, Ward, and Tellez 1997) which is paraphrased here.

Unless athletes are aware of what is natural and what is unnatural, their efforts could slow them down. Often, athletes feel that they have to bear down, stay low, and pull to run fast. The scientific analysis of running suggests just the opposite. Reaching maximum speed depends greatly on how relaxed one can keep the body in a naturally upright position. The human machine is much better at pushing than pulling, partly because the formation of the leg is unsuited to acting as a pulling force. To run faster, remember that sprinting is primarily a pushing action against the ground.

During the running stride, the leg cycles through three different phases: (1) the drive phase, when the foot is in contact with the ground; (2) the recovery phase, when the leg swings from the hip while the foot clears the ground; and (3) the support phase, when the runner's weight is on the entire foot.

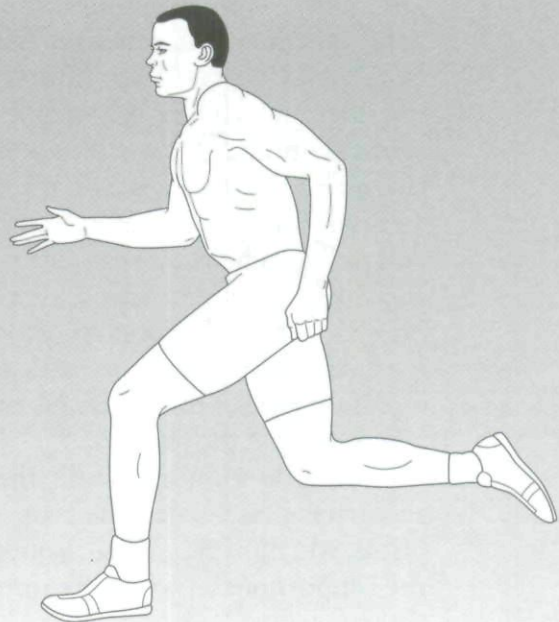
Drive Phase

During the drive phase, the power comes from a pushing action off the ball of the foot. Remember that stride length is the result of a pushing action. The goal of the drive phase is to create the maximum push off the ground. The ball of the foot is the only part of the foot capable of creating an efficient and powerful push. Some misinformed sport coaches believe that the pushing action of the drive phase comes from the toes. Pushing from the toes, however, reduces both power and stability and slows the runner. The drive phase contributes to overall speed only when the runner pushes off the ground using the ball of the foot.



Recovery Phase

During the recovery phase, the knee joint closes and the foot cycles through as it comes close to the body. As the knee joint opens and the leg begins to straighten, the foot comes closer to the ground in preparation for the support phase. An important point to remember about the recovery phase is that the runner does not reach for the ground or perform a stamping action. The leg should remain relaxed and allow the foot to strike the ground naturally.



Support Phase

During the support phase, the foot makes initial contact with the ground on the outside edge of the ball of the foot. The weight of the body is then supported at a point that varies according to the speed of the athlete. The faster the speed, the higher the contact point on the ball of the foot. Striking the ground first with this part of the foot maximizes speed but requires great energy. At slower speeds, such as jogging, the contact point moves toward the rear of the foot between the arch and heel. During longer and slower runs, using a flat foot plant saves energy. At all running speeds, the support phase begins with a slight load on the support foot that then rides onto the full sole. Even during sprinting, the heel makes brief but definite contact with the ground. Analysis of the support phase shows that it is impossible to reach maximum speed by running on the toes.



Arm Action

Arm action in sprinting is critical to developing the most efficient stride length. The arms work in opposition to the legs, with the right arm and left leg coming forward as the left arm and right leg go backward (see drive phase) and vice versa. The shoulders should be relaxed, with the swing coming from the shoulder joint. The shoulders should stay perpendicular to the direction of the run. The swing should be strong but relaxed. The hands should also be relaxed. On the upswing, the hand should rise naturally to a point just in front of the chin and just inside the shoulder. During the upswing, the arm angle is about 90 degrees or less, coordinating with the quick recovery of the forward swing of the leg (see recovery phase).

During the downswing, a natural straightening at the elbow corresponds with the longer leverage of the driving leg on the opposite side of the body to allow horizontal drive. As the arm swings down, the elbow will extend slightly. At the bottom of the swing, the hand should be next to the thigh (see support phase). Toward the end of its backward movement, the arm bends and speeds up again to match the final, fast stage of the leg drive. The elbows should stay close to the body; holding the elbows away from the body prevents relaxation of the shoulders and reduces the efficiency of running mechanics. The arm action in sprinting is never forced or tense.

The mechanics of sprinting dictate that athletes who want to run faster must concentrate on pushing off the ground, landing with the proper foot placement, using the correct arm action, and staying relaxed.

Speed Drills

The following bounding, sprinting, and other form workout drills help establish correct neuromuscular movement patterns to improve stride rate and length and to eliminate wasted energy that does not contribute to forward movement. Athletes in practically every sport would benefit by using these drills in each workout for 8 to 10 minutes, following proper warm-up and stretching. Bounding drills are designed to develop the explosive leg power required in starting and acceleration. Sprinting drills are designed to develop the mechanics, strength and power needed to produce maximum sprinting speed.

Straight Bounding

Beginning from a slow jog, bound as high into the air as possible, emphasizing high knee lift. Land on the opposite leg and continue bounding down the field.



Outside Bounding

This drill is similar to straight bounding except that the foot is placed laterally outside the normal landing position, and the body is projected laterally outward as well as up and forward.



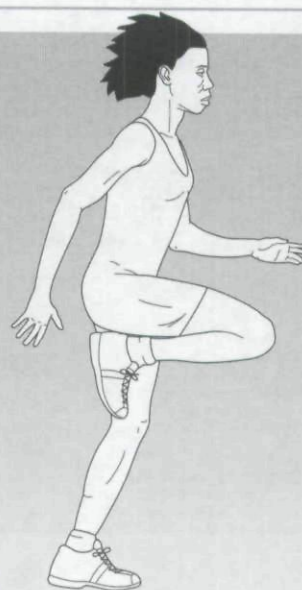
Inside Bounding

This drill is similar to outside bounding except that the foot is placed laterally inside the normal landing position, and the body is projected laterally inward as well as up and forward.



Butt Kicker

From a jog, the lower leg is allowed to swing back and bounce off the buttocks. The upper leg should not move much; focus on allowing (not forcing) the heel to come up to the butt.



Wall Slide

From a jog, the action is the same as that in the butt kickers except the heel of the recovery leg must not travel behind the body. Imagine a wall of glass running down the back, and do not allow the heel to break the glass. This action will produce knee lift without forcing the action.

Start and Sprint

From a stationary position, start quickly and feel the power being applied behind the body. Ten yards out, quickly shift from running in back of the body to sprinting in front of the body.

Quick Feet

From a jog, increase stride rate and take as many steps as possible in a 10-yard interval. Jog for 10 yards and repeat, emphasizing quick turnover, with the legs moving in front of the body, not behind or under it.

Cycling

Leaning against a wall, bar, or other support, the athlete cycles one leg through in a sprinting manner. Emphasize keeping the leg from extending behind the body, allowing the foot to kick the butt during recovery, and pawing the ground to complete the action. Ten cycles with each leg make up one set.

Down-and-Off

From a high-knee position, the athlete brings the foot down and back up. The emphasis is on decreasing foot-ground contact by hitting the ground with the ball of the foot and getting off as quickly as possible. The effort on the ground should bounce the leg up into a high-knee position. Ten down-and-offs make up one set.



Pull-Through

Extending the leg in front of the body like a hurdler, the athlete brings the leg down and through ground contact in a power motion. Ten pull-throughs with each leg make up one set.



Stick Sprint

Place 20 sticks (18 to 24 inches in length) 18 inches apart on a grass surface. Athletes sprint through the sticks as fast as possible, touching one foot down between each. Emphasize high knee lift and quick ground contact. One run equals one set.

African Dance

While running forward, the athlete raises each leg to the side of the body as in hurdling and taps each heel with the hand. A 10-yard run equals one set.



Drum Major

While running forward, the athlete rotates the leg inward to the midline of the body and taps the heel at the midline. A 10-yard run equals one set.



Speed-Endurance Training

As mentioned earlier, speed-endurance training will prevent athletes from slowing down late in the game, at the end of a long sprint, or after sprinting several times with little rest in between. Poor speed endurance becomes evident when a halfback is tackled from behind by a slower player, when a sprinter is passed in the final 10 to 20 meters of a race, when a baseball player runs out of steam and is tagged out at home, or when a basketball player is beaten to the ball by a slower player. High levels of speed endurance provide athletes with a fresh start on each short sprint.

Speed-endurance training programs are designed using the distances of the sprint and the recovery intervals commonly performed in the sport. The number of sets and repetitions simulate the competitive situations that occur in each sport. A typical program for soccer, rugby, and lacrosse would involve gradually increasing the sprint distance from 10 to 50 yards, increasing the number of repetitions from 5 to 15, and decreasing the jogging recovery or rest interval from 20 seconds to 5.

Pickup sprints are an easy, effective program for improving speed endurance in most sports; the sprinting distances and rest intervals are simply adjusted to those that normally occur in the particular sport. In football, for example, short sprints of 10 to 40 yards occur three to seven times at 25- to 30-second (length of huddle) intervals. Speed-endurance training for football players uses these values to develop the foundation of the program. Using pickup sprints, an athlete jogs 25 yards, strides at three-quarter speed for 25 yards, sprints 25 yards, and ends the set with a 25-yard walk. The walking period provides the only rest period between sets. As improvement occurs, lengthen the distance of the segments to 40 and 60 yards. Sprints of longer distances can be used occasionally along with a series of maximum-effort drills (300- and 400-meter sprints, sprinting in place to exhaustion, etc.) at the end of the workout.

Sprint-Assisted Training

The purpose of sprint-assisted training is to increase stride rate and stride length by forcing faster and longer steps than the athlete can take without assistance. Experts feel that such exercises train the nervous system by exposing both the nervous and muscular systems to higher contraction rates. A neurosurgeon, speaking at the national convention of NASE, put it in layman's terms: "After several weeks of sprint-assisted training, the nervous system allows you to continue these higher rates without any assistance." Although this is only theory, research shows that the number of steps taken per second and the length of the stride improve following four to eight weeks of sprint-assisted training.

To achieve maximum results, sprint-assisted training of any kind must be executed according to the following guidelines.

- Begin each workout with a general warm-up routine designed to increase core temperature. Use the large muscle groups first with a slow jog for one-fourth to one-half mile, followed by a faster jog and striding at three-quarter speed for an additional one-fourth mile or more. After perspiring freely, athletes stop and stretch for 8 to 10 minutes. Next are walk-jog-stride-sprint segments (walk 15 steps, jog 15 steps, stride 15 steps at three-quarter speed, and sprint 15 steps), continuing for at least one-fourth mile.
- Expect muscle soreness for one to two days after the first workout. Sprint-assisted training is demanding and will recruit motor units and muscle fibers previously unused.
- Use sprint-assisted training in the beginning of the workout, immediately after completing the warm-up and stretching session. Sprint-assisted training should be avoided if athletes are fatigued from drills, calisthenics, scrimmage, anaerobic training, weight training, or plyometrics. The object is to take faster

and longer steps than ever before, not to improve anaerobic conditioning.

- Emphasize quality form in all repetitions. Athletes should avoid sprinting out of control.

The four basic methods of sprint-assisted training are (1) downhill sprinting, (2) high-speed stationary cycling, (3) towing with surgical tubing and pulley devices, and (4) high-speed treadmill sprint training.

Downhill Sprinting

Locate a 50-meter area with a slope no greater than 3 to 7 degrees, which offers only a slight decline. Slopes greater than 7 degrees increase the risk of a fall and produce overstriding, landing on the heels, and ground contact beyond the center of gravity, which produces a braking effect. The braking effect and deviation from natural sprinting form are even noticeable in some athletes when using slopes of no more than 3 or 4 degrees. The ideal area allows a 20-meter sprint on a perfectly flat surface (to accelerate to near maximum speed) followed by a 15-meter sprint on a downhill slope of 3 to 7 degrees (to force higher than normal stride lengths, stride rates, and speed) and ends with a 15-meter sprint on a flat area (to allow athletes to hold the higher speed without the assistance of gravity).

High-Speed Stationary Cycling

During high-speed stationary cycling, the effects of wind resistance, gravity, and body weight are eliminated, allowing more revolutions (similar to steps in sprinting) per second than the sprinting action. This sprint-assisted training technique should be combined with another method, such as towing or downhill sprinting (as shown in table 9.5), to guarantee success.

Towing

Towing, or pulling athletes to sprint faster, is not a new approach. Before the use of surgical tubing and two-person pulley arrangements, motorscooters, motorcycles, and even automobiles were used. Towing produces higher stride rates and increases stride length more effectively than downhill sprinting or high-speed cycling.

Use towing only on a soft, grassy area, after inspecting the surface for broken glass and other objects. Towing requires a 20- to 25-foot piece of elastic or surgical tubing attached to the athlete's waist by a belt. The opposite end can be fastened to another athlete or a stationary object such as a tree or a goalpost to allow individuals to work out alone. Athletes back up to stretch the tubing slightly and run at three-quarter speed with the pull until they make adjustments and master balance. It is possible to stretch the tubing seven times its length (20 feet $\times$ 7 = 140 feet) before sprinting at high speed with the pull. Athletes can also make stationary runs from a three-point start. Some athletes have completed stationary 40-yard dashes in 3.7 seconds while being pulled with surgical tubing.

Several towing drills are available:

- Attach one end of the tubing to the front of the waist and the other to the goalpost. The athlete stretches the tubing by walking backward about 20 yards. He or she jogs forward toward the goalpost with the pull. The athlete repeats

Table 9.6 Downhill Sprinting and Cycling Program

Week	Repetitions	Acceleration distance	Sprint-assisted distance*	Progression (repetitions)	Rest (minutes)
1	2-3	10-15 yards (1.5-2 seconds)	20-25 yards (1-1.5 seconds)	Add one to two per workout	2:00
2	4-6	15-20 yards (2-2.5 seconds)	20-25 yards (1.5-2 seconds)	Add one each workout	2:30
3	7-9	20-25 yards (2.5-3 seconds)	20-25 yards (1.5-2 seconds)	Add one each workout	3:00
4	9-10	20-25 yards (2.5-3 seconds)	20-25 yards (1.5-2.5 seconds)	Add one each workout	3:30
5	9-10	20-25 yards (2.5-3 seconds)	20-25 yards (1.5-2.5 seconds)	Add one each workout	3:30

*Sprint-assisted distance is the actual distance (or time) athletes are sprinting downhill or pedaling at high speeds.

this drill four times, two with a run at three-quarter speed and two with a full-speed sprint. Within the next three sprints, the athlete backs up an extra 5 to 8 yards each time to increase the pull and the speed.

- Repeat the last part of the drill described above using high knee lifts.
- Athletes required to sprint backward or sideways in their sports (defensive backs in football and soccer, rugby and lacrosse players) repeat the drills using those movements.
- Complete the two-person drill by attaching one end of the tubing to the waist and the other to a partner's back. The partner sprints 25 to 30 yards ahead against the resistance, then stops. The other athlete then sprints toward the partner in an overspeed run.

Follow the sprint-assisted training program given in table 9.7 two to three times per week (every other day) during the preseason period and one to two times per week during the competitive season. Keep in mind that using surgical tubing can be dangerous. Provide adequate supervision and a soft grassy area.

Two other pieces of equipment that can be used for sprint-assisted training are the UltraSpeed Pacer and the Sprint Master. The Ultra Speed Pacer is a simple pulley device based on leverage. The pulley can be fastened to a fixed object or held by a partner. Two athletes can also lock on the belts, with one sprinting at a 45-degree angle away from the pulley and the other toward the pulley to receive considerable pull. The device has the potential to provide a strong pull and produce very high stride rates, stride lengths, and sprinting speed.

The Sprint Master machine is precisely engineered to pull athletes at speeds faster than any human can sprint. It attaches to the goalposts of a football or soccer field and provides controlled, variable speed for each athlete. The device increases safety by providing the athlete who loses balance the option of simply releasing his or her grip.

Table 9.7 Sprint-Assisted Training Using Surgical Tubing and the Sprint Master

Week	Repetitions	Distance*	Rest (minutes)	Progression
1	3–5	10–15 yards	2	Three-quarter speed runs only to acclimate
2	3–5	10–15 yards	2	Maximum speed
3	5–7	15–20 yards	3	Maximum speed
4	7–9	20–25 yards	3	Maximum speed
5	7–9	20–25 yards	3	Maximum speed
6–9	7–9	25–30 yards	3–5	Maximum speed with weighted vest, progressing from one to five pounds over three weeks. Used only for the final two repetitions of the workout.

*Represents the total distance an athlete can sprint at maximum speed.

High-Speed Treadmill Sprint Training

In the Virginia Commonwealth University laboratory, the A.R. Young high-speed treadmill (capable of speeds of 0.0 to 26.0 miles per hour) has been used to improve stride length, stride rate, form, acceleration, speed endurance, and speed. Cinematography identifies differences in stride length and rate at various speeds in both treadmill sprinting and unaided, flat-surface sprinting. An expert standing on a stool facing and looking down at the subject corrects form during high-speed sprinting. The treadmill is also an excellent piece of equipment for sprint-assisted training.

Sequence of Training Programs

Although opinions differ among conditioning coaches, there is a logical sequence to using the programs in this chapter, particularly when several training programs are used within the same workout.

Start with a formal warm-up routine involving actions specific to the sport that bring about perspiration. Perform stretching exercises next. Follow immediately with sprint-assisted training, keeping in mind that the purpose is to improve stride rate and length, not speed endurance. Scrimmage and drills are fourth in sequence, completed while the body is still relatively fresh, capable of high speeds under game conditions, and less apt to be injured. Conditioning activities such as calisthenics, speed-endurance training, plyometrics, and weight training are the last items on the workout schedule. It is best to avoid scheduling plyometrics and weight training within the same training session. A final 5- to 10-minute cool-down period may include additional stretching, particularly following a plyometric or weight-training session.

Table 9.8 identifies the role of each training program in altering the four ways of improving acceleration and speed. This information allows coaches and ath-

Table 9.8 Training Programs to Improve Acceleration and Speed

How sprinting speed is improved	Specific training programs
Improved acceleration	Starting-time training specific to the sport Plyometrics Muscle imbalance strength training Functional strength and power training Sprint loading Sprint-assisted training
Increased stride length	Functional strength and power training Muscle imbalance strength training Plyometrics Sprint loading Sprint-assisted training Form training Flexibility training
Increased stride rate	Sprint-assisted training Muscle imbalance strength training
Improved form and speed endurance	Form training Speed-endurance training Sprint loading

Note: The table assumes that athletes already possess an acceptable level of body fat, general conditioning, and strength.

letes to select the major areas of emphasis and to focus on the training programs that are likely to bring about improvement.

SUMMARY

The major areas of emphasis for speed improvement for each athlete depend on the sport and individual testing results. The object is to adjust each training program to simulate the activities of the sport while focusing on the areas of weakness uncovered.

Key points in this chapter include the following:

- In most sports, what is referred to as speed is really acceleration because athletes rarely reach maximum speed during competition.
- Although some athletes are born with more fast-twitch muscle fibers than others and are more genetically suited for sprinting, all athletes, regardless of their genetic makeup, can improve their speed and acceleration with proper training. Sprint loading, strength-power training, speed-endurance training, plyometrics, and sprint-assisted training produce the greatest changes in the exercised fast-twitch muscle fibers.
- Acceleration and speed can be improved by taking faster steps, taking longer steps, and improving sprinting form. Performance deterioration in short sprints as the game progresses can be avoided by improving speed endurance.

- Fast sprinters come in all sizes and shapes; no body type provides a significant edge. Excess body fat can significantly impair acceleration and speed. Although the gap is closing, male sprinters possess better times in the 100 meters and 200 meters, and take faster and longer steps than female sprinters.
- An analysis of correct sprinting form has allowed researchers to identify the significant factors contributing to efficient movement. Research has also revealed a diversity of style and technique among champion sprinters, suggesting that athletes should improve their basic style without trying to mimic the exact technique of others.
- Before a personalized program can be designed to improve acceleration and speed, it is important to evaluate speed, stride length, stride rate, strength, power, flexibility, body composition, and muscle balance. Programs can then be designed to eliminate the areas of weakness that are limiting improvement.
- Apply the concept of working fast to be fast in all training programs.
- All athletes need a solid foundation of functional strength and power before proceeding to training programs designed to improve acceleration and speed. One area that must receive more emphasis in these programs is the hamstring muscle group, the sprinter's weakest link.
- To ensure proper progression and to enable athletes to reach peak performance at the appropriate time for their sport, use periodized training in the speed-improvement program. This approach groups each training program and workout into phases or cycles to help athletes achieve their peak performance at just the right time.
- Plyometric training bridges the gap between strength and speed by using exercises that simulate sprinting movements and use a "down" time (foot-ground contact time) less than that used during the actual sprinting action.
- Sprint loading is a program that involves placing the exact muscles used in acceleration and maximum sprinting under resistance using a sled, a slight incline, or stadium stairs in order to improve power and acceleration while emphasizing correct form.
- Form training can improve acceleration and speed, and should be a part of an athlete's regular workout in all sports. Although the workout drills are difficult to execute correctly at first, once they can be performed with ease neuromuscular patterns become established that ensure proper sprinting mechanics in all activities.
- Speed-endurance training should be tailored to each sport in terms of the typical distance covered, rest interval, and number of repetitions in order to improve training specificity and carryover to a sport.
- Sprint-assisted training forces athletes to take faster and longer steps than they are capable of taking without assistance by using surgical tubing, pulleys, a slope, stationary bicycle, Ultra Speed Pacer, Sprint Master, or treadmill. Full recovery is necessary before performing the next repetition. The purpose of this workout is to train the neuromuscular system so that athletes can eventually take faster and longer steps without assistance. This normally occurs in 6 to 10 weeks.

- If maximum improvement is to occur, the training programs must be sequenced logically. Athletes should begin with a general warm-up, move on to stretching, sprint-assisted training, drills or scrimmage, and end with conditioning activities (calisthenics, plyometrics, or weight training) and a cool-down period that may include brief stretching.

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